Mid Pecan Bayou: Historical Water Quality, Source Survey and Geographic Information System Inventory

Prepared for:

Texas State Soil and Water Conservation Board
Project 10-53

Prepared by:

Jimmy Millican
Todd Adams
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Texas Institute for Applied Environmental Research
Tarleton State University
Stephenville, Texas

TR1105

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Cover photograph is Mid Pecan Bayou at station 12502 (Mid Pecan Bayou downstream of Willis Creek confluence) taken by TIAER on April 14, 2011.

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SECTION 1

Introduction

Problem Statement

Mid Pecan Bayou (Segment 1431) is located southeast of the City of Brownwood and is comprised of a single assessment unit (AU 1431_01) representing the entire waterbody (Figure 1). Segment 1431 is defined as Pecan Bayou from a point immediately upstream of the confluence of Mackinally Creek in Brown County to a point immediately upstream of Willis Creek in Brown County (TCEQ, 2010a). Because the impaired segment is comprised of only one AU, the AU descriptor is unnecessarily cumbersome and in this report Mid Pecan Bayou will be referred to synonymously as Segment 1431. This classified segment was first listed on the 2006 Texas 303(d) List and every subsequent 303(d) List due to excessive bacteria based on the geometric mean of *Escherichia coli* (*E. coli*) concentrations of assessment data (TCEQ, 2010a). There are also concerns due to exceedances of nutrient screening levels; specifically nitrate, orthophosphorus, and total phosphorus (TCEQ, 2010b). Designated uses for Segment 1431 include primary contact recreation, general use, and fish consumption with an assumed high aquatic life use.

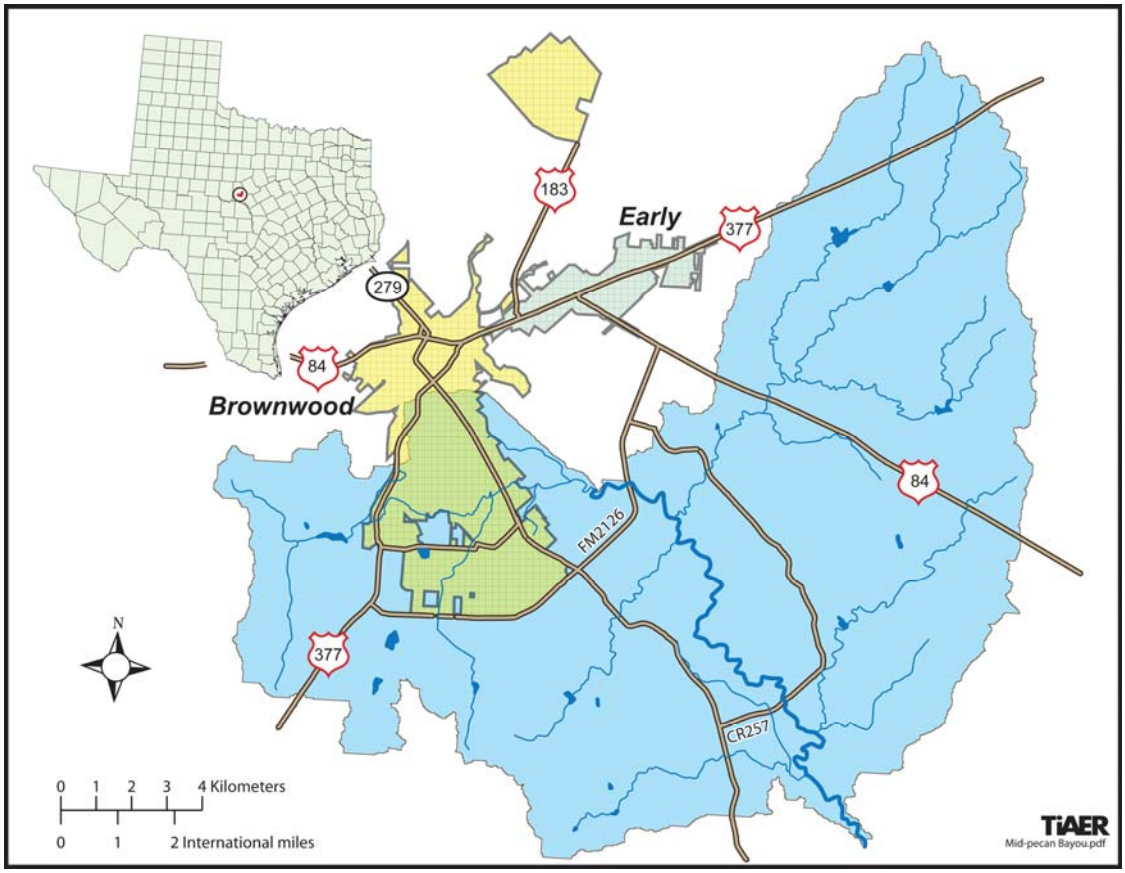

Figure 1 General map of Mid Pecan Bayou watershed for Segment 1431.

Study Area

Pecan Bayou is reportedly the western most bayou in the United States (LCRA, 2007). The Mid Pecan Bayou watershed is in a subtropical-subhumid region of Texas characterized by hot and humid summers and mild and dry winters (Office of Texas State Climatologist, 1983). The headwaters of Pecan Bayou begin in Callahan County and flow for approximately 100 miles to the confluence with the Colorado River in Mills County. The Bayou is impounded about midway to form Lake Brownwood. The Pecan Bayou watershed contains six classified segments as defined by TCEQ. Segment 1419 is defined as Lake Coleman (an impoundment of Jim Ned Creek, a tributary to Pecan Bayou), Segment 1420 is Pecan Bayou above Lake Brownwood, Segment 1418 is Lake Brownwood, Segment 1432 is Upper Pecan Bayou, Segment 1431 is Mid Pecan Bayou, and Segment 1417 is Lower Pecan Bayou. Flows along Upper Pecan Bayou (Segment 1432) and downstream Segments 1431 (Mid Pecan Bayou) and 1417 (Lower Pecan Bayou) are influenced largely by releases from Lake Brownwood (LCRA, 2007). Segments 1432, 1431 and 1417 are influenced largely by releases from Lake Brownwood (LCRA, 2007). Flows along Segment 1431 and to a lesser degree Segment 1417 are also influenced by discharges from the City of Brownwood wastewater treatment facility (WWTF).

Segment 1431 representing Mid Pecan Bayou is about 13 miles long (LCRA, 2007), and lies within the Cross Timbers and Central Great Plains Ecoregions (Griffith et al., 2004). The watershed of Segment 1431 includes the Camp Bowie Military Reservation and the southern portion of the City of Brownwood with the remainder of the watershed lying largely within rural areas dominated by agricultural production. The flow type for Mid Pecan Bayou is described as perennial, which means it flows throughout the year (TCEQ, 2010b).

SECTION 2

GIS Inventory

A comprehensive GIS inventory was developed for the Mid Pecan Bayou watershed using information from existing sources. This section describes the findings of the GIS inventory and the sources of specific GIS layers.

Digital Elevation Models (DEMs)

Digital elevation models with 30 meter resolution were downloaded from the USGS seamless server (USGS, 2010a). Delineation of the project watershed and subwatersheds were performed using ArcView 3.2 and the ArcView Soil and Water Assessment Tool (AVSWAT-X for SWAT 2005, released July 2006).

Land Use/Land Cover Classification

The 2006 National Land Cover Database (NLCD) was downloaded from the USGS seamless server as the most current land use/land cover data for the watershed (USGS, 2010b). The land use/land cover categories for NLCD are described in Homer et al. (2004) as follows:

Shrub/Scrub – areas dominated by shrubs less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Forest – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Forest includes deciduous forest, evergreen forest and mixed forest.

Grassland/Herbaceous – areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing and are also commonly referred to as rangeland.

Developed – areas characterized by a high percentage (30% or greater) of constructed materials (e.g., asphalt, concrete, buildings, etc.). Developed land includes open space and low, medium and high intensity developed areas.

Cultivated Crops – areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Pasture/Hay – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

Open Water – areas of open water, generally with less than 25% cover of vegetation or soil.

Barren Land – areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation present regardless of its inherent ability to support life. Vegetation, if present, is more widely spaced and scrubby than that in the green vegetated categories; lichen cover may be extensive. Generally, vegetation accounts for less than 15% of total cover.

Wetlands – areas where the soil or substrate is periodically saturated with or covered with water.

Classifications as output from the 2006 NLCD for the Mid Pecan Bayou watershed are defined along with the combined classifications used to summarize the dataset (Table 1). The combined classifications are presented in Table 2 and Figure 2.

Table 1 NLCD and combined land use/land cover classifications.

NLCD GRIDCODE	NLCD Classifications	Combined Classifications
11	Open Water	Open Water
21	Developed, Open Space	Developed
22	Developed, Low Intensity	
23	Developed, Medium Intensity	
24	Developed, High Intensity	
31	Barren Land	Barren Land
41	Deciduous Forest	Forest
42	Evergreen Forest	
43	Mixed Forest	
52	Shrub/Scrub	Shrub/Scrub
71	Grassland/Herbaceous	Grassland/Herbaceous
81	Pasture/Hay	Pasture/Hay
82	Cultivated Crops	Cultivated Crops
90	Woody Wetlands	Wetlands

Table 2 Land use/land cover classes within the Mid Pecan Bayou watershed (Source: 2006 National Land Cover Database).

Classification	Area (ha)	Percent (%)
Shrub/Scrub	12,957	47.4
Forest	5,010	18.3
Grassland/Herbaceous	4,313	15.8
Developed	3,690	13.5
Cultivated Crops	591	2.2
Pasture/Hay	498	1.8
Open Water	148	0.5
Barren Land	113	0.4
Wetlands	43	0.2
Total	**27,363**	

The dominant land use categories within the Mid Pecan Bayou watershed reflect a generally rural landscape (Figure 2). Shrub/scrub accounts for 47 percent of the watershed area followed by forest and grassland/herbaceous, which comprise 18 percent and 16 percent respectively (Table 2). The urban landscape (developed use) accounts for 13 percent of the of the total land use and is largely attributable to the City of Brownwood in the vicinity of the Willis Creek tributary.

Other Features

Other features of the watershed that were obtained as GIS layers included soils data, the stream network, roads, reservoirs, municipalities and digital orthophoto quarter quads (DOQQs). Sources of these other GIS layers are presented below. Most of these additional features are shown in Figure 3, except soils data. Included in Figure 3 are the monitoring sites used for the recreational use attainability analysis (RUAA) conducted for this project. For reference, the RUAA site descriptions are provided in Table 3.

Soils

Soils data for Brown County were obtained from the USDA Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database (NRCS, 2011). The SSURGO database represents the most detailed level of soil mapping done by the NRCS and provides in a digital format the information within the county level soil surveys.

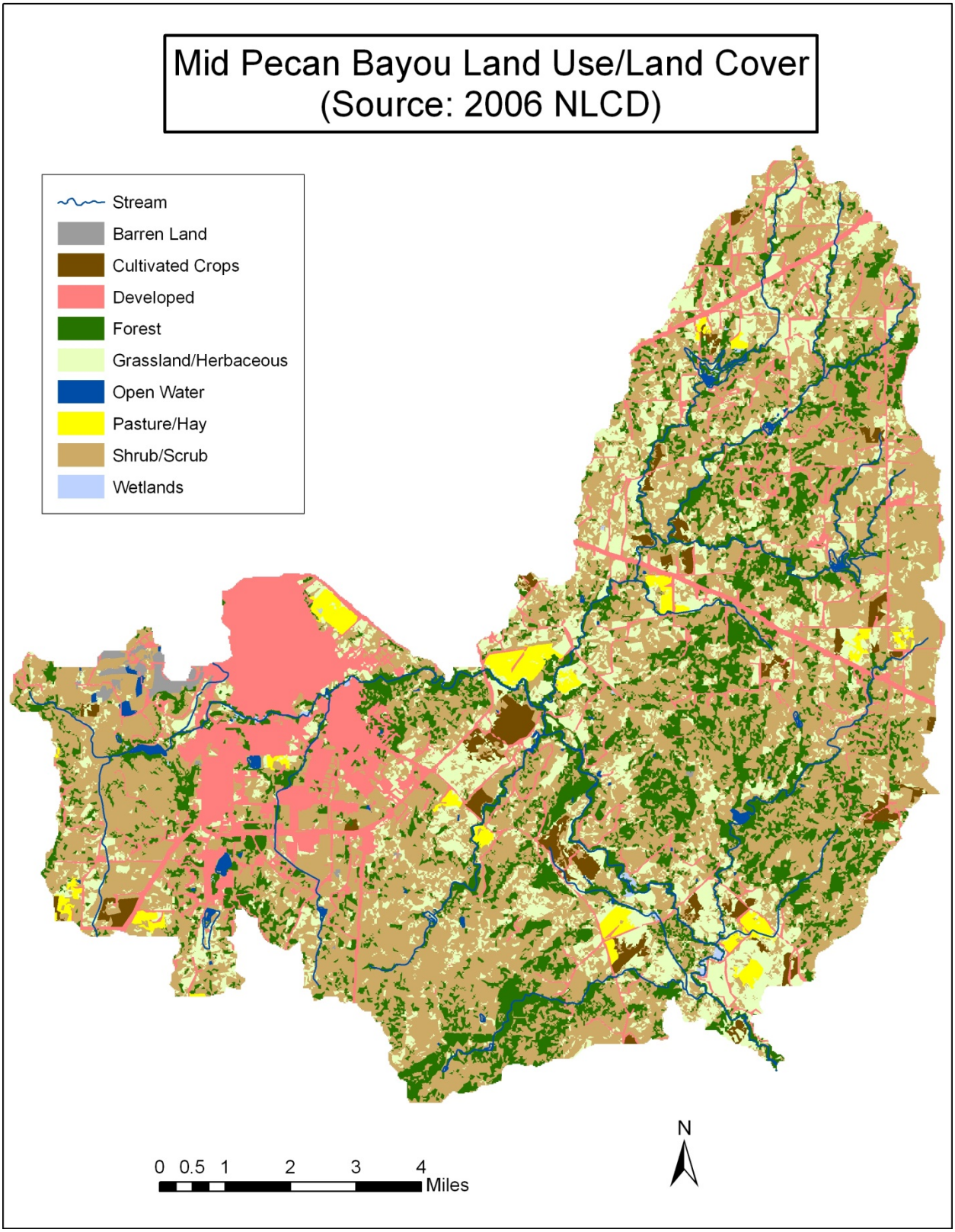

Figure 2 Land use/land cover within the Mid Pecan Bayou watershed (Source: 2006 National Land Cover Database).

Stream Network

A spatial GIS layer of the stream network for the State of Texas was obtained from the National Hydrography Dataset (NHD), which is maintained by the United States Geological Survey (USGS, 2010c). The NHD is a digital vector dataset that contains features such as lakes, ponds, streams, rivers, canals, dams and stream gages. These data are designed to be used in general mapping and in the analysis of surface-water systems.

Roads

Spatial information on roads was obtained from the Texas Natural Resources Information System (TNRIS) website maintained by the Texas Water Development Board (TWDB, 2010a). The road file represents the StratMap transportation layer is an updated, digital version of the transportation features found on the 7.5 minute, 1:24,000 scale USGS quadrangle maps.

PL566 Reservoirs

The shapefile for Public Law 566 reservoirs (floodwater retarding structures) was provided by the TSSWCB to TIAER on January 14, 2011 via email.

Municipalities

A GIS layer for municipalities was downloaded from TCEQ website containing GIS data for the Atlas of Texas Surface Waters in September 2010. These data are organized at the basin level. The link to this website was discovered broken on October 13, 2011, so could not be verified for this report.

DOQQs

DOQQs are aerial photos that have been geometrically corrected to remove distortions. Digital aerial images for the Mid Pecan Bayou watershed were obtained from TNRIS website (TWDB, 2010b) and represent National Agricultural Imagery Program (NAIP) produced by the United States Department of Agriculture (USDA) Farm Service Agency Aerial Photography Field Office. The images obtained are from the 2005 NAIP 2 meter.

Public Access Points

Public access to Mid Pecan Bayou was available only at two road crossing noted by RUAA monitoring sites MP003 at CR 257 and MP007 at FM 2126 (Figure 3). All other access to Mid Pecan Bayou was via private land or from up or downstream within the bayou.

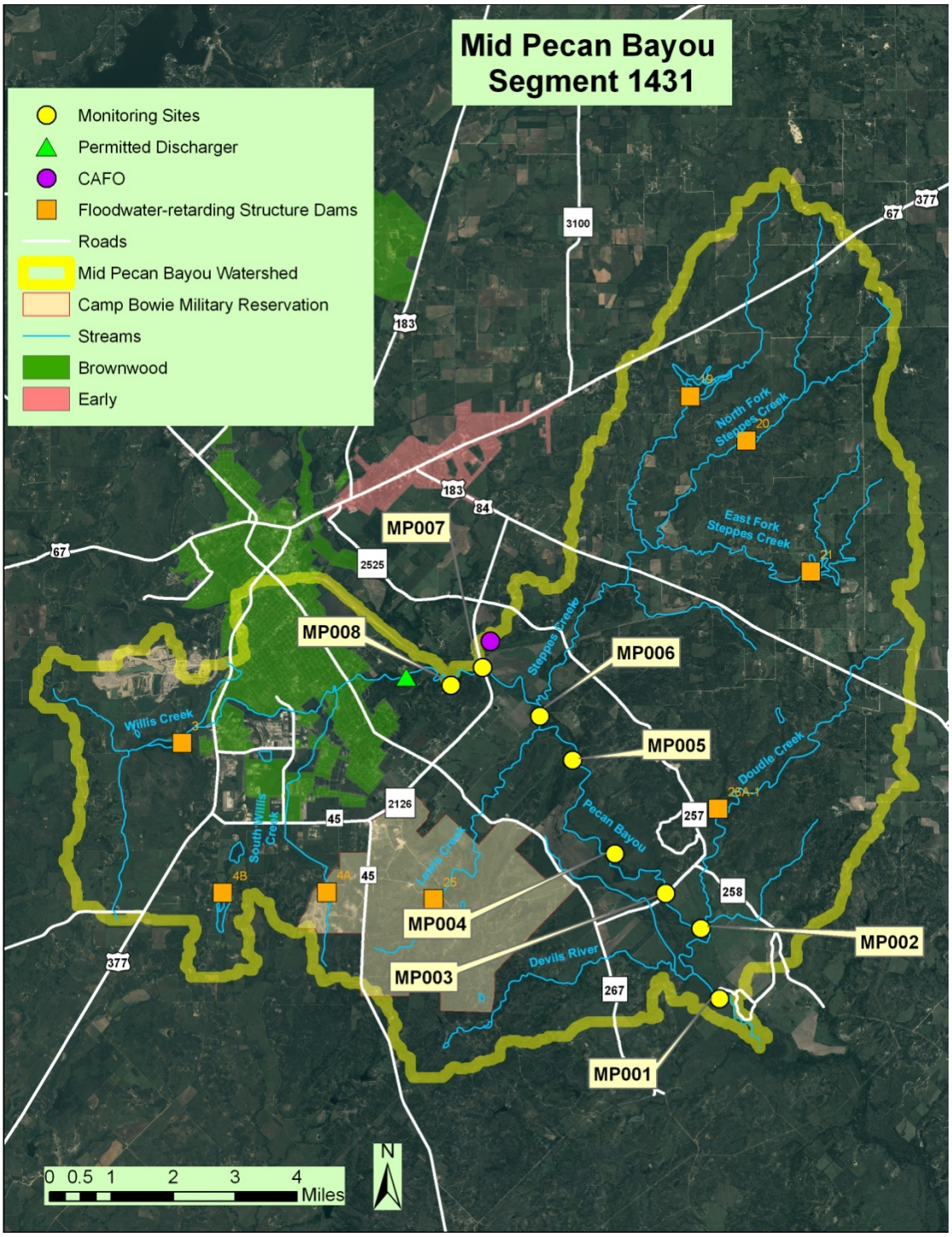

Figure 3 Map of Mid Pecan Bayou watershed for Segment 1431 showing dominate features including monitoring sites used for the RUAA.

Table 3 Location and description of RUAA monitoring sites.

Mid Pecan Bayou Watershed Segment 1431									
Sites listed in upstream to downstream order									
TCEQ ID	**Map Legend**	**Site Description**	**Latitude**	**Longitude**	**Distance to Previous Station (km)**	**Distance from Upper Segment Boundary (km)**	**Distance from Lower Segment Boundary (km)**	**Private or Public Access**	**Private Access Landowner Approved**
12502	MP008	Mid Pecan Bayou downstream of Willis Creek confluence	31.691389	-98.935555	0.00	0.45	21.74	Private	Yes
12504	MP007	Mid Pecan Bayou at FM 2126 southeast of Brownwood, TX	31.695460	-98.92710	1.14	1.59	20.60	Public	Not Applicable
- - -	MP006	Mid Pecan Bayou 0.39 km downstream of the confluence with Steppes Creek south of Brownwood, TX	31.684065	-98.911486	2.80	4.39	17.80	Private	Yes
12505	MP005	Mid Pecan Bayou 4.88 km downstream of FM 2126	31.673889	-98.902809	2.20	6.59	15.60	Private	Yes
- - -	MP004	Mid Pecan Bayou 3.1 km upstream of Brown CR 257	31.652208	-98.891161	4.67	11.26	10.93	Private	Yes
12507	MP003	Mid Pecan Bayou at Brown CR 257 (Ten Mile Crossing) 12.19 km downstream of FM 2126	31.642320	-98.877251	3.08	14.34	7.85	Public	Not Applicable
20800	MP002	Mid Pecan Bayou 1.6 km downstream of Brown CR 257	31.634271	-98.866911	1.55	15.89	6.30	Private	Yes
- - -	MP001	Mid Pecan Bayou 1.0 km downstream of the confluence with Devils River, south of Brownwood, TX	31.617719	-98.862308	3.90	19.79	2.40	Private	Yes

SECTION 3

Inventory of Historical Data

Historical Water Quality Data

Historical water quality data were obtained through TCEQ's publicly available online Surface Water Quality Monitoring Information System (SWQMIS) for stations within Segment 1431 (TCEQ, 2010c). Of the 13 stations listed for Segment 1431 (Table 4), only 8 stations were directly on the mainstem of Mid Pecan Bayou (Figure 4). The other five stations were located on Willis Creek, a tributary of Mid Pecan Bayou that largely flows through the City of Brownwood. Sampling at these tributary stations on Willis Creek was mainly associated with a special study conducted in 1979 focusing on 24-hr dissolved oxygen data. Of note, data collected by the Lower Colorado River Authority (LCRA) were included in the SWQMIS database, so data from the LCRA were not separately accessed.

Table 4 SWQMIS stations within Mid Pecan Bayou, Segment 1431.

TCEQ Station No.	Station Location Description	Station Type (mainstem or tributary)	Latitude	Longitude
12502	Mid Pecan Bayou 450 meters downstream of Willis Creek Confluence	Mainstem	31.691389	-98.935555
12503	Mid Pecan Bayou 0.38 km upstream of FM 2126	Mainstem	31.694166	-98.929443
12504	Mid Pecan Bayou at FM 2126 southeast of Brownwood	Mainstem	31.695460	-98.92710
12505	Mid Pecan Bayou 4.88 km downstream of FM 2126	Mainstem	31.673889	-98.902809
12506	Mid Pecan Bayou 3.34 km upstream of Brown CR 257	Mainstem	31.654444	-98.894997
12507	Mid Pecan Bayou at Brown CR 257 (Ten Mile Crossing) 12.19 km downstream of FM 2126	Mainstem	31.642320	-98.877251
20800	Mid Pecan Bayou 1.6 km downstream of Brown CR 257	Mainstem	31.634271	-98.866911
20799	Mid Pecan Bayou approximately 1.72 km upstream of Brown CR 257	Mainstem	31.64646	-98.884370
12173	Willis Creek approximately 30 meters downstream of FM 2524	Tributary	31.692287	-98.963658
12174	Willis Creek 10 meters upstream of Sulfur Draw confluence	Tributary	31.694902	-98.944247
12175	Willis Creek near Sulfur Draw	Tributary	31.695195	-98.944477
12176	Willis Creek 0.63 km upstream of Pecan Bayou Confluence	Tributary	31.694082	-98.940113
15537	Willis Creek upstream of City of Brownwood WWTP discharge, 1,550 meters downstream of FM 2524	Tributary	31.692778	-98.950279

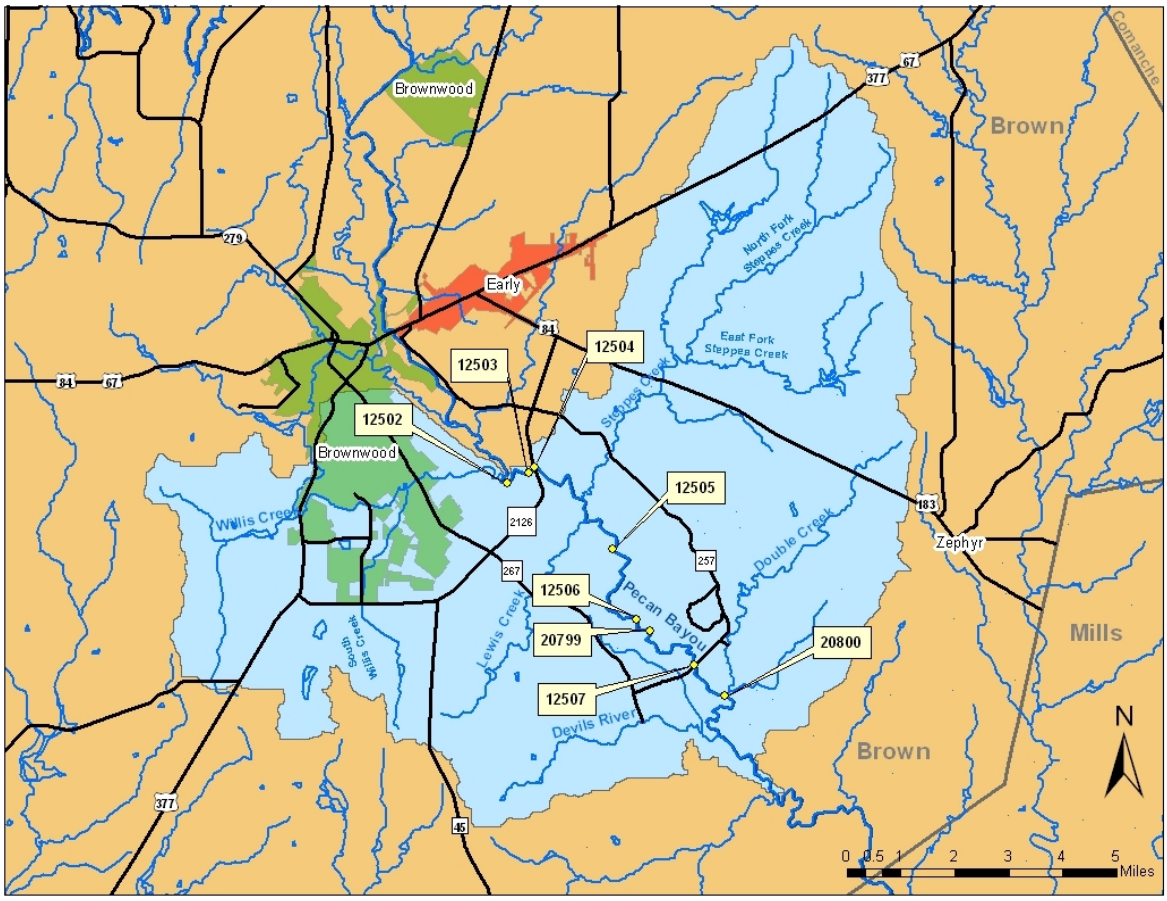

Figure 4 SWQM stations along Mid Pecan Bayou (Segment 1431).

Of the eight sampling stations located along Segment 1431, only two stations, 12503 and 12504, had nutrient or bacteria data since 1980. Station 12503 had one nutrient sample in March 2003, while station 12504 had significant amounts of data associated with bacteria and nutrient samples (see Table 5 for full history of available data for station 12504). A few other stations had nutrient data collected back in 1979, but these data represented single sampling events and were not considered relevant to the more recent assessments of water quality for Segment 1431. Of note, station 12504 is located in the upper most portion of Segment 1431 and, thus, water quality at station 12504 represents primarily upstream loadings largely associated with Segment 1432 (Upper Pecan Bayou), and contributions from Wills Creek, a tributary that flows through the City of Brownwood and into which Brownwood's WWTF discharges.

Table 5 History of water quality constituents monitored at Station 12504 associated with impairment or concerns for Mid Pecan Bayou, Segment 1431. Data accessed October 8, 2010 from SWQMIS (TCEQ, 2010c).

Constituent	Parameter Codes	Method Description	Station	Period of Record	Number of Observations
Fecal Coliform	31616	Membrane filter, M-FC broth	12504	Sep. 1973 - Nov. 2003	181
Escherichia coli	31648 & 31699	MTEC & Colilert, IDEXX	12504	Feb. 1996 - May 2010	37[a]
Orthophosphate-phosphorus (dissolved)	70507 & 00671	Filter > 15 min & Field Filter < 15 min	12504	Nov. 1973 - Feb. 2010	225[b]
Total Phosphorus	00665	Wet method	12504	Feb. 1972 - May 2010	232
Nitrite+Nitrate Nitrogen[c]	00593 & 00630	Total NO_2+NO_3 Whatman GF/F Filter & NO_2+NO_3 Total 1 Det.	12504	Jun. 1979 - Feb. 2010	194[d]

a. For *E. coli*, 5 samples were associated with parameter code 31648 (MTEC method) and 32 samples with parameter code 31699 (Colilert, IDEXX method).
b. For orthophosphate-phosphorus, 15 samples were associated with parameter code 70507n (Filter > 15 min method) and 210 samples with parameter code 00671 (Field Filter < 15 min method).
c. Nitrate is often measured as nitrite (NO_2) plus nitrate (NO_3) because NO_2 is generally found at very low concentrations and easily converts to NO_3.
d. For nitrite+nitrate nitrogen, 44 samples were associated with parameter code 00593 (Whatman GF/F method) and 141 with parameter code 00630 (Filter 1 Det. Method). Of note on nine sampling dates, a value for nitrite+nitrate nitrogen was not available, but values representing the separate analysis of total nitrite (parameter code 00615) and total nitrate (parameter code 00620) were present. For these nine samples, the separate values for nitrite and nitrate were added together to represent nitrite+nitrate nitrogen.

Water Quality Assessment Findings

A biennial assessment of water quality in Texas waterbodies is performed by the TCEQ and submitted to the EPA on even-numbered years. These biennial assessments serve to evaluate and identify waterbodies in Texas that do not meet uses and criteria defined in the TSWQS (TCEQ, 2010d). Designated uses for waterbodies in Texas include: aquatic life use, public water supply use, fish consumption use, noncontact recreation use, contact recreation use (primary, secondary 1, or secondary 2), and general use. For the purposes of this report, only the contact recreation and general uses will addressed.

Evaluation of the suitability of a waterbody for contact recreation is often based on the concentration of fecal coliform bacteria. Fecal coliforms are gram negative, facultative anaerobic, lactose fermenting bacteria that are commonly found in the intestines of homeotherms (Talaro and Talaro, 1999). *Escherichia coli*, a species of coliform bacteria, is often used as an indicator of the possible presence of fecal pathogens in water, because its concentration in water is relatively easy to measure and it is often the most abundant species of the fecal coliform

bacteria (Talaro and Talaro, 1999). While based on the testing method, *E. coli* concentrations are often expressed as a most probable number per 100 milliliters of water (MPN/100 mL), while fecal coliform concentrations are typically expressed as the number of colony forming units per 100 milliliters of water (cfu/100 mL). Both units of expression (MPN/100 mL and cfu/100 mL) are considered synonymous for assessment purposes. The 2010 TSWQS indicate for primary contact recreation in freshwater that the geometric mean concentration for *E. coli* should not exceed 126 MPN/100 mL (TCEQ, 2010d). *E. coli* is the preferred indicator for assessing recreation use in freshwaters, while previous water quality standards have been based on fecal coliform. The 1997 TSWQS indicate that the geometric mean of fecal coliform concentrations should not exceed 200 cfu/100 mL (TNRCC, 1997). Of note prior to 2004 most bacteria data were reported as fecal coliform as TCEQ gradually phased from fecal coliform to *E. coli* as the primarily indicator of bacteria in freshwaters.

Mid Pecan Bayou (Segment 1431) first occurred on the 2006 Texas 303(d) List due to *E. coli* concentrations that exceeded the geometric mean criteria for contact recreation use (Table 6). Also beginning in 2006, there was a concern noted due to elevated nitrate, orthophosphorus, and total phosphorus concentrations that exceeded nutrient screening levels associated with general use (Table 7). Of note, screening levels for nutrients are statistically derived by TCEQ from statewide surface water quality monitoring data and represent the 85th percentile value for each parameter in freshwater streams and are used to indicate concerns, not impairments (TCEQ, 2010e). While a variety of other parameters were evaluated in assessing water quality, no other impairments or concerns were noted.

The bacteria impairment for Segment 1431 continued to appear on the 2008 Texas 303(d) List and also on the most recent 2010 Texas 303(d) List. Concerns for nitrate, orthophosphorus, and total phosphorus concentrations also continued as part of the 2008 and 2010 water quality assessments. As part of the 2010 assessment results for Segment 1431, a concern for near non-attainment was also noted for fecal coliform concentrations for exceeding the geometric mean criterion of 200 cfu/100 mL. The concern for near non-attainment was noted rather than a non-supporting designation for fecal coliform because the dataset contained only seven samples, which is less than the minimum required number of ten samples for assessment purposes. Values and number of samples used to assess bacteria against the recreation use criteria and nutrients against the general use screening levels are presented by assessment year in Tables 6 and 7. The assessments of Segment 1431 included data from stations 12503, 12504 and 12505 (TCEQ, 2010b), although the majority of the bacteria and nutrient data were from station 12504, located in the upper portion of the segment (see Figure 4). Station 12503 had nutrient data for one sampling period and no nutrient or bacteria data were available for station 12505 for these assessment periods, although station 12505 included other types of assessment data for parameters, such as pH and dissolved oxygen. Both the bacteria impairment and nutrient concerns for Segment 1431 are attributed to municipal point source discharges and agricultural nonpoint sources (TCEQ, 2010b).

Table 6 Bacteria assessment information reported by TCEQ in determining impairment status of Segment 1431.

Assessment Year	Period of Record Assessed	Constituent	Number of Samples	Geometric Mean Criterion (cfu or MPN/100 mL)	Geometric Mean (MPN or cfu/100 mL)
2006	1999 - 2004	*E. coli*	13	126	242
		Fecal coliform	15	200	104
2008	1999 - 2006	*E. coli*	21	126	282
		Fecal coliform	15	200	104
2010	2001 - 2008	*E. coli*	26	126	228
		Fecal coliform	7	200	258

Table 7 Assessment values reported by TCEQ in determining nutrient concerns for Segment 1431.

Assessment Year	Period of Record Assessed	Constituent	Number of Samples	Screening Level (mg/L)	Number of Samples That Exceed Screening Level	Mean of Samples That Exceed Screening Level (mg/L)
2006	1999 - 2004	Nitrate	20	1.95	15	9.36
		Orthophosphorus	20	0.37	14	1.43
		Total Phosphorus	20	0.69	14	1.50
2008	1999 - 2006	Nitrate	28	1.95	22	10.6
		Orthophosphorus	28	0.37	21	1.60
		Total Phosphorus	28	0.69	20	1.74
2010	2001 - 2008	Nitrate	29	1.95	22	16.8
		Orthophosphorus	28	0.37	21	1.70
		Total Phosphorus	29	0.69	21	1.87

Streamflow and Water Level Data

With regard to streamflow and water level data, no records were found for Segment 1431 within the SWQMIS data, although estimated flow (parameter code 74069) was occasionally reported. Flow severity (parameter code 01351), which is reported as 1 (no flow), 2 (low flow), 3 (normal flow), 4 (flood flow), 5 (high flow) and 6 (dry), was commonly indicated with water quality data. Flow severity is an observational measurement that is highly dependent on the waterbody and the knowledge of the monitoring personnel, but is useful as an indicator of flow conditions at the time water quality samples are collected.

The nearest active United States Geological Survey (USGS) gage (08143600) was located about 15 miles downstream of Segment 1431 on Pecan Bayou near Mullin, Texas (USGS, 2010d). The history of daily data for USGS gage 08143600 extends back to 1967 for discharge and 1998 for gage height. Real-time or instantaneous data are also available for 08143600 starting in October 1996. Patterns of flow for Pecan Bayou at gage 08143600 for data since 1990 indicate the highest flows generally in February and June and the lowest flows often in January, August and

September (Figure 5). Pecan Bayou generally has flow year round, but at times during the late summer and early fall has shown zero or no flow conditions. Provisional data indicate that the lowest overall flow conditions have occurred during the most recent water year, 2011. While located well downstream of Segment 1431, the flows at USGS gage 08143600 should be indicative of the relative flow conditions within Mid Pecan Bayou.

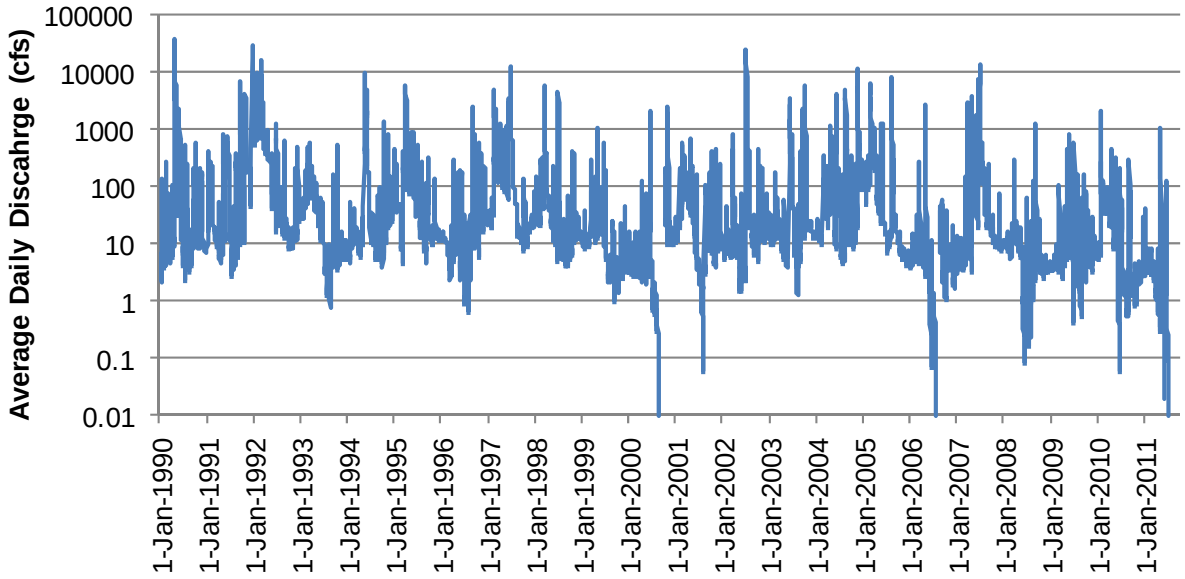

Figure 5 Daily average flow for USGS Station 08143600 Pecan Bayou near Mullin, Texas.

Precipitation Records

The National Weather Service (NWS) currently maintains a weather station within the Brownwood area. Daily weather data for a period of 30 years (1981-2010) from the NWS Brownwood station (Station number: 411138) were downloaded via the National Climatic Data Center (NCDC) website (NCDC, 2011).

Daily precipitation data obtained from the NWS station in Brownwood indicates that annual rainfall totals have been quite variable during the past 30 years (Figure 6). The 30-year average rainfall for the Brownwood area was calculated as 776 mm (30.6 inches). It should be noted that the 30-year average excludes data from the years 1984, 1985, 1987, 1994, 1998, and 2004 due to significant amounts of missing precipitation data during these six years. The wettest months are generally May, June, and September, while the driest months are generally January, November and December.

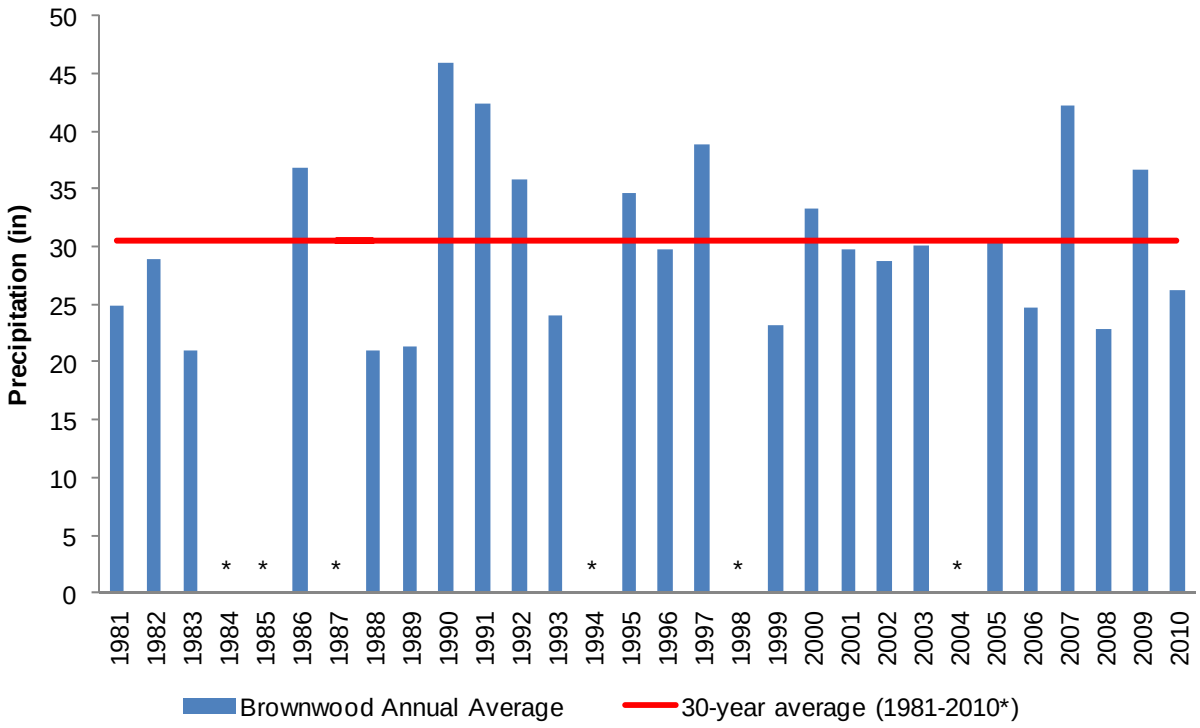

Figure 6 Temporal variability of annual precipitation at Brownwood, Texas. Data source: National Weather Service. Asterisks (*) indicate years with incomplete data excluded in calculating the 30-yr average.

SECTION 4

Bacteria Source Survey

Potential sources of fecal pollution, as measured by indicator bacteria *E. coli*, can be divided into two primary categories: *regulated* and *non-regulated*. Pollution sources that are regulated have permits issued by TCEQ under the Texas Pollutant Discharge Elimination System (TPDES) and/or by the USEPA under the National Pollutant Discharge Elimination System and are generally point sources. Examples of regulated sources are WWTF discharges and stormwater discharges from industries, construction, and municipal separate storm sewer systems (MS4s) of cities; and concentrated animal feeding operations (CAFOs). These various regulated sources are required to have either an individual permit that is specific for their facility or operate under a general permit. Non-regulated sources are typically nonpoint source in nature, meaning the pollution originates from multiple diffuse locations and is usually carried to surface waters by rainfall runoff and is not regulated by permit under the TPDES.

Permitted Sources

Wastewater Treatment Facilities

There is one permitted WWTF located within Segment 1431 that is operated by the City of Brownwood (permit WQ0010565-001). The WWTF is located at the southeast end of Hoover Avenue within the City of Brownwood (see Figure 3). Treated domestic wastewater effluent is discharged into Willis Creek, a tributary to Mid Pecan Bayou. The WWTF is authorized to discharge domestic wastewater at an annual average flow not to exceed 4.54 million gallons per day (MGD). Monthly average discharge data from February 2005 through March 2009 for Brownwood's WWTF was obtained from the United States Environmental Protection Agency (USEPA) permit compliance system (PCS) database (USEPA, 2010). Based on the data obtained from the USEPA website the actual annual average flow for the City of Brownwood WWTF was 2.57 million gallons per day.

Brownwood's WWTF is an activated sludge process plant operating in the extended aeration mode. The Brownwood WWTF utilizes a chlorine contact chamber for disinfection of wastewater. As of January 1, 2010, a new TCEQ rule requiring bacteria effluent limits and monitoring requirements has been established for new and amended WWTF permits statewide. The TCEQ has not yet applied these rules to the Brownwood WWTF permit. As such, there is no *E. coli* effluent limit or *E. coli* effluent monitoring requirements in Brownwood's permit. There were no bacteria monitoring data available for the WWTF effluent discharge either through the USEPA compliance database or from the Brownwood WWTF. A compliance history review conducted utilizing the PCS database and personal communications with the TCEQ Region 3 office did not reveal any significant compliance issues with the Brownwood WWTF.

Regulated Stormwater

The TPDES MS4 Phase I and II rules require municipalities and certain other entities in urban areas to obtain permits for their stormwater systems. Phase I permits are individual permits for large and medium sized communities with populations exceeding 100,000, whereas Phase II permits are for smaller communities that are located within an "Urbanized Area". An "Urbanized Area" is defined by the U.S. Census Bureau as an area with populations greater than 50,000 and

with an overall population density of at least 1,000 people per square mile. Further, TCEQ is also authorized to "designate" MS4 Phase II applicable coverage outside of UAs if the area's population is greater than 10,000 with a density of at least 1,000 people per square mile. The City of Brownwood has a total population of 19,288 based on 2010 population estimates from U.S. Census Bureau (Texas State Data Center, 2011) and is not considered to be located in an Urbanized Area based on population density, thus, the City of Brownwood does not meet the designated MS4 thresholds and is not required to obtain a permit for their MS4.

Concentrated Animal Feeding Operations

There is currently one permitted CAFO located within Segment 1431. The Brown-Tex Feedlot is located at 1900 FM 2126 along the northern boundary of the Mid Pecan Bayou watershed (see Figure 3). The Brown-Tex Feedlot is currently permitted by TCEQ to hold 2,500 head of beef cattle under permit number TXG921184. A compliance history review revealed a formal TCEQ enforcement action against the feedlot in response to a complaint investigation performed in March 2010. The investigation of the complaint resulted in a finding of an unauthorized discharge of agricultural waste. A review of the agreed order (docket number 2010-0865-AGR-E) indicates that corrective action had been implemented. Subsequently, a comprehensive compliance investigation conducted by TCEQ on the Brown-Tex Feedlot in April 2011 found the facility to be in compliance.

Permitted Land Application of Sewage and Septage Sludge

A query performed on September 12, 2011 of the TCEQ database for registered land application sites by a member of the TCEQ Municipal Permits Team indicated that there are currently no registered land application sites in Brown County that receive Class B sewage sludge or septage sludge.

Non-permitted Sources

Non-Permitted Agricultural Activities and Domesticated Animals

Statistics of livestock in Brown County based on 2010 estimates obtained from United States Department of Agriculture (USDA) National Agricultural Statistics Service website (USDA, 2011) indicate that a variety of livestock reside within the watershed (Table 8). These livestock numbers represent the entirety of Brown County and do not reflect actual numbers in the Mid Pecan Bayou watershed; however, the livestock numbers should reflect anticipated relative livestock populations, e.g., more cattle present than goats.

It should be noted that the livestock numbers obtained by the USDA represent the number of livestock present in the County at the time the survey was conducted, and those numbers likely change throughout the year due to economic factors and environmental conditions (e.g., market values, drought, etc.). The Mid Pecan Bayou watershed is entirely within Brown County and comprises about 11 percent of the county (Figure 7). Activities such as livestock grazing close to waterbodies and agricultural use of manure as fertilizer, can contribute *E. coli* to nearby waterbodies. Furthermore, pets can also be sources of *E. coli* bacteria, because storm runoff carries the animal wastes into streams (USEPA, 2009).

Table 8 Livestock statistics for Brown County (Source USDA, 2011).

Livestock	Number within Brown County	Estimated Number within the Mid Pecan Bayou Watershed[a]
All Cattle and Calves	59,000	6,490
All Goats (meat and other)	14,000	1,540
All Sheep and Lambs	6,000	660
Hens and Pullets of Laying age	2,000	220
Equine	2,300	250

a. Estimated livestock numbers for Mid Pecan Bayou derived as a direct proportion of the watershed area within Brown County.

Wildlife

E. coli bacteria are common inhabitants of the intestines of all warm blooded animals, including wildlife, such as deer, raccoons, and birds. With access to the stream channel, direct deposition of animal waste can be a concentrated source of bacteria loading to a waterbody. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. The Texas Parks and Wildlife Department (TPWD), including the local game warden, were contacted, but information was unavailable regarding wildlife population estimates for the watershed of Segment 1431.

Feral Hogs

While feral hogs are not natural wildlife, they are an invasive species and as unmanaged or feral animals, they also contribute bacteria to streams in a manner similar to wildlife. Feral hogs are noted for moving in groups along waterways, and particularly in times of drought will congregate near perennial water sources to drink and wallow. Texas Parks and Wildlife Department classifies feral hogs as unprotected, exotic, non-game animals (Taylor, 2003). Although found throughout much of Texas, there is a scarcity of data on feral hog densities in Texas. Studies in comparable bottomland habitats indicate typical densities of nearly 30 hogs per square mile (Tate, 1984 and Hone, 1988).

Failing On-Site Sewage Facilities

OSSFs, also known as septic systems, are often used in rural areas that do not have the ability to connect to a central wastewater collection system. The following information was obtained through personal communications with the Brown County OSSF program designated representative. Currently there are 2,912 permitted OSSFs located in Brown County, most of which are anaerobic systems. It should be noted that the total OSSF count is for the entirety of Brown County and does not include “grandfathered” OSSFs that are exempt from permitting requirements. The representative indicated that most of the OSSF complaints received were regarding OSSFs located near Lake Brownwood north of the Mid Pecan Bayou watershed. The representative added that the rural areas of Brown County rarely submitted complaints regarding OSSFs and was likely due to the low population density in those areas.

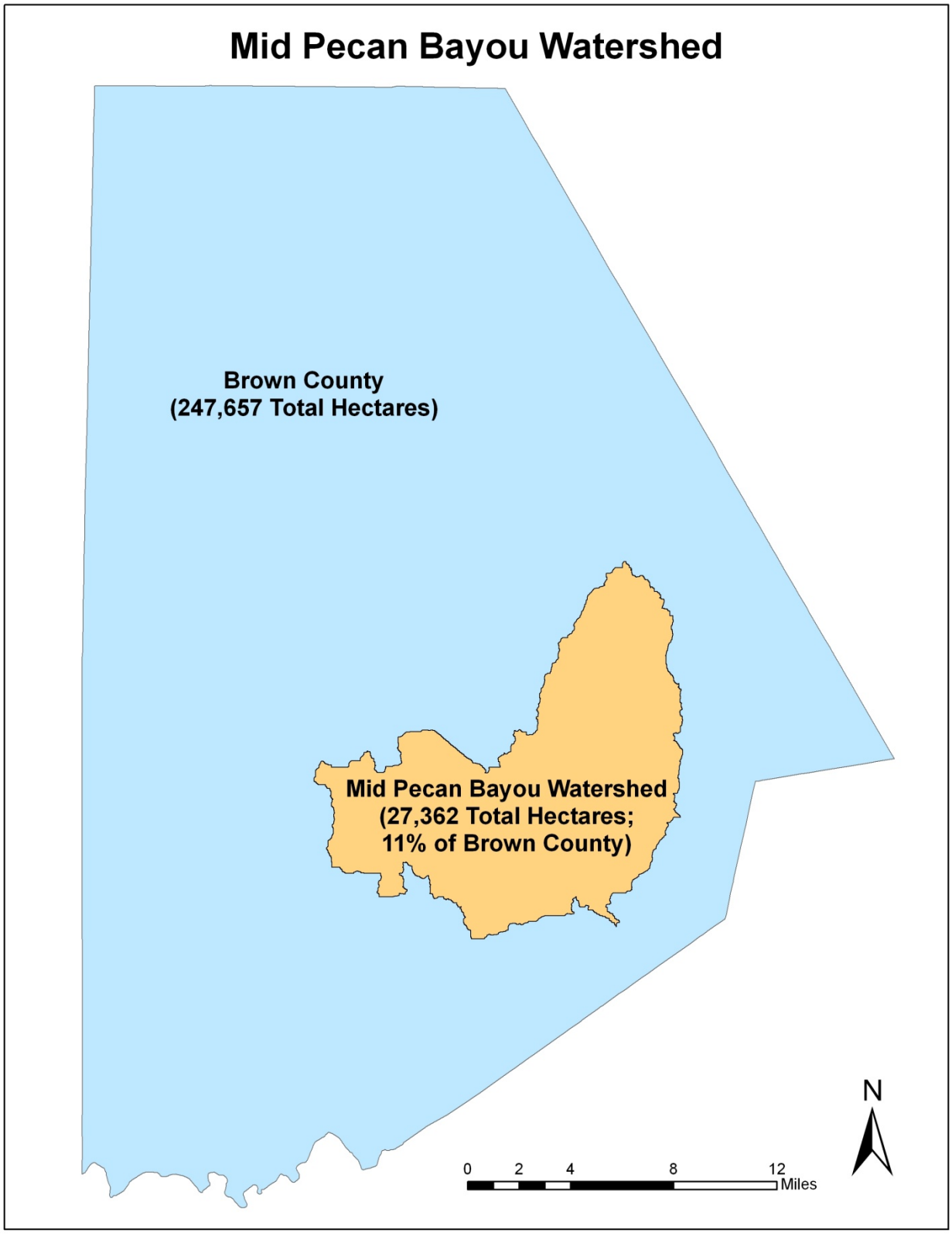

Figure 7 Location and area covered by Mid Pecan Bayou watershed within Brown County, Texas.

Observed Sources

As part of the site reconnaissance for the RUAA and during the RUAA surveys conducted for this project, TIAER field staff noted any observations of potential bacteria sources to Mid Pecan Bayou. The most common potential sources observed were birds, wildlife, feral hogs, and livestock. Some unidentified pipes were noted leading directly into the stream, but these were most likely related to uptake of irrigation water from the stream rather than discharge.

Birds

Avian rookeries were noted along Mid Pecan Bayou (Figure 8) as shown near RUAA site MP004 (see Figure 3 and Table 3 for specific locations of RUAA sites), while swallow nests and bird droppings where apparent below the bridge on FM 2126 near RUAA site MP007 (Figure 9). Turkey tracks were also noted at several sites as shown in Figure 10.

Figure 8 Avian rookery near RUAA site MP004 and bird droppings below rookery (Photos taken September 3, 2011).

Figure 9 Swallow nests and bird droppings under bridge at FM 2126 near RUAA site MP007 (Photos taken June 10, 2011).

Figure 10 Turkey tracks noted at RUAA site MP001 on Mid Pecan Bayou (Photo taken September 2, 2011).

Wildlife

Raccoon tracks were the main sign of wildlife noted along Mid Pecan Bayou, while deer tracks were also common. Raccoon and deer tracks were noted all along Mid Pecan Bayou during both RUAA surveys conducted in June and September 2011 with examples shown in Figure 11. In similar floodplain areas, raccoons have been estimated to potentially deposit the most *E. coli*, followed by feral hogs, opossums, and white-tailed deer (Parker, 2009). The TSSWCB is currently funding a project to help identify, characterize, and quantify *E. coli* depositions to floodplains from the major free-ranging wildlife contributors (i.e., TSSWCB Project 07-06 *Fate and Transport of E. coli in Rural Texas Landscapes and Streams*).

Figure 11 Raccoon and deer tracks along the bank of Mid Pecan Bayou near RUAA site MP001 (Photos taken September 2, 2011).

Invasive Species (feral hogs)

Feral hog dung was noted at RUAA sites MP001, MP002, and MP004 during the June 2011 survey (example shown in Figure 12). At MP004, a hog run was clearly visable, indicating frequent hog activity at this location (Figure 12).

Figure 12 Examples of hog activity as shown by hog dung and a hog run at RUAA monitoring site MP004 (Photos taken June 10, 2011).

Livestock

Cattle tracks and cow dung were noted at almost all the RUAA sites along Mid Pecan Bayou during the June and September 2011 monitoring surveys as well as during the scouting trip in April 2011. Examples of livestock prescence are shown in Figure 13.

a) b)

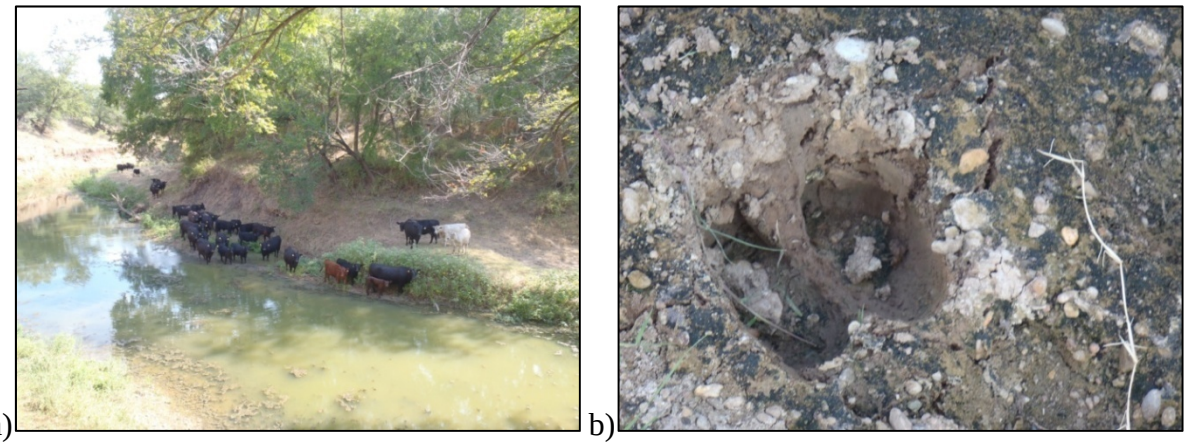

Figure 13 Signs of livestock along Mid Pecan Bayou at a) MP004 and b) cow tracks at MP001 (Photos taken September 3 and 2, 2011, respectively).

Unidentified Pipes

Unidentified pipes were noted at several locations along Mid Pecan Bayou, primarily near RUAA sites MP007 and MP008, but also at MP005 (Figure 14). All of these pipes appeared to be related to irrigation withdrawls from Mid Pecan Bayou rather than discharges to the bayou.

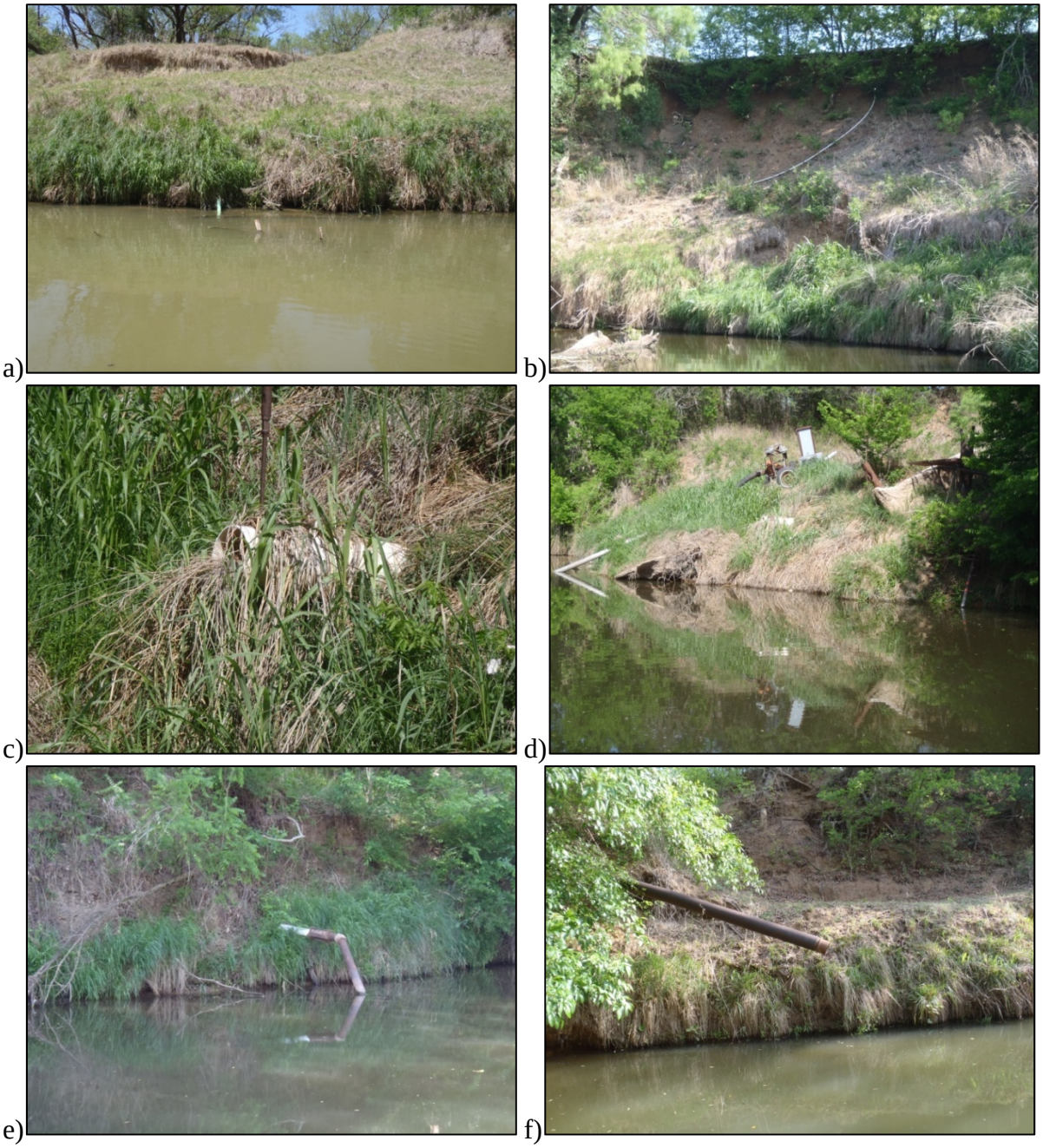

Figure 14 Unidentified pipes: a) pipe near MP005, b) pipe 30 m downstream MP007, c) pipe 90 m downstream MP007, d) pump and pipe 90 m downstream MP007, e) pipe 120 m downstream MP007, and f) pipe downstream of MP008 near Willis Creek confluence (Photos taken April 14, 2011).

Upstream Contributions

Mid Pecan Bayou is not an isolated waterbody in that it receives flow from immediately upstream from Upper Pecan Bayou (Segment 1432). In quering SWQMIS, bacteria data were only available for station 12508 (Pecan Bayou at US 377) along Upper Pecan Bayou through May 5, 2010 (Figure 15; TCEQ, 2010c). Station 12508 is located about four miles upstream of where Segment 1431 for Mid Pecan Bayou begins. The 2010 water quality assessment indicates for data collected between 2001 and 2008 that the Upper Pecan Bayou is fully supporting of the criterion for primary contract recreation use (TCEQ, 2010b). The 2010 water quality assessment indicates a geometric mean for Segment 1432 of 101 most probable number per 100 milliliters (MPN/100 mL) for *E. coli* based on 25 samples. For comparison, a geometric mean for Segment 1431 was indicated of 228 MPN/100 mL based on 26 samples.

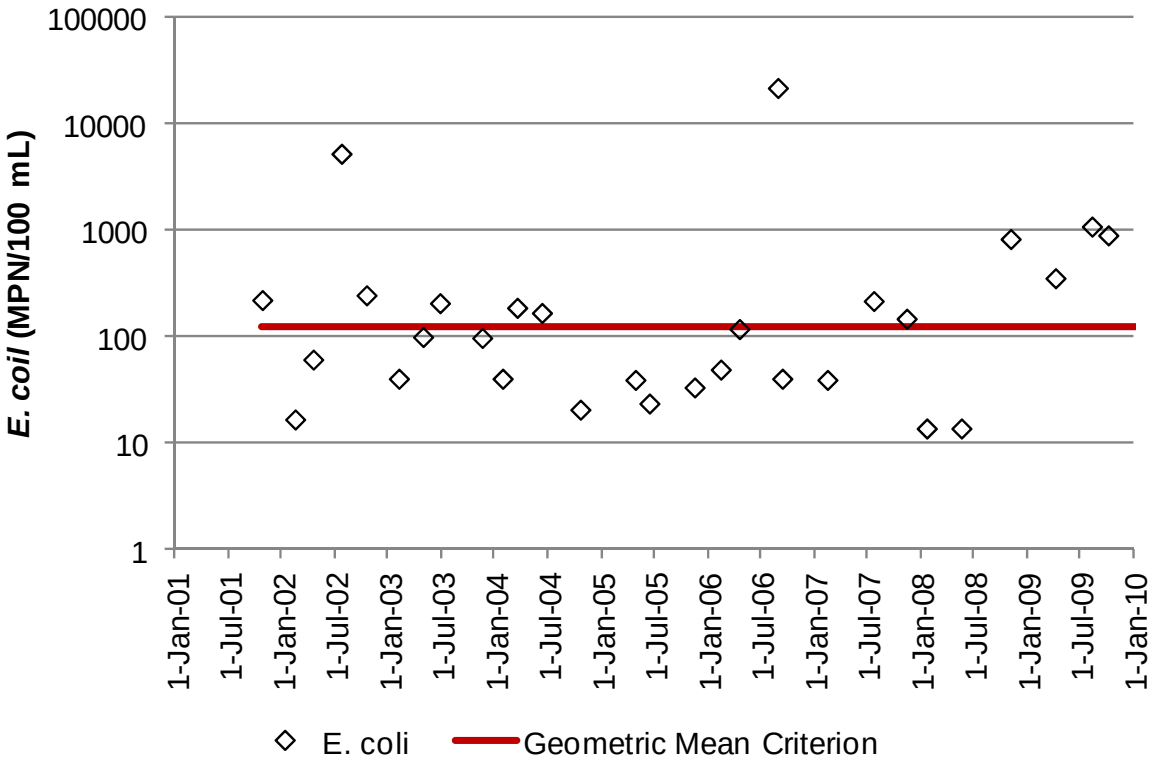

Figure 15 Historical data from station 12508 along Upper Pecan Bayou (Segment 1432) for *E. coli*.

SECTION 5

Water Quality Analysis

Assessment Review

Historical water quality data as noted in Section 3 for *E. coli*, fecal coliform, nitrate, orthophosphorus, and total phosphorus for stations 12503 and 12504 in Segment 1431 were obtained from TCEQ's publicly available online SWQMIS database (see Table 5 for specific constituents and parameter codes). These data were evaluated using TCEQ assessment guidance for the same periods of record used by TCEQ (see Tables 6 and 7). As mentioned previously, station 12503 only had one sampling event with nutrient data and no bacteria data since 1999. No other sampling stations within Segment 1431, except 12503 and 12504, had nutrient or bacteria data during the assessment periods. Assessment of these historical data was performed by TIAER following TCEQ's publications "Guidance for Assessing and Reporting Surface Water Quality in Texas" as used for each assessment period beginning with the 2006 assessment (TCEQ, 2006, 2008, 2010). The results of TIAER's assessment matched those performed by TCEQ and confirm the impairments and concerns noted on the Texas 303(d) List for Segment 1431 noted in Tables 6 and 7.

Trends

All available data from station 12504 pertaining to bacteria and nutrient concentrations relevant to this study were plotted to obtain a general overview of changes over time (Figures 16-19). This dataset varies from what was used in the assessment review of Segment 1431 in that the data were not truncated to a specific period of record. In addition data from station 12503 were utilized in the assessment of Segment 1431; however data from 12503 were excluded from the trend plots, because only two data points were available for nutrient constituents and none for bacteria at station 12503 for the entire period of record.

A relatively long period of record for fecal coliform concentrations (Sep. 1973—Nov. 2003) was available for station 12504 (Figure 16a). A shorter period of record was available for *E. coli* concentrations (Feb. 1996—May 2010) that also contained a fairly large gap in the dataset between December 1996 and October 2001 (Figure 16b). Plots of the fecal coliform and *E. coli* concentrations did not indicate a clear association with increases or decreases in concentrations over time.

A relatively long period of record for nitrate, orthophosphorus, and total phosphorus was available for station 12504 (Figures 17-19). As noted in Table 5, nitrate is represented in the data analysis as measurements of nitrite + nitrate nitrogen (NO_2-N+NO_3-N). Plots of all three nutrient constituents indicate that exceedances in the screening criteria for each constituent have been common throughout the available period of record. Concentrations of nitrite + nitrate nitrogen appeared to increase over time, while phosphorus concentrations showed a slight decrease starting in the early 1990s, but still frequently exceeded screening levels.

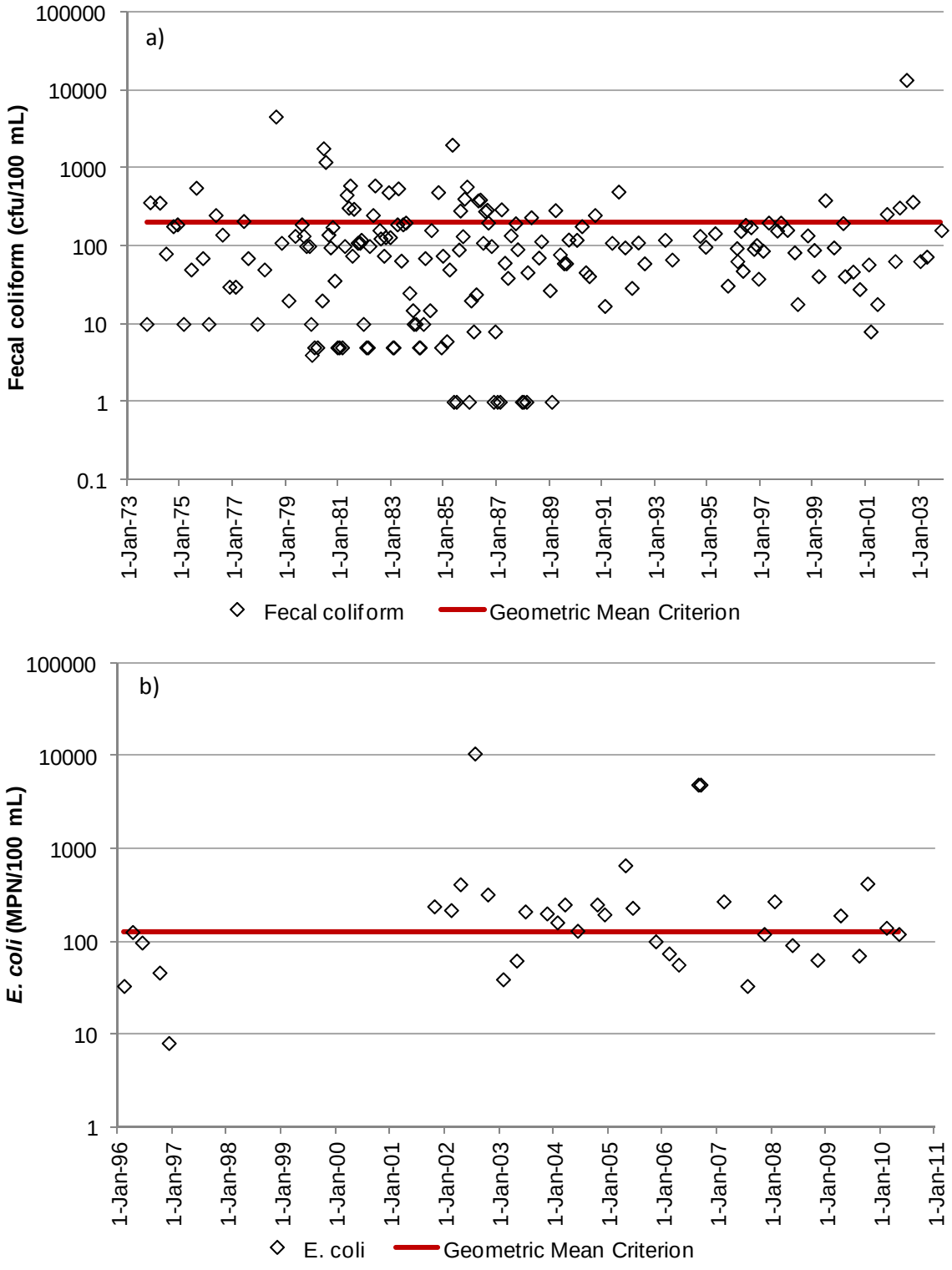

Figure 16 Historical data from Mid Pecan Bayou (Segment 1431) station 12504 for a) fecal coliform and b) *E. coli*.

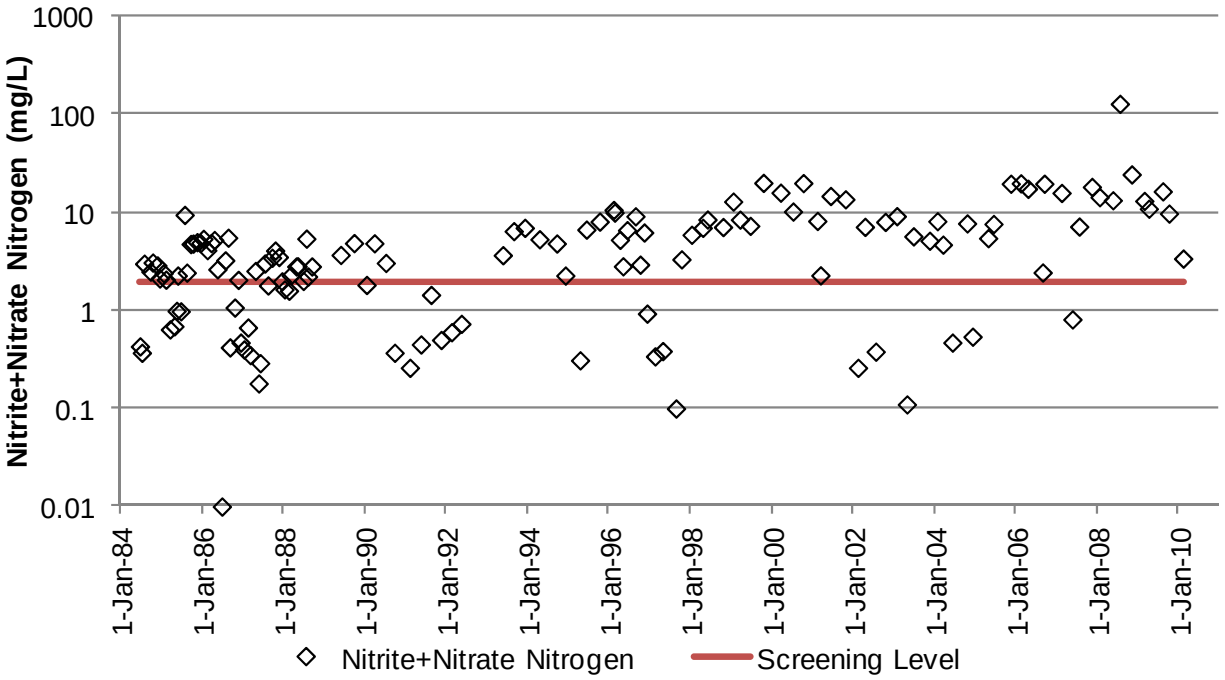

Figure 17 Historical data from Mid Pecan Bayou (Segment 1431) station 12504 for nitrite+nitrate nitrogen.

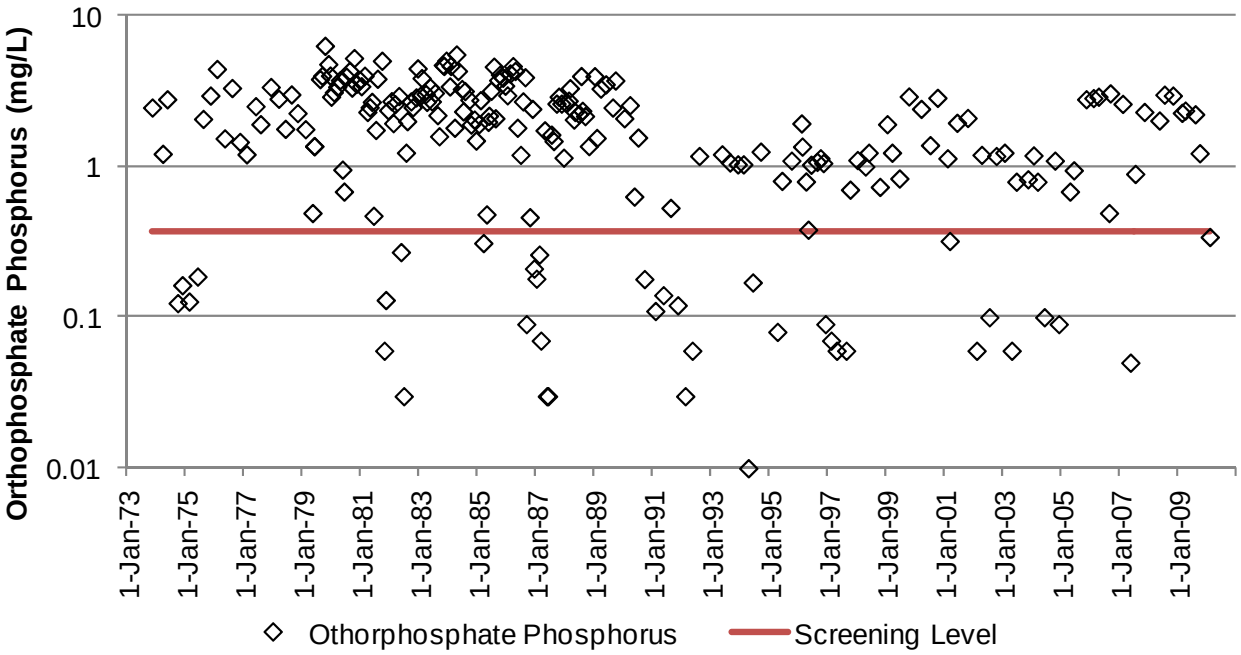

Figure 18 Historical data from Mid Pecan Bayou (Segment 1431) station 12504 for orthophosphate phosphorus.

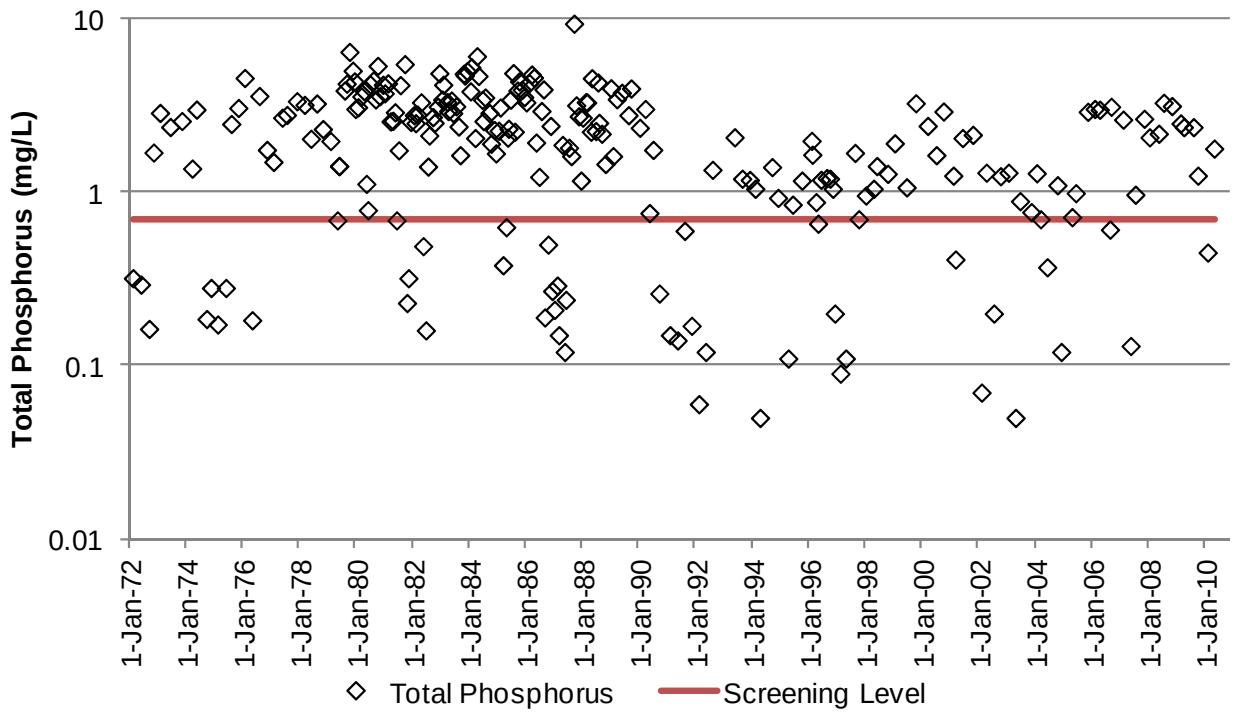

Figure 19 Historical data from Mid Pecan Bayou (Segment 1431) station 12504 for total phosphorus concentrations.

SECTION 6

Summary and Recommendations

In assessing sources of bacterial impairment, it is important to identify the potential for bacteria contributions from wildlife including birds and unmanaged feral animals. Wildlife are naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a waterbody. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. However, there are currently insufficient data available to estimate populations and spatial distribution of wildlife and avian species in the watershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category. Studies in other watersheds have found avian species to be important contributors to the bacteria load (e.g., Hussong et al., 1979; Hyer and Moyer, 2003). There is also little information available on contributions from feral animals, such as hogs, in the watershed.

In addition to wildlife, domestic pets and livestock can also contribute to bacteria. Fecal matter from pets and livestock is transported to streams by runoff in both urban and rural areas and can be a potential source of bacteria loading. Activities, such as livestock grazing close to waterbodies and use of manure and liquid waste as fertilizer on fields, can contribute *E. coli* to nearby waterbodies.

Permitted sources within the Mid Pecan Bayou watershed include a CAFO (Brown-Tex Feedlot) and the City of Brownwood WWTF. A compliance history review indicated that formal enforcement action had been taken against the CAFO; however a recent comprehensive compliance inspection revealed that the CAFO has resolved the issue and is currently in compliance. A compliance history review conducted on the Brownwood WWTF indicated that the facility was in compliance.

In reviewing historical water quality data, plots of the fecal coliform and *E. coli* concentrations did not appear to increase or decrease over time, so it is possible that potential sources of bacteria to the Mid Pecan Bayou watershed have remained the same since the early 1970's. Concentrations of nitrite + nitrate nitrogen appeared to increase over time, while phosphorus concentrations showed a slight decrease starting in the early 1990s. Although phosphorus concentrations showed a decrease, phosphorus concentrations still frequently exceeded screening levels. Based on the source survey, potential sources of pollutants in the watershed include both permitted and non-permitted sources. Further analyses, such as load duration curves (e.g., Cleland, 2003) and use of locally weighted scatter-plot smoothing (LOWESS) regression methods (e.g., Helsel and Hirsch, 1992), which assess the impact of hydrologic conditions associated with when water quality samples were collected would aid in determining the relative contribution of point and nonpoint sources, but were beyond the scope of the current project.

Also of note, almost all of the data used in assessing the water quality and defining the bacteria impairment of Segment 1431 comes from station 12504, which is located in the upper portion of the watershed. Water quality at station 12504 is largely impacted by upstream water quality associated with Segment 1432 (Upper Pecan Bayou) and contributions from Willis Creek, a

tributary that flows through the City of Brownwood and into which Brownwood's wastewater treatment facility (WWTF) discharges. To better assess water quality and define pollutant sources along Mid Pecan Bayou (Segment 1431), an additional monitoring station at the lower end of the AU would be useful, particularly if some remedial action, such as a Total Maximum Daily Load or Watershed Protection Plan, is taken to resolve the bacteria impairment.

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