Basin Approach to Address Bacterial Impairments in the Navasota River Watershed

Texas Water Resources Institute TR-476
May 2015

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Year One Report

Segment Numbers: 1209, 1210A, 1253

TCEQ Contract Number 582-14-42129-01

Funding Source
TCEQ FY 14/15 Categorical 106 WPC Grant
USEPA QTRAK# 14-304
Federal Grant # I9-8665307
State USAS Grant # 998817

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Texas Water Resources Institute Technical Report 476
May 2015
College Station, Texas

Submitted To
Total Maximum Daily Load Program
Office of Water, Planning and Implementation Section
Texas Commission on Environmental Quality
P.O Box 13087, MC-203
Austin, Texas 78711-3087

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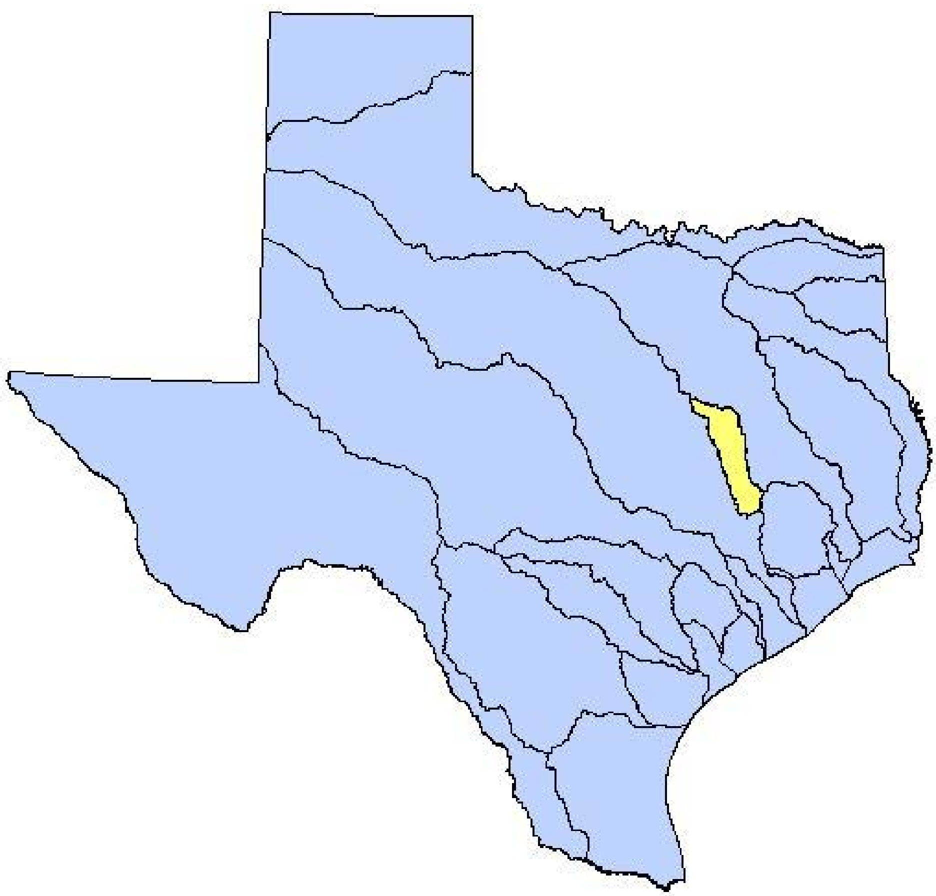


The Navasota River watershed in Texas

List of Acronyms

AU	Assessment Unit
BRA	Brazos River Authority
CAFO	Concentrated Animal Feeding Operation
CCN	Certificates of Convenience and Necessity
cfs	Cubic feet per second
cfu	Colony-forming unit (for bacteria)
CWA	Clean Water Act
DO	Dissolved Oxygen
ECHO	Enforcement and Compliance History Online
EPA	Environmental Protection Agency
FDC	Flow Duration Curve
GIS	Geographic Information System
ICIS	Integrated Compliance Information System
LDC	Load Duration Curve
MS4	Municipal separate storm sewer systems
MSGP	Multi-sector general permit
NC	Non-Compliance
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
OSSF	On-Site Sewage Facilities
RUAA	Recreational Use Attainability Analysis
SNC	Significant Non-compliance
SSO	Sanitary Sewer Overflow
SWQMIS	Surface Water Quality Monitoring Information System
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TPWD	Texas Parks and Wildlife Department
TSSWCB	Texas State Soil and Water Conservation Board
TWDB	Texas Water Development Board
USGS	United States Geological Survey
WPP	Watershed Protection Plan
WQMP	Water Quality Management Plans
WWTF	Wastewater Treatment Facility

Introduction

The *2012 Texas Integrated Report – Texas 303(d) List* identifies 11 impaired waterbody segments along the Navasota River due to *Escherichia coli (E.coli)* bacteria (Figure 1). The Clean Water Act (CWA) requires water bodies that are impaired for a specific parameter or condition, to be restored and their water quality maintained. Efforts to restore impaired waterbodies include additional monitoring, assessing the current standards and conditions of the waterbody, stakeholder outreach and education, and exploring opportunities for developing watershed restoration plans. Previous reports regarding the watershed have revealed *E. coli* levels to be elevated in specific tributaries since as early as 1999 (TCEQ 2013b; BRA 2011). The river's elevated *E.coli* levels do not comply with the state's recreational water quality criteria for primary contact recreation, which is established at 126 cfu/100 mL. Segment 1210A of the river, which lies above Lake Mexia, is an unclassified waterbody that has been named impaired by bacterial contamination since 2002. The Navasota River below Lake Mexia, segment 1253, is considered impaired for depressed dissolved oxygen (DO) because of frequent low water levels (BRA 2011). The project's goals include: (1) characterize the current bacteria loading and sources for the watershed, (2) determine the necessary levels of loading reduction to restore the water body, (3) work with stakeholders to select and prioritize management measures necessary to restore the waterbody, and (4) develop a watershed protection plan for the Navasota River below Lake Limestone.

This report discusses the climatic, physical, demographic, and hydrological conditions as well the potential sources of pollution within the watershed. The report also includes an assessment of current and historical conditions within the Navasota River watershed and aims to begin the process of defining its current bacteria levels. Information is largely presented on a watershed-wide basis; however, where appropriate and possible, information is discussed on a more refined scale.

Description of the Watershed

The Navasota River Watershed covers 1,438,718 acres spanning parts of 8 counties. These include Brazos, Freestone, Grimes, Hill, Leon, Limestone, Madison, and Robertson County (Figure 1). The area of the watershed within each county, percent of the county in the watershed, and the percent of the watershed in each county are all presented in Table 1.

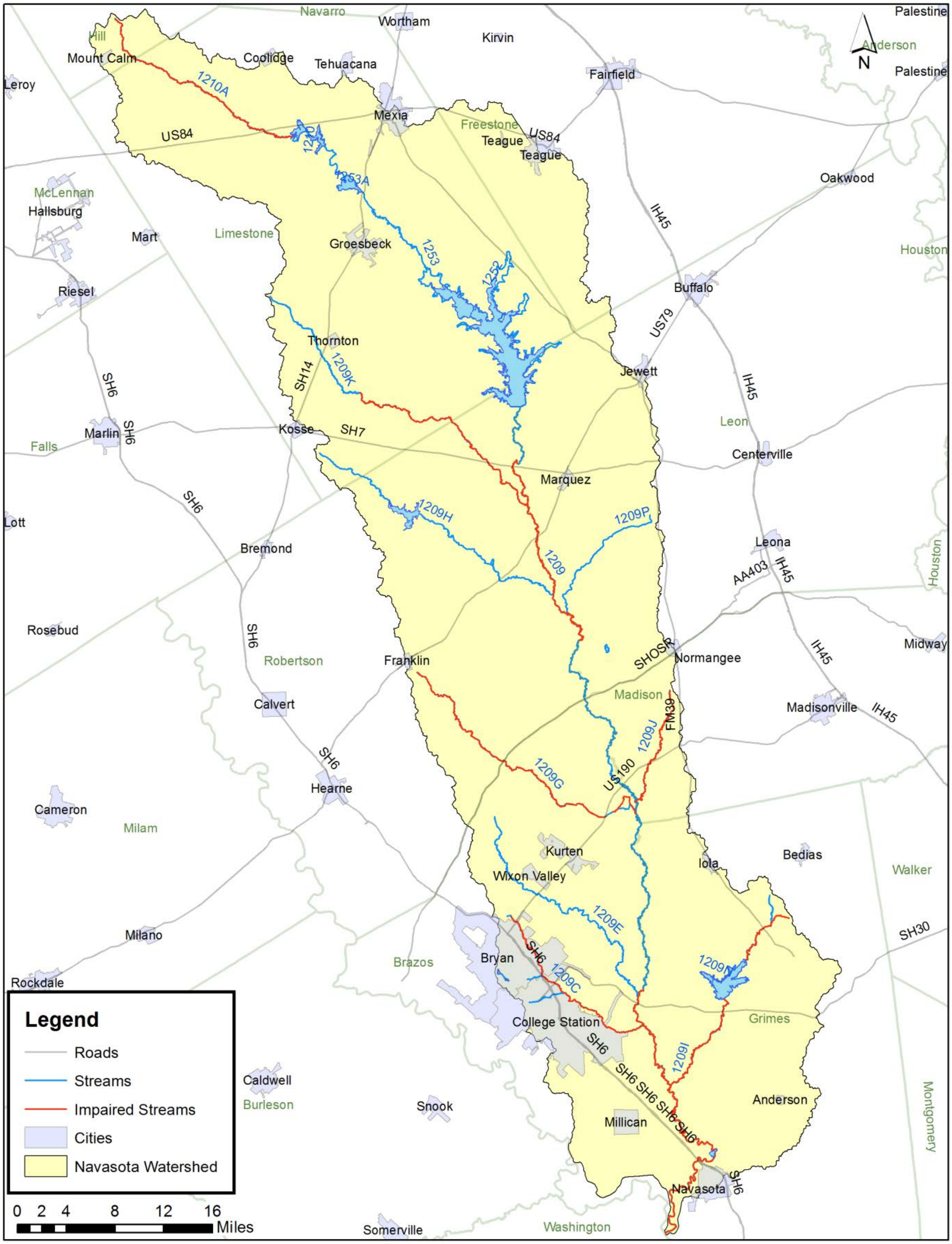


Figure 1. The Navasota River Watershed

Table 1. General Numerical Characteristics of the Watershed Distribution Within Each County

	Area of Total County (acres)	Area of watershed within the county (acres)	Percent of the total county within the watershed (%)	Percent of the watershed within each county (%)
Brazos	378,118	266,781	70.6	18.5
Freestone	571,546	66,276	11.6	4.6
Grimes	514,240	206,915	40.2	14.4
Hill	630,810	12,270	1.9	0.9
Leon	692,301	173,087	25.0	12.0
Limestone	597,530	431,493	72.2	30.0
Madison	302,771	44,939	14.8	3.1
Robertson	554,368	236,957	42.7	16.5
Entire Watershed		1,438,718		

The river forms in southern Hill County and extends southeast until connecting with the Brazos River at the southern-most extent of Brazos County. The watershed encompasses a predominantly rural portion of Texas. Grazing lands and forests cover much of the area and the only sizable urban areas are the cities of Bryan and College Station in Brazos County. Agricultural interests dominate the use of the watershed area; however, industrial operations such as oil and gas exploration and production, coal mining, steel production and power generation are also common in the watershed. High quality wildlife habitat is also a cornerstone of the watershed as it contains one of the largest remaining bottomland hardwood forests in Texas. These forests include oak, hickory, elm, pecan, sweetgum, and redbud trees.

Lakes Limestone and Mexia significantly impact the hydrology of the watershed and essentially divide the river into three primary segments: the Navasota River above Lake Mexia (segment 1210A), the Navasota River below Lake Mexia (segment 1253), and the Navasota River below Lake Limestone (segment 1209) (Figure 2). The Texas Commission on Environmental Quality (TCEQ) describes these segments in the *2012 Texas Water Quality Integrated Report* as:

- <u>Navasota River below Lake Limestone (Segment 1209):</u> From the confluence with the Brazos River in Grimes County to Sterling C. Robertson Dam in Leon/Robertson County
- <u>Navasota River above Lake Mexia (Segment 1210A):</u> From the confluence with the headwaters of Lake Mexia in Limestone County to a point 1.25 miles upstream of SH 31 in Hill County
- <u>Navasota River below Lake Mexia (Segment 1253):</u> From a point 2.3 km (1.4 miles) downstream of SH 164 in Limestone County to Bistone Dam in Limestone County

Other sizable reservoirs in the watershed include Springfield Lake on the Navasota River between Lakes Limestone and Mexia, Twin Oak Reservoir on Duck Creek in Robertson County, and Gibbons Creek Reservoir in Grimes County. These reservoirs provide water supplies for cooling water, recreation, and public consumption.

Hydrology

The Navasota River extends approximately 139 miles from southern Hill County to its confluence with the Brazos River (BRA 2007). The river above and below Lake Mexia (segments 1210A and 1253) is characterized as a small prairie stream experiencing little to no flow frequently throughout the year (TCEQ 2010c). The Navasota River below Lake Limestone (segment 1209) begins at the outfall of the Sterling C. Robertson Dam and continues downstream to its confluence with the Brazos River, west of the town of Navasota (Figure 1). The river traverses some of the few remaining bottomland hardwood habitats in the state. This segment of the river is characterized by its narrow shape with river banks ranging from relatively accessible to very steep and incised. Groundwater return flows and wastewater inputs sustain the river's flow between storm events. Lake releases from Lake Limestone also have a significant influence on instream water levels in Segment 1209; however, releases are most commonly made following storm events and less frequently to supply water to downstream users.

This region of the river lies in a large floodplain and is prone to frequent floods after large rainfalls. Historical data available from U.S. Geological Survey (USGS) gaging stations and summarized in Phillips (2007) notes floods of record on the Navasota River at US Hwy 79 occurring in 1899 when recorded streamflow reached 90,000 cubic feet per second (cfs). Downstream at Old San Antonio Road, the flood of record was measured in 1999 when the river crested at 6 feet above flood stage, and flow was measured at 30,100 cfs. The rural nature of the watershed, which is dominated by mixed forests and managed pastures or rangelands, naturally attenuates these floods by absorbing vast amounts of water to the point of saturation before yielding runoff that produces a flood. Much like a truly natural system functions, high flow conditions following a flood are typically extended as the watershed slowly releases stored moisture. The cities of Bryan and College Station produce the largest amount of stormwater runoff, which can and do cause rapid rises and falls in local stream flow.

Numerous tributaries of the Navasota River drain the watershed and 11 of them have been given segment identification codes by TCEQ. Of these, four lie within the cities of Bryan and College Station while the other seven flow through rural areas. All 11 of these tributaries contribute water to the Navasota River below Lake Limestone. Table 2 provides the segment ID, name of the stream and TCEQ's description of the waterbody while their location in the watershed can be seen in Figures 1 and 2.

The tributary network across the watershed enables the watershed to be subdivided into smaller units that are useful when discussing specific areas of the watershed. The hydrology of the system was used to create these smaller management units. In most cases, one of the tributaries described earlier was used as the aggregating unit. Using this approach, 16 smaller subwatersheds were produced, with 13 of those being downstream of Lake Limestone. Figure 3 depicts the location of these subwatersheds.

Table 2. Segments of the Navasota Watershed

Segment ID	Name	Description
1210A	Navasota River above Lake Mexia	From the confluence with the headwaters of Lake Mexia in Limestone County to a point 1.25 miles upstream of SH 31 in Hill County
1253	Navasota River below Lake Mexia	From a point 2.3 km (1.4 miles) downstream of SH 164 in Limestone County to Bistone Dam in Limestone County
1209	Navasota River below Lake Limestone	From the confluence with the Brazos River in Grimes County to Sterling C. Robertson Dam in Leon/Robertson County
1209C	Carter's Creek	Perennial stream from the confluence with the Navasota River southeast of College Station in Brazos County upstream to the confluence of an unnamed tributary 0.5 km upstream of FM 158 in Brazos County
1209E	Wickson Creek	Perennial stream from the confluence with an unnamed first order tributary (approximately 1.3 km upstream of Reliance Road crossing) upstream to the confluence with an unnamed first order tributary approximately 15 meters upstream of Dilly Shaw Road
1209G	Cedar Creek	From the confluence with the Navasota River in Brazos County to the confluence with Moores Branch and Rocky Branch in Robertson County
1209H	Duck Creek	From the confluence with the Navasota river in Robertson County to Twin Oak Reservoir dam in Robertson County
1209I	Gibbon's Creek	From confluence with Navasota River in Grimes County to SH 90 in Grimes County
1209J	Shepherd Creek	From the confluence with the Navasota River in Madison County to a point 0.7 miles upstream of FM 1452 in Madison County
1209K	Steele Creek	From confluence with Navasota River in Robertson County to a point 2.4 miles upstream of FM 147 in Limestone County
1209L	Burton Creek	From the confluence with Carters Creek in College Station, upstream to its headwaters located 0.4 miles east of Fin Feather Lake in Brazos County.
1209P	Clear Creek	From the confluence with Navasota River below Lake Limestone upstream to headwaters, 11 km southeast of Marquez in Leon County

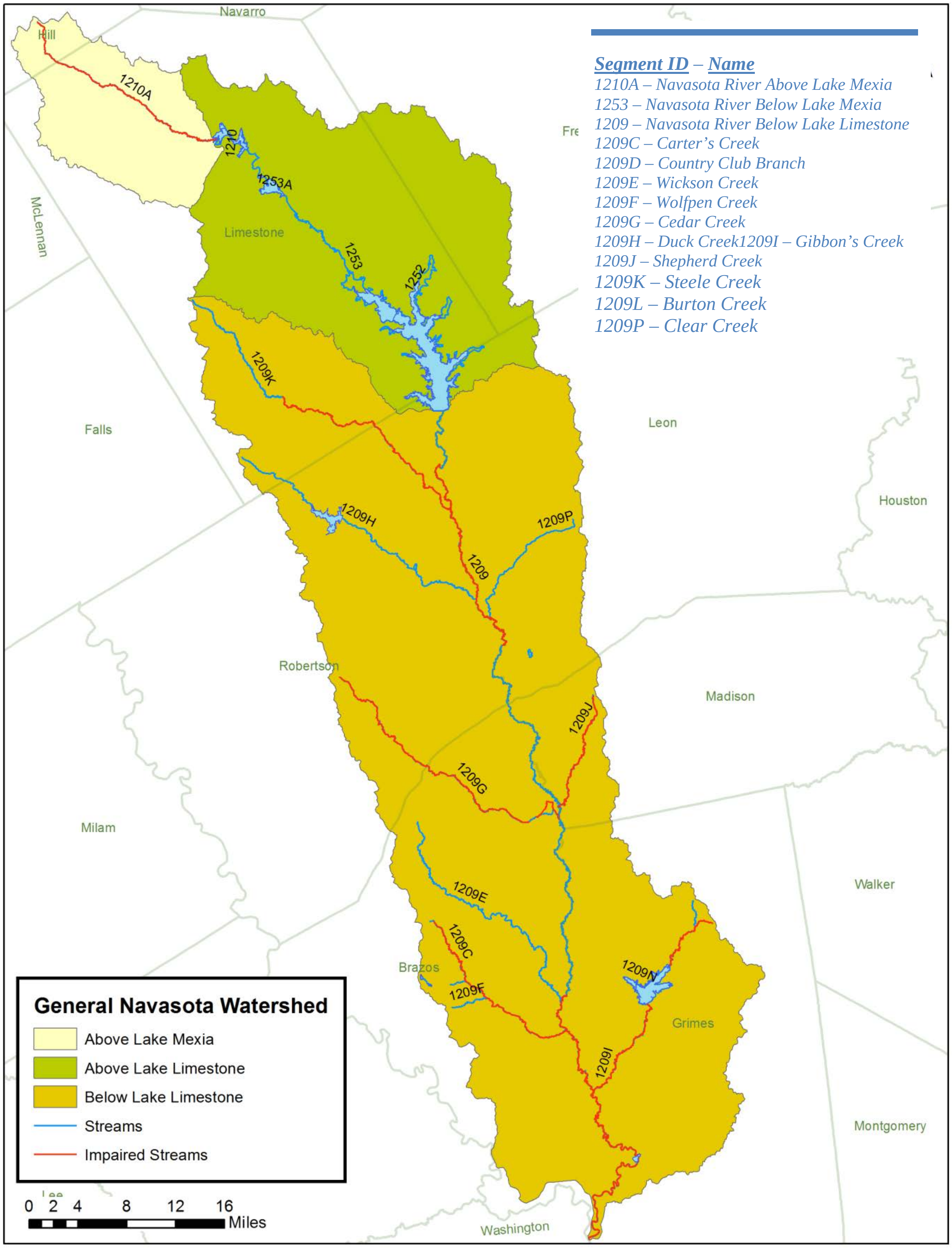


Figure 2. The Navasota Watershed Divided into Three General Watersheds

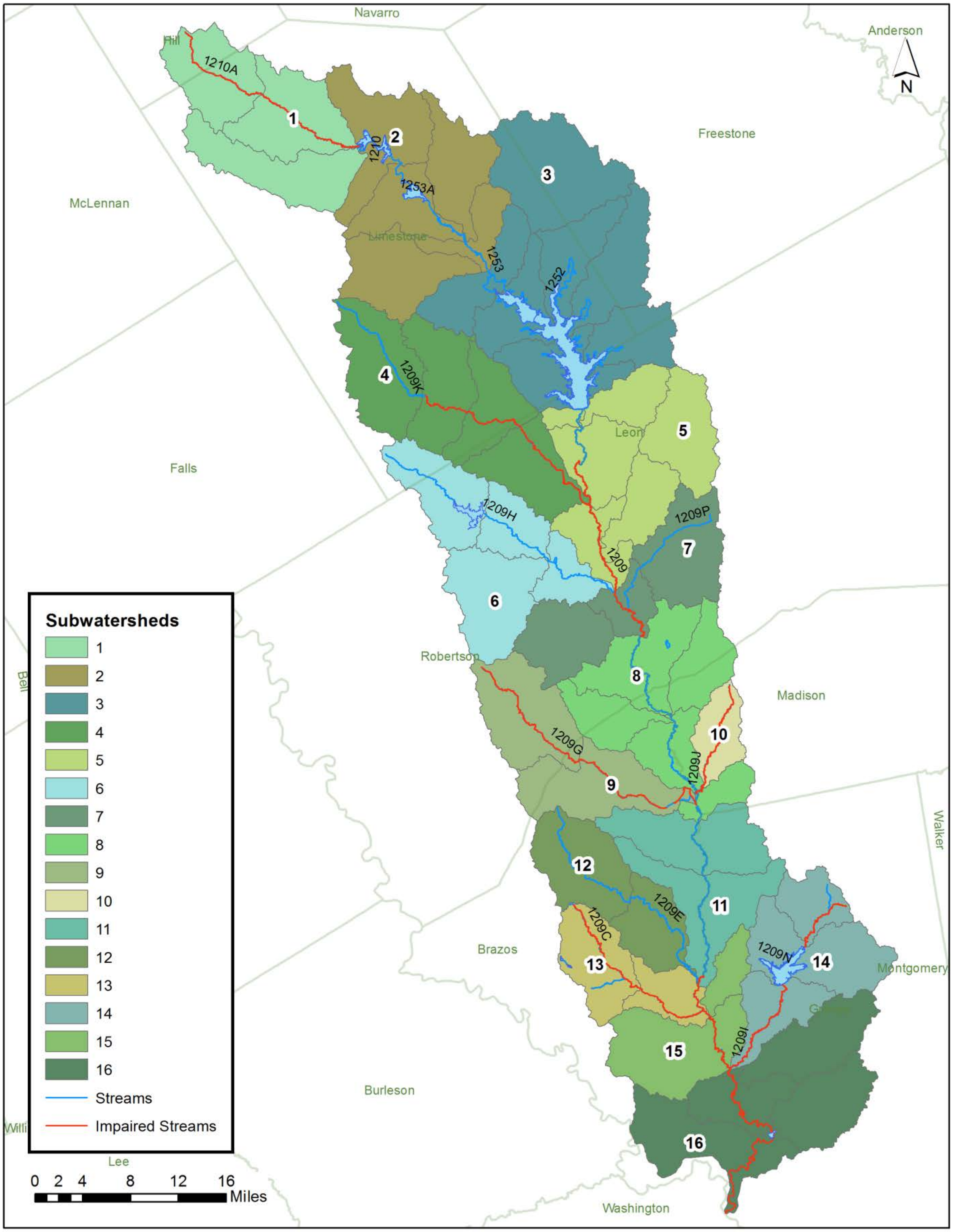


Figure 3. Subwatersheds of the Navasota River

Ecoregions

An ecoregion is a large area of land containing a geographically distinct ecosystem that has a unique environmental conditions, species, natural communities, and natural resources (Omernik 2004). Ecoregions are essential for structuring and implementing ecosystem management strategies for maintaining and using resources within the area (Omernik 1995). They are subdivided into four levels: ecoregion I is the most general classification while ecoregion IV is the most defined. The Navasota watershed lies within the level III ecoregions 32, the Texas Blackland Prairies, and 33, the East Central Texas Plains. More specifically, the watershed lies within the level IV ecoregions 32a, 32b, 33b, 33c, and 33f (Figure 4).

The Northern Blackland Prairie (32a) ecoregion is considered a rolling to nearly level plain that consists of mostly fine textured, dark and productive Vertisols. Upland areas were historically mid or tall grass prairies and bottomlands were wooded much as they are today. Most, if not all, of this ecoregion in the watershed has been converted to cropland or non-native pastures (Griffith et al., 2004). Bottomland hardwood forests still exist widely across the area.

The Southern Blackland Prairie (32b) ecoregion is similar to its Northern counterpart; however, its landscape is generally more dissected, the elevation is lower, and less extensive cropland exists. Soils are similar, but are less dominated by Vertisols and widely include Alfisols and Mollisols. Historic land cover was thought to consist primarily of tall grass prairie species and more widespread post oak woodland (Griffith et al., 2004).

The Southern Post Oak Savanna (33b) ecoregion is more forested than neighboring prairie regions. Wooded areas consist primarily of hardwoods such as post oak as the name suggests, but also include thick stands of yaupon and eastern redcedar understory in some areas. The ecoregion also contains areas of improved pasture and rangelands. Soils in this ecoregion are sandier than surrounding prairie areas (Griffith et al., 2004).

The San Antonio Prairie (33c) ecoregion is a narrow band of prairie surrounded by post oak savanna. Soils are mostly Alfisols with interspersed Mollisols and Vertisols. Historic vegetation in this area was tall grass prairie species. This area was extensively settled in the 1830s as it contained the primary road between San Antonio and Nacogdoches, the Old San Antonio Road (Griffith et al., 2004).

The Flood Plain and Low Terraces (33f) ecoregion encompasses the wide floodplain of the lower portion of the watershed. This area is dominated by bottomland hardwood forests but many of these areas, especially in the lower portion of the watershed, have been converted to cropland (Griffith et al., 2004).

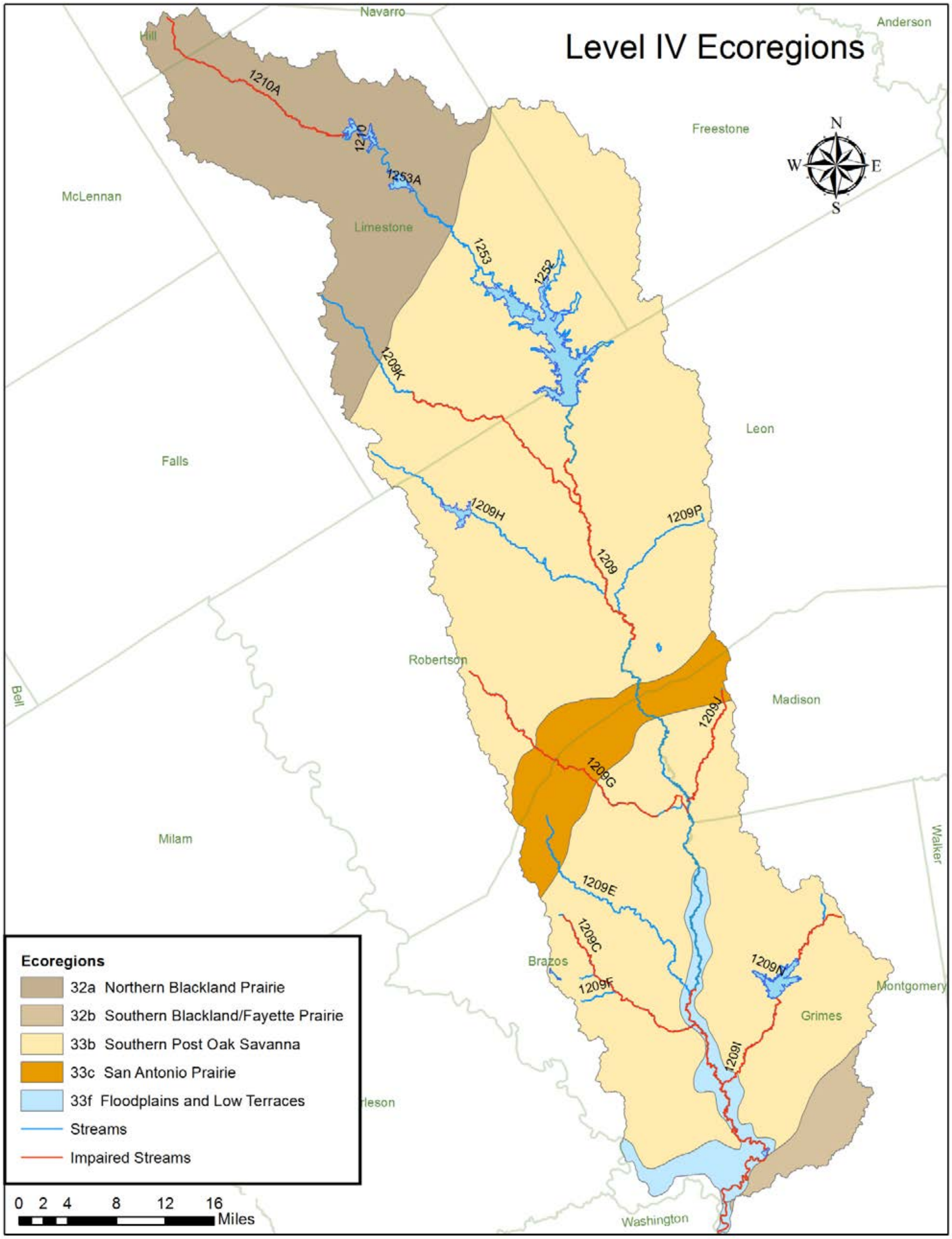


Figure 4. Level IV ecoregions in the Navasota Watershed (Griffith et al. 2004)

Land Use

Land use within the watershed was obtained from the 2011 National Land Cover Database (NLCD) (Figure 5). This dataset defines land cover and uses nationally and combines similar land use/land cover categories to provide a general representation of current uses at the time of its development. The categories for displayed land uses/land cover are described below.

- **Developed** – Land use category that includes areas of high, medium, and low development and open space. Development includes areas where people reside or work in high numbers to areas with a mixture of vegetation and constructed materials. Open space includes areas where vegetation cover is dominant with some development, such as golf courses, parks, and large homes. Impervious surfaces account for 50-100% for development areas and less than 20% for open space. For this combined category, development is present and impervious surfaces are between 0-100%.

- **Barren Land** – Bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material compose the barren land classification. Generally, vegetation accounts for less than 15% of total cover.

- **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.

- **Forest** –Areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Tree species include deciduous, evergreen, and those that do not fall into either category.

- **Wetlands** – Includes wetlands and emergent herbaceous wetland. The vegetation in wetlands consists of forests, shrublands, and/or perennial herbaceous vegetation, accounting for 25-100% of cover. Emergent herbaceous wetlands consist of 75-100% of perennial herbaceous vegetation and the soil or substrate is covered or periodically saturated with water.

- **Hay/Pasture** – Areas that include a variety of grasses, legumes, or grass-legume mixtures plant 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.

- **Herbaceous** – Areas that are dominated by grammanoid (grasses) or herbaceous vegetation with the areas consisting of 80% total vegetation. The areas may be utilized for grazing, but not for intensive management practices.

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

- **Shrub/Scrub** – Areas that are dominated by woody plants or shrubs that are less than 5 meters tall and a canopy typically greater than 20% of total vegetation.

Table 3 describes the Navasota River watershed as a predominately rural landscape. Prominent land uses in the watershed include hay/pasture land (37.0%), followed by forest (22.1%) and herbaceous (13.6%). The smallest percentage of land cover in the watershed is barren land (1.2%). The different land covers are not evenly distributed across the watershed. Most development can be found in the far southwest corner of the watershed, where the cities of Bryan and College Station are located. Forest cover appears to be spread throughout the watershed, as well as hay/pasture land.

Table 4 describes the land use conditions of each subwatershed within the Navasota River Watershed. Quantitatively describing the acres and percentage of the specific land use conditions for each subwatershed is necessary in future planning measures. Hay/pasture land is the most predominant land cover across the subwatersheds and barren land has the smallest land cover percentage across the subwatersheds.

Cattle grazing in pastureland along US 84 in the upper portion of the watershed.

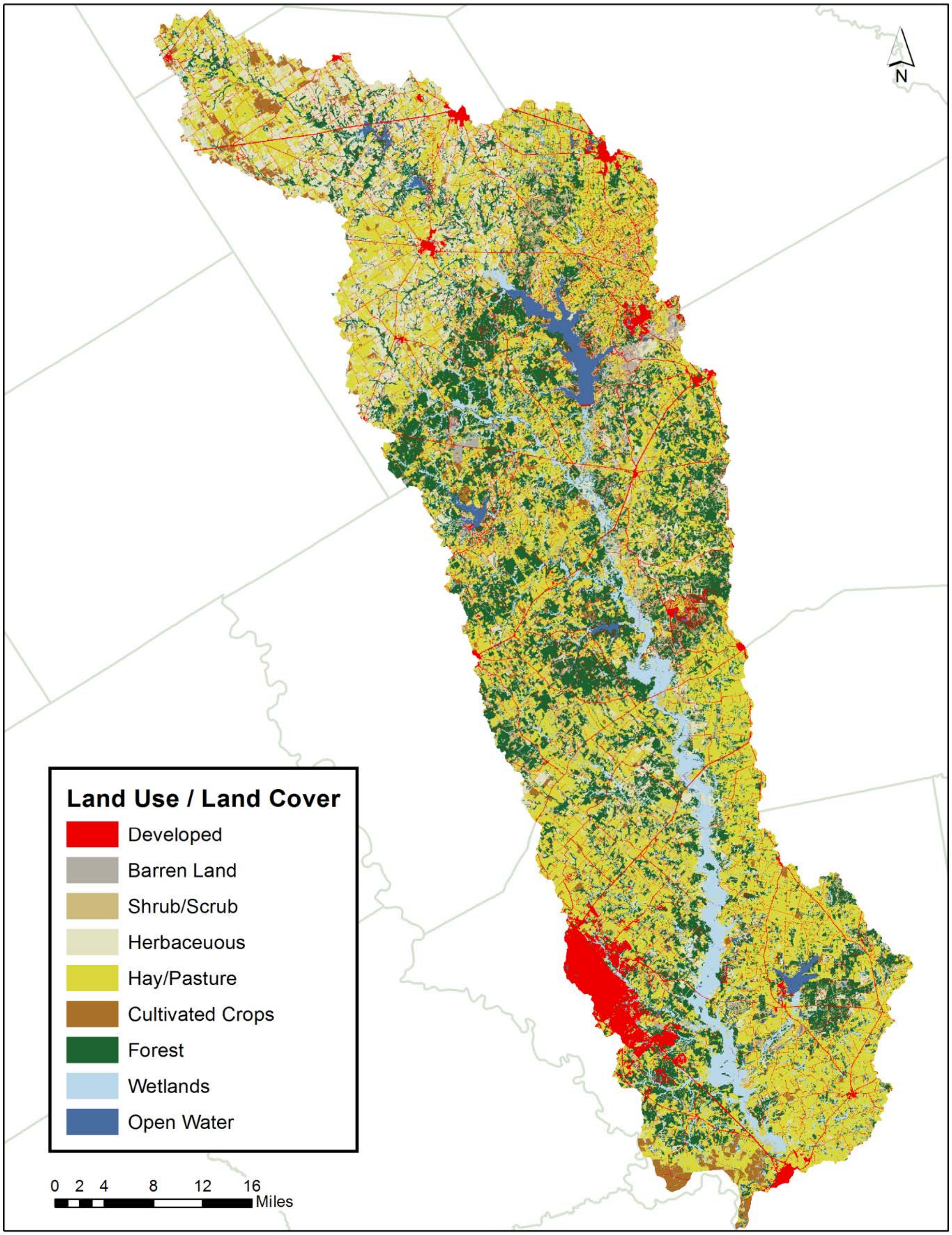


Figure 5. Land Use/Land Cover Within the Navasota Watershed (NLCD 2011)

Table 3. Acres of Land Use/Land Cover per County (NLCD 2011)

County	Acres & Percents of Land Use and Land Cover Categories																		Total Acres of County	
	Developed		Barren Land		Shrub/ Scrub		Herbaceous		Hay/ Pasture		Cultivated Crops		Forest		Wetlands		Open Water		Total Acres	Percent of Watershed
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Brazos	35,538	13.39	738	0.28	25,600	10.46	17,506	6.60	88,936	33.51	9,189	3.46	56,894	21.43	29,644	11.17	1,385	0.52	265,428	18.54
Freestone	9,036	13.70	2,096	3.18	3,450	5.23	4,138	6.27	36,572	55.46	0	0.0	8,675	13.16	1,557	2.36	418	0.63	65,942	4.61
Grimes	12,773	6.20	1,003	0.49	11,601	5.64	11,534	5.6	110,683	53.78	2,505	1.22	33,952	16.50	17,169	8.34	4,597	2.23	205,817	14.38
Hill	875	7.16	2	0.02	12	0.1	4,546	37.21	4,858	39.77	849	6.95	1,001	8.19	32	0.269	42	0.34	12,216	.085
Madison	1,759	3.93	57	0.13	3,088	6.91	2,405	5.38	25,685	57.46	29	0.06	6,023	13.47	5,420	12.12	238	0.53	44,703	3.12
Leon	12,643	7.34	5,921	3.44	25,237	14.66	17,605	10.22	51,408	29.86	289	0.17	48,511	28.17	7,309	4.24	3,267	1.90	172,189	12.03
Limestone	25,652	5.98	4,277	1.0	22,050	5.13	120,245	28.00	133,112	31.00	13,050	3.04	84,850	19.76	14,580	3.4	11,617	2.71	429,437	30.00
Robertson	11,829	5.02	2,562	1.09	23,224	9.85	16,277	6.9	78,201	4.05	5,191	2.2	76,347	32.81	17,492	7.42	4,656	1.97	235,779	16.47
Total Acres of Category in the Watershed	**110,105**		**16,656**		**114,262**		**194,256**		**529,455**		**31,102**		**316,253**		**93,203**		**26,220**		**1,431,511**	
Total Percent of Category in the Watershed	**7.7**		**1.2**		**8.0**		**13.6**		**37.0**		**2.2**		**22.1**		**6.5**		**1.8**			

Table 4. Acres of Land Use/Land Cover by Subwatershed

Sub-watershed	Acres & Percents of Land Use and Land Cover Categories																		Total Acres of Subwatershed	
	Developed		Barren Land		Shrub/ Scrub		Herbaceous		Hay/ Pasture		Cultivated Crops		Forest		Wetlands		Open Water		Total Acres	% of watershed
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
1	4,969	4.97	22	0.02	789	0.79	41,603	41.63	32,693	32.71	8,927	8.93	10,038	10.04	775	0.78	125	0.13	99,941	6.98
2	9,207	7.00	520	0.4	2,115	1.61	51,907	39.48	43,399	33.01	2,124	1.62	17,658	13.43	2,581	1.96	1,952	1.49	131,464	9.18
3	18,954	9.53	6,644	3.34	18,760	9.43	20,041	10.08	73,592	37.0	925	0.47	40,278	20.25	6502	3.27	13,209	6.64	198,907	13.89
4	5,271	4.46	2,240	1.90	8,183	6.93	19,809	16.77	37,757	31.96	2,641	2.24	32,730	27.70	9,173	7.76	342	0.29	118,147	8.25
5	6,698	6.21	2,697	2.50	15,261	14.16	9,880	9.17	36,834	34.17	656	0.61	29,823	27.67	5,298	4.92	638	0.59	107,784	7.53
6	5,052	5.27	1,316	1.37	8,480	8.85	7,168	7.48	32,643	34.07	2,325	2.43	31,548	32.93	5,106	5.33	2,166	2.26	95,803	6.69
7	4,128	5.65	974	1.33	8,445	11.56	6,898	9.45	16,881	23.12	666	0.91	29,807	40.82	4,116	5.64	1,113	1.52	73,027	5.10
8	5,422	5.59	296	0.30	10,265	10.58	7,320	7.54	33,792	34.83	410	0.42	24,428	25.18	14,373	14.81	726	0.75	97,033	6.78
9	2,902	3.78	371	0.48	10,023	13.06	8,146	10.61	28,294	36.86	1,107	1.44	22,051	28.73	3,697	4.82	173	0.23	76,764	5.36
10	780	4.69	27	0.16	960	5.78	143	0.86	11,781	70.88	0	0	2,070	12.45	789	4.75	72.3	0.43	16,621	1.16
11	2,990	4.01	38	0.05	6,063	8.14	6,110	8.2	32,065	43.04	700	0.94	13,612	6.09	12,549	16.84	376	0.5	74,503	5.20
12	3586	6.39	36	0.06	5,836	10.40	3,425	6.10	29,585	52.72	1,021	1.82	10,321	18.39	2,100	3.74	207	0.37	56,117	3.92
13	20,883	48.16	80	0.18	2,931	6.76	1,274	2.94	6,635	15.30	252	0.58	6,450	14.88	4,694	10.83	158	0.36	43,357	3.03
14	4,338	5.76	629	0.84	5,554	7.37	4,677	6.21	35,570	47.2	407	0.54	17,297	22.95	3,520	4.67	3,365	4.47	75,357	5.26
15	7,749	14.91	565	1.09	4,104	7.89	2,195	4.22	15,228	29.29	35	0.07	13,286	25.54	8,064	15.51	766	1.47	51,992	3.63
16	7,177	6.26	201	0.17	6,492	5.66	3,664	3.19	62,705	54.67	8,908	7.77	14,854	12.95	9,864	8.60	830	0.72	114,694	8.01
Acres of Category Watershed	**110,106**		**16,656**		**114,261**		**194,260**		**529,454**		**31,104**		**316,251**		**93,201**		**26,218**		**1,431,511**	
Percent of Category Watershed	**7.7**		**1.2**		**8.0**		**13.6**		**37.0**		**2.2**		**22.1**		**6.5**		**1.8**			

Watershed Climate

The Navasota watershed is located in East Texas and typically experiences 34 to 44 inches of rainfall annually (Figure 6; TWDB 2014a). Hot, humid summers, and mild winters are common in the watershed. Average annual temperatures in the watershed range from a low in the mid-50s°F to a high of nearly 80°F. Monthly average lows range from 35 to 4°F and the monthly average high is 96°F. Figure 7 depicts monthly average values for precipitation and temperature as reported by the National Oceanic and Atmospheric Administration (NOAA) at College Station, Franklin and Mexia (NOAA, 2014).

Navasota River at US 79

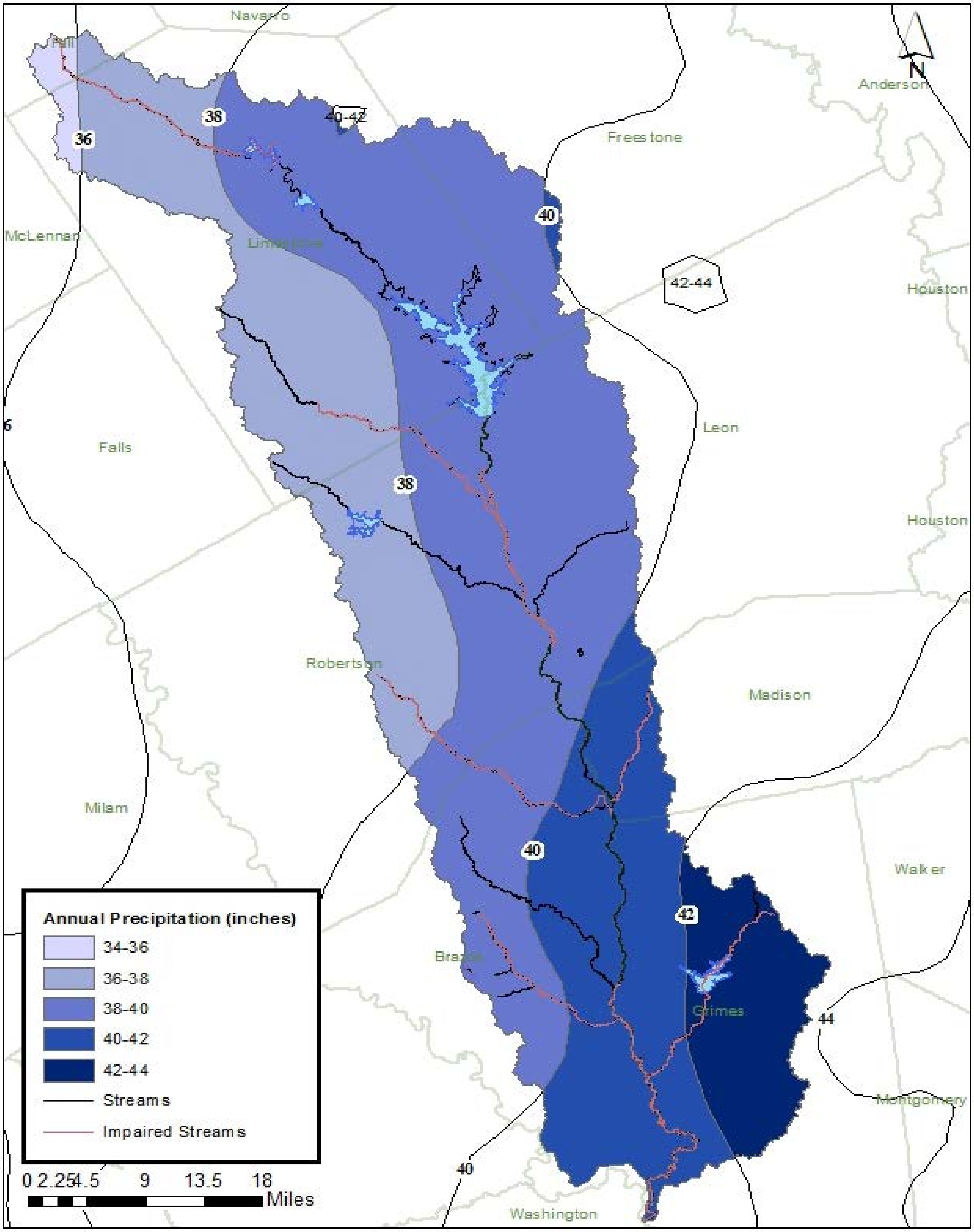
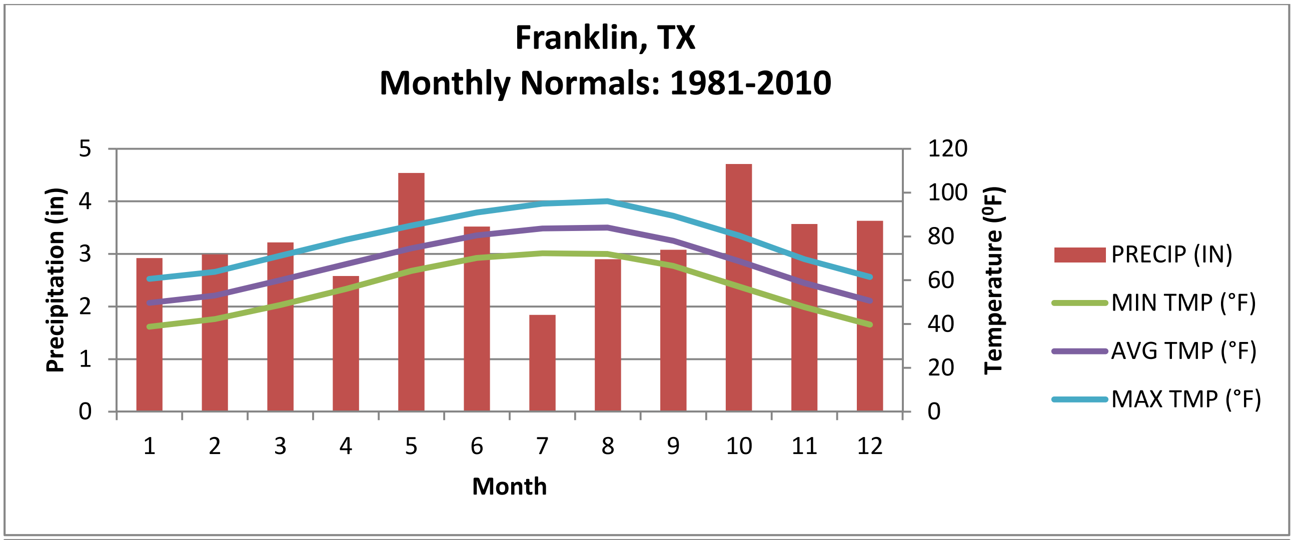
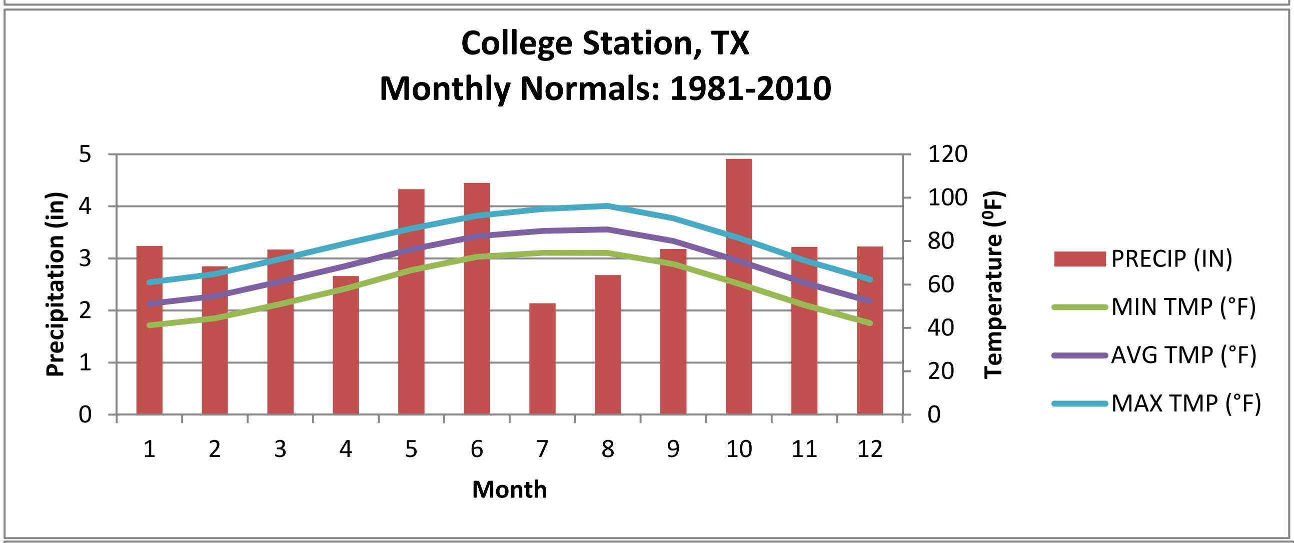


Figure 6. Annual Average Precipitation (inches) for the Navasota Watershed (TWDB 2014a)





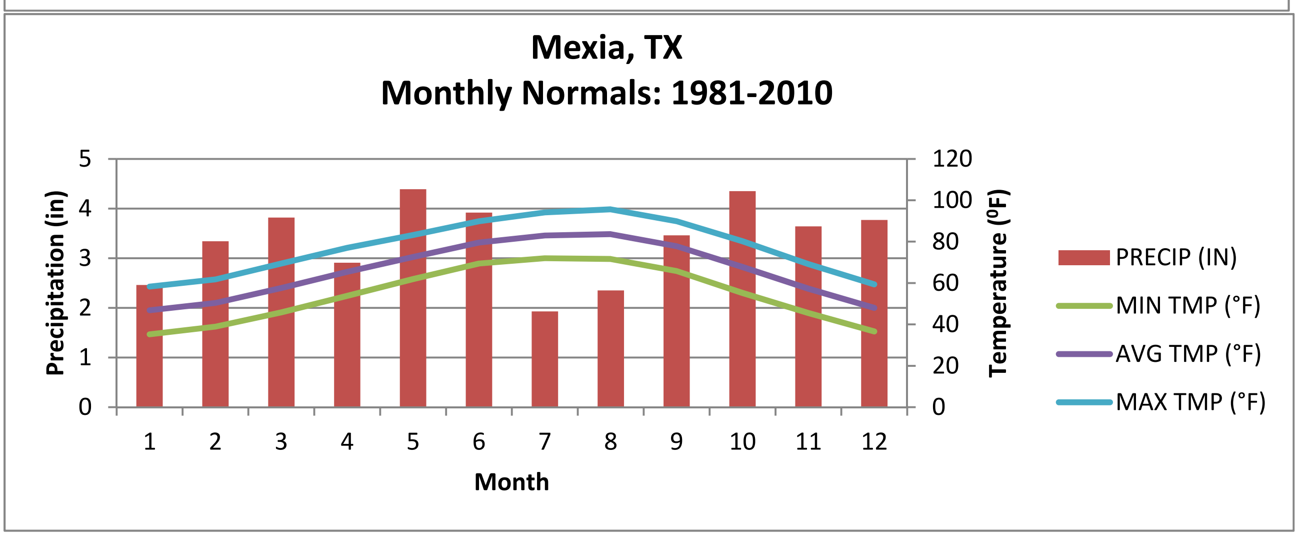


Figure 7. Average Monthly Climate Data from College Station, Franklin and Mexia, TX (NOAA 2014)

Watershed Population and Population Projections

The watershed is primarily located in a sparsely populated and rural landscape (Guillen & Wrast 2010). Population data from the 2010 Census were distributed within census blocks in the Navasota River watershed to obtain a map based on population density for the entire watershed (Figure 8). The cities of Bryan, College Station, and Groesbeck have the highest population densities. Figure 8 also shows the population density within each county. Of the eight counties within the watershed, Brazos county has the largest population of 156,941 and Hill County has the smallest population of 652 (Table 5). Table 6 shows the population for each county and their future population projections. All counties are expected to experience population increases from 2020-2070 with Freestone county projected to have the largest percentage-based population increase of 270% and Hill county to have the smallest population growth of 31% (Table 6). Figure 8 describes the population density per square mile, which was determined by gathering population totals from census blocks located within the watershed and dividing by the county area within the watershed.

Table 5. Population Statistics from the 2010 Census Blocks within the Watershed

County	Population	Population Density Per Square Mile
Brazos	156,941	341
Freestone	4,733	30
Grimes	11,170	28
Hill	652	19
Madison	1,419	17
Leon	5,357	18
Limestone	20,146	27
Roberston	4,630	11

Table 6. 2010 Population Census and 2020-2070 Population Projections for Counties in the Navasota River Watershed (TWDB 2014b; U.S. Census Bureau 2010)

County	2010 U.S. Census	2020 Population Projection	2030 Population Projection	2040 Population Projection	2050 Population Projection	2060 Population Projection	2070 Population Projection	Percent Increase (2010-2070)
Brazos	203,164	227,654	264,665	302,997	349,894	400,135	455,529	124%
Freestone	19,816	20,437	21,077	22,947	31,142	44,475	73,287	270%
Grimes	26,859	29,441	32,179	34,258	36,454	38,277	39,867	48%
Hill	35,089	37,828	40,277	41,935	43,643	44,937	45,989	31%
Madison	13,781	14,753	15,817	16,786	17,872	18,886	19,877	44%
Leon	16,742	18,211	19,536	20,603	22,071	23,340	24,582	47%
Limestone	23,326	25,136	26,615	27,817	29,134	30,206	31,152	34%
Robertson	16,486	18,358	20,150	21,801	23,525	25,174	26,771	62%
Total	355,263	391,818	440,316	489,144	553,735	625,430	717,054	

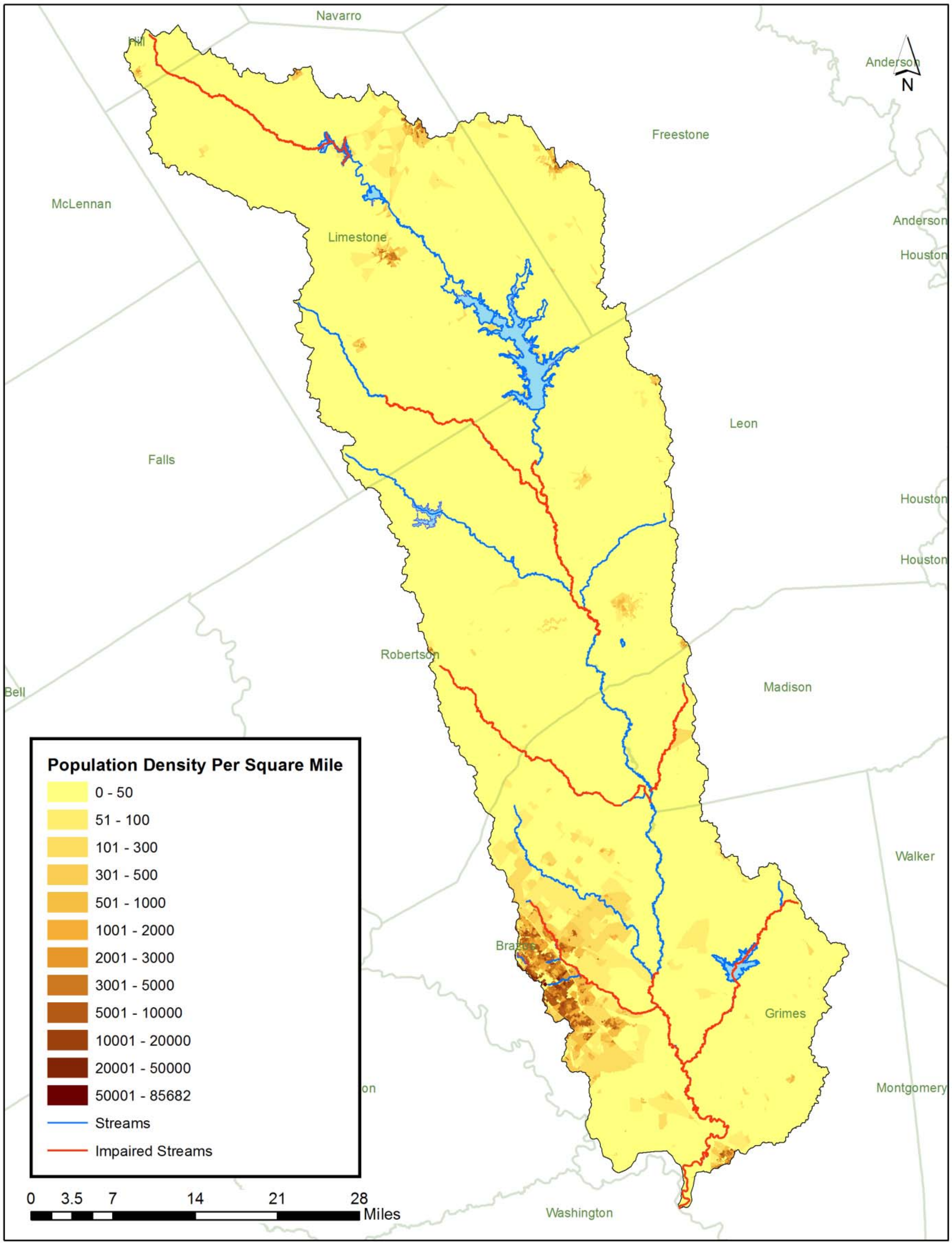


Figure 8. Population by Census Blocks (U.S. Census Bureau 2010)

Existing Literature on the Watershed

The earliest ecological survey found regarding the Navasota River was published in 1973 by the Texas Water Resources Institute under the Principal Investigator William J. Clark (Clark 1973). The limnological study collected data concerning the physical and biological characteristics of the watershed. Sites sampled, excluding previously established USGS stations, included Holland Creek, Cedar Creek, and Brushy Creek (Clark 1973).

In 2007, the Texas Water Development Board (TWDB) contracted a geomorphic assessment of the Navasota to support the state's instream flow planning process. In this document, the physical characteristics of the river below Lake Limestone are described and the river's hydrology is summarized where data is available. The river is described as ranging from a stream with a steep slope that is partly confined within its channel yet has high connectivity with its moderately wide floodplain in its upper reach, to one that is meandering across and highly connected to its floodplain which ranges from moderately wide to a narrow valley in the middle reach, to being an incised, meandering channel that is highly connected to its floodplain. Within the length of the river, cutbanks, active subchannels, oxbows, sloughs, swamps, stable vegetated point bars, alluvial terraces, and bedrock outcrops are commonly found (Phillips 2007). Hydrologically, Phillips notes frequent overbank flow, which drives aggradation of the river's floodplain. The river channel is noted as active but migration of the channel is not readily evident. That said, evidence presented in the report notes 27 locations along the Navasota where it has changed course yet remains highly connected to the abandoned river channels (2007).

Prior monitoring by the USGS of the Navasota River's discharge and river stages began as early as 1924 in Easterly and in 1997 in Normangee, TX, (Phillips 2007). The Navasota River at Easterly has experienced a mean daily flow of 422 ft^3/sec and a flow of nearly 90,000 ft^3/sec in the 1899 flood of record. The Navasota River at Normangee has been monitored for a much shorter time, but the daily mean flow has been estimated at 570 ft^3/sec and a flow of 30,100 ft^3/sec in the 1999 flood of record. The Navasota River experiences frequent minor flooding that may not always be recorded in gaging station data since USGS stations located at bridge crossings do not always represent cross-sections of the river (Phillips 2007).

Each year, the Brazos River Authority (BRA) publishes either a basin highlights or summary document that briefly discusses current conditions across the entire Brazos River basin. Within these reports, the Navasota River and some of its tributaries are specifically discussed upon occasion. Reports dating back to 2008 are available BRA's Clean Rivers Program website at: http://www.brazos.org/crpHistoricalReports.asp.

In the *2010 Brazos River Basin Highlig*hts *Report,* impairments for segments 1210A, 1253, and 1209 are discussed and the waterbodies are described. Segment 1210A, Navasota River above Lake Mexia is considered intermittent and is impaired by bacteria from potential sources including wildlife waste, stormwater runoff, and on-site sewage facilities (BRA 2010). Segment 1253, the Navasota River below Lake Mexia, is listed for depressed (DO) levels and chlorophyll a, most likely resulting from low water levels preventing the waterbody from buffering against high air temperatures and potentially nutrient rich runoff, which also may elevate chlorophyll-a levels (BRA 2010). Segment 1209, the Navasota River below Lake Limestone and nine of its tributaries were listed as having impaired contact recreation uses. The tributaries were noted as being potential sources contributing to Segment 1209's impairment. These include Carter's

Creek (1209C), Country Club Branch (1209D), Wickson Creek (1209E), Cedar Creek (1209G), Gibbons Creek (1209I), Duck Creek (1209H), Steele Creek (1209K), Shepherd Creek (1209J) and Burton Creek (1209L). Potential pollution sources contributing to these bacteria impairments range greatly and include municipal wastewater discharge and stormwater runoff, to contributions from wildlife, livestock, and on-site sewage facilities. Nutrient enrichment concerns in this reach of the river include nitrate and orthophosphorus as they have been identified to exceed TCEQ screening levels (BRA 2011). The *2012 and 2013 Brazos River Basin Summaries* reiterate these concerns and impairments.

In 2010, TCEQ implemented changes to the Texas Surface Water Quality Standards by adding two additional categories of contact recreation use (TCEQ 2010a). The primary contact recreation use was almost ubiquitously applied across the state and is in place to designate water quality levels that are acceptable to the state for activities constituting primary contact such as swimming, diving, wading by children, or whitewater sports where a significant risk of water ingestion occurs. Non-contact is the rarely utilized use as it is reserved for activities that do not involve a significant risk of water ingestion such as shoreline activity, and for waters that primary contact is not safe or allowable by law. Secondary contact 1 and 2 were added as allowable uses for waterbodies where the risk of water ingestion is lower involves a presumed risk of water ingestion (secondary contact 1 activities include frequent fishing, canoeing, and boating, while secondary contact 2 includes the same activities, but they happen on a less frequent basis due to physical constraints of the stream or limited public access). For a waterbody to have its contact recreation standard changed from primary contact, to either secondary 1 or 2, evidence documenting the current and historical use and the physical characteristics must be provided through a process known as a recreational use attainability analysis (RUAA).

Also beginning in 2010, TCEQ began the RUAA process for the Navasota River above Lake Mexia, Navasota River below Lake Limestone, and seven of its tributaries. RUAA reports for these efforts documented the observed uses of the waterbody, historical uses as noted in referenced materials and in stakeholder surveys, and the physical characteristics of the stream. At this point, TCEQ has not published recommendations for these RUAAs (Guillen & Wrast 2010, TCEQ 2014a).

Routine Water Quality Monitoring Data Review

TCEQ and its designees conduct water monitoring throughout the state of Texas to identify waterbodies failing to meet their designated water quality standards and uphold sections 303(d) and 304(a) of the Clean Water Act. Water quality standards are listed for each segment and can be found in the Texas Surface Water Quality Standards portion of the Texas Administrative code (TAC), Title 30, Chapter 307(30 TAC § 307) or from the 2012 Texas Integrated Report: Assessment Results for Basin 12 (TCEQ 2013a). TCEQ utilizes data from the most recent 7-year period and at least 10 data points (20 data points if assessing bacteria) for an assessment on a waterbody. Monitoring within the Navasota River watershed has occurred at 29 different sites at some point in time. Data from these collection events are described in Tables 7 to 36. Inconsistent data collection at individual stations plagues the watershed; therefore, it is difficult to determine the current state of the tributaries and segments of the waterbody by solely relying on existing data. Monitoring data that exceeds the screening level more than 20% of the time using the binomial method is listed as concern for impairment.

Existing Water Quality Data

Water quality data for the watershed's specific segments was obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS) on November 26, 2014. Data retrieved dated back to December 1, 1998 and included the data used by TCEQ in the development of the 2012 Texas Integrated Report (December 1, 2003 – November 30, 2010). Data summaries presented in the following tables describe all data gathered for each of the monitoring stations in the watershed with data present (TCEQ 2014b). Figure 9 shows the overall locations of the monitoring stations while the tables provide descriptive statistics for available data at each of the denoted water quality monitoring stations.

Analysis of Bacteria Data

The Navasota River and its tributaries are required to meet water quality standards for primary contact recreation and therefore must maintain *E.coli* levels at or below a geometric mean of 126cfu/100mL. The standard serves as a protective measure for human health since *E.coli* is a fecal indicator bacteria whose presence may also indicate the presence of other pathogenic organisms found in fecal matter. If levels of *E. coli* are found to exceed their standard limits, the number of swimmers that may contract gastrointestinal illnesses is expected to increase.

According to the 2012 Texas Integrated Report, waterbodies in the study area that are impaired for *E.coli* include: the Navasota River below Lake Limestone, Carter's Creek (Segment 1209C), Country Club Branch (Segment 1209D), Wickson Creek (Segment 1209E), Cedar Creek (Segment 1209G), Duck Creek (Segment 1209H), Gibbons Creek (Segment 1209I), Shepherd Creek (Segment 1209J), Steele Creek (Segment 1209K), Burton Creek (Segment 1209L) and the Navasota River above Lake Mexia (Segment 1210A).

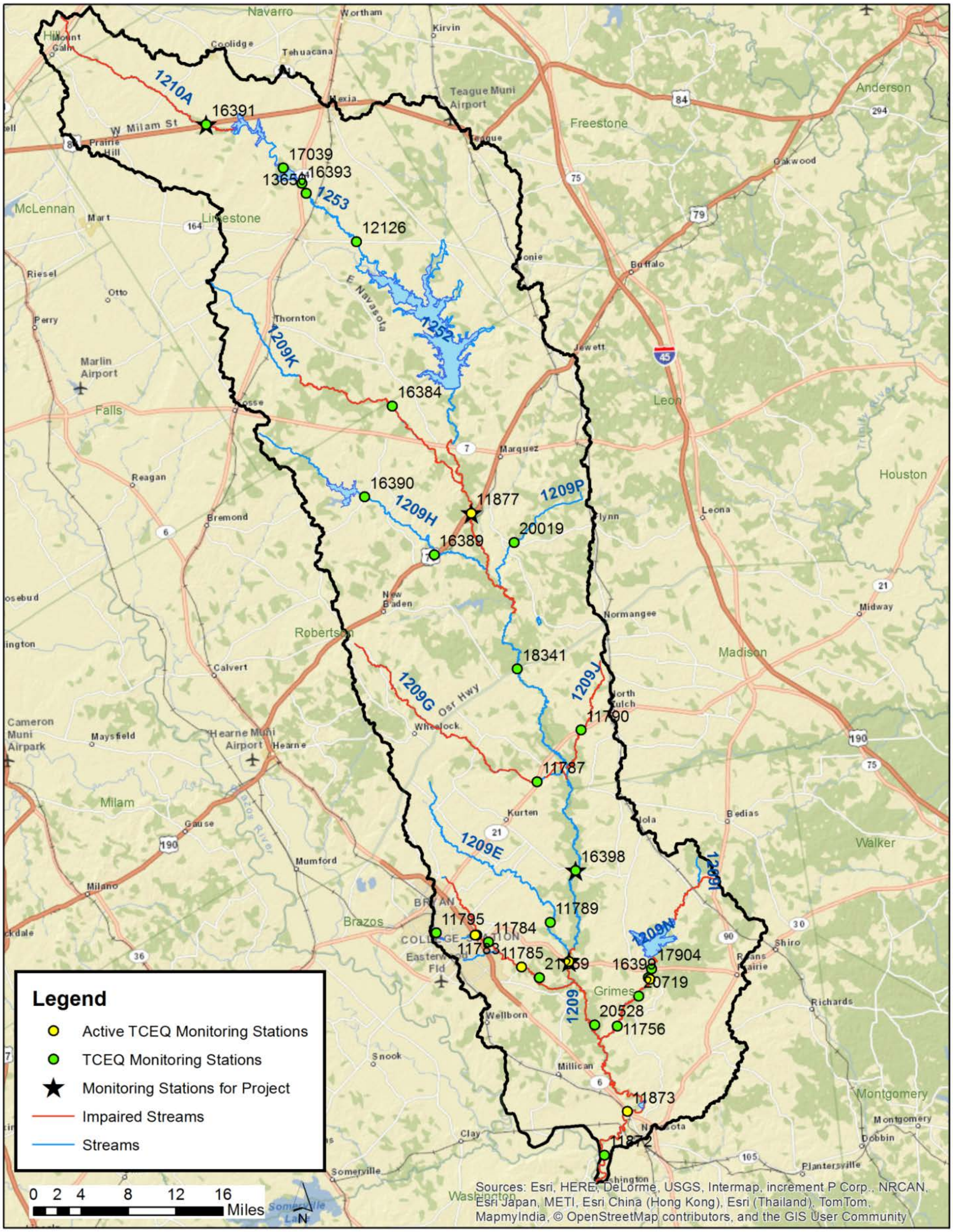


Figure 9. Water Quality Monitoring Stations in the Navasota River Watershed

Table 7. Historic Water Quality Data Collected from the Main Branch of the Navasota River (Station 11872), Located at SH 105 (segment 1209)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	73	6.88	30.71	21.74		33.9 maximum	
Dissolved Oxygen (mg/L)	71	3.4	12.12	6.97		5.0/3.0 (grab avg/min)*	
pH (standard units)	73	7	8.29	7.55		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	59	0.02	5.4	1.65		1.95	
Orthophosphorus (mg/L)	14	0.04	0.96	0.30		0.37 (>20% exceedance)***	
Chloride (mg/L)	58	13.34	151.08	50.04		140.00	
Sulfate (mg/L)	56	11.81	290.66	47.78		100.00	
E. coli (cfu/100mL)	46	6	2419.2		85.64	126 (geometric mean)	
Fecal Coliform (cfu/100mL)	40	1	4000		191.53	200 (geometric mean)	
Flow (cfs)	11	0.04	3.4	1.27			
Specific Conductance (US/cm @ 25°C)	73	116.7	2480	715.74			
Transparency, Secchi Disc, (m)	13	0.07	0.26	0.17			
Turbidity (NTU)	5	11.23	59.76	29.4			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 8. Historic Water Quality Data Collected from the Main Branch of the Navasota River (Station 11873), Located at SH 6 (segment 1209) (This is a currently active station where data is being collected quarterly.)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	34	7.3	32.5	21.35		33.9 maximum	
Dissolved Oxygen (mg/L)	34	4.4	11.3	7.29		5.0/3.0 (grab avg/min)*	
pH (standard units)	34	6.8	8.7	7.87		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	17	0.05	0.08	0.05		0.33 (>20% exceedance)***	
Nitrate Nitrogen (mg/L)	26	0.1	13.92	3.88		1.95	Concern
Total Phosphorus (mg/L)	11	0.18	2.26	0.95		0.69 (>20% exceedance)***	Concern
Orthophosphorus (mg/L)	24	0.08	2.17	0.65		0.37 (>20% exceedance)***	Concern
Chloride (mg/L)	27	14.81	93.26	53.95		140.00	
Sulfate (mg/L)	27	17.33	74.57	44.61		100.00	
E. coli (cfu/100mL)	27	1	24000		100.10	126 (geometric mean)	
Specific Conductance (US/cm @ 25°C)	34	187	1210	598.26			
Transparency, Secchi Disc, (m)	34	0.06	0.41	0.15			
Turbidity (NTU)	27	13.24	210	68.2			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 9. Historic Water Quality Data Collected from the Main Branch of the Navasota River (Station 11875), Located at SH 30 (segment 1209) (This is a currently active station where data is being collected twice monthly.)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	93	4.45	30.9	20.34		33.9 maximum	
Dissolved Oxygen (mg/L)	91	2.4	15.04	7.44		5.0/3.0 (grab avg/min)*	
pH (standard units)	93	6.8	7.9	7.35		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	87	< 0.02	0.73	0.22		1.95	
Orthophosphorus (mg/L)	84	< 0.04	0.39	0.05		0.37 (>20% exceedance)***	
Chloride (mg/L)	87	1.87	90.56	40.64		140.00	
Sulfate (mg/L)	85	2.67	88.8	41.44		100.00	
E. coli (cfu/100mL)	58	4	9677		145.74	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	49	20	6000		202.18	200 (geometric mean)	Impaired
Flow (cfs)	4	< 0.05	0.5	0.28			
Specific Conductance (US/cm @ 25°C)	92	114.6	634	326.46			
Transparency, Secchi Disc, (m)	40	0.09	0.9	0.28			
Turbidity (NTU)	32	10	85	30.52			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 10. Historic Water Quality Data Collected from the Main Branch of the Navasota River (Station 11877), Located at US 79 (This is a currently active station where data is being collected twice monthly.)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	106	7.9	31	20.28		33.9 maximum	
Dissolved Oxygen (mg/L)	95	4.67	12.37	8.00		5.0/3.0 (grab avg/min)*	
pH (standard units)	95	6.72	7.8	7.29		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	11	0.05	0.45	0.09		0.33 (>20% exceedance)***	
Nitrate Nitrogen (mg/L)	84	0.02	1.3	0.24		1.95	
Total Phosphorus (mg/L)	10	< 0.05	0.45	0.13		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	87	< 0.04	0.28	0.05		0.37 (>20% exceedance)***	
Chloride (mg/L)	89	11.63	118.39	38.89		140.00	
Sulfate (mg/L)	90	10.94	114.15	41.75		100.00	
E. coli (cfu/100mL)	63	6	24200		142.71	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	51	16	4000		169.15	200 (geometric mean)	
Flow (cfs)	75	0.05	7700	537.50			
Specific Conductance (US/cm @ 25°C)	106	113.2	644.2	314.01			
Transparency, Secchi Disc, (m)	44	0.04	0.55	0.24			
Turbidity (NTU)	32	6.3	170	37.52			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 11. Historic Water Quality Data Collected from the Main Branch of the Navasota River (Station 16398), located at Grimes CR 162 (segment 1209) (This is a currently active station where data is being collected twice monthly.)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	60	6.1	30.68	20.88		33.9 maximum	
Dissolved Oxygen (mg/L)	58	4.76	12.6	7.45		5.0/3.0 (grab avg/min)*	
pH (standard units)	60	5.52	7.79	7.21		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	57	0.02	0.73	0.24		1.95	
Orthophosphorus (mg/L)	53	0.04	0.15	0.05		0.37 (>20% exceedance)***	
Chloride (mg/L)	55	11.84	83.74	42.77		140.00	
Sulfate (mg/L)	53	11.9	92.05	45.08		100.00	
E. coli (cfu/100mL)	29	11	2419.2		114.6	126 (geometric mean)	
Fecal Coliform (cfu/100mL)	40	8	2240		102.06	200 (geometric mean)	
Flow (cfs)	2 (1999)	0.5	0.5	0.5			
Specific Conductance (US/cm @ 25°C)	60	164	564.4	331.14			
Transparency, Secchi Disc, (m)	14	0.08	0.6	0.22			
Turbidity (NTU)	5	17.25	52.9	32.19			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 12. Historic Water Quality Data Collected from the Main Branch of the Navasota River (Station 18341), Located at Old Spanish Rd. (segment 1209)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	6	7.5	22.5	15.5		33.9 maximum	
Flow (cfs)	6	13.5	19600	4932.7	145.75		
Specific Conductance (US/cm @ 25°C)	6	150	449	232.67			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 13. Historic Water Quality Data Collected from the Main Branch of the Navasota River (Station 20528), Located 3.7km Upstream of the Confluence with Gibbons Creek (segment 1209)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Nitrate Nitrogen (mg/L)	1 (2010)	3.42	3.42	3.42		1.95	Concern
Total Phosphorus (mg/L)	1 (2010)	0.98	0.98	0.98		0.69 (>20% exceedance)***	Concern
Orthophosphorus (mg/L)	1 (2010)	0.83	0.83	0.83		0.37 (>20% exceedance)***	Concern
Chloride (mg/L)	1 (2010)	98.77	98.77	98.77		140.00	
Sulfate (mg/L)	1 (2010)	76.29	76.29	76.29		100.00	
Flow (cfs)	1 (2010)	53	53	53			
Transparency, Secchi Disc, (m)	1 (2010)	0.27	0.27	0.27			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)

***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**

**** The listed impairment/concern is according to the 2012 303 (d) List**

***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 14. Historic Water Quality Data Collected from Carters Creek (Station 11782), Located 15 meters Upstream of Burton Creek Confluence Near SH6 in College Station (segment 1209C)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	12	10.6	26.8	18.87		33.9 maximum	
Dissolved Oxygen (mg/L)	12	4.3	11.7	6.89		5.0/3.0 (grab avg/min)*	
pH (standard units)	12	6.9	9.5	8.02		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	1	0.02	0.02	0.02		0.33 (>20% exceedance)***	
Nitrate Nitrogen (mg/L)	2	0.25	2.38	1.32		1.95	Concern
Total Phosphorus (mg/L)	2	0.39	2.31	1.35		0.69 (>20% exceedance)***	Concern
Orthophosphorus (mg/L)	2	0.32	1.98	1.15		0.37 (>20% exceedance)***	Concern
Chloride (mg/L)	2	32	84	58			
Sulfate (mg/L)	1	81	81	81			
Chlorophyll-a (µg/L)	3	7	41.2	13.73		14.1 (>20% exceedance)***	Concern
E. coli (cfu/100mL)	12	16	7400		169.06	126 (geometric mean)	Impaired
Flow (cfs)	12	-0.136	10	1.37			
Specific Conductance (US/cm @ 25°C)	12	263	1230	548.17			
Transparency, Secchi Disc, (m)	13	0.07	0.7	0.34			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 15. Historic Water Quality Data Collected from Carters Creek (Station 11784) Located 85m Downstream of Harvey Rd/SH 30 in College Station (Segment 1209C)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	69	8.62	34.8	22.96		33.9 maximum	
Dissolved Oxygen (mg/L)	66	6.31	17.47	9.51		5.0/3.0 (grab avg/min)*	
pH (standard units)	69	6.57	9.4	7.94		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	63	0.14	19.88	9.09		1.95	Concern
Total Phosphorus (mg/L)	15	0.06	4.82	2.23		0.69 (>20% exceedance)***	Concern
Orthophosphorus (mg/L)	59	0.05	3.84	2.22		0.37 (>20% exceedance)***	Concern
Chloride (mg/L)	63	3.61	124.33	77.0			
Sulfate (mg/L)	61	5.1	50	28.23			
Chlorophyll-a (µg/L)	2	25.7	53.7	39.55		14.1 (>20% exceedance)***	Concern
E. coli (MPN/100mL)	34	4	24000		643.81	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	49	100	4000		535.49	200 (geometric mean)	Impaired
Flow (cfs)	26	2.1	28.3	9.26			
Specific Conductance (US/cm @ 25°C)	69	34.7	1376	947.92			
Transparency, Secchi Disc, (m)	16	0.1	1	0.42			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)

***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**

**** The listed impairment/concern is according to the 2012 303 (d) List**

***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 16. Historic Water Quality Data Collected from Carters Creek (Station 11785) Located 44m Downstream of Bird Pond Rd, Southeast of College Station (segment 1209C) (This is a currently active station where data is being collected quarterly.)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	86	6.49	32.39	21.20		33.9 maximum	
Dissolved Oxygen (mg/L)	86	5.9	14.49	9.25		5.0/3.0 (grab avg/min)*	
pH (standard units)	86	6.34	8.9	8.06		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	65	0.2	19.79	11.13		1.95	Concern
Total Phosphorus (mg/L)	28	0.06	4.62	2.42		0.69 (>20% exceedance)***	Concern
Orthophosphorus (mg/L)	62	0.15	3.76	2.20		0.37 (>20% exceedance)***	Concern
Chloride (mg/L)	65	2.63	110.76	75.12			
Sulfate (mg/L)	64	4.3	80.3	39.83			
Chlorophyll-a (µg/L)	1	27.2	27.2	27.2		14.1 (>20% exceedance)***	Concern
E. coli (cfu/100mL)	73	4	24000		704.30	126 (geometric mean)	Impaired
Fecal Coliform (cfu & MPN/100mL)	28	125	4000		536.37	200 (geometric mean)	Impaired
Flow (cfs)	24	1.6	136	16.68			
Specific Conductance (US/cm @ 25°C)	86	37.1	1307	976.92			
Transparency, Secchi Disc, (m)	41	0.07	1.1	0.44			
Turbidity (NTU)	32	3.12	75	16.41			

Sources- Data: (TCEQ 2014), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 17. Historic Water Quality Data Collected from Carters Creek (Station 21259) Located 30m Upstream of William D. Fitch Parkway SE of College Station (Segment 1209C)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	14	10.3	29.8	20.64		33.9 maximum	
Dissolved Oxygen (mg/L)	15	5.9	11.3	8		5.0/3.0 (grab avg/min)*	
pH (standard units)	15	8	9.4	8.53		6.5-9.0 range	
E. coli (cfu/100mL)	15	100	820		348.62	126 (geometric mean)	Impaired
Flow (cfs)	15	12	24	17.67			
Specific Conductance (US/cm @ 25°C)	15	744	1230	1057.8			

Sources- Data: (TCEQ 2014), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 18. Historic Water Quality Data Collected from Country Club Branch (Station 11795) Located at Duncan St. in Bryan (Segment 1209D)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	15	10.8	31	20.37		33.9 maximum	
Dissolved Oxygen (mg/L)	16	4.7	11.7	9.3		5.0/3.0 (grab avg/min)*	
pH (standard units)	16	7.5	8.9	8.2		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	16	0.05	0.22	0.07		0.33 (>20% exceedance)***	
Nitrate Nitrogen (mg/L)	5	0.05	0.10	0.07		1.95	
Total Phosphorus (mg/L)	16	0.66	1.61	0.98		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	13	0.06	1.71	0.39		0.37 (>20% exceedance)***	
Chloride (mg/L)	17	9	117	38.94			
Sulfate (mg/L)	17	23	639	165.88			
Chlorophyll-a (µg/L)	11	10	21.4	11.71		14.1 (>20% exceedance)***	
E. coli (cfu/100mL)	16	46	24000		493.80	126 (geometric mean)	Impaired
Flow (cfs)	11	0.04	0.44	0.18			
Specific Conductance (US/cm @ 25°C)	15	269	2210	796.33			
Transparency, Secchi Disc, (m)	14	0.1	0.63	0.32			

Sources- Data: (TCEQ 2014), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 19. Historic Water Quality Data Collected from Wickson Creek (Station 11789) Located Immediately Upstream of Weedon Loop 4km Southeast of Forest Lake (1209E)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	47	4	27.89	17.97		33.9 maximum	
Dissolved Oxygen (mg/L)	46	2.99	15.52	7.37		5.0/3.0 (grab avg/min)*	
pH (standard units)	47	5.98	7.4	7.06		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	45	0.02	0.94	0.24		1.95	
Orthophosphorus (mg/L)	42	0.04	0.56	0.11		0.37 (>20% exceedance)***	
Chloride (mg/L)	44	5.6	102.19	31.11			
Sulfate (mg/L)	43	8.1	103.79	44.87			
E. coli (cfu/100mL)	27	31	9676.8		419.72	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	38	28	3140		135.74	200 (geometric mean)	
Flow (cfs)	11	0	7.1	1.28			
Specific Conductance (US/cm @ 25°C)	47	101	645.6	307.31			
Transparency, Secchi Disc, (m)	13	0.07	0.7	0.34			
Turbidity (NTU)	5	8.13	66.8	29.15			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 20. Historic Water Quality Data Collected from Cedar Creek (Station 11787) Located at US 190/SH 21 (Segment 1209G)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	84	3.94	29.6	18.8		33.9 maximum	
Dissolved Oxygen (mg/L)	81	2.5	16.6	6.62		5.0/3.0 (grab avg/min)*	Concern
pH (standard units)	84	5.17	7.8	7.00		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	56	0.02	1.17	0.28		1.95	
Orthophosphorus (mg/L)	52	0.04	0.85	0.06		0.37 (>20% exceedance)***	
Chloride (mg/L)	55	1.64	169.8	73.26			
Sulfate (mg/L)	54	3.54	432.53	96.76			
E. coli (cfu/100mL)	58	4	16000		207.35	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	42	36	4000		288.15	200 (geometric mean)	Impaired
Flow (cfs)	29	0	37	2.88			
Specific Conductance (US/cm @ 25°C)	83	141	1192	513.84			
Transparency, Secchi Disc, (m)	40	0.08	> 1.2	0.44			
Turbidity (NTU)	6	10.05	117	35.32			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)

***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**

**** The listed impairment/concern is according to the 2012 303 (d) List**

***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 21. Historic Water Quality Collected from Duck Creek (Station 16389) Located at SH 79 in the Town of Easterly (Segment 1209H)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	287	3.67	28.9	22.54		33.9 maximum	
Dissolved Oxygen (mg/L)	285	1.3	14.28	4.84		5.0/3.0 (grab avg/min)*	Concern/ Impaired
pH (standard units)	284	6.42	7.7	6.97		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	24	0.05	0.16	0.08		0.33 (>20% exceedance)***	
Nitrate Nitrogen (mg/L)	83	0.02	1	0.36		1.95	
Total Phosphorus (mg/L)	36	0.05	0.45	0.11		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	84	0.00	0.17	0.05		0.37 (>20% exceedance)***	
Chloride (mg/L)	87	13.55	101.41	54.34			
Sulfate (mg/L)	88	17.08	149.53	53.86			
Chlorophyll-a (µg/L)	4	0.9	< 5	2.98		14.1 (>20% exceedance)***	
E. coli (cfu/100mL)	55	31	24200		274.90	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	50	24	1200		180.54	200 (geometric mean)	
Flow (cfs)	23	0	11.38	4.90			
Specific Conductance (US/cm @ 25°C)	288	130	672.3	442.30			
Transparency, Secchi Disc, (m)	41	0.04	> 1.2	0.58			
Turbidity (NTU)	25	3.21	60	15.97			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 22. Historic Water Quality Data Collected from Duck Creek (Station 16390) Located at FM 979 West of Bremond (Segment 1209H)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	68	4.53	29.2	19.16		33.9 maximum	
Dissolved Oxygen (mg/L)	67	1.94	13.46	6.32		5.0/3.0 (grab avg/min)*	Concern/ Impaired
pH (standard units)	67	6.36	7.66	7.14		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	60	0.02	0.57	0.23		1.95	
Orthophosphorus (mg/L)	62	0.04	0.17	0.05		0.37 (>20% exceedance)***	
Chloride (mg/L)	64	8.64	84.14	39.65			
Sulfate (mg/L)	65	5.52	31.51	14.55			
E. coli (cfu/100mL)	36	27	24200		178.33	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	51	40	1200		170.80	200 (geometric mean)	
Flow (cfs)	19	0.05	24.34	2.77			
Specific Conductance (US/cm @ 25°C)	67	87.6	596.8	278.79			
Transparency, Secchi Disc, (m)	15	0.05	> 1.2	0.63			
Turbidity (NTU)	6	1.82	87.8	30.16			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 23. Historic Water Quality Data Collected from Gibbons Creek (Station 11756) Located Immediately Downstream of Grimes CR 190 and 4.1km Upstream of the Confluence with the Navasota (Segment 1209I)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	85	4.9	29.51	19.51		33.9 maximum	
Dissolved Oxygen (mg/L)	83	0.5	13.04	5.52		5.0/3.0 (grab avg/min)*	Concern
pH (standard units)	85	6	7.5	6.94		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	66	0.10	0.54	0.10		1.95	
Total Phosphorus (mg/L)	16	0.06	0.2	0.10		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	17	0.04	0.1	0.04		0.37 (>20% exceedance)***	
Chloride (mg/L)	64	20.91	502.11	110.05			
Sulfate (mg/L)	62	38.8	710.66	177.02			
Chlorophyll-a (µg/L)	2	7.5	18.2	12.85		14.1 (>20% exceedance)***	
E. coli (cfu/100mL)	51	14	9676.8		235.00	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	49	68	3040		288.48	200 (geometric mean)	Impaired
Flow (cfs)	35	0	21	2.60			
Specific Conductance (US/cm @ 25°C)	84	199	3403	784.90			
Transparency, Secchi Disc, (m)	36	0.19	> 1.2	0.52			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 24. Historic Water Quality Data Collected from Gibbons Creek (Station 16399) Located 20m Upstream of FM 244 between Iola and Carlos (Segment 1209I)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	56	5.16	29.63	18.80		33.9 maximum	
Dissolved Oxygen (mg/L)	54	0.27	11.3	3.28		5.0/3.0 (grab avg/min)*	
pH (standard units)	56	6.17	7.24	6.79		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	56	< 0.02	0.76	0.09		1.95	
Total Phosphorus (mg/L)	8	< 0.06	0.16	0.08		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	11	< 0.04	0.25	0.10		0.37 (>20% exceedance)***	
Chloride (mg/L)	54	12.22	151.22	57.71			
Sulfate (mg/L)	53	11.78	194.7	72.43			
Chlorophyll-a (µg/L)	1	55	55	55		14.1 (>20% exceedance)***	
E. coli (cfu/100mL)	27	18.5	2419		165.39	126 (geometric mean)	Concern
Fecal Coliform (cfu/100mL)	47	4	5300	113.41		200 (geometric mean)	
Flow (cfs)	16	0	0.5	0.13			
Specific Conductance (US/cm @ 25°C)	56	227.9	825	466.31			
Transparency, Secchi Disc, (m)	12	0.22	> 1.2	0.60			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 25. Historic Water Quality Data Collected from Gibbons Creek (Station 17904) Located East of Carlos at SH30 (Segment 1209I)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	16	23.5	30.3	26.19		33.9 maximum	
Dissolved Oxygen (mg/L)	16	2.9	5.9	4.87		5.0/3.0 (grab avg/min)*	
pH (standard units)	16	6.3	7.3	6.76		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	5	0.07	0.14	0.09		0.33 (>20% exceedance)***	
Total Phosphorus (mg/L)	10	0.08	0.21	0.17		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	9	0.02	0.15	0.09		0.37 (>20% exceedance)***	
Chloride (mg/L)	10	24	74	39.7			
Sulfate (mg/L)	10	17	121	58.6			
Chlorophyll-a (µg/L)	4	5	57.4	20.8		14.1 (>20% exceedance)***	
Flow (cfs)	15	0.76	4.9	1.93			
Specific Conductance (US/cm @ 25°C)	16	268	584	383.13			
Transparency, Secchi Disc, (m)	14	0.24	> 0.53	0.37			
Turbidity (NTU)	3	0	4	2			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 26. Historic Water Quality Data Collected from Gibbons Creek (Station 18800) Located 25m Upstream of FM 244 (Segment 1209I) (This is a currently active station where data is being collected quarterly.)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	30	5.8	29.2	19.89		33.9 maximum	
Dissolved Oxygen (mg/L)	30	1.2	10.3	5.93		5.0/3.0 (grab avg/min)*	
pH (standard units)	30	5.4	8.4	6.99		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	26	0.04	0.16	0.06		1.95	
Total Phosphorus (mg/L)	20	0.03	0.22	0.11		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	26	0.04	0.16	0.06		0.37 (>20% exceedance)***	
Chloride (mg/L)	28	10.39	167.26	73.02			
Sulfate (mg/L)	28	34.87	246.84	107.11			
Chlorophyll-a (µg/L)	2	3	9.3	6.15		14.1 (>20% exceedance)***	
E. coli (cfu/100mL)	27	8	1600		209.97	126 (geometric mean)	Impaired
Flow (cfs)	4	0.5	1.3	0.93			
Specific Conductance (US/cm @ 25°C)	30	219	1090	583.67			
Transparency, Secchi Disc, (m)	29	0.3	> 1.2	0.8			
Turbidity (NTU)	28	2.3	20	6.83			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)

***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**

**** The listed impairment/concern is according to the 2012 303 (d) List**

***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 27. Historic Water Quality Data Collected from Gibbons Creek (Station 20719) which is Located on North-South Haul Rd (Segment 1209I)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	17	4.8	29.3	18.65		33.9 maximum	
Dissolved Oxygen (mg/L)	17	4.7	11.5	7.72		5.0/3.0 (grab avg/min)*	
pH (standard units)	17	5.5	7.6	7.12		6.5-9.0 range	
E. coli (cfu/100mL)	17	11	730		94.24	126 (geometric mean)	
Fecal Coliform (cfu/100mL)						200 (geometric mean)	
Flow (cfs)	17	0	12	2.51			
Specific Conductance (US/cm @ 25°C)	17	493	1220	741.65			
Transparency, Secchi Disc, (m)	17	0.25	> 1.2				

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 28. Historic Water Quality Data Collected from Shepherd Creek (Station 11790) Located Southwest of North Zulch and Immediately Downstream of US 190/SH 21 (Segment 1209J)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	23	4.7	25.3	17.12		33.9 maximum	
Dissolved Oxygen (mg/L)	21	0.79	11.3	5.55		5.0/3.0 (grab avg/min)*	Concern
pH (standard units)	23	6.39	7.7	7.00		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	10	0.05	0.56	0.28		1.95	
Orthophosphorus (mg/L)	10	< 0.05	0.46	0.11		0.37 (>20% exceedance)***	
Chloride (mg/L)	10	5.87	123.55	48.18			
Sulfate (mg/L)	10	11.66	236.35	67.7			
E. coli (cfu/100mL)	13	26	19000		332.21	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	9	150	1200		784.75	200 (geometric mean)	Impaired
Flow (cfs)	13	0	160	13.21			
Specific Conductance (US/cm @ 25°C)	23	69	1180	532.26			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 29. Historic Water Quality Data Collected from Steele Creek (Station 16384) Located at Robertson CR 477 (Segment 1209K)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	36	5.3	28.5	18.51		33.9 maximum	
Dissolved Oxygen (mg/L)	37	1.1	11.9	6.71		5.0/3.0 (grab avg/min)*	
pH (standard units)	37	6.75	8.3	7.31		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	13	0.05	0.62	0.23		1.95	
Orthophosphorus (mg/L)	13	0.05	0.05	0.05		0.37 (>20% exceedance)***	
Chloride (mg/L)	16	14.44	188.43	73.95			
Sulfate (mg/L)	16	10.54	152.92	79.36			
E. coli (cfu/100mL)	24	5	14000		218.40	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	11	105	1200		392.15	200 (geometric mean)	Impaired
Flow (cfs)	23	0	249	17.50			
Specific Conductance (US/cm @ 25°C)	36	117	1080				

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 30. Historic Water Quality Data Collected from Burton Creek (Station 11783) Located Downstream of the City of Bryan's WWTF, Upstream of SH 6 Southbound (Segment 1209L)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	62	4.4	31.07	22.05		33.9 maximum	
Dissolved Oxygen (mg/L)	62	3.9	13.3	8.01		5.0/3.0 (grab avg/min)*	
pH (standard units)	60	7.26	8.1	7.65		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	38	0.84	21.37	10.89		1.95	Concern
Total Phosphorus (mg/L)	1	2.17	2.17	2.17		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	34	0.31	3.88	2.39		0.37 (>20% exceedance)***	Concern
E. coli (cfu/100mL)	45	12	24000		506.02	126 (geometric mean)	Impaired
Fecal Coliform (cfu/100mL)	31	80	6000		552.93	200 (geometric mean)	Impaired
Flow (cfs)	21	0	15	4.79			
Specific Conductance (US/cm @ 25°C)	62	176	1349	1042.8			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 31. Historic Water Quality Data Collected from Clear Creek (Station 20019) Located Immediately Upstream of Leon CR 977 and 500m Upstream of Pigeon Roost Creek Confluence (Segment 1209P)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	244	20.5	26.3	24.12		33.9 maximum	
Dissolved Oxygen (mg/L)	196	5.6	8.1	6.89		5.0/3.0 (grab avg/min)*	
pH (standard units)	244	6.5	7.6	6.89		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	4	0.005	0.09	0.06		0.33 (>20% exceedance)***	
Nitrate Nitrogen (mg/L)	4	0.28	0.41	0.36		1.95	
Total Phosphorus (mg/L)	4	0.03	0.10	0.06		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	4	0.002	0.003	0.003		0.37 (>20% exceedance)***	
Chloride (mg/L)	4	16.4	22.5	19.68			
Sulfate (mg/L)	4	7.02	17.3	10.69			
Chlorophyll-a (µg/L)	1	0.6	0.6	0.6		14.1 (>20% exceedance)***	
Flow (cfs)	8	0.5	5.9	2.98			
Specific Conductance (US/cm @ 25°C)	244	132	210	154.94			
Transparency, Secchi Disc, (m)	4	0.3	0.8	0.54			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)

***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**

**** The listed impairment/concern is according to the 2012 303 (d) List**

***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists.**

Table 32. Historic Water Quality Data Collected from the Navasota River below Lake Mexia (Station 12126) Located East of Groesbeck, 81 Meters Downstream of SH 164 (Segment 1253)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	99	3.62	32.2	19.94		33.9 maximum	
Dissolved Oxygen (mg/L)	98	1.1	15.7	8.07		5.0/3.0 (grab avg/min)*	Concern
pH (standard units)	98	7.27	9.1	7.91		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	4	0.05	0.05	0.05		0.33 (>20% exceedance)***	
Nitrate Nitrogen (mg/L)	85	0.02	3.85	0.43		1.95	
Total Phosphorus (mg/L)	4	0.07	0.42	0.24		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	88	0.04	1.3	0.18		0.37 (>20% exceedance)***	
Chloride (mg/L)	91	4.74	316	85.31		440	
Sulfate (mg/L)	92	6.65	180	52.8		150	
E. coli (cfu/100mL)	63	1	3300		62.63	126 (geometric mean)	
Fecal Coliform (cfu/100mL)	47	4	1240		125.5	200 (geometric mean)	
Flow (cfs)	8	0	0.5	0.32			
Specific Conductance (US/cm @ 25°C)	100	99.9	1443	591.05			
Transparency, Secchi Disc, (m)	3 (2014)	0.27	0.35	0.30			
Turbidity (NTU)	3 (2014)	14	16	14.67			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 33. Historic Water Quality Collected from the Navasota River below Lake Mexia (Station 13650) Located near Groesbeck (Segment 1253)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	7	8	27.7	18.19		33.9 maximum	
Flow (cfs)	7	1.24	1270	264.26	48.09		
Specific Conductance (US/cm @ 25°C)	7	146	540	290.57			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**
*** *** The is station only had recorded data from 2000-2001**

Table 34. Historic Water Quality Data Collected from the Navasota River below Lake Mexia (Station 16393) Located at SH 14, near Fort Parker State Park, North of Groesbeck (Segment 1253)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	69	3.45	30.04	19.89		33.9 maximum	
Dissolved Oxygen (mg/L)	68	1.7	14.3	7.38		5.0/3.0 (grab avg/min)*	Concern
pH (standard units)	67	7	8.46	7.64		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	59	0.02	0.73	0.20		1.95	
Orthophosphorus (mg/L)	61	0.04	0.33	0.06		0.37 (>20% exceedance)***	
Chloride (mg/L)	63	2.69	82.51	16.52		440	
Sulfate (mg/L)	64	3.9	261.7	15.97		150	
E. coli (cfu/100mL)	36	1	1414		21.77	126 (geometric mean)	
Fecal Coliform (cfu/100mL)	46	1	1200		37.91	200 (geometric mean)	
Flow (cfs)	20	0	327	30.84			
Specific Conductance (US/cm @ 25°C)	69	89.2	1582	380.9			
Transparency, Secchi Disc, (m)	15	0.16	0.65	0.42			
Turbidity (NTU)	5	2.55	30.65	14.43			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 35. Historic Water Quality Data Collected from the Navasota River below Lake Mexia (Station 17039) Located at Fort Parker State Park, near Park Road 28 and is 806 meters Upstream of Springfield Lake (Segment 1253)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	166	6.8	31.6	20.28		33.9 maximum	
Dissolved Oxygen (mg/L)	161	0.3	13.1	5.06		5.0/3.0 (grab avg/min)*	Concern
pH (standard units)	166	6.2	8.6	7.48		6.5-9.0 range	
Ammonia Nitrogen (mg/L)	21	0.05	0.22	0.09		0.33 (>20% exceedance)***	
Nitrate Nitrogen (mg/L)	7	0.05	0.53	0.21		1.95	
Total Phosphorus (mg/L)	21	0.08	0.25	0.15		0.69 (>20% exceedance)***	
Orthophosphorus (mg/L)	19	0.06	0.17	0.07		0.37 (>20% exceedance)***	
Chloride (mg/L)	22	3	57	18.86		440	
Sulfate (mg/L)	22	4	16	8.87		150	
Chlorophyll-a (µg/L)	22	1	36.8	15.62		14.1 (>20% exceedance)***	
E. coli (cfu/100mL)	12	6	613		55.87	126 (geometric mean)	
Fecal Coliform (cfu/100mL)	12	3	430		59.97	200 (geometric mean)	
Specific Conductance (US/cm @ 25°C)	160	145	493	302.76			
Transparency, Secchi Disc, (m)	28	0.2	0.85	0.46			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exists**

Table 36. Historic Water Quality Data Collected from the Navasota River above Lake Mexia (Station 16391) Located at US 84 and is 5.6km Upstream of Lake Mexia (Segment 1210A)

Parameter Description	# of Samples	Min	Max	Avg	Geometric Mean	TCEQ Standard *Screening Criteria*	Impaired/ Concern**
Water Temperature (°C)	45	2.63	27.35	16.46		33.9 maximum	
Dissolved Oxygen (mg/L)	44	1.26	13.88	6.91		5.0/3.0 (grab avg/min)*	
pH (standard units)	44	6.84	7.7	7.40		6.5-9.0 range	
Nitrate Nitrogen (mg/L)	40	0.02	0.98	0.23		1.95	
Orthophosphorus (mg/L)	40	0.04	0.4	0.11		0.37 (>20% exceedance)***	
Chloride (mg/L)	42	2.9	175	42.65		440	
Sulfate (mg/L)	43	6.8	397.75	133.09		150	
E. coli (cfu/100mL)	25	6	7100		276.77	126 (geometric mean)	
Fecal Coliform (cfu/100mL)	35	4	4000		240.27	200 (geometric mean)	
Flow (cfs)	13	0	1	0.13			
Specific Conductance (US/cm @ 25°C)	45	127.9	1825	690.77			
Transparency, Secchi Disc, (m)	11	0.04	0.7	0.34			
Turbidity (NTU)	4	5.47	327.4	87.57			

Sources- Data: (TCEQ 2014b), Criteria: (TCEQ 2013a)
***A grab sample is an instantaneously collected sample that records a specific parameter at a specific time; these are minimum standards**
**** The listed impairment/concern is according to the 2012 303 (d) List**
***** If the screening level is exceeded greater than 20% of the time using the binomial method, a concern exist**

Potential Sources of Fecal Indicator Bacteria

Potential sources of fecal indicator bacteria are classified as originating from either regulated or nonregulated sources. Regulated pollution sources are permitted by designated permits from the National Pollutant Discharge Elimination System (NPDES) and the Texas Pollutant Discharge Elimination System (TPDES). Regulated discharge sources include wastewater treatment facilities (WWTF), cooling water, processing water and stormwater runoff discharges from urban, industrial, and select agricultural areas. Unregulated pollution sources are nonpoint sources in which pollution originates from multiple locations. These sources of pollution are not regulated by an issued permit and include sources such as runoff from rural areas or direct deposition of fecal matter to a stream from individual animals.

Point Source Discharges

Point sources for pollution consist of a regulated end-of-pipe outlet for cooling water, wastewater or stormwater originating from industrial or municipal treatment systems (TCEQ and TSSWCB 2013). Point source discharges require a permit issued by TCEQ and typically include municipal and industrial WWTFs, general wastewater and general stormwater permits. Sanitary sewer overflows and illicit/dry weather discharges are also discussed as regulated pollution sources in the watershed; however, they are not permitted discharges, but are instead unintentional discharges from permitted systems. Table 37 provides summarized information about each permitted facility in the watershed as reported by TCEQ and through the Environmental Protection Agency (EPA) Enforcement and Compliance History Online (ECHO).

Domestic Wastewater Treatment Facility Discharges

Within the watershed, 18 wastewater treatment facilities are permitted to discharge treated effluent into the Navasota River watershed. The majority of the permitted wastewater discharge occurs in the Bryan/College Station area and flows through Burton Creek, Carters Creek and Lick Creek before flowing into the Navasota River below Lake Limestone (Segment 1209C) East of College Station. The final permitted discharge limit of WWTFs in the watershed ranges from 8,500 to 9,500,000 gallons per day. Permit numbers, facility names, a description of the receiving waters, permitted flow rates and recently recorded flow rates are included in Table 37.

Burton Creek (1209L), downstream of the Burton Creek Wastewater Treatment Plant. This urban stream now maintains flow year-round due to inputs from the plant.

Table 37. Permitted Point Source Discharge Facilities in the Navasota River Watershed

TPDES Permit No.	NPDES No.	Facility	Receiving Waters	Final Permitted Discharges (MGD)[a]	Recent Discharge (MGD)
N/A	TX0108863	ARKEMA INC	N/A	*	*
WQ0013931001	TX0116378	CITY OF ANDERSON: WWTF	To an unnamed tributary, thence to Holland Creek and to the Navasota River Below Lake Limestone in Segment 1209 of the Brazos River Basin	0.065	0.01
WQ0001906000	TX0027952	CITY OF BRYAN: Atkins Street Power Station	To Fin Feather Lake, thence to Country Club Branch and Country Club Lake, then to Burton Creek, to Carters Creek and then to Navasota River Below Lake Limestone	0.385	0.073
WQ0010426001	TX0022616	CITY OF BRYAN: Burton Creek WWTF	To an unnamed tributary, then to Burton Creek, Carter's Creek and then to the Navasota River Below Lake Limestone	8.0	12.1
WQ0013153001	TX0098663	CITY OF COLLEGE STATION: Carter Lake WWTF	To an unnamed tributary of Carters Creek, then to Carters Creek and to Navasota River Below Lake Limestone	0.0085	0.006
WQ0010024003	TX0093262	CITY OF COLLEGE STATION: Lick Creek WWTF	To Alum Creek, then to Lick Creek and to Navasota River Below Lake Limestone	2.0	1.178
WQ0010024006	TX0047163	CITY OF COLLEGE STATION: Carters Creek WWTF	To Carters Creek and then to the Navasota River Below Lake Limestone	9.5	6.33
WQ0013980001	TX0117579	CITY OF MARQUEZ: WWTF	To an unnamed tributary, then to Brushy Creek and to the Navasota River below Lake Limestone	0.04	0.03
WQ0010824001	TX0075639	CITY OF THORNTON: WWTF	To an unnamed tributary, then to Steele Creek and to the Navasota River Below Lake Limestone	0.041	0.016
WQ0004770000	TX0124401	LINDE LLC: WWTF	To an unnamed tributary, then to Brushy Creek and to Navasota River Below Lake Limestone	0.04	0.011
WQ0014879001	TX0131440	NI AMERICA TEXAS DEVELOPMENT LLC: Myers Reserve WWTF	To an unnamed tributary and then to the Navasota River Below Lake Limestone	0.075	*
WQ0001986000	TX0068021	OAK GROVE MANAGEMENT CO LLC: Oak Grove Steam Electric Station	Via Outfall 001 to an unnamed final discharge canal and into Twin Oak Reservoir, then to Duck Creek; via Outfall 002 to Twin Oak Reservoir, then to Duck Creek and to the Navasota River Below Lake Limestone	1610	1542
WQ0002699000	TX0076465	OAK GROVE MINING CO LLC: Kosse Mine	N/A	*	2

TPDES Permit No.	NPDES No.	Facility	Receiving Waters	Final Permitted Discharges (MGD)[a]	Recent Discharge (MGD)
WQ0012296001	TX0085456	R&B MOBILE PARK LLC DBA GLEN OAKS MOBILE HOME PARK	To an unnamed tributary, to Carters Creek and then to the Navasota River Below Lake Limestone	0.013	0.001
WQ0005138000	TX0135615	SANDERSON FARMS INC (Franklin Feed Mill)	To an unnamed tributary then to Mineral Creek, Duck Creek and to the Navasota River below Lake Limestone	0.040	0.014
WQ0003996000	TX0120146	TENASKA FRONTIER PARTNERS LTD	To an unnamed tributary, to Sulphur Creek, to Gibbons Creek Reservoir, to Gibbons Creek and then to the Navasota River Below Lake Limestone	2.5	0.764
WQ0004002000	TX0002747	TEXAS A&M UNIVERSITY	To an unnamed tributary, then to Wolf Pen Creek, to Carters Creek and then to the Navasota River Below Lake Limestone	0.93	0.58
WQ0002120000	TX0074438	TEXAS MUNICIPAL POWER AGENCY: Gibbons Creek Steam Station	N/A	*	1.14
WQ0002460000	TX0083101	TEXAS MUNICIPAL POWER AGENCY: Gibbons Creek Lignite Mine	To Lake Carlos visa Outfall 001, to Big Branch and to an unnamed tributary, to Gibbons Creek and then to Navasota River Below Lake Limestone; the discharge route for Outfall 008 is to unnamed tributaries, to Gibbons Creek and to Navasota River Below Lake Limestone	Self Report	3.888
WQ0001176000	TX0001368	US SILICA CO: Kosse Plant	Via Outfall 003 to an unnamed tributary, to White Branch, to Steele Creek and to Navasota River Below Lake Limestone; and via Outfall 001, 002, 004 and 005 to White Branch, to Steele Creek and then to the Navasota River Below Lake Limestone	2.5	1.6
WQ0013850001	TX0118672	MEADOWCREEK WWTF	To a stormwater detention pond; then to unnamed tributary, then to Peach Creek and finally to the Navasota River below Lake Limestone	0.12	0.0317
WQ0011464001	TX0062162	CITY OF MOUNT CALM WWTF	Unnamed tributary of the Navasota River, Lake Mexia	0.036	0.0285
WQ0002430000	TX0082651	LIMESTONE ELECTRIC GENERATING STATION	Lynn Creek, Lamb Creek and then to Lake Limestone	2.304 Max Daily Flow Permitted	0.18
WQ0011405001	TX0105015	CITY OF KOSSE WWTF	Burleson Branch to Polecat Creek to Buckhorn Creek to the Little Brazos River and then the Brazos River above the Navasota River	0.04	0.023
WQ0014012001	TX0091758	CITY OF PERSONVILLE WWTF	Unnamed tributary of Big Creek, to Big Creek, then to Lake Limestone	0.075	0.104

TPDES Permit No.	NPDES No.	Facility	Receiving Waters	Final Permitted Discharges (MGD)[a]	Recent Discharge (MGD)
WQ0010182001	TX0054445	CITY OF GROESBECK WWTF	Unnamed tributary of the Navasota River then to the Navasota River below Lake Mexia	0.525	0.289
WQ0010222001	TX0052990	MEXIA WWTF	Concrete lined ditch, to unnamed tributary to Plummers Creek and then Navasota River below Lake Mexia (segment 1253)	2.0	0.925
WQ010717001	TX0030775	MEXIA STATE SCHOOL WWTF	Unnamed tributary to Rocky Creek to Jacks Creek and then to the Navasota River below Lake Mexia (segment 1253)	0.45	0.79
WQ0010182002	TX0117587	CITY OF GROESBECK: Drinking Water TP	Directly to the Navasota River below Lake Mexia	0.24	0.088
WQ0010300001	TX0034509	CITY OF TEAGUE WWTF	Unnamed tributary to White Rock Creek to Holman Creek to Big Creek then to Lake Limestone	0.21	0.104

[a] Significant figures reflect MGDs as available in TPDES permits
***** no discharge information was available for the facility

TPDES General Permits

Facilities that release processed wastewater discharges, besides that of individual wastewater treatment facilities, require a TPDES general permit. TPDES general permits include construction general permits, municipal separate storm sewer system (MS4), concrete production plant general permits, wastewater evaporation pond permits and concentrated animal feeding operation (CAFO) general permits. Facilities found to reside in the watershed that have been issued general permits include:

- TXG110000 – concrete production facilities
- TXG92000 – concentrated animal feeding operations
- WQG100000 – wastewater evaporation ponds

A review of active general permits within segments 1209, 1210A and 1253 within the Navasota River watershed (TCEQ 2013c) as of October 2, 2014, found five facilities discharging wastewater. Counties in the watershed impacted by the permits include Brazos (3), Grimes (1) and Robertson (1). Of the five permits issued, two are for CAFO operations, two are for concrete production facilities and one permit is for wastewater evaporation ponds with Sanderson Farms Inc.

Of the facility types that have been issued permits, concrete production facilities do not pose a significant risk of bacterial contribution to surrounding waterbodies. CAFOs can potentially pose a risk for bacterial contamination of neighboring waterbodies if the wastewater is not properly treated. Specifically, large rainfall events can overload the treatment systems can cause improperly treated water containing bacteria to flow directly into waterbodies (EPA 2012a). The two permits issued for CAFOs are for operations in Brazos County. Wastewater evaporation ponds can pose a threat to water quality and contribute to bacterial loading and when not constructed properly (EPA 2014b).

Stormwater General Permits

Stormwater discharges originating from industrial facilities, construction sites, Phase II urbanized areas or from other activities that require a general stormwater permit, must be filed under one of the mandated TPDES general permits:

- TXG110000-concrete production facilities
- TXR150000-construction activities that disturb greater than one or more acres and are part of a larger common plan of development
- TXR050000-multi-sector general permit (MSGP) for industrial facilities stormwater discharge
- TXR040000-Phase II MS4 general permit for urbanized areas

The stormwater general permit for concrete production facilities also allows the discharge of wastewater as described in the TPDES General Permit. MS4, MSGP, and construction activities permits pertain solely to stormwater discharge.

A review of active stormwater general permits pertaining to the stormwater flow in the Navasota River watershed on 3 December, 2014 includes permits for concrete production facilities

(TXG11), construction activities disturbing greater than one acre and part of a larger development (TXR15), MS4 for urbanized areas (TXR04), and a multi-sector general permit for industrial stormwater discharge (TXR05). Of the 153 stormwater general permits issued to facilities in operation in the watershed, 92 of the facilities are found in Brazos County. The remaining facilities with stormwater issued permits are found in Grimes (23), Limestone (22) Leon (8), Robertson (6) and Freestone (1) counties. Brazos county stormwater general permits include those for construction, concrete production, MSGP, and MS4 Phase II sites.

Sanitary Sewer Overflows

Sanitary sewer overflows (SSOs) are defined as unauthorized discharges from a sewer system and must be addressed by either the owner of the collection system that is connected to the permitted system, or the TPDES permittee. During dry weather, SSOs occur primarily from blockages in the sewer collection pipes, which are typically caused by grease, tree roots, or other debris. Sewer overflow can also occur from severe weather events, improper operation and maintenance of the system, sewer defects, power failures, and vandalism (EPA 2012b). Inflow and infiltration can be responsible for sewer overflows and water contamination during events in which high water flows from excess water in sewer pipes and stormwater overburdens a wastewater treatment facility's design capacity (King County 2011). Information reported to TCEQ by the permitted entity concerning known SSO events occurring in the Navasota River Watershed is presented in Table 38. SSO events are not always recorded and thus the accuracy of all the overflow events occurring is unknown.

Table 38. Reported SSO Incidences in the Navasota River Watershed

Facility Name	Segment	# of SSO Events in Last 3 to 5 years	Estimated Total Gallons Spilled
Burton Creek WWTF (City of Bryan)	1209	77	147,417
Meadowcreek WWTF	1209	1	None reported
City of Kosse WWTF	1242 (Brazos River above the Navasota River)	2	7,000
City of Groesbeck WWTF	1253	12	19,350
Mexia WWTF	1253	8	33,000
City of Teague WWTF	1252 (Lake Limestone)	5	775

Dry Weather Discharges/Illicit Discharges

Dry weather and illicit discharges are defined as any discharge to a storm sewer that is not entirely composed of stormwater under the TPDES General Permit No. 040000 for Phase II MS4s, (TCEQ 2013c). Bacteria loads can enter streams from illicit discharges and permitted outfalls during dry and wet conditions. Illicit discharges include a variety of direct and indirect sources. Direct entry occurs when the discharge is directly connected by a pipe to a storm drain such as illegal dumping and cross connections between sewage and stormwater conveyance systems (Brown et al. 2004). Indirect illicit discharges typically occur by means of flows generated outside the storm drain system that enter through pipe failures or drain inlets. Examples of indirect illicit discharges include groundwater seepage into a storm drain pipe, spills entering a system through an inlet, outdoor washing practices that flow discharge into a storm drain inlet, and non-target irrigation that enters the storm drain system (Brown et al. 2004). There is currently no record of dry weather or illicit discharges in the Navasota River watershed, yet it is likely that some form of these discharges may exist.

Review of Compliance Information on Permitted Sources

A review of the EPA's ECHO and Integrated Compliance Information System (ICIS) databases (EPA 2014a) identified non-compliance issues regarding *E.coli* permit levels for 7 WWTFs on March 17, 2015, in the watershed. From September 1, 2010 to September 30, 2014, the following 7 facilities reported *E.coli* levels surpassing their daily maximum discharge limits at least once:

- City of Anderson WWTF
- Lick Creek WWTF (City of College Station)
- Carter Creek WWTF (City of College Station)
- City of Marquez WWTF
- City of Mount Calm WWTF
- City of Kosse WWTF
- City of Groesbeck WWTF (TX0054445)
- City of Coolidge WWTF

The ECHO database was reviewed for Significant Non-compliance (SNC) violations, which can result from late, or missing reports and discharges above the facilities' stated limitations. Unresolved SNC violations identified within the within the watershed at the following facilities:

- City of Groesbeck WWTF (TX0054445)
- City of Teague WWTF

Several WWTFs recently had *E. coli* limits added to their TPDES permits. As a result, no self-reported data has been loaded into the ECHO or ICIS databases. The other stations listed in Table 39 do not have permit limitations or current data concerning bacterial discharges.

- Carter Lake WWTF (City of College Station)
- City of Thornton WWTF
- Myers Reserve WWTF (Ni America Texas Development LLC)
- Meadowcreek WWTF
- Glen Oaks Mobile Home Park WWTF

Table 39. Bacterial Monitoring Requirements and Compliance Status for Wastewater Treatment Facilities (WWTF) in the Navasota River Watershed

TPDES Permit No.	EPA ID	Facility	Permit Monitoring Requirement	Min. Self-Monitoring Requirement-Frequency	Permit Limits		Recent Reported Values	
					Daily Average (CFU/100mL)	Daily Max per Sample (CFU/100mL)	Daily Average	# of Grab Samples Exceeding Daily Max
WQ0013931001	TX0116378	City of Anderson WWTF	*E.coli*	1/month	126 Daily avg	399 single grab	558.23	8
WQ0010426001	TX0022616	Burton Creek WWTF (City of Bryan)	*E.coli*	1/week	120 Daily avg	381 single grab	12.36	0
WQ0013153001	TX0098663	Carter Lake WWTF (City of College Station)	*E.coli*	1/month	120 Daily avg	380 single grab	--	--
WQ0010024003	TX0093262	Lick Creek WWTF (City of College Station)	*E.coli*	Daily	126 Daily avg	399 single grab	65.47	5
WQ0010024006	TX0047163	Carter Creek WWTF (City of College Station)	*E.coli*	Daily	120 Daily avg	380 single grab	64.93	5
WQ0013980001	TX0117579	City of Marquez WWTF	*E.coli*	1/month	126 Daily avg	399 single grab	82.46	2
WQ0010824001	TX0075639	City of Thornton WWTF	*E.coli*	1/quarter	126 Daily avg	399 single grab	--	--
WQ0004770000	TX0124401	Linde North America LLC	*E.coli*	1/week	Report	Report (must report reading)	16.24	--
WQ0014879001	TX0131440	Myers Reserve WWTF (Ni America Texas Development LLC)	*E.coli*	1/ quarter	126 Daily avg	399 single grab	--	--
WQ0012296001	TX0085456	Glen Oaks Mobile Home Park WWTF (R&B Mobile Park LLC DBA)	*E. coli*	1/quarter	120	381 Single grab	*	*

TPDES Permit No.	EPA ID	Facility	Permit Monitoring Requirement	Min. Self-Monitoring Requirement-Frequency	Permit Limits		Recent Reported Values	
					Daily Average (CFU/100mL)	Daily Max per Sample (CFU/100mL)	Daily Average	# of Grab Samples Exceeding Daily Max
WQ0013850001	TX0118672	Meadowcreek WWTF	*E.coli*	1/month	126 Daily Avg	399 Single grab	*	*
WQ0011464001	TX0062162	City of Mount Calm WWTF	*E. coli*	1/week	126 Daily avg	394 single grab	270.128	26
WQ0011405001	TX0105015	City of Kosse WWTF	*E.coli*	1/month	126 Daily avg	399 single grab	123.0345	6
WQ0014012001	TX0091758	City of Personville WWTF	no *E.coli*	--	--	--	--	--
WQ0010182001	TX0054445	City of Groesbeck WWTF	*E.coli*	2/month	126 Daily avg	394 single grab	8.472712	1
WQ0010222001	TX0052990	Mexia WWTF	*E.coli*	1/month	126 Daily avg	394 single grab	36.713	0
WQ010717001	TX0030775	Mexia State School WWTF	*E.coli*	1/month	126 Daily avg	399 single grab	2.606129	0
WQ0010300001	TX0034509	City of Teague WWTF	*E.coli*	1/month	126 Daily avg	399 single grab	4.402215	0

--No compliance information or data is available through ECHO or ICIS. Compliance statuses were recorded between September 2010 and September 2014 and made available through the EPA's Enforcement & Compliance History Online (ECHO) database.

* No self-report data available yet. These facilities recently began monitoring for *E.coli* levels.

Nonpoint Sources

Nonpoint source pollution is defined as water pollution that does not come from regulated or point sources (TCEQ and TSSWCB 2013). Unregulated sources of *E.coli* typically consist of nonpoint sources stemming from wildlife, feral hogs, agricultural practices, livestock, land management, leaking on-site sewage facilities (OSSFs), urban and agricultural runoff, and domestic pets.

Non-Permitted Agricultural Activities

Livestock grazing in the watershed contributes to the overall *E. coli* load contributed to the watershed. The number and distribution of animals present across the watershed also strongly influences the potential for *E. coli* originating from these animals to actually reach the waterways. For example, livestock or wildlife in a pasture with creek access have a higher chance of contributing *E. coli* to the stream than those several miles from the nearest stream. The National Agricultural Statistics Service's 2012 Census of Agriculture provides county-level livestock counts that can be scaled down to approximate watershed specific numbers (USDA 2012). The estimated number of animals within the watershed was determined by identifying the portion of each county within the watershed (Table 1) and multiplying the total number of animals or animal units by the percentage of the county located in the watershed. The number of farms or ranches in the county, average farm size and total number of livestock produced are also included. Table 40 lists the estimated numbers of specific animals to be found in each county included in the Navasota River watershed.

Table 40. Estimated Animal Populations in the Watershed

		Farm Statistics and Production			Inventory of Livestock (# of head)					
County	Percentage in Watershed	# of Farms	Land in Farms (ac.)	Average Farm Size (ac.)	Cattle and Calves	Horses	Goats	Sheep and Lamb	Laying Hens	Hogs and Pigs
Brazos	70.6%	997	211,170	149.7	33,529	1,979	1,315	590	*	357
Freestone	11.6%	176	48,871	32.0	7,152	27	137	44	2,267	40
Grimes	40.2%	677	167,691	99.7	22,939	1,273	483	78	21,244	492
Hill	1.9%	36	9,578	5.1	987	52	70	41	66	2
Leon	25.0%	491	148,598	75.8	19,526	730	456	91	21,682	66
Limestone	72.2%	1,102	351,460	230.3	53,040	339	1,110	336	*	122
Madison	14.8%	144	43,120	300.4	6,438	51	148	52	*	443
Robertson	42.7%	649	199,652	307.6	30,918	217	520	266	*	352
Watershed Total		4,272	1,180,140	150	174,529	4,668	4,239	1,498	45,259	1,874

*Indicates information that cannot be disclosed.

Water Quality Management Plans

Some agricultural operations in the watershed manage their properties under the guidance of the Texas State Soil and Water Conservation Board (TSSWCB) and the Natural Resources Conservation Service (NRCS) through water quality management plans (WQMPs). These are site specific plans developed through and approved by soil and water conservation districts that strive to meet the goals of the producer. Plans commonly include land treatment practices, production practices and management measures that are designed to achieve a level of pollution abatement or prevention that is consistent with state water quality standards when they are properly implemented and maintained. Anyone can request that a plan be developed; however, dry poultry production facilities are required to adhere to a developed and approved WQMP.

Within the Navasota River watershed, at total of 59 WQMPs exist and prescribe management on 15,215 acres of the watershed (Figure 10). Of these, 57 are developed in association with poultry operations that are common throughout the watershed. These plans focus on establishing animal mortality facilities to properly dispose of deceased birds, litter storage and composting facilities, filter strips, prescribed grazing, heavy use area protection, nutrient management, pest management and waste utilization. The other two WQMPs are focused more on cattle but contain many of the same practices. Upland wildlife habitat management, forage harvest management, forage planting and conservation cover planting are other popular practices included in the established WQMPs. Table 41 describes the extent of management practices established through WQMPs in the watershed and Figure 10 depicts the general distribution of WQMPs across the watershed.

Prescribed grazing planned through WQMPs include utilizing proper stocking rates, cross fencing and a rotational grazing strategy to maximize forage production, improve cattle weight gain, and reduce input cost. The prescribed grazing also improves onsite water holding capacity and reduces the amount of runoff leaving the property.

Table 41. WQMP Summary for the Navasota River Watershed

HUC 12	Non-AFO/CAFO	CAFO	CAFO- Poultry	AFO - Poultry	AFO- Non Poultry	# WQMPs	Animal Type (Pullet)	Animal Type (Breeder)	Animal Type (Broiler)	Animal Type (Auction Barn)	Total acres	Estimated Litter Produced Annually (tons)	Planned Litter Allowable To Be Utilized On-Site (tons)	Excess Litter To Be Utilized Off-Site (tons)	Estimated Solids Produced Annually (tons)	Excess Solids To Be Utilized Off-Site (tons)	312 # of Waste Management System	313 # of Waste Storage Facility	316 # of Animal Mortality Facility	316A # of Animal Mortality Facility-Incinerators	316B # of Animal Mortality Facility-Freezers	316D # of Animal Mortality Facility- Composters	317 # of Composting Facilities
120701030105				1		1		44,000			20	732	0	732						1			
120701030107					1	1				180	27.7				376	376							
120701030108			1			1			184,000		97	1,093	0	1,093						2			
120701030203				1		1		22,000			50	366	0	366									
120701030204			2			2			593,800		242	3,309	28.4	3,281				2		4	4		2
120701030301			4	1		5		22,000	1,459,400		576	10,313	0	10,313				4		12			
120701030303			1	1		2	47,326		154,200		206	1,243	114.7	1,128						2			
120701030304			3			3			434,000		218	3,945	0	3,945				1		7			3
120701030307			6			6			1,189,800		840	7,772	603.9	7,168				2	2	10			
120701030308			3			3			903,200		382	5,585	132.4	5,452						5			4
120701030309			3			3			1,291,400		487	8,296	251	8,045				1	9	12			1
120701030401			5	1		6		44,480	1,229,200		5,438	9,074	1,952	7,328					5	6	2	1	2
120701030402		1	1	1		3			606,000		322	4,368	208	4,160				1	3	6	5		1
120701030403			2			2			220,384		506	3,500		2,412					3	3			
120701030404			5			5			1,056,800		859	6,362	532	5,829				2		12	2		4
120701030406			1			1			536,000		155	2,687	212.1	2,475				2	3	3			
120701030407			1	1		2	47,600		328,800		1,518	2,237	730	1,507				3	3	3			
120701030501			3	2		5			1,288,400		1,244	8,661	161	8,499				2		5	2		1
120701030503				1		1	48,000				257	238	479	0						1			
120701030506			2			2			495,000		508	3,266	619	2,648				4		2			3
120701030509	1					1					218												
120701030601			1			1			165,000		249	1,043	82	961						1			
120701030705			1	1		2		46,200	660,000		795	4,103	0	4,103			4	1		4			
Total	1	1	45	11	1	59	142,926	178,680	12,795,384	180	15,215	88,193	6,105	81,445	376	376	4	25	28	101	15	1	21

HUC 12	327 (acres) Conservation Cover	328 (acres) Conservation Crop Rotation	342 (acres) Critical Area Planting	382 (feet) Fence	393 (acres) Filter Strip	394 (feet) Firebreak	460 (acres) Land Clearing	511 (acres) Forage Harvest Management	512 (acres) Forage and Biomass Planting	528 (acres) Prescribed Grazing	561 (acres) Heavy Use Area Protection	562 (acres) Recreation Area Improvement	590 (acres) Nutrient Management	595 (acres) Pest Management	612 (acres) Tree and Shrub Establishment	632 # of Solid/Liquid Waste Separation Facility	633 (acres) Waste Utilization	634 # of Manure Transfers	642 # of Livestock Water Wells	645 (acres) Upland Wildlife Management	650 (feet) Windbreak and Shelterbelt Renovation	666 (acres) Forest Stand Improvement	n/a (acres) Other Land Management
120701030105											20			20									
120701030107										13.4	8.7		13.4	13.4			0.1						5.6
120701030108	65										32			32									
120701030203	38										12			12									
120701030204	127				6					50	65	21	13	94			13						
120701030301	205	21	56		11			95			161		66	256		66			5	94	5,000		
120701030303	53		18		10			32		150	20		103	170			65		3	36			
120701030304	40										62			62						116			
120701030307			90		67			86		474	114		425	651			389		3	203			
120701030308	140.5				31			140		140	91		106	231			106			10			
120701030309			100		7			139		107	142		122	325			122		5	163			
120701030401	7		43		89		20	338	20	1,189	129		709	1,400			269	440	3	300			
120701030402	44				23			60		208	59		171	278			98						
120701030403	170				37			171		215	85		215	300			215			36			
120701030404	26		17		135			154		496	112		469	762			365			71			
120701030406	28							61			31		61	92									
120701030407			11		37			195		269	37		203	306			203						
120701030501	89		28		56			195		583	130		386	763			377		3	407			
120701030503					20			31		131	18		31	163.4			133			77			
120701030506	22				48			347		386	48		305	440			305			46			
120701030509				990		13,761				159					22					218		12	
120701030601					4			83			24		67	88			67			13			
120701030705	356				51			215		131	93		292	439			292						
Total	1,411	21	363	990	632	13,761	20	2,342	20	4,701	1,494	21	3,757	6,898	22	66	3,019	440	22	1,790	5,000	12	6

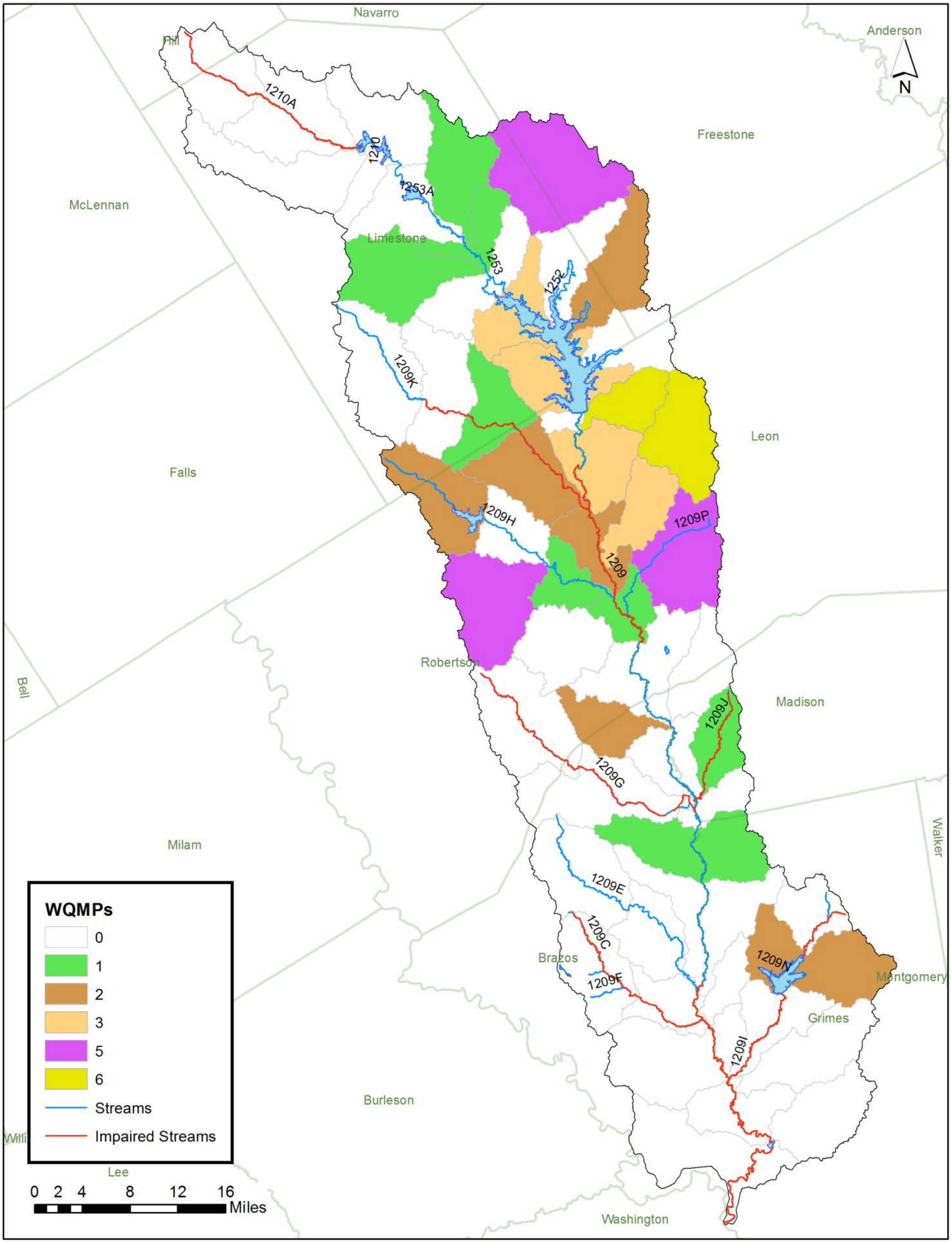


Figure 10. WQMPs Within the Navasota Watershed, Divided by Subwatersheds.

Domestic Pets

Household pets can also be a source of fecal bacterial contamination during episodes of stormwater runoff. The AVMA has estimated the dogs per household as 0.584 of the number of persons per household and the cat population per household was estimated at 0.638. According to the 2010 Census data gathered, the average persons per household in the watershed is 2.6. The formulas to determine dog and cat populations are provided below. The estimated number of dogs in the watershed is 46,057 and the estimated number of cats is 50,316.

Number of Households= Human Population/2.6

Number of Dogs= 0.584*(Total Number of Households)

Number of Cats= 0.638*(Total Number of Households)

Table 42. Estimated Dog and Cat populations in the Watershed

County	Human Population	Number of Households	Estimated Dog Population	Estimated Cat Population
Brazos	156,941	60,362	35,251	38,511
Freestone	4,733	1,820	1,063	1,161
Grimes	11,170	4,296	2,509	2,741
Hill	652	251	146	160
Leon	5,357	2,060	1,203	1,315
Limestone	20,146	7,748	4,525	4,944
Madison	1,419	546	319	348
Robertson	4,630	1,781	1,040	1,136
Watershed Total	205,048	78,865	46,057	50,316

Wildlife and Unmanaged Animal Contributions

Wildlife can contribute a significant amount of *E. coli* into the watershed. Riparian corridors of streams and rivers provide excellent habitat for wildlife as it meets their three primary needs: shelter, food and water. Logically, animals spend the majority of their time in these areas and thus expel the most waste in these areas as well. Subsequent runoff events then have a higher likelihood of washing this fecal matter into the stream. Some species even congregate in or near the water and are known to directly defecate into the waterbody. These primarily include feral hogs and waterfowl. As a result, estimating the potential contribution of fecal loading from wildlife is essential to evaluating the overall *E. coli* load in the watershed; however, population estimates of wildlife and feral animals are extremely limited. Species that reasonable estimates can be made for include white-tailed deer and feral hogs.

The Texas Parks and Wildlife Department (TPWD) routinely estimates White-tailed deer densities, which can be translated into a watershed-wide population estimate. In a phone interview with the TPWD regional biologist, the most recent White-tailed deer density in the watershed is estimated to be one deer per 25 acres of suitable habitat (Phone interview with Timothy Siegmund, October 30, 2014). White-tailed deer are commonly found in or near habitat that provides ample cover and are near ample food. This type of area is usually found in riparian areas and in upland forested areas. For purposes of estimating a watershed-wide population, this density was applied to forest, wetlands, shrub/scrub, cultivated crops and herbaceous areas in the watershed and yielded an estimate of 29,963 animals in the watershed (Table 43).

Feral hog population densities can vary greatly and are difficult to determine. Various estimates have been developed to quantify their density and they also vary widely. One estimate that is commonly utilized in Texas is a density of one hog per 33.3 acres (Wagner and Moench 2009). Applying this density to the same suitable habitat as White-tailed deer yields an estimated watershed population of 22,495 hogs (Table 43).

Table 43. Estimated Deer and Feral Hog Population in the Watershed Based on Land Cover

Landcover Type	Acres	# of Deer	# of Feral Hogs
Wetlands	93,202	3,728	2,799
Forest	316,252	12,650	9,497
Herbaceous	1,945,260	7,770	5,834
Shrub/Scrub	114,262	4,571	3,431
Cultivated Crops	31,102	1,244	934
Total	749,076	29,963	22,495

Failing On-Site Sewage Facilities

OSSFs also represent a potential source for *E. coli* loading to the watershed. Several factors exist that can influence the likelihood that pollutants from an OSSF would enter a waterway. These include functional status of the system, location, soils of the system, density of the systems in the selected area and the age of the system. Understanding the number of OSSFs in watershed is beneficial for assessing the potential risk for impacting water quality.

Comprehensive data concerning the locations of OSSFs in the Navasota River Watershed are not available, thus secondary sources of information must be relied upon to approximation the number of OSSFs present. One approach to accomplish this is to compare information available in the 1990 and 2010 Census, 911 addresses points, and recent aerial imagery (Gregory et al. 2013). As this work noted, the age of the 1990 Census data limits its utility in this assessment, thus it was not included here. Using the other three data sets, a best estimate of the number and distribution of OSSFs in the watershed was developed. The use of this data does require that assumptions regarding the presence of OSSFs be made and therefore it carries a certain level of uncertainty that can only be removed with on-site inspections.

To develop this OSSF estimate, 911 address point data was obtained from all counties in the project area in the form of a Geographic Information System (GIS) shapefile. Data were processed in the Environmental Systems Research Institute’s ArcGIS 10.2 to remove data points outside the watershed. Address points are typically provided on a public roadway rather than on the physical structure. As a result, points near the watershed boundary may be erroneously included or excluded if their location is solely used as a screening factor. Additionally, address points are typically given to any point with an electrical connection, including businesses, radio towers, barns, churches, irrigation well motors and other hospitable structures, potentially overestimating the number of OSSFs within the study area (Gregory et al. 2013). To minimize potential overestimate of OSSFs, aerial imagery is used to screen 911 address points.

Aerial imagery available through the ArcGIS 10.2 BaseMap World Imagery (0.3m resolution, March 2011) was used to determine if the point corresponded with a habitable structure. Observations made led to assumptions regarding the type and use of structures and whether it had an active OSSF. Features observed included presence of cars in the driveway, quality and type of road to the structure, shape and condition of the structure and the presence of green areas around the structure (septic drain fields). This approach enabled some 911 address points that were obviously not heavily utilized or suspected to not have an OSSF were excluded.

Data collected during the 2010 U.S. Census was also utilized. Data recorded at the census block level notes the number of households within that block. This information can also be used to approximate the number of OSSFs in the watershed. Its use does possibly represent an overestimate of the number of housing units within the study area because many census blocks extend outside of the watershed boundary. To buffer this, the percent of census block area inside the watershed was calculated and the number of housing units in census block was reduced by that percentage.

To further refine this estimate, addresses and housing units within cities and communities within the watershed that are served by wastewater treatment facilities were excluded. The presence of WWTF outfalls as verified through existing permits was used to determine if there was a sewer system present in the area. Service area maps for all WWTFs were not available, therefore city limit boundaries were assumed to be the extent of the serviced area in these cases. TCEQ also maintains certificates of convenience and necessity (CCN) data for some WWTFs. This data denotes the extent of the service area and was utilized where possible.

Using this approach, an estimated total of 22,216 OSSFs exist within the watershed. Table 44 displays the estimated numbers of OSSFs in the watershed by county and the soil's suitability to receive leachate from the systems according to NRCS guidelines. The OSSFs estimated through this approach have not been verified by on-site inspections but through the processes listed above.

OSSF density within an area can potentially influence local water quality. If the density of OSSFs is high, the capacity of the soil to absorb and mitigate pollutants from these systems may be exceeded. In cases where soils become saturated, effluent can percolate into shallow groundwater or pond on the surface. Ponded effluent can then runoff during a rain event and impact nearby water quality. The greatest densities of OSSFs are found outside of Bryan/College Station and northwest of Normangee with densities ranging between 55-76 septic systems per square mile. Upstream of Lake Limestone, OSSF density is typically less than 10 systems per square mile with a few areas having a density ranging between 10-18 systems per square mile. Figure 11 illustrates the densities of the estimated OSSF systems across the watershed.

Proximity of OSSFs to the stream network can also increase potential water quality impacts of these systems. The closer a single system or cluster of systems are to a waterbody, the distance that any improperly managed effluent has to travel to the stream is reduced thus increasing the pollution risk. Within the watershed, 678 OSSFs are estimated to be within 100 yards of perennial streams and 318 facilities are expected to be within 50 yards of intermittent streams. Figure 12 identifies locations where OSSFs are expected to fall within these distances to the stream.

Table 44. Estimated OSSFs Numbers by County and Soil Suitability Conditions

Soil Condition	Total OSSFs by County								Total OSSF by Soil Condition
	Hill	Limestone	Freestone	Robertson	Leon	Brazos	Madison	Grimes	
Very Limited	91	1,635	446	1,022	746	5,697	418	2,750	12,805
Somewhat Limited	0	361	0	414	169	646	114	478	2,182
Not Limited	0	1,316	228	1,014	2,011	1,843	172	594	7,178
Not Rated	0	4	2	1	1	0	5	38	51
Total by County	91	3,316	676	2,451	2,927	8,186	709	3,860	22,216

Soils have a considerable impact on OSSF function and therefore the potential for failure and subsequent pollution concerns. The NRCS's Soil Survey Geographic Database is comprised of national soil data and includes a soil suitability rating for OSSF leach-fields. Soils are classified as not limiting, somewhat limiting, very limiting, and not rated. The classifications help determine the ability of the soil to effectively treat receiving OSSF effluent, but do not take the place of a site-specific soil evaluation. Within the watershed, 57.6% of OSSFs are located in very-limited soils, 9.8% are located in somewhat-limited soils, 32.3% are in not-limited soils while the remaining 0.2% is considered not rated.

Several other factors influence the possibility for OSSFs to fail, including age, improper design, lack of owner education, and poor system maintenance; however, this information is unavailable for this watershed.

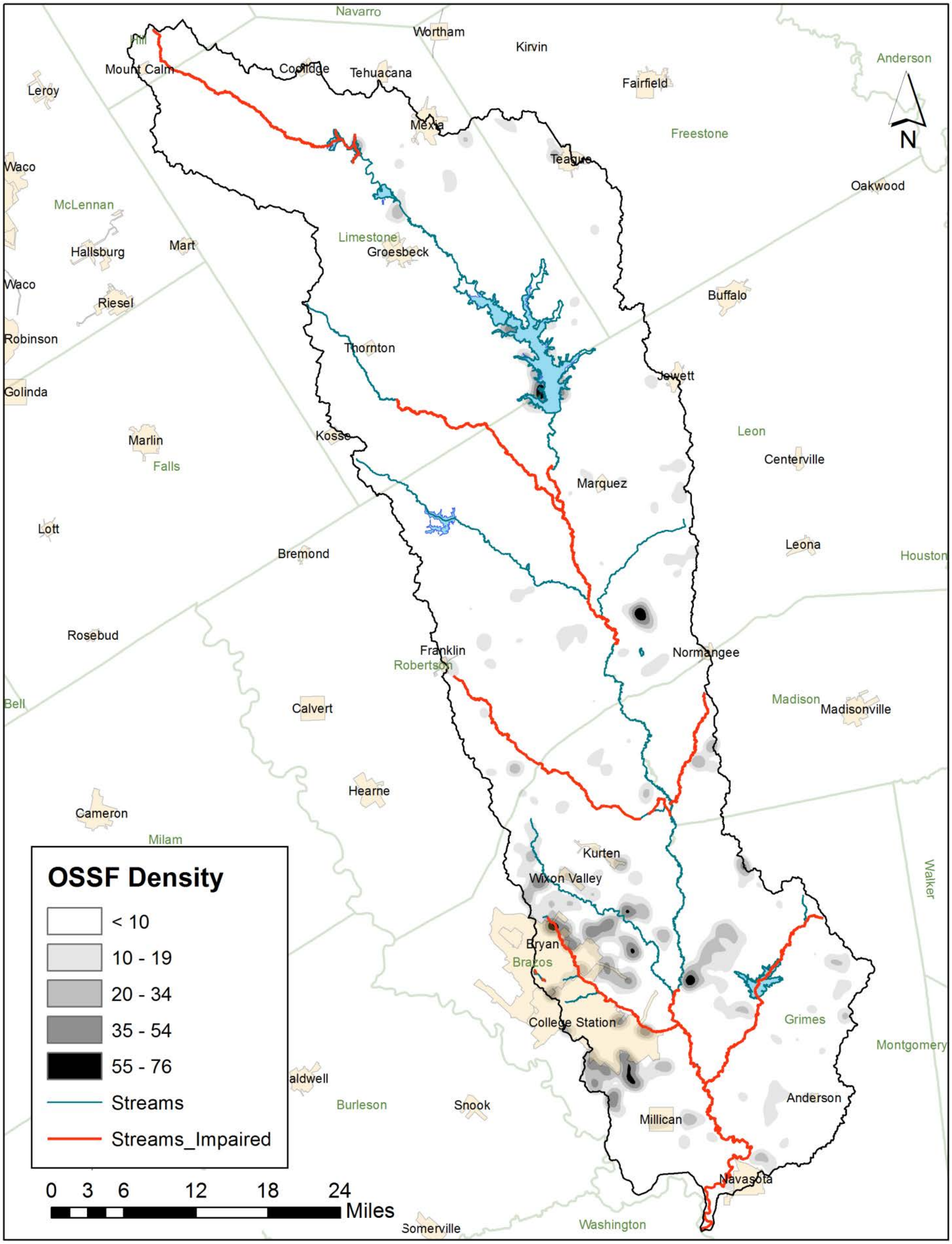


Figure 11. OSSF Density within the Watershed.

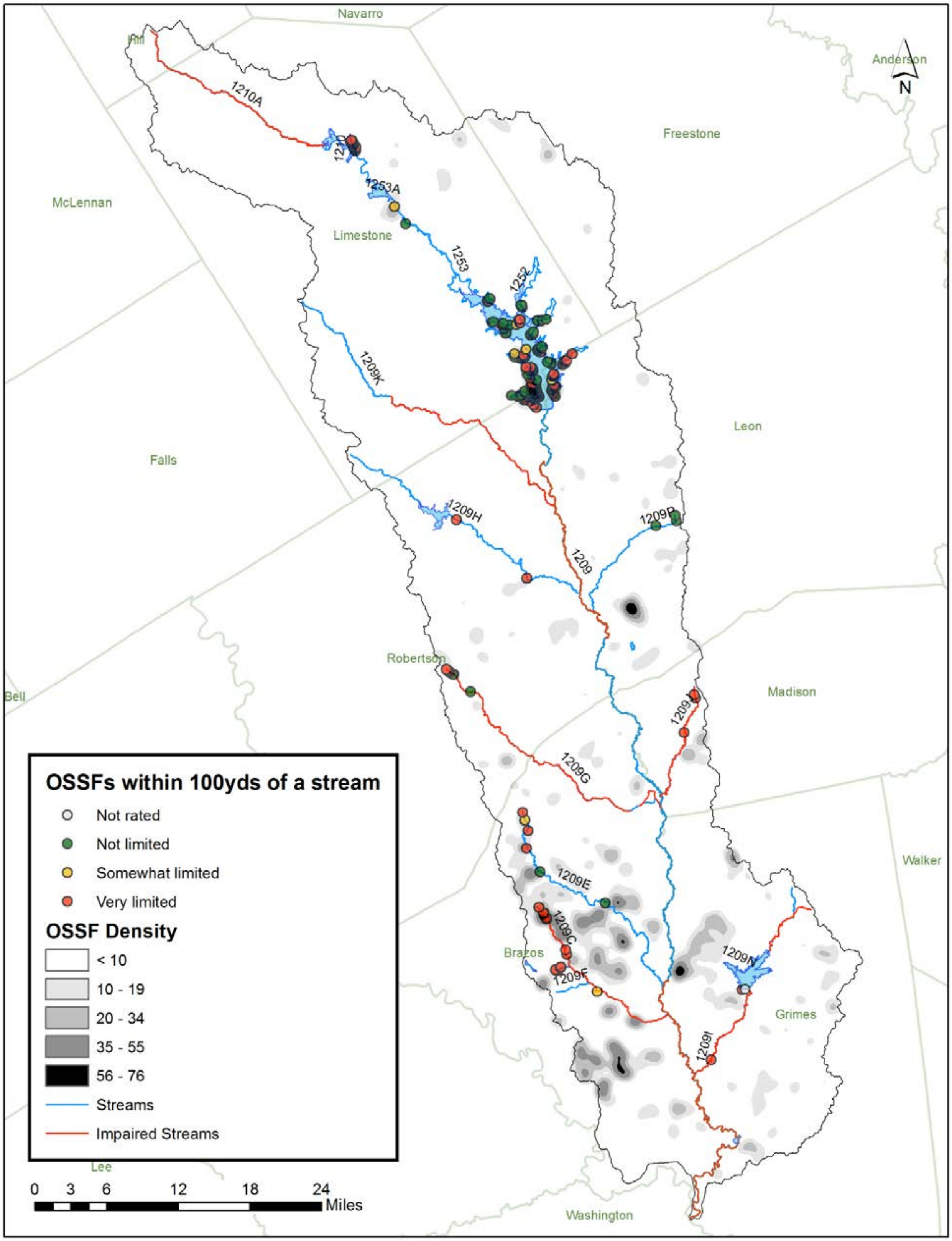


Figure 12. OSSFs within 100 Yards of a Stream.

Pollution Source Assessment

Load Duration Curve Analysis

Load Duration Curves (LDCs) are an effective tool for evaluating the relationship between measured *E. coli* levels and stream flow rates at defined monitoring stations. These curves utilize *E. coli* and stream flows measured during the same monitoring event to approximate pollutant loading over a wide range of stream flow conditions. LDCs serve as analytical tools to calculate and identify the allowable bacterial loadings over a range of anticipated or known flow conditions in an evaluated waterbody (Millican et al. 2010).

LDCs are developed by first constructing a flow duration curve (FDC). Stream flow data available at a specific site are ranked from highest to lowest and the rank value is divided by the total number of flow points to produce the percent of time that flows are expected to exceed that level. Once completed, stream flow levels are often separated into specific flow categories: low flows, dry conditions, mid- range conditions, moist conditions and high flows. These categories typically represent the range of flow conditions observed or expected to occur in the stream (Borel et al.2012). These flow categories can be modified if needed to better represent the hydrology of the evaluated stream.

The FDC is then multiplied by the water quality standard and appropriate unit conversion to produce the total maximum daily load (TMDL) line. This line graphically defines the maximum allowable pollutant load that the waterbody can carry and still meet its designated water quality standards. Actual monitoring data is then plotted around the TMDL line by multiplying the monitored concentration (such as *E. coli*) and recorded stream flow data to produce the observed loads under that specific flow condition. Plotted *E. coli* data should lie predominantly below the TMDL line when the waterbody meets water quality standards. For waterbodies not meeting water quality standards, *E. coli* data will typically be above the TMDL line.

LDCs can also identify the level of pollutant load reduction needed in a waterbody to achieve its water quality goals (Borel et al. 2012). Plotting a regression line through the monitored data points estimates the pollutant load for the waterbody. The level of pollutant reduction necessary for water quality standards to be met under specific flow conditions is then obtained by averaging the difference between the TMDL line and the estimated load (Borel et al. 2012).

The distribution of monitored data aids in identifying the general type of pollutant loading that is occurring. Excessive loadings on the left side of the graph, located in the high flow or moist conditions, most likely result from nonpoint source pollution or sediment re-suspension from stormwater or rain. Excessive loadings to the right side of the graph in the dry or low flow conditions can indicate point source pollution, streambed disturbance or direct deposition of bacteria. The specific timing of pollutant loading or defined sources cannot be determined however.

To develop LDCs, an absolute minimum of paired stream flow and pollutant concentration data points must be available; however, the confidence in the curve produced is not great (Runkel et al., 2004). In fact, 18 data points within each flow category are needed to achieve 85% confidence in the estimated loadings (Borel et al. 2012). Working with the water quality data available on the Navasota River and its tributaries in TCEQ’s SWQMIS, the minimum data threshold was only met at monitoring stations 11877, 11783, 11785, and 21259. Station 11782 on Carters Creek also had ample data points to conduct an LDC; however, numerous flow readings were negative due to the proximity of the stream's confluence with Burton Creek. As a result, no LDC was developed for this site. LDCs and the estimated loads and loading reductions needed to achieve water quality standards for each site listed are found in Figures 13-16 and Tables 45-48 respectively. The figures display measured *E. coli* loadings with specific flow conditions, indicating conditions in which bacterial loading was above or below TMDL requirements.

Site Specific Loading Assessments

Station 11877 located on the Navasota River at US 79 had the most extensive data record available for use in developing an LDC. The presence of USGS Stream Gaging Station 08110500 at this site enabled many *E. coli* data points that did not have associated stream flow values to be utilized. In these cases, the daily mean streamflow value as reported at the USGS gage was utilized to approximate the flow level on the date the *E. coli* sample was collected. Additionally, all daily mean streamflow values reported by the USGS gage from March 2008 to March 2015 were used to construct the FDC and TMDL line in Figure 13. This greatly improved the accuracy of expected flow levels at this site.

In total, 63 *E. coli* data points collected between 2001 and 2015 were available at this site and were utilized to develop the LDC (Figure 13) and needed load reductions (Table 45) for this site. The LDC revealed that under mid-range, dry conditions and low flows, monitored *E. coli* loads are relatively well distributed near or slightly under the TMDL line thus suggesting that point sources or direct deposition of *E. coli* is not problematic. Under high flow and moist conditions, recorded *E. coli* levels were more commonly found to be above allowable levels indicating that nonpoint source pollution and/or sediment resuspension from within the stream are primary contributors to the observed *E. coli* levels.

Table 45. Percent Based Load Reductions Needed to Achieve Water Quality Standards and Predicted *E.coli* Loadings at Station 11877

Flow Condition	% Flow Exceedance	Average Daily Load Reduction Needed	Average Daily Loading (cfu/day)	Average Annual Loading (cfu/year)
High Flow	0-10%	9.17E+13	1.57E+14	5.75E+16
Moist Conditions	10-40%	1.47E+12	3.89E+12	1.42E+15
Mid-Range	40-60%	7.18E+10	1.51E+11	5.52E+13
Dry Conditions	60-90%	N/A	4.33E+10	1.58E+13
Low Flow	90-100%	N/A	1.22E+10	4.44E+12

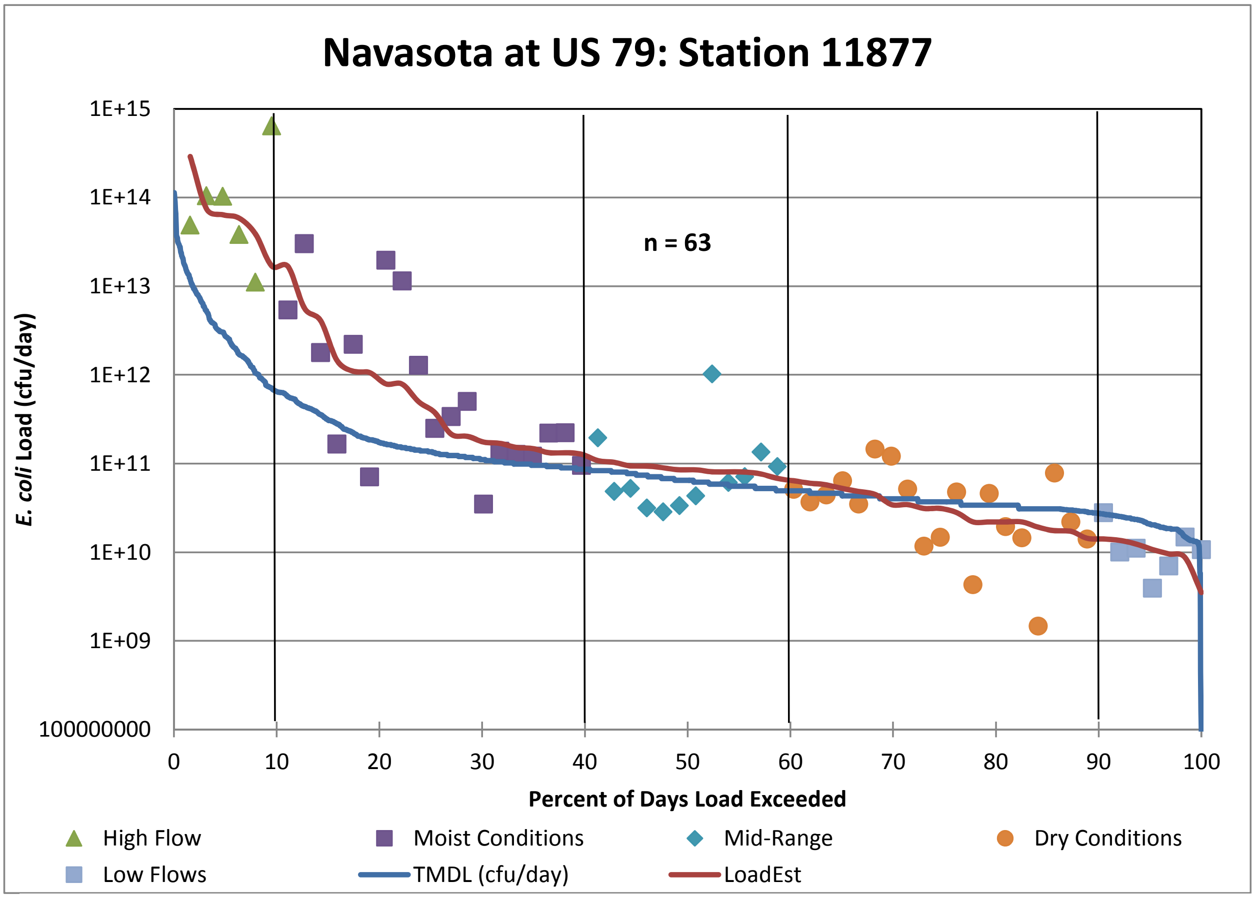


Figure 13. LDC for the Navasota River at US 79, Station 11877

Station 11783 located on Burton Creek at SH 6 also had a sufficient data record available to develop a LDC. In total, 25 paired *E. coli* and stream flow data points collected between 2003 and 2015 were available at this site and were utilized to develop the LDC (Figure 14) and needed load reductions (Table 46) for this site. The LDC revealed that under all flow conditions recorded *E. coli* levels were found to be above allowable levels indicating that point sources, direct deposition, nonpoint source pollution and/or sediment resuspension from within the stream are all contributors to the observed *E. coli* levels.

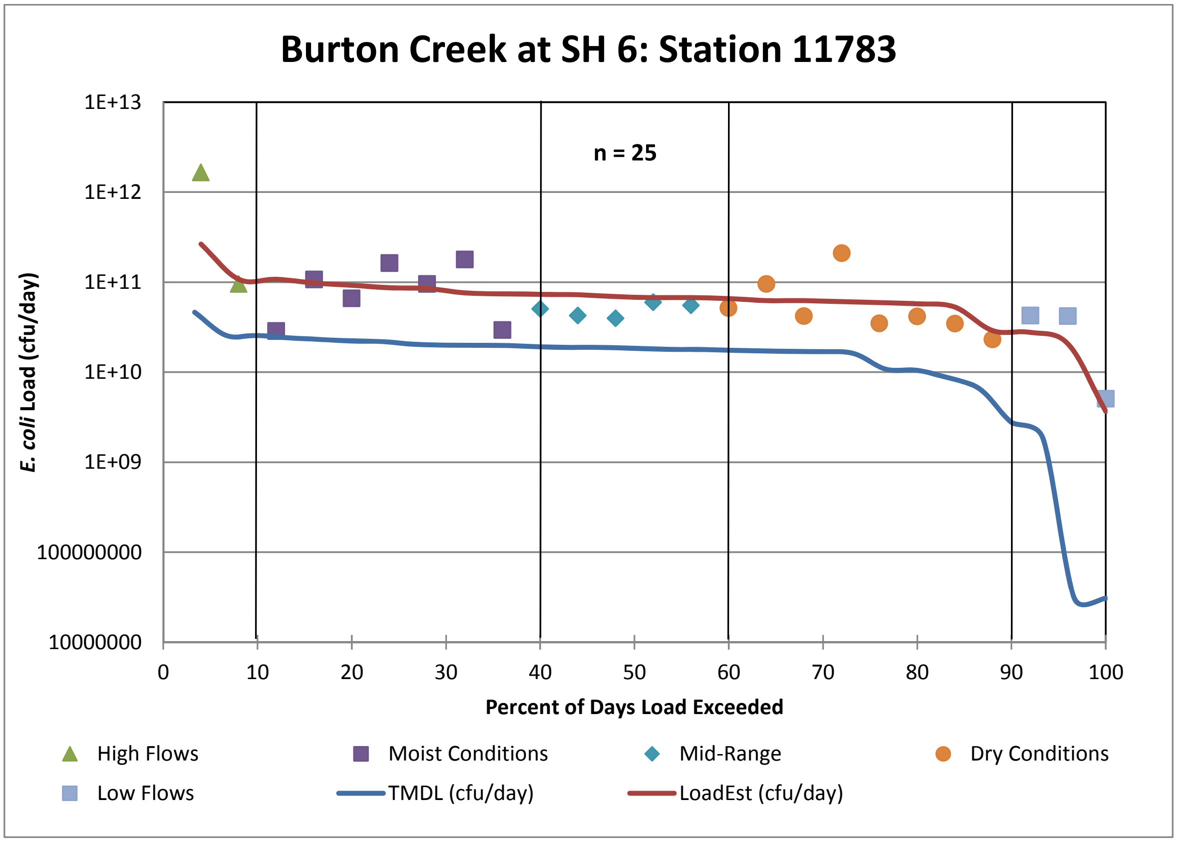


Figure 14. LDC for Burton Creek Upstream of SH6 at Station 11783

Table 46. Percent Based Load Reductions Needed to Achieve Water Quality Standards and Predicted *E.coli* Loadings at Station 11783

Flow Condition	% Flow Exceedance	Average Daily Load Reduction Needed	Average Daily Loading (cfu/day)	Average Annual Loading (cfu/year)
High Flow	0-10%	8.38E+11	8.73E+11	3.19E+14
Moist Conditions	10-40%	7.27E+10	9.51E+10	3.47E+13
Mid-Range	40-60%	3.02E+10	4.95E+10	1.81E+13
Dry Conditions	60-90%	4.98E+10	6.64E+10	2.43E+13
Low Flow	90-100%	2.25E+10	2.98E+10	1.09E+13

Station 11785 located on Carters Creek at Bird Pond Road had a total of 30 paired *E. coli* and stream flow data points available for use in developing the LDC (Figure 15) and needed load reductions (Table 47) for this site. These data were collected between 2002 and 2015. An additional 12 flow measurements were available and utilized to enhance the FDC for this monitoring station. The LDC revealed that under all flow conditions, recorded *E. coli* levels were found to be above allowable levels indicating that point sources, direct deposition, nonpoint source pollution, and/or sediment resuspension from within the stream are all contributors to the observed *E. coli* levels.

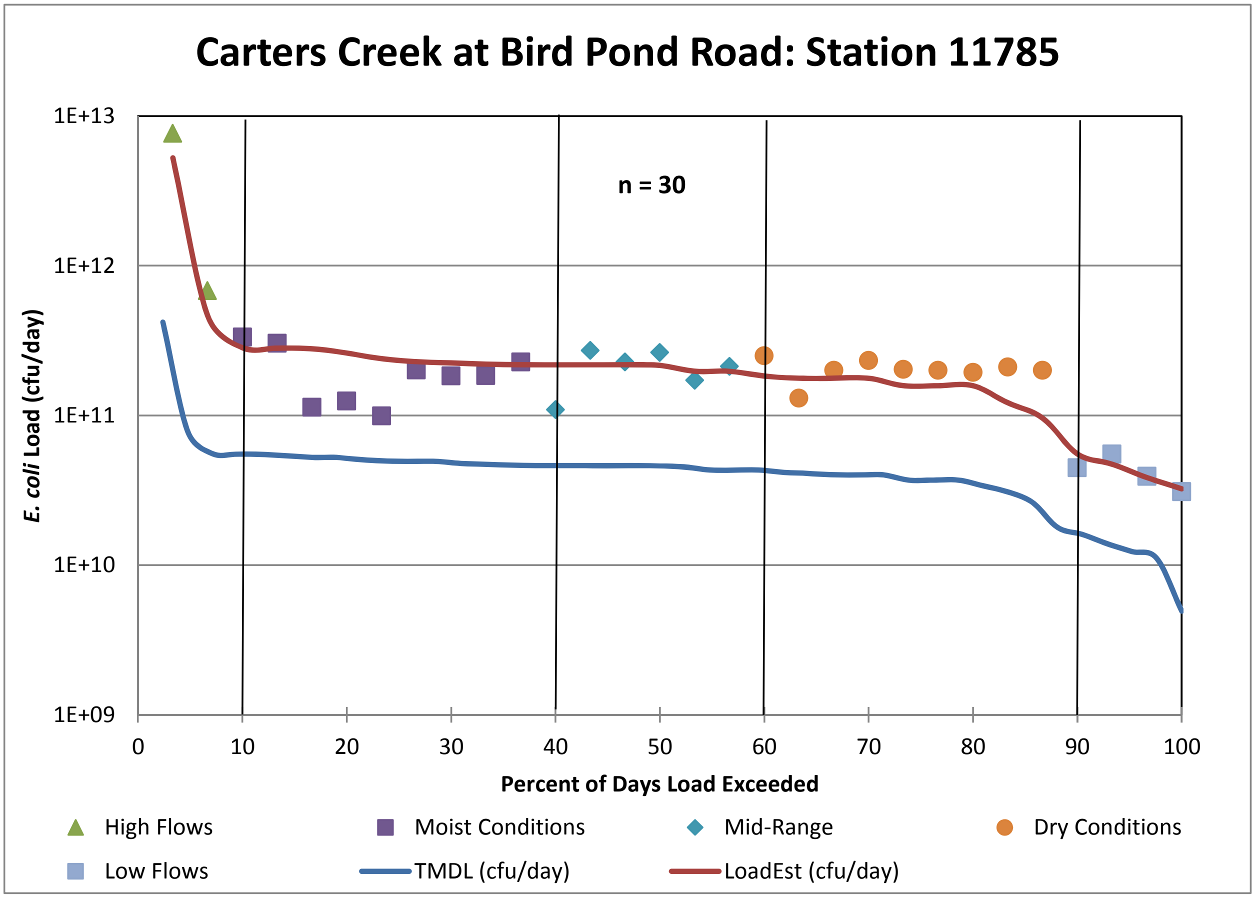


Figure 15. LDC for Carters Creek at Bird Pond Road, Station 11785

Table 47. Percent Based Load Reductions Needed to Achieve Water Quality Standards and Predicted *E. coli* Loadings at Station 11785

Flow Condition	% Flow Exceedance	Average Daily Load Reduction Needed	Average Daily Loading (cfu/day)	Average Annual Loading (cfu/year)
High Flow	0-10%	3.92E+12	2.24E+12	8.18E+14
Moist Conditions	10-40%	1.46E+11	1.51E+11	5.51E+13
Mid-Range	40-60%	1.64E+11	2.12E+11	7.73E+13
Dry Conditions	60-90%	1.66E+11	1.86E+11	6.80E+13
Low Flow	90-100%	2.75E+10	4.18E+10	1.52E+13

Station 21259 located on Carters Creek at SH 40, or William D. Fitch Parkway, had a total of 24 paired *E. coli* and stream flow data points collected from 2013 to 2015 available for use in developing the LDC (Figure 16) and needed load reductions (Table 48) for this site. No additional flow measurements were available for use at this station. The LDC revealed that under all flow conditions, recorded *E. coli* levels were commonly found to be above allowable levels indicating that point sources, direct deposition, nonpoint source pollution, and/or sediment resuspension from within the stream are all contributors to the observed *E. coli* levels.

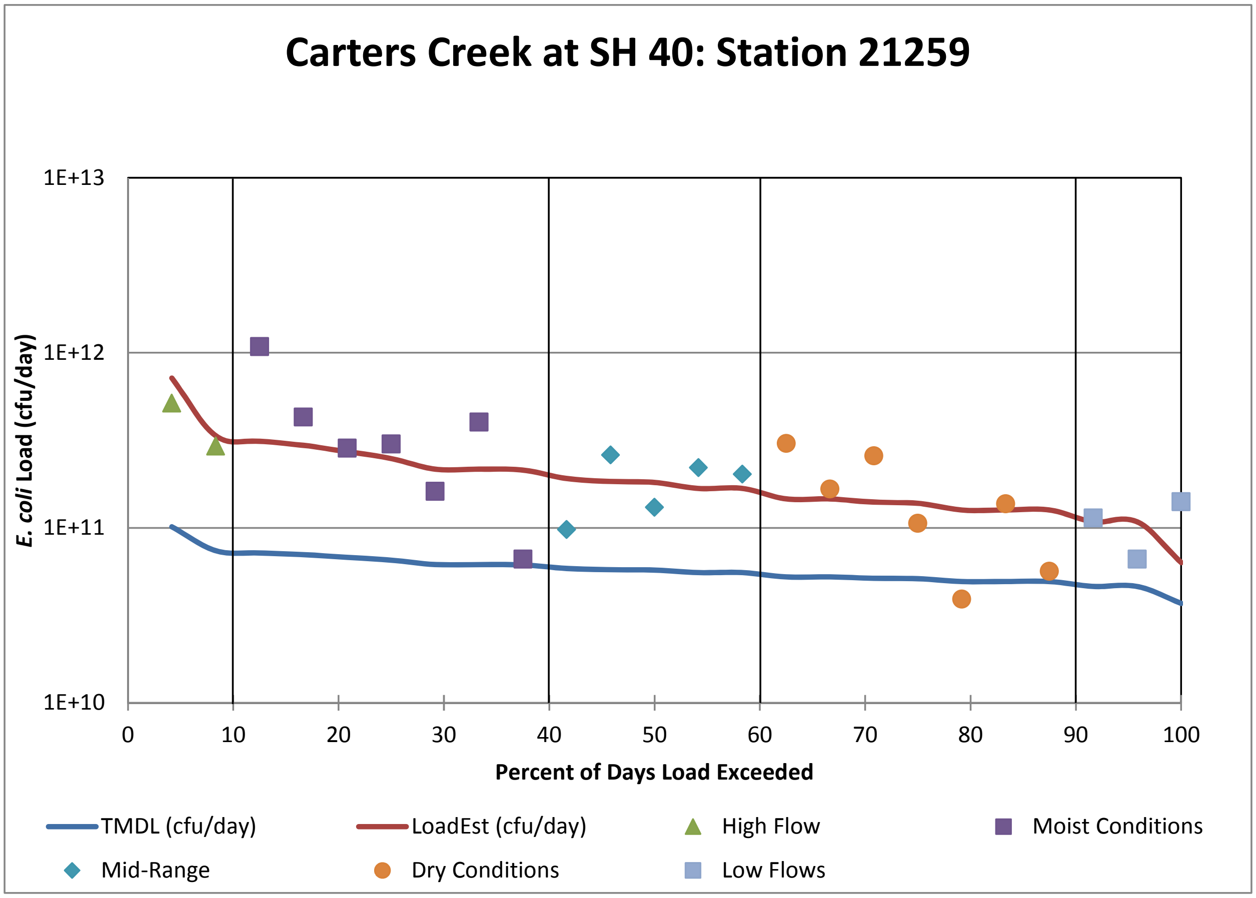


Figure 16. LDC for Carters Creek at SH 40 (William D. Fitch Pkwy), Station 21259

Table 48. Percent Based Load Reductions Needed to Achieve Water Quality Standards and Predicted *E.coli* Loadings at Station 21259

Flow Condition	% Flow Exceedance	Average Daily Load Reduction Needed	Average Daily Loading (cfu/day)	Average Annual Loading (cfu/year)
High Flow	0-10%	3.17E+11	4.04E+11	1.48E+14
Moist Conditions	10-40%	3.24E+11	3.90E+11	1.42E+14
Mid-Range	40-60%	1.26E+11	1.82E+11	6.66E+13
Dry Conditions	60-90%	1.01E+11	1.52E+11	5.56E+13
Low Flow	90-100%	6.38E+10	1.07E+11	3.90E+13

High flow event on Carters Creek at WM D. Fitch Pkwy (Station 21259) in October 2013. Events such as this have caused severe erosion at this site as is evidenced by the near vertical creek bank on the right side of the photo.

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