Nolan Creek/South Nolan Creek Water Quality and Trends

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Background information characterizing the watershed was developed as part of a previous project, *Assessment of Water Quality and Watershed Based Planning for Nolan Creek/South Nolan Creek,* also funded through the TCEQ Nonpoint Source Program Clean Water Act §319(h) (Contract No. 582-13-30061, U.S. Environmental Protection Agency Federal ID #99614617). TIAER in partnership with the City of Killeen conducted this previous project and associated reports can be accessed from TIAER's website at: http://tiaer.tarleton.edu/ruaa/nolan-creek-watershed.html.

Mention of trade names or commercial products does not constitute their endorsement.

For more information about the Nolan Creek/South Nolan Creek Watershed Protection Plan, please visit the project website at: http://www.nolancreekwpp.com/.

Cover photograph is station 11908 at Levi Crossing taken on August 21, 2018.

Table of Contents

List of Tables

List of Figures

Introduction

Monthly monitoring was conducted between September 2016 and August 2018 at up to 10 stations each month along Nolan Creek/South Nolan Creek, Segment 1218. This monitoring provided stakeholders with water quality data used to assist in development of the Nolan Creek/South Nolan Creek watershed protection plan (WPP). Monitoring stations were selected based on availability of historical data and stakeholder input. A preference was given to sites with historical data allowing assessment of trends over time, while stakeholders also recommended some new monitoring locations to better spatially target potential pollutant sources. Water quality results were periodically presented to stakeholders with some changes made in monitoring locations based on stakeholder feedback. This monitoring data provided stakeholders up to date water quality information as they worked to define and prioritize practices needed to address the bacteria impairment and nutrient concerns within the watershed. The purpose of this report is to provide a summary of the data collected including a spatial assessment, comparison to criterion and screening levels, a temporal comparison for stations with historical data, and a comparison to previously developed load duration curves (LDCs).

Since 1996, Segment 1218 has been listed as impaired due to elevated bacteria concentrations (TCEQ, 2015a), so the focus of this report is on bacteria. Bacteria measured as *Escherichia coli* is used within the Texas Surface Water Quality Standards to assess safe recreational use of freshwater streams and reservoirs as an indicator of the potential presence of pathogens (TCEQ, 2018). The WPP developed in conjunction with this monitoring focuses on controlling bacteria, but also addresses concerns regarding elevated nutrients.

Watershed Description

The Nolan Creek/South Nolan Creek watershed comprises 72,800 acres located almost entirely within Bell County (Figure 1). Municipalities within the watershed include most of Killeen, all of Nolanville, and large portions of Harker Heights and Belton. The Fort Hood Military Reservation also covers much of the northern portion of the watershed. Throughout the watershed, there are several small lakes and reservoirs on tributaries, but none directly along the main channel of Nolan Creek/South Nolan Creek. Nolan Creek converges with the Leon River after it passes through the City of Belton.

The TCEQ has divided Segment 1218 into six assessment units (AUs) (Figure 1) in part based on monitoring under a project led by the City of Killeen (see City of Killeen and Jacobs, 2008). Descriptions of Segment 1218 and associated AUs are as follows:

> 1218: Nolan Creek/South Nolan Creek - from confluence with the Leon River in Bell County to a point 100 meters upstream to the most upstream crossing of US 190 and Loop 172 in Bell County.

- 1218_01: Portion of Nolan Creek from the confluence with the Leon River upstream to confluence with North Nolan/South Nolan Creek fork in Bell County.

- 1218_02: Portion of South Nolan Creek from confluence with North Nolan/Nolan Creek fork upstream to confluence with Liberty Ditch in city of Killeen in Bell County.
- 1218_03: Portion of South Nolan Creek from confluence with Liberty Ditch in Killeen upstream to a point 100 meters upstream of the most upstream crossing of US 190 near the intersection of US 190 and Loop 172 in Bell County.
- 1218A: Unnamed Tributary to Little Nolan Creek - from the confluence with Little Nolan Creek upstream to headwaters in the city of Killeen, Bell County.
- 1218B: South Nolan Creek - from 100 meters upstream of the most upstream crossing of US 190 near the intersection of US 190 and Loop 172 upstream to headwaters in the city of Killeen, Bell County.
- 1218C: Little Nolan Creek - from the confluence with Nolan Creek/South Nolan Creek upstream to headwaters in the city of Killeen, Bell County.

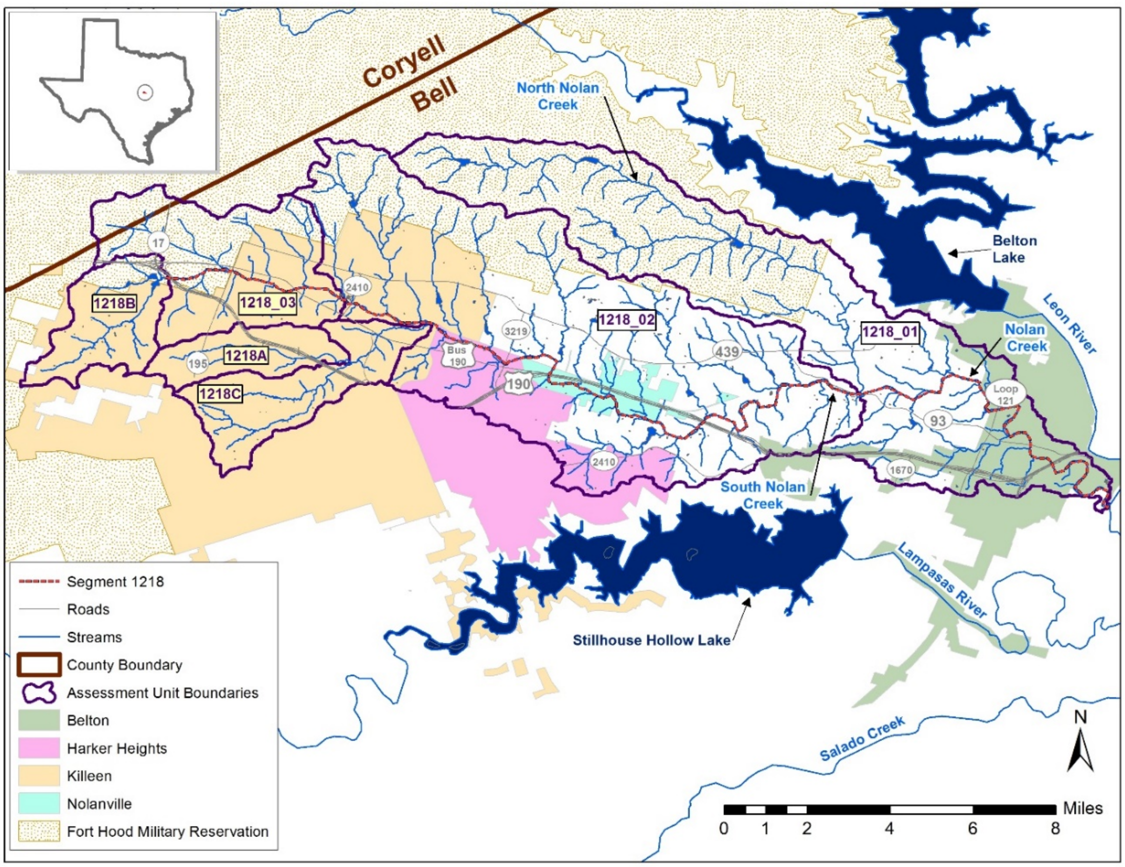

Figure 1 Nolan Creek/South Nolan Creek watershed for Segment 1218 and associated subwatersheds for assessment units.

Water Quality Concerns and Impairments

Nolan Creek/South Nolan Creek (Segment 1218) has a history of elevated bacteria concentrations, and since 1996, has been listed as impaired for bacteria based on Texas State Water Quality Standards (TCEQ, 2015a). This impairment means that portions of the creek do not meet the assessment criterion for primary contact recreation (PCR). Having concentrations above the criterion indicates an increased health risk if participating in activities, such as swimming, which have a high likelihood of water ingestion. The criterion for PCR is 126 colonies per 100 milliliters (mL). Units for *E. coli* in this report are presented as most probably number (MPN)/100 mL, which is used interchangeably by TCEQ with units of colonies/100 mL. The TCEQ assesses support by comparing the geometric mean of *Escherichia coli* from samples collected over a set period (generally 10 years) as part of its water quality inventory, which is conducted once every two years (TCEQ, 2015b). This water quality inventory is presented within the Texas Integrated Surface Water Quality Report. The most recently approved Texas Integrated Report as of December 2018 is from 2014 and indicates bacteria impairments within AUs 1218A, Little Nolan Creek, and 1218_02, a portion of South Nolan Creek (Figures 1 and 2). Concerns are also indicated for elevated bacteria concentrations along AU 1218C, a tributary to Little Nolan Creek. Within the 2014 Texas Integrated Report, concerns for elevated nitrate and total phosphorus concentrations are also noted in comparison to statewide screening levels within AU 1218_02 (Table 1).

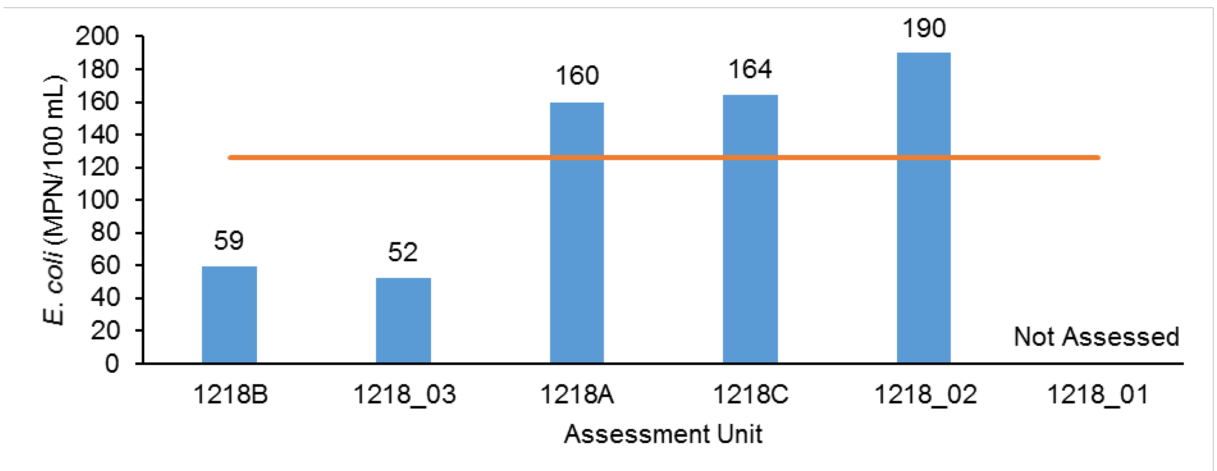

Figure 2 Geometric mean assessment results for *E. coli* by AU along Nolan Creek/South Nolan Creek.

Values above bars are geometric means reported in the 2014 Texas Integrated Report based on data collected between December 1, 2005 and November 30, 2012. The red line indicates the assessment criterion (126 MPN/100 mL) for primary contact recreation.

Table 1 Nitrate and total phosphorus assessment results for AU 1218_02.

Values are from the 2014 Texas Integrated Report for data collected between December 1, 2005 and November 30, 2012.

1218_02	# Exceeded	# Samples	Screening Level	Mean of Samples Exceeding Screening Level
Nitrate	37	38	1.95	8.64
Total Phosphorus	22	28	0.69	1.93

Monitoring Design and Rationale

As part of continued monitoring in the watershed, routine monthly samples were collected at 10 stations. Monthly monitoring parameters included dissolved oxygen (DO), specific conductance, pH, and water temperature measured in situ. Laboratory parameters included *E. coli*, chlorophyll-a (CHLA), nitrite-nitrate-nitrogen (NO_2-N+NO_3-N), orthophosphate-phosphorus (PO_4-P), total phosphorus (total-P), total Kjeldahl nitrogen (TKN), and total suspended solids (TSS). Instantaneous flow was measured in conjunction with the collection of water quality samples, when stream conditions were safe for wading.

Site Selection

Site selection initially was based on findings associated with the following reports produced as part of the previous characterization project:

- Data Inventory Report (McFarland and Adams, 2015a) – Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218 (available at http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan_Data_Inventory_Report(revDec2015)FINAL.pdf), and
- Monitoring Report (McFarland and Adams, 2015b)- Characterizing Water Quality within Nolan Creek/South Nolan Creek (available at http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan_Monitoring_Report(revDec2015)FINAL.pdf).

The Data Inventory Report provided detailed information about land use and potential sources as well as a review of historical water quality monitoring data collected at stations throughout the watershed. The Monitoring Report focused on data collected between May 2013 and June 2015, which included routine monthly monitoring at 11 stations and quarterly storm monitoring at 4 stations (Figure 3 and Table 2).

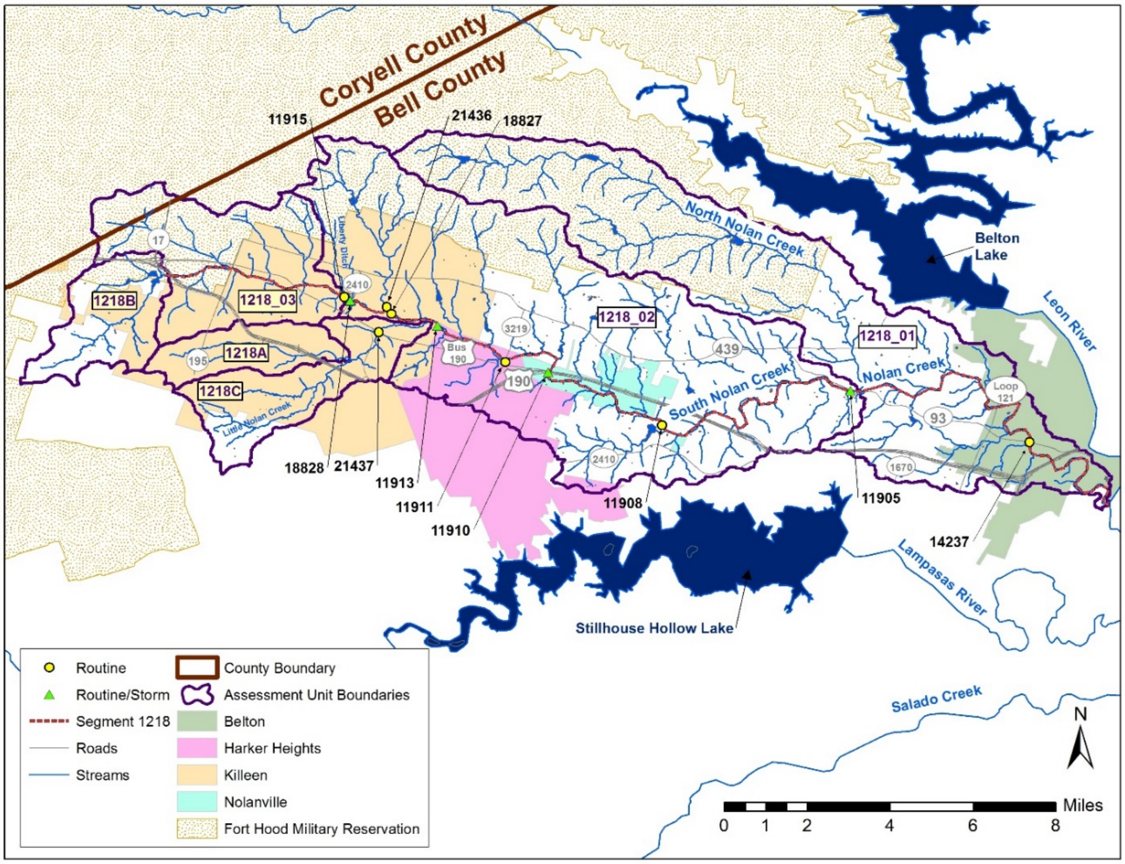

Figure 3 Previous sampling stations for the Nolan Creek/South Nolan Creek characterization project monitored between May 2013 and June 2015.

Table 2 Station descriptions of previously monitored sites for Nolan Creek/South Nolan Creek characterization project.

Stations listed in upstream to downstream order and monitored May 2013 through June 2015.

Station ID	Station Description
11915	South Nolan Creek upstream of WWTF[a] outfall
18828	South Nolan Creek at 38th Street
21436	Long Branch just upstream of crossing of South Nolan Creek at Twin Creek Drive
18827	South Nolan Creek at Twin Creek Drive
21437	Little Nolan Creek off US 190
11913	South Nolan Creek at Roy Reynolds Road
11911	Nolan Creek at FM 3219
11910	Nolan Creek at US 190

Station ID	Station Description
11908	Nolan Creek at Levi Crossing
11905	Nolan Creek at Backstrom Crossing (above confluence of North Nolan Creek)
14237	Nolan Creek at SH 93 in Belton

a. WWTF indicated wastewater treatment facility.

The geometric mean *E. coli* of monthly data from May 2013 through June 2015 indicates potential contributing sources along Long Branch and Little Nolan Creek as well as between stations 11913 and 11911 (Figure 4). Based on these findings and interactions with stakeholders during and after the characterization project, it was recommended that future monitoring occur at various locations along Long Branch as well as between stations 11913 and 11911 to better isolate potential bacteria sources. It was also recommended that the monitoring station on Little Nolan Creek be maintained as well as stations 18827, 11913, and 11911 for tracking trends in water quality over time (Figure 5 and Table 3).

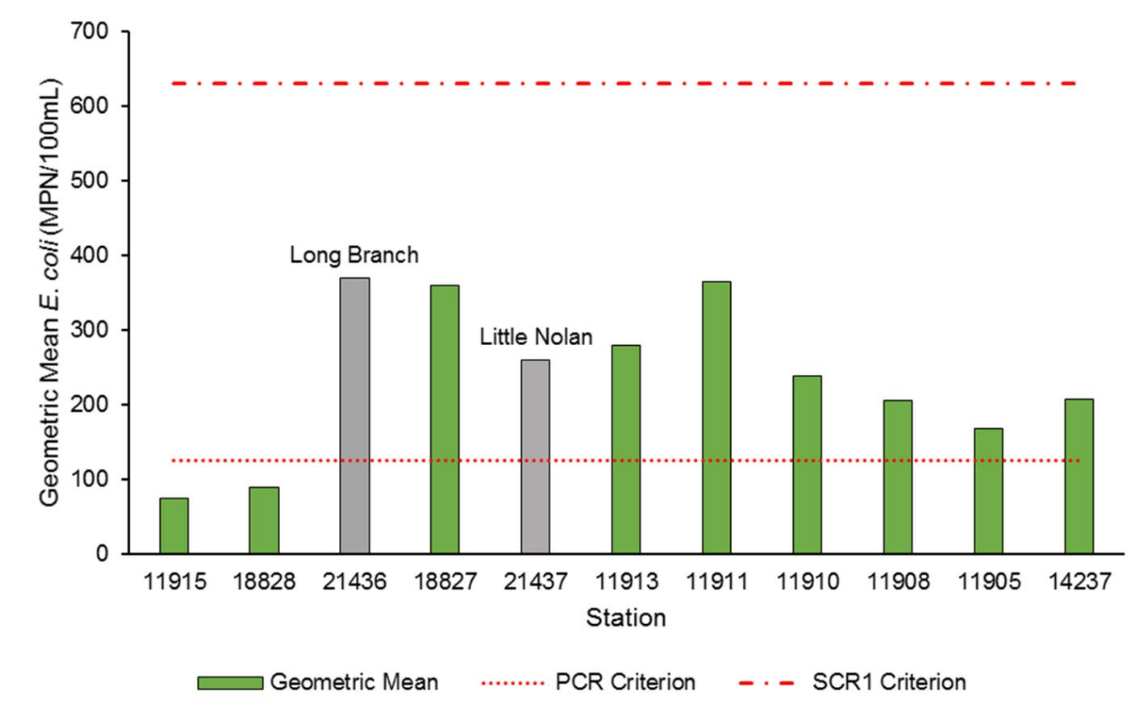

Figure 4 Geometric mean *E. coli* concentrations for routine monthly grab samples collected between May 2013 and June 2015 compared to assessment criteria.

Tributaries to South Nolan Creek/Nolan Creek colored in grey. PCR = primary contact recreation and SCR1 = secondary contact recreation 1.

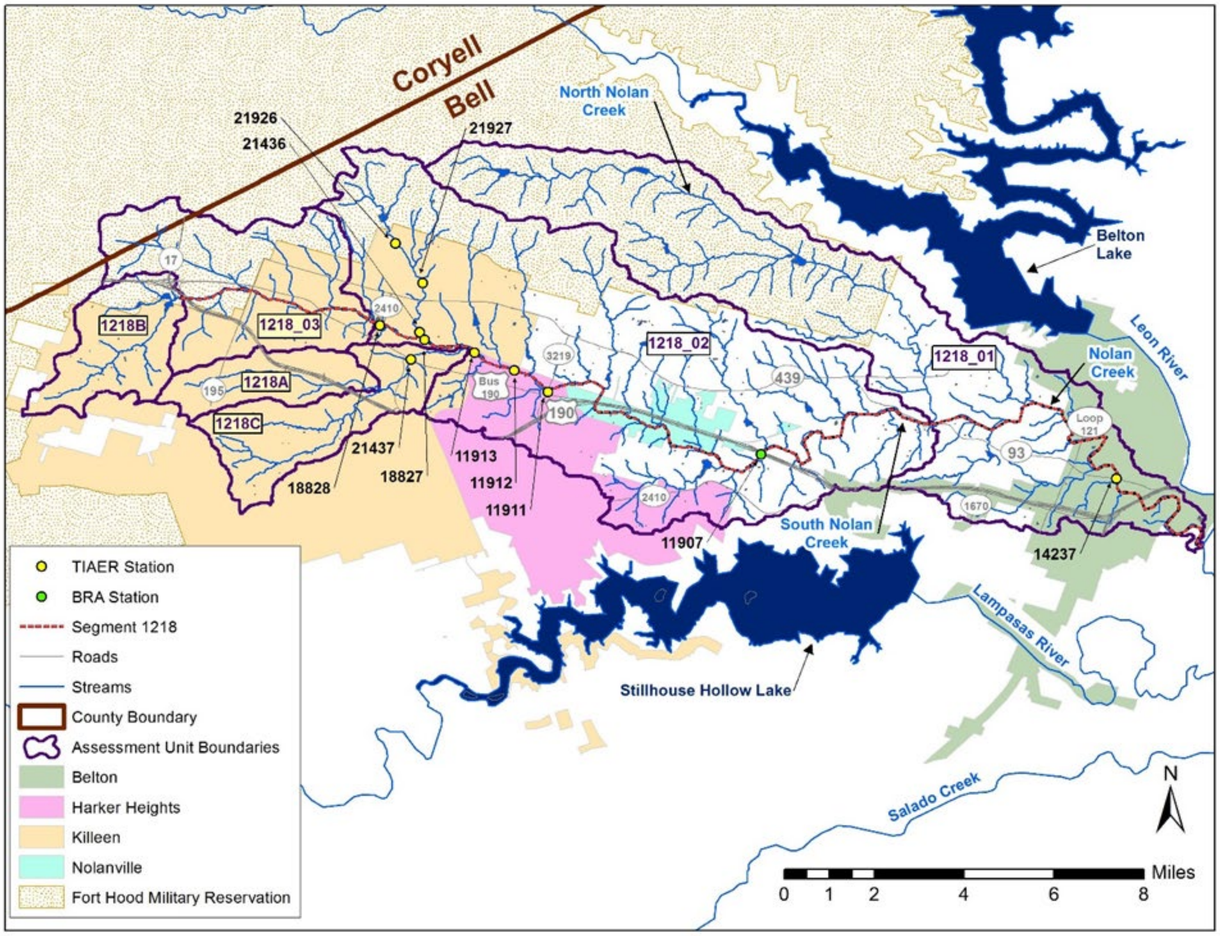

Figure 5 Primary stations monitored by TIAER for the Nolan Creek/South Nolan Creek WPP project, September 2016 through August 2017.

Station 11907 is monitored quarterly by the Brazos River Authority (BRA) under the Clean Rivers Program. All other stations monitored monthly by TIAER.

To focus monitoring along Long Branch, two new stations were monitored between September 2016 and August 2017, one at crossing with Tripp Trail (21926) and the other at crossing of Lake Road (21927) in Killeen (see Figure 5). The location on Tripp Trail is the second road crossing below the reservoir on Long Branch and is located in a residential area. The first road crossing below the reservoir (Westcliff Road) is fenced off on the upstream side representing a boundary with Fort Hood and on the downstream side, access to the creek was limited due to dense vegetation and fencing. A monitoring location along the more upstream portion of Long Branch was considered desirable to better isolate potential contributions from grazing animals associated with land on Fort Hood. The site on Lake Road was selected as it captures a portion of the Long Branch watershed just below the confluence of a couple small, unnamed tributaries. The site on Lake Road is located just above Long Branch Park in the City of Killeen. Of note, considerations for all monitoring locations include accessibility and safety for monitoring personnel for sample collection and measurement of stream flow.

Table 3 Initial monitoring sites and selection rationale for Nolan Creek/South Nolan Creek WPP Project for September 2016 through August 2017.

Stations listed in upstream to downstream order.

TCEQ Station (Temp. ID)[a]	Site Description	Rationale for Selection	Latitude	Longitude
18828	South Nolan Creek at 38th St in Killeen	Represents most upstream location of AU 1218_02 with background concentrations generally below PCR criterion for bacteria. Located just below Bell County WCID1[b] Main Plant WWTF discharge. Of note, the City of Killeen opened Mickey's Dog Park just above this location in June 2015.	31.108091	-97.702156
21926 (LB_TR)	Long Branch at Tripp Trail in Killeen	Located below reservoir along upper third of Long Branch. Station added to aid in isolating sources on Long Branch.	31.134587	-97.697216
21927 (LB_LR)	Long Branch at Lake Road in Killeen	Located just above Long Branch Park in Killeen below the confluence with an unnamed tributary on Long Branch. Station added to aid in isolating sources on Long Branch.	31.12176	-97.688445
21436	Long Branch just upstream of crossing of South Nolan Creek at Twin Creek Dr in Killeen	Considered a potential contributing source based on increasing concentrations noted between stations 18828 and 18827.	31.105946	-97.689364
18827	South Nolan Creek at Twin Creek Dr in Killeen	Elevated bacteria concentrations indicated at this location downstream of confluence of Long Branch, a major tributary to South Nolan Creek.	31.103470	-97.687851

TCEQ Station (Temp. ID)[a]	Site Description	Rationale for Selection	Latitude	Longitude
21437	Little Nolan Creek off US 190 in Killeen	Considered a potential contributing source to South Nolan Creek between stations 18827 and 11913. Little Nolan Creek indicated elevated bacteria concentrations in the 2014 Texas Integrated Report.	31.097143	-97.692268
11913	South Nolan Creek at Roy Reynolds Road in Killeen	Elevated concentrations indicated at this location on South Nolan just after confluence of Little Nolan Creek.	31.099382	-97.671748
11912	South Nolan Creek at Amy Lane in Harker Heights	Located between station 11913 and 11911 where increases in bacteria are occurring.	31.09361	-97.6589
11911	South Nolan Creek at FM 3219 in Harker Heights	Located below WWTF discharge associated with Harker Heights. Elevated bacteria concentrations noted between stations 11913 and 11911.	31.086666	-97.648056
11907	Nolan Creek at US 190 downstream of Nolanville	Monitoring by Brazos River Authority as part of the Clean Rivers Program.	31.06656	-97.5795
14237	Nolan Creek at SH 93 in Belton	Within Yettie Polk Park, a recreational area in Belton. Included to complement quarterly monitoring under the Clean Rivers Program that had been occurring at station 14237 in assessing water quality within AU 1218_01.	31.058743	-97.464989

a. Temporary station designations for the two new sites on Long Branch (LB_TR and LB_LR) were assigned until official TCEQ SWQM location identification numbers were assigned.
b. WCID indicates Water Control Improvement District

In focusing on water quality between stations 11913 and 11911, station 11912 at the crossing of South Nolan Creek with Amy Lane in Harker Heights was added. Monitoring at station 11912 was intended to aid in isolating flows from a major tributary (unnamed) between stations 11913 and 11911. Data collected at station 11912 was expected to help direct site selection during the second 12 months of monitoring for this project by indicating whether increases in bacteria noted at station 11911 were occurring above or below station 11912.

There was also interest in maintaining station 18828 at 38th Street in Killeen and station 14237 at State Highway 93 in Belton. Station 18828 is the most upstream station in AU 1218_02 and has had a geometric mean concentrations below the criterion for PCR (Figure 4). Just above station 18828, a public dog park opened in June 2015, and there was interest in seeing if the dog park might have a localized impact on water quality. Station 14237 is located near Yettie Polk Park within the City of Belton and represents an area of the creek where people may use the water for recreation.

As part of developing the monitoring plan, the Coordinated Monitoring Schedule (CMS) maintained by the Texas Clean Rivers Program was consulted (https://cms.lcra.org/). The CMS for FY17 indicated quarterly monitoring at station 11907 for conventional parameters, bacteria, and field parameters by the Brazos River Authority (BRA). Station 11907 has been long-term, monitoring station within Segment 1218 with bacteria data as fecal coliform dating back to 1980 and *E. coli* samples starting in January 2001. Station 11907 is located between stations 11908 and 11905 (see Figures 3 and 5). Quarterly monitoring data collected over similar timeframes at stations 11908 and 11906 show comparable *E. coli* concentrations (Table 4), so data from station 11907 collected by the BRA were considered to provide a good assessment of water quality for this portion of South Nolan Creek.

Table 4 Geometric mean *E. coli* concentrations for samples collected between May 2013 and June 2015 for stations 11908, 11907, and 11905.

Station	Monitoring Period	Monitoring Frequency	Geometric Mean *E. coli* (MPN/100 mL)	Number of Samples
11908	May 2013 – June 2015	Monthly	205	26
11907	June 2013 – June 2015	Quarterly	154	9
11905	May 2013 – June 2015	Monthly	169	26

While it would be ideal to place a large number of monitoring stations throughout the watershed, project funding for monitoring was limited to monthly monitoring at 10 stations for 24 months. At a meeting on May 4, 2016, stakeholders suggested that after 12 months, they revisit the monitoring plan to determine if some monitoring sites should be moved to better target potential sources. This proposal was reviewed by TCEQ and considered feasible if accompanied by an expedited amendment of the Quality Assurance Project Plan (QAPP).

Some changes to the initial monitoring plan were addressed at a stakeholder meeting held on October 27, 2016, after initial monitoring at the two most upstream stations on Long Branch were found to be pooled or dry during the September 2016 monitoring event. To make best use of limited monitoring resources, six alternate monitoring stations were established for when primary stations were pooled or dry. These six stations included two tributaries near Harker Heights, two mainstem stations previously monitored, and two stations associated with Little Nolan Creek (Table 5 and Figure 6). The use of these alternate stations was approved in a November 2016 amendment to the project QAPP.

Table 5 Alternate monitoring stations for when primary stations were pooled or dry implemented November 2016 and continued through August 2017.

Station ID	Station Description	Priority Ranking[a]
21960	Hay Branch in Harker Heights	1
21961	Unnamed Tributary to South Nolan Creek in Harker Heights just west of crossing with FM 3219	2
11910	South Nolan Creek at US 190 in Nolanville	3
11908	South Nolan Creek at Levi Crossing	4
18833	Unnamed Tributary of Little Nolan Creek at US 190	5
18834	Little Nolan Creek at US 190	6

a. Alternate stations were used only when primary stations were pooled or dry. The priority ranking considered one first and six last.

While the first 12 months of monitoring were conducted, TIAER worked with the stakeholder committee to determine other monitoring locations of interest. Updates during the first year of monitoring were presented at meetings in March, May, and August 2017. Information was also provided to stakeholders via the project website (http://www.nolancreekwpp.com/) as well as through direct email communications.

As an outcome of these discussions, some changes to the monitoring plan were made that were initiated in September 2017. It was decided that the two most upstream stations on Long Branch (21926 and 21927) were providing limited information due to often pooled or dry conditions and should be removed to allow monitoring at other locations. A suggestion was also made to remove station 11912 on Amy Lane in Harker Heights as this station is in fairly close proximity and appears to show water quality that is similar to station 11911. Representatives from Harker Heights indicated that they find value in the data from station 11912 and would like to see it maintained, so station 11912 was not removed.

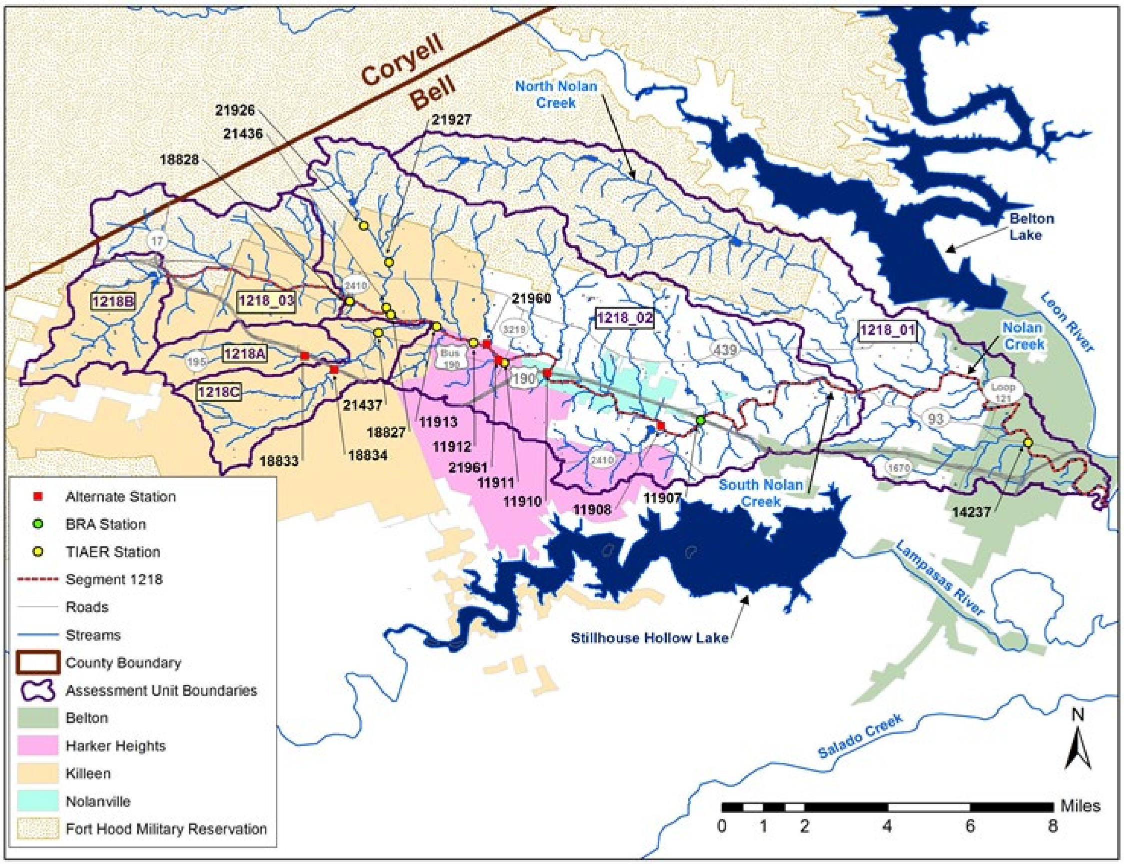

Figure 6 Primary and alternate stations monitored by TIAER for the Nolan Creek/South Nolan Creek WPP project, September 2016 through August 2017.

Station 11907 is monitored quarterly by the BRA under the Clean Rivers Program. All other stations monitored monthly by TIAER.

Several other suggestions were made regarding stations to add, which are summarized as follows:

- A few stakeholders expressed a desire that station 11908, currently an alternate station, be made a primary station. Station 11908 is located at Levi Crossing, a location where trash and debris often accumulates, particularly after high flow events. Although outside any municipal boundaries, it is just downstream of Nolanville, so monitoring at this station may aid in tracking changes associated with practices, such as bioswales, that the City of Nolanville is interested in implementing.

- Another suggestion was to add a station along North Nolan Creek, which represents a large portion of AU 1218_01. No historical monitoring data exists to indicate conditions along North Nolan Creek, although it is assumed that North Nolan Creek contributes low bacteria concentrations, because the land use is predominately forest and rangeland. The closest road crossing of North Nolan Creek upstream from the confluence with Nolan Creek is Farm-to-Market (FM) 439.

- A couple of stakeholders noted that there is a long distance between stations 11911 and 14237 under current monitoring and would like to see something in between but made no specific recommendations.

- A fourth suggestion, presented by one of the technical advisors, was to consider stations associated with the load duration curve (LDC) modeling done as part of the previous characterization project. The current monitoring includes only two (18828 and 11913) of the four stations included in the LDC modeling (see McFarland and Adams, 2016). For evaluating implementation impacts of the WPP, it was recommended that stations 11910 and 11905 be added and stations 18828 and 11913 be maintained.

While the desire by stakeholders to add stations exceeded the desire to remove stations, the following revisions to the monitoring plan were made for samples collected between September 2017 and August 2018 (see Figure 7):

- Stations 21926 and 21436 on Long Branch were removed after August 2017.

- Stations 18828, 21436, 18827, 21437, 11913, 11912, 11911, and 14237 were maintained as primary stations for monthly monitoring.

- Station 11905 at Backstrom Crossing was added as a primary station for monthly monitoring. Station 11905 is the most downstream monitoring location on South Nolan Creek and was used in the LDC modeling. While not on North Nolan Creek, it would be representative of conditions on South Nolan Creek just prior to merging with North Nolan Creek.

- Station 11908 at Levi Crossing on South Nolan Creek was made a primary station. Increasing the monitoring frequency at station 11908 was done to provide more background information to aid in evaluating anticipated implementation practices within the City of Nolanville.

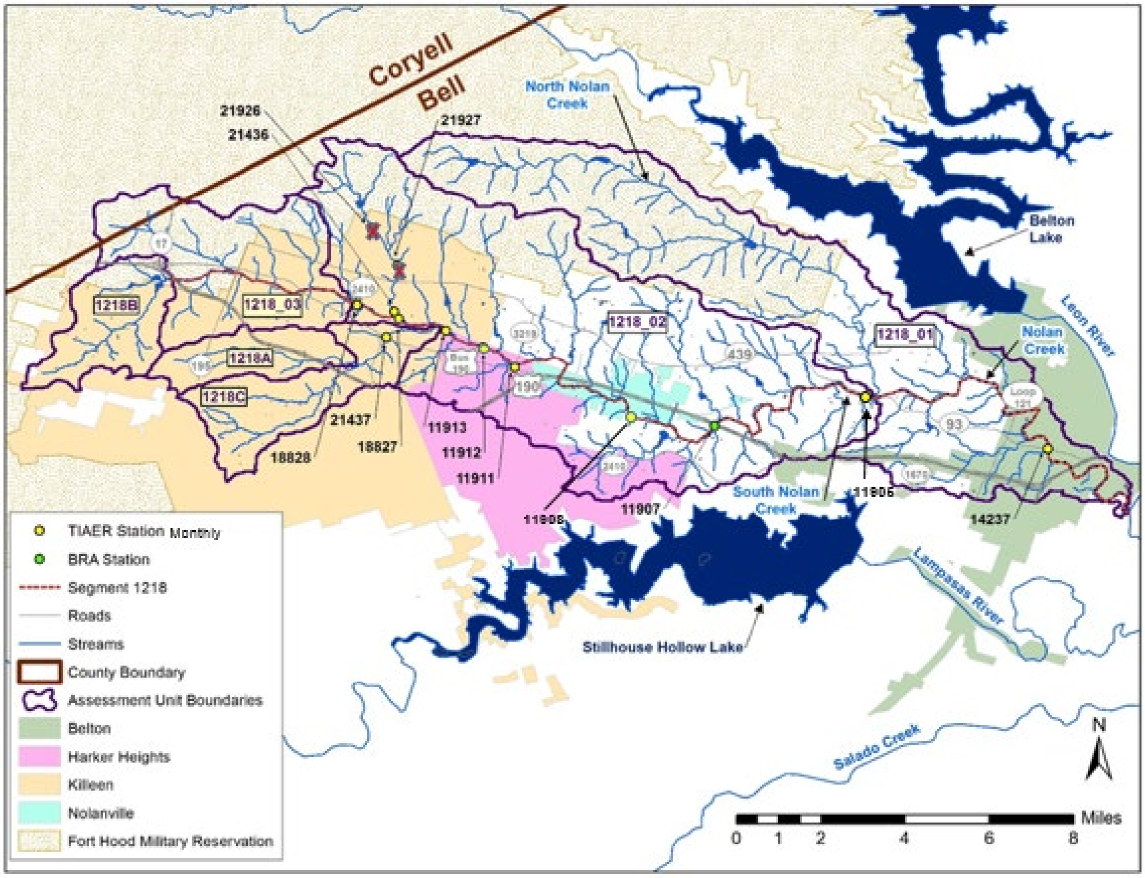

Figure 7 Stations monitored by TIAER for the Nolan Creek/South Nolan Creek WPP project, September 2017 through August 2018.

Station 11907 is monitored quarterly by the BRA under the Clean Rivers Program. All other stations monitored monthly by TIAER. Stations 21436 and 21926 removed and 11908 and 11905 added as primary monthly stations.

The QAPP was revised and approved in September 2017 to reflect monthly monitoring at the 10 stations noted in Figure 7. Alternate stations listed in Table 5 were no longer considered, as it was anticipated that these 10 selected stations in the revised monitoring plan would have perennial flow. This revised monitoring plan largely addressed stakeholder feedback, while maintaining the limitation of only 10 monthly monitoring stations per month. Of the suggestions not directly addressed, it was decided that adding a station on North Nolan Creek would not be the best use of resources. Reconnaissance conducted in mid-August indicated that North Nolan Creek was pooled, indicating intermittent rather than perennial flow, so actual sample collection would be limited. The revised monitoring program also left out one of the stations used for LDCs, station 11910. Given the interest by the City of Nolanville in implementing management practices, such as bioswales, it seemed more appropriate to increase monitoring at station 11908 than at station 11910 located upstream of Nolanville.

Sampling Procedures

Routine samples were collected monthly (Table 6) and involved the following at each station:

- Measurement of instantaneous stream flow in conjunction with routine water quality samples and documentation of flow measurement method.
- Measurement in situ of DO, specific conductance, water temperature, and pH using YSI multiprobes.
- Collection of a water sample for CHLA, nutrient, and TSS analysis in appropriate containers.
- Collection of a sample for *E. coli* analysis in a sterile container.
- Documentation of field conditions including days since last precipitation (DSLP), flow severity, and comments on stream characteristics or sampling conditions.

Field data and samples were collected following the TCEQ guidance document *Surface Water Quality Monitoring Procedures, Volume 1* (TCEQ, 2012). Field parameters, methods, and parameter codes are listed in Table 7, and Table 8 lists parameters analyzed by the lab with monthly samples. All laboratory analyses were conducted by the TIAER laboratory, which is accredited for these parameters by the TCEQ through the National Environmental Laboratory Accreditation Program.

Laboratory Analyses and Censored Values

For laboratory analyses, on only one occasion for one sample were NO_2-N+NO_3-N or PO_4-P lab filtered rather than field filtered. Lab filtration occurred for NO_2-N+NO_3-N and PO_4-P for the sample collected at station 14237 on February 14, 2017 due to high sediment levels. The results for this field-filtered sample were combined with other NO_2-N+NO_3-N and PO_4-P results for data summary and evaluation in this report.

For censored data, left censored data or values measured below the reporting limit as indicated by the limit of quantification (LOQ) in the project QAPP were set to one-half the reporting limit prior to data analysis (Table 9). Results for CHLA and TSS were frequently below the reporting limit or LOQ. Nutrient parameters were most often below the reporting limit at tributary stations, which were not impacted by WWTF discharges. No right-censored values were reported for any laboratory parameters.

Table 6 Dates and stations monitored between September 2016 and August 2018.

No samples were collected at alternate stations 18833, 18834, 21960, or 21961 during the monitoring period.

Date	18828	21926	21927	21436	18827	21437	11913	11912	11911	11910	11908	11905	14237
21-Sep-16	X			X	X	X	X	X	X				X
11-Oct-16	X	X	X	X	X	X	X	X	X				X
16-Nov-16	X	X	X	X	X	X	X	X	X				X
13-Dec-16	X	X	X	X	X	X	X	X	X				X
10-Jan-17	X	X	X	X	X	X	X	X	X				X
14-Feb-17	X	X	X	X	X	X	X	X	X				X
8-Mar-17	X	X	X	X	X	X	X	X	X				X
19-Apr-17	X	X	X	X	X	X	X	X	X				X
10-May-17	X	X	X	X	X	X	X	X	X				X
13-Jun-17	X			X	X	X	X	X	X	X	X		X
26-Jul-17	X			X	X	X	X	X	X	X	X		X
15-Aug-17	X			X	X	X	X	X	X	X	X		X
27-Sep-17	X			X	X	X	X	X	X		X	X	X
17-Oct-17	X			X	X	X	X	X	X		X	X	X
8-Nov-17	X			X	X	X	X	X	X		X	X	X
6-Dec-17	X			X	X	X	X	X	X		X	X	X
10-Jan-18	X			X	X	X	X	X	X		X	X	X
13-Feb-18	X			X	X	X	X	X	X		X	X	X
6-Mar-18	X			X	X	X	X	X	X		X	X	X
4-Apr-18	X			X	X	X	X	X	X		X	X	X
2-May-18	X			X	X	X	X	X	X		X	X	X
5-Jun-18	X			X	X	X	X	X	X		X	X	X
17-Jul-18	X			X	X	X	X	X	X		X	X	X
21-Aug-18	X			X	X	X	X	X	X		X	X	X

Table 7 Field parameters collected with routine grab samples.

Parameter	Abbreviation	Units	Method[a]	Parameter Code
pH (standard units), field determined	pH	pH units	EPA 150.1 & TCEQ SOP	00400
Oxygen, dissolved, field determined	DO	mg/L	EPA 360.1 & TCEQ SOP	00300
Specific conductance, field determined (µS/cm @ 25ºC)	Conductivity	µS/cm	EPA 120.1 & TCEQ SOP	00094
Temperature, water, field determined	Temp.	ºC	EPA 170.1 & TCEQ SOP	00010
Flow, stream, instantaneous (cubic feet per second)	Flow	cfs	TCEQ SOP	00061
Flow Method	F-Method	1-gage, 2-electric, 3-mechnical, 4-weir/flume, 5-doppler	TCEQ SOP	89835
Days Since Last Precipitation	DSLP	days	TCEQ SOP	72053
Flow Severity	Flowsev	1-no flow, 2-low, 3-normal, 4-flood, 5-high, 6-dry	TCEQ SOP	01351

a. EPA refers to *Methods for Chemical Analysis of Water and Wastewater*, Manual #EPA-600/4-79-020 (March 1983) and TCEQ SOP refers to *Surface Water Quality Monitoring Procedures*, Volume 1 (RG-415, revised August 2012).

Table 8 Laboratory parameters analyzed with routine grab samples.

Parameter	Abbreviation	Units	Method[a]	Parameter Code
Nitrite plus nitrate, dissolved (mg/L as N)	NO_2-N+ NO_3-N	mg/L	SM 4500-NO3-F	00631
Nitrite plus nitrate, total, one lab determined value (acidified field, lab filtered)[b]	NO_2-N+ NO_3-N	mg/L	SM 4500-NO3-F	00630
Phosphorus, total, wet method (mg/L as P)	Total-P	mg/L	EPA 365.4	00665
Nitrogen, Kjeldahl, total	TKN	mg/L	SM 4500-NH3G	00625
Residue, total nonfilterable (also referred to as total suspended solids)	TSS	mg/L	SM 2540 D	00530
Orthophosphate phosphorus, dissolved, field filtered < 15 min	PO_4-P	mg/L	SM 4500P-E	00671
Orthophosphate phosphorus, dissolved, lab filtered > 15 min [b]	PO_4-P	mg/L	SM 4500-P E	70507
E. coli, Colilert, IDEXX method	*E. coli*	MPN/100 mL	IDEXX Colilert ®	31699
Chlorophyll-a spectrophotometric acid. method	CHLA	µg/L	SM 10200-H	32211

a. EPA refers to *Methods for Chemical Analysis of Water and Wastewater*, EPA-600/4-79-020 and SM refers to *Standard Methods for the Examination of Water and Wastewater* (latest online edition or APHA, AWWA and WEF, 2016).
b. The total form of NO_2-N+NO_3-N and PO_4-P (lab filtered) are analyzed only if routine grabs cannot be field filtered due to excessive sediment; otherwise, dissolved forms of these parameters are analyzed for consistency with historical data.

Table 9 Reporting limits and number of left censored values by parameter.

Parameter	Reporting Limit	Number of Results[a]	Number of Left Censored Values
E. coli	1 MPN/100 mL	238	0
CHLA	3 µg/L	228	171
NO_2-N+NO_3-N	0.05 mg/L	235	7
PO_4-P	0.005 mg/L	228	14
Total-P	0.06 mg/L	237	21
TKN	0.20 mg/L	237	26
TSS	4 mg/L	238	183

a. A total of 238 samples were analyzed. Number of results represents sample values that passed laboratory quality assurance and quality control criteria as outlined in the project QAPP.

Reporting Data from WWTFs

Besides rainfall runoff, baseflow through much of the mainstem of Nolan Creek/South Nolan Creek is considered effluent dominated with contributions from discharges of WWTFs. There are eight permitted point source outfalls along Nolan Creek/South Nolan Creek providing discharges from WWTFs (Figure 8 and Table 10). These effluent discharges, along with some groundwater discharge, provide a continuous source of baseflow to the creek. In the upper portion of South Nolan Creek, discharges from the Bell County WCID No. 1 Main Plant and Plant 2 represents over 80 percent of baseflow based on monthly field measurements between upstream and downstream of the discharge point (McFarland and Adams, 2015a). All eight WWTFs have an average daily discharge limit for *E. coli* of 126 MPN/100 mL and a daily maximum of 399 MPN/100 mL. As an aid in interpretation of instream monitored data, monthly reported WWTF discharge and bacteria data were accessed from the EPA Enforcement and Compliance History Online website (https://echo.epa.gov/) and are presented in conjunction with evaluation of stream water quality data.

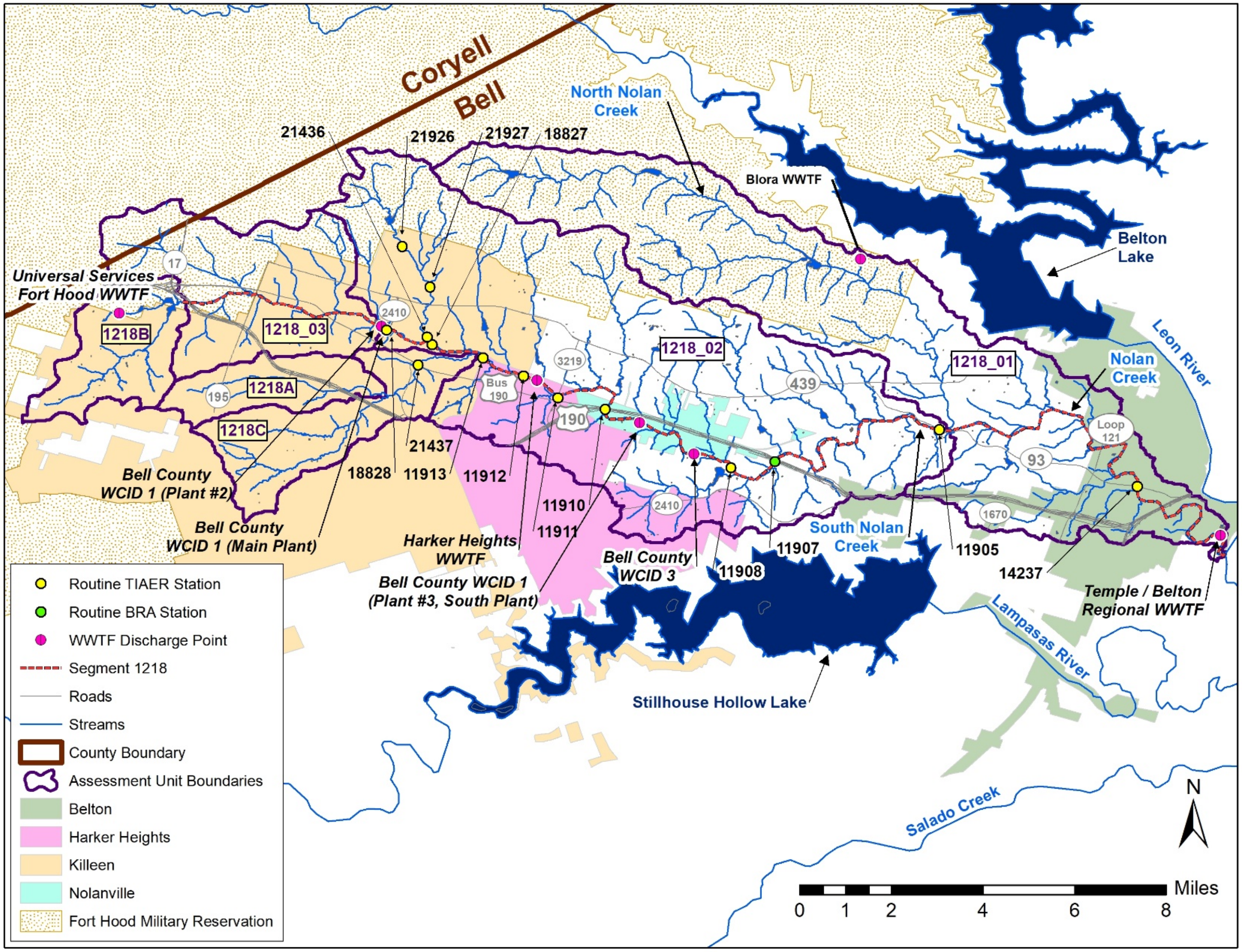

Figure 8 Monitoring stations and WWTF discharge points within the Nolan Creek/South Nolan Creek watershed.

Table 10 Permitted WWTFs within the Nolan Creek/South Nolan Creek watershed.

Facility Name	Abbreviation	Operator	TCEQ Permit #	Permitted Discharge (MGD)	Permitted Discharge (cfs)	Reported Mean ± Std (MGD)[b]	Reported Mean ± Std (cfs)
Universal Services Fort Hood WWTF	Univ_Ser	Universal Services Fort Hood, Inc.	WQ0013358001	0.09	0.14	0.057 ± 0.004	0.088 ± 0.006
Bell County WCID No. 1 (Plant 2)	WCID1_MP[a]	Bell County WCID No. 1	WQ0010351003	6	9.3	0[a]	0[a]
Bell County WCID No. 1 WWTF (Main Plant)	WCID1_MP[a]	Bell County WCID No. 1	WQ0010351002	18	27.9	10.7 ± 1.59	16.6 ± 2.47
City of Harker Heights WWTF	Harker_H	City of Harker Heights	WQ0010155001	3	4.6	1.86 ± 0.28	2.88 ± 0.43
Bell County WCID No. 1 (Plant 3, South Plant)	WCID1_SP	Bell County WCID No. 1	WQ0014387001	6	9.3	2.36 ± 0.53	3.66 ± 0.82
Bell County WCID No. 3 WWTF	WCID3	Bell County WCID No. 3	WQ0010797001	0.675	1	0.29 ± 0.06	0.46 ± 0.09
Blora WWTF	Blora	American Water Operations and Maintenance	WQ0014994001	0.03	0.05	0.012 ± 0.003	0.018 ± 0.005
Temple Belton Regional WWTF	Belton	Brazos River Authority	WQ0011318001	10	15.5	6.28 ± 1.25	9.73 ± 1.93

a. Discharges for WCID No. 1 (Plant 2) have a value of zero reported, because they are reported as combined with discharges for the Bell Count WCID No. 1 (Main Plant), thus, both WWTFs are given the same abbreviation in data summaries.
b. Reported represents an average of monthly average discharge values for each facility for September 2016 through August 2018 as obtained from the EPA Enforcement and Compliance History Online website (https://echo.epa.gov/).

Monitoring Results and Data Evaluation

Monitoring results by station and monitoring event are presented in Appendix A. To summarize and evaluate these data, the following steps were taken:

- Box-and-whisker plots focusing on bacteria data were developed to evaluate variability in results by station and to provide a visual comparison of data collected between stations. Other parameters evaluated with box-and-whisker plots included flow as well as NO_2-N+NO_3-N and total-P for sampling stations. Because WWTFs are a known contributing source of bacteria in the watershed, box-and-whisker plots were also developed of voluntary reporting data from WWTFs discharges for reported *E. coli* concentrations and flow through conduit.

- Data were summarized and compared to the *E. coli* criterion and nutrient screening levels for NO_2-N+NO_3-N and total-P. For selected monitoring stations that were monitored during the full 24-month period, a nonparametric Kruskal-Wallis test was applied to evaluated for differences in median *E. coli* concentrations between stations.

- Time series plots were used to compare direct data collected under this project (2016-2018) with historical data collected under the previous characterization project (2013-2015). The influence of seasonality and flow on E. coli concentrations was evaluated for the full data set including data from both periods. For stations with data during both periods, a nonparametric Kruskal-Wallis test was applied to determine if temporal changes in bacteria concentrations could be detected by station after taking into account seasonality and variations with *E. coli* concentrations due to storm influences as indicated by DSLP.

- For stations 18828, 11913, 11910, and 11905, direct data collected under this project (2016-2018) were overlaid to evaluate for changes overtime based on flow regime on previously development of LDCs (see McFarland and Adams, 2016).

Box-and-Whisker Plots

Box-and-whisker plots provided an initial comparison of water quality between stations. These box-and-whisker plots graphically depict data by quartiles showing the distribution of data at each station (Figure 9). In some studies, data points above the 90^{th} percentile and below the 10^{th} percentile are referenced as outliers. With stream data, a wide variance in *E. coli* results is anticipated, particularly in areas where nonpoint source contributions occur.

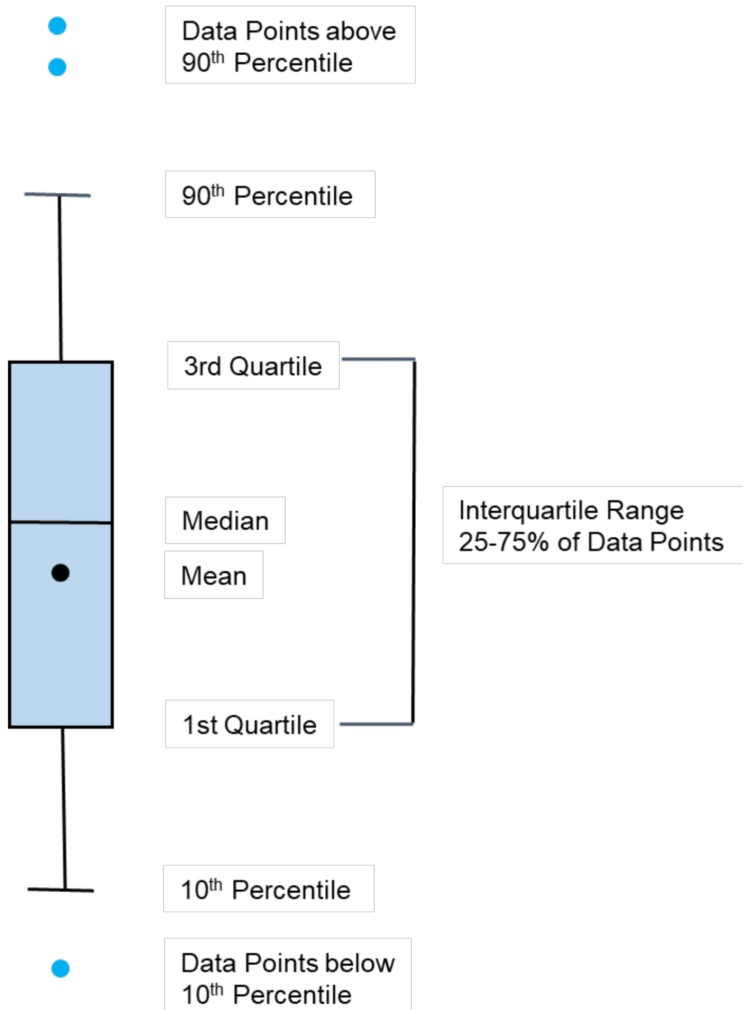

Figure 9 Example box-and-whisker plot for a single station.

Flow

As the focus was on routine monitoring, conditions primarily represented baseflow between storm events (Figure 10). Flow was measured during all monthly events except in February 2017, when flow conditions were too elevated for safe wading. Due to the large variability in flow measurements, the natural-log scale shown in Figure 11 more clearly indicates the similarity in flow between upstream to downstream stations along the mainstem of the creek with tributary stations generally contributing relatively small amounts of baseflow. As previously noted, WWTF discharges provide a large portion of baseflow. Discharges from the WCID1 Main Plant and Plant 2 that flow in just above station 18828 contributing about 17 cfs on average (Table 10). Between stations 11912 and 11911, discharges from the Harker Heights WWTF occur contributing about 3 cfs on average. Between stations 11910 and 11908, discharges from the WCID1 South Plant and the WCID3 Plant occur. The WCID1 South Plant contributes on average about 4 cfs, while the WCID3 Plant contributes about 0.5 cfs. Other WWTF discharges represent minor contributions or, as with the Temple-Belton WWTF, discharge below the most downstream monitoring station (see Figure 8).

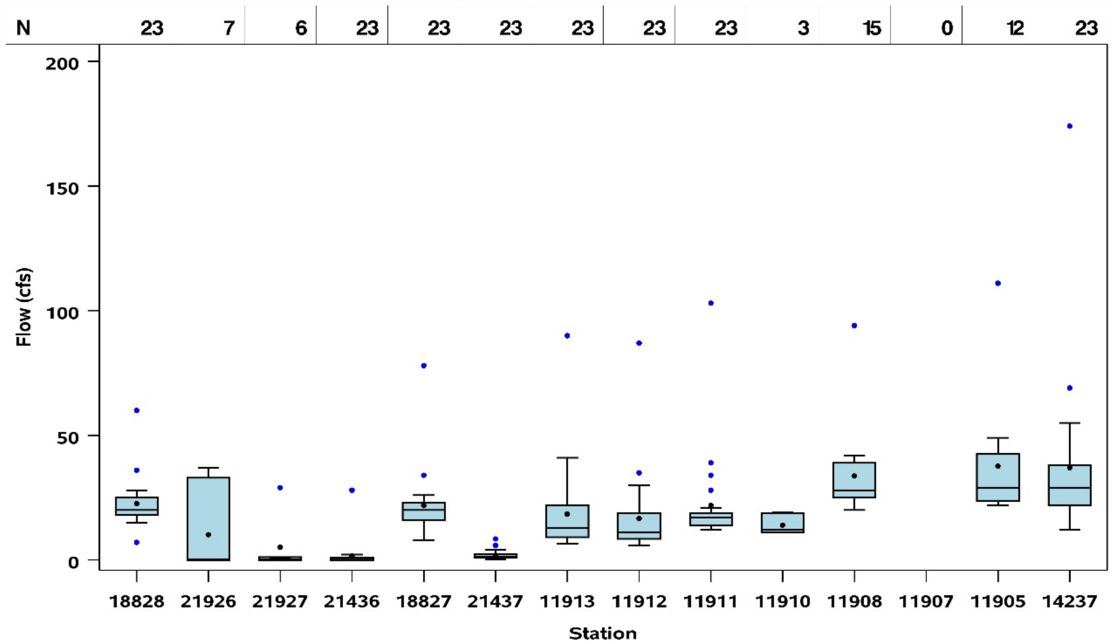

Figure 10 Box-and-whisker plots of flow results using normal scale.

N represents the data points for each station.

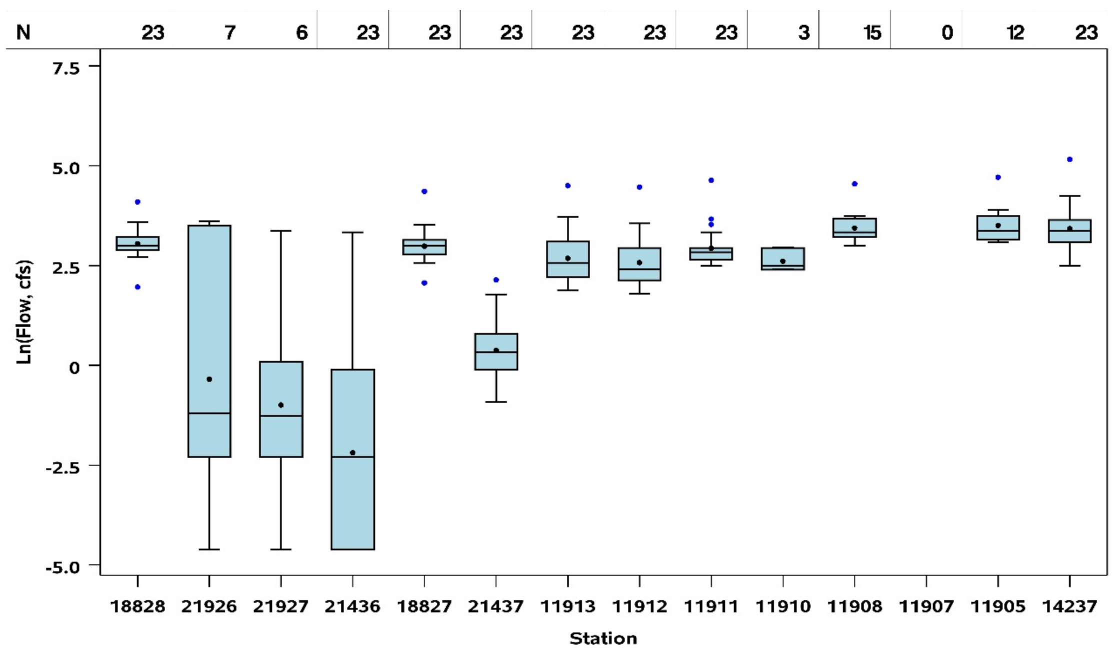

Figure 11 Box-and-whisker plots of measured flow using natural-log scale.

Ln represents the natural-log scale. N represents the data points for each station.

While monitoring was not conducted specifically during storm events, several routine events were reflective of stormwater runoff as indicated by values of the field parameter DSLP of three days or less. These included the following five dates:

- February 14, 2017 (no flow measured due to elevated stream levels)
- April 19, 2017 (not all stations had a DSLP <4 days denoted due to variability in precipitation across the watershed, but based on elevated flow measurements at all stations, a DSLP of < 4 days was associated with all stations on this date for data evaluation purposes)
- December 6, 2017
- April 4, 2018
- June 5, 2018

These storm influenced events do not necessarily have elevated flows associated with them, as monitoring generally occurred on the tail of the hydrograph after water levels had largely receded rather during the peak of these storm events. As shown in the discussion of bacteria data in the next section, these storm influenced events have a notable impact on stream bacteria concentrations.

Bacteria

Results for *E. coli* are presented on a normal and natural-log scale to better visually assess the full range of data collected (Figures 12 and 13). The natural-log scale deemphasizes the few high values often encountered with bacteria data allowing a view of the distribution of results that is compressed when presented on a normal scale. To give an indication of the variability in bacteria data, the widest range of values occurred at station 21437 on Little Nolan Creek with *E. coli* concentrations ranging from a low of 15 MPN/100 mL to a high of 29,000 MPN/100 mL.

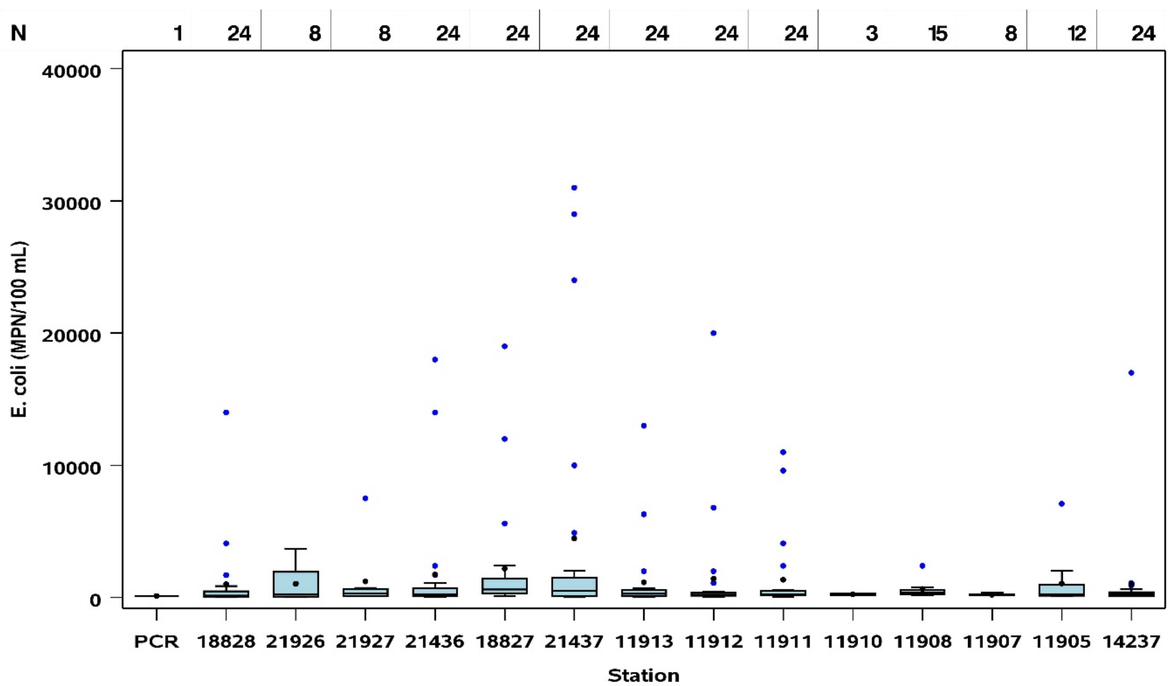

Figure 12 Box-and-whisker plots of *E. coli* results on a normal scale.

PCR represents the criterion for primary contact recreation (TCEQ, 2015b). N represents the number of data points for each station.

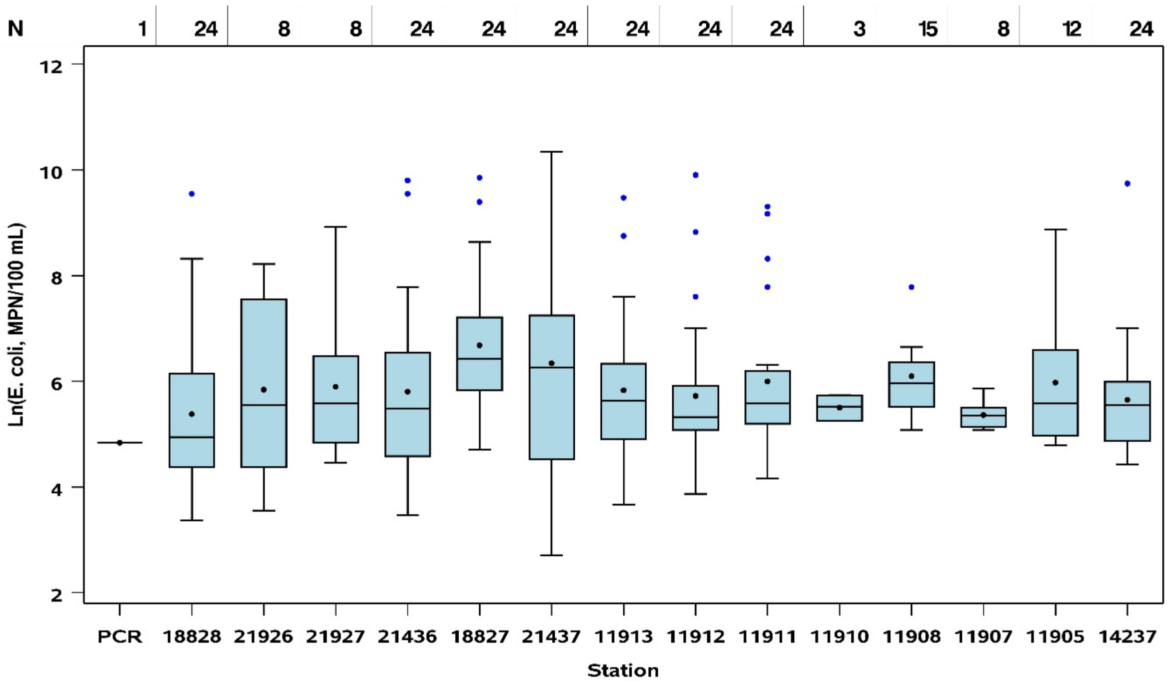

Figure 13 Box-and-whisker plots of *E. coli* results on a natural-log scale.

PCR represents the criterion for primary contact recreation (TCEQ, 2015b). Ln represents the natural log. N represents the number of data points for each station.

Rainfall runoff was often associated with higher *E. coli* concentrations, so data for *E. coli* were evaluated removing those values with a DSLP value less than 4 days (Figure 14). A DSLP of less than 4 days was selected as it had previously been used in the development of load duration curves to separate data into wet weather or storm influenced (DSLP < 4 days) versus normal or baseflow conditions (DSLP > 3 days) for LDC development (McFarland and Adams, 2016). When events associated with a DSLP of less than 4 days were removed (Figure 14), many of the “outliers” (points greater than the 90 percentile of samples evaluated) shown with the full dataset (Figure 13) disappeared. This indicates that nonpoint source contributions related to stormwater runoff are likely the source of many of the higher *E. coli* concentrations measured during the two-year period.

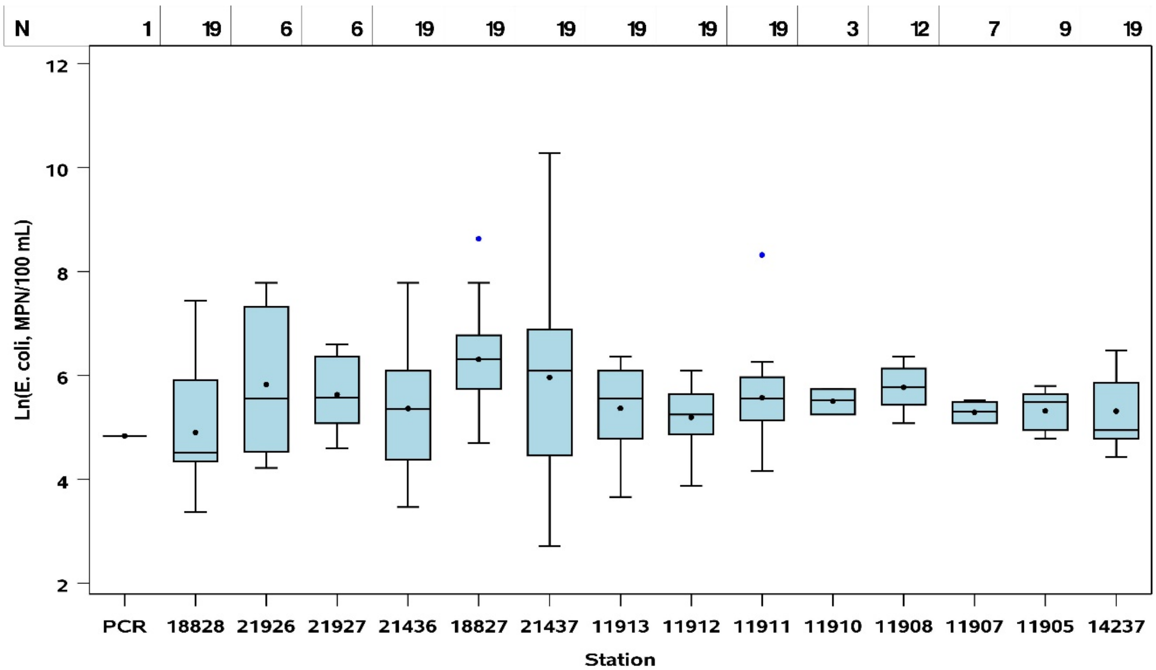

Figure 14 Box-and-whisker plots of *E. coli* results on a natural-log scale limited to observations with a reported DSLP greater than 3 days.

PCR represents the criterion for primary contact recreation (TCEQ, 2015b). Ln represents the natural log scale. N represents the data points for each station.

Nutrients

For nutrients, NO_2-N+NO_3-N and total-P were evaluated as parameters of concern based on TCEQ assessment (TCEQ, 2015a). Box-and-whisker plots of NO_2-N+NO_3-N and total-P showed much higher concentrations along the mainstem than at tributary stations (Figures 15 and 16), most likely due to the influence of WWTF discharges along South Nolan Creek (Figure 8 and Table 10). For nutrients, there was little difference in the concentrations monitored when results associated with monitoring events with a DSLP less than 4 days were removed, so only plots with all data values are presented. Of note, during storm events monitored with the previous characterization project, very clear decreases in nutrient concentrations were seen with dilution from high flow events (see McFarland and Adams, 2015b). Because flow along the mainstem is largely dominated by WWTF discharges, this dilution of nutrients was not apparent with routine monitoring.

Nutrients are often monitored as a potential indicator of excessive algal growth. In most aquatic systems, background levels of nutrients are low, and the addition of nutrients can lead to accelerated growth of algae. Chlorophyll-a was included as a measure of algae within the water column. Although average nutrient concentrations for nitrates and total-P were above TCEQ screening levels, concentrations of CHLA were often below the LOQ or < 3 µg/L during many of the sampling events at stations throughout the watershed (see Appendix A) and generally well below the screening level for freshwater streams of 14.1 µg/L (TCEQ, 2015b).

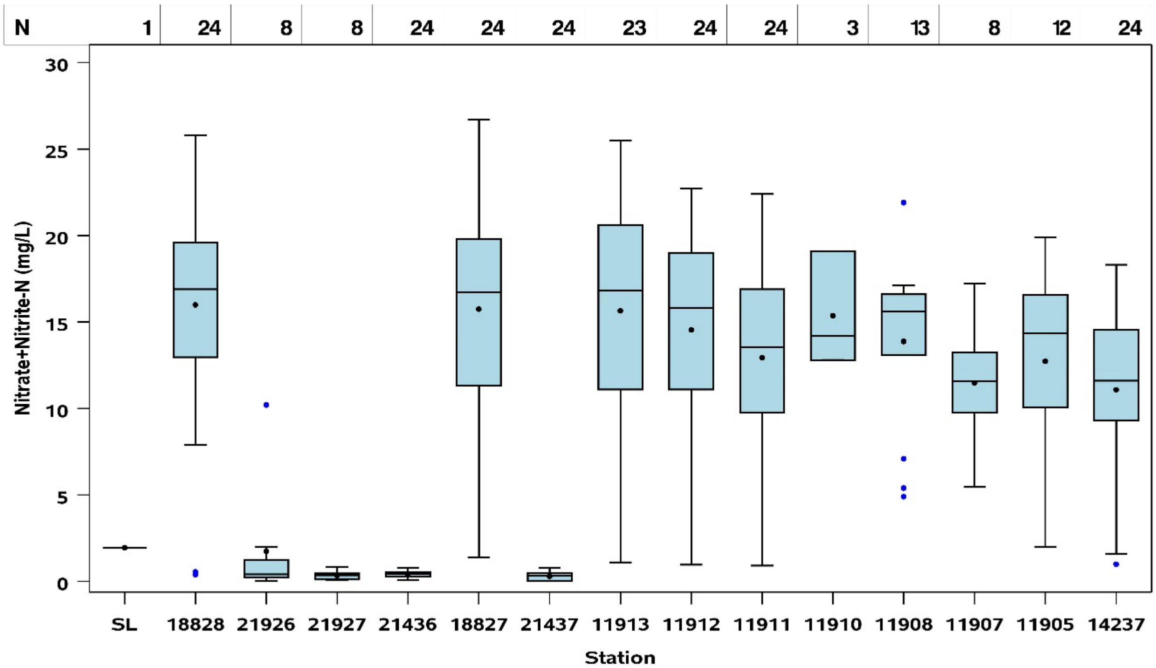

Figure 15 Box-and-whisker plots of NO_2-N+NO_3-N results for all monitoring events.

SL represents the nutrient screening level used by TCEQ for assessment of nutrient concerns for NO_2-N+NO_3-N (TCEQ, 2015b).

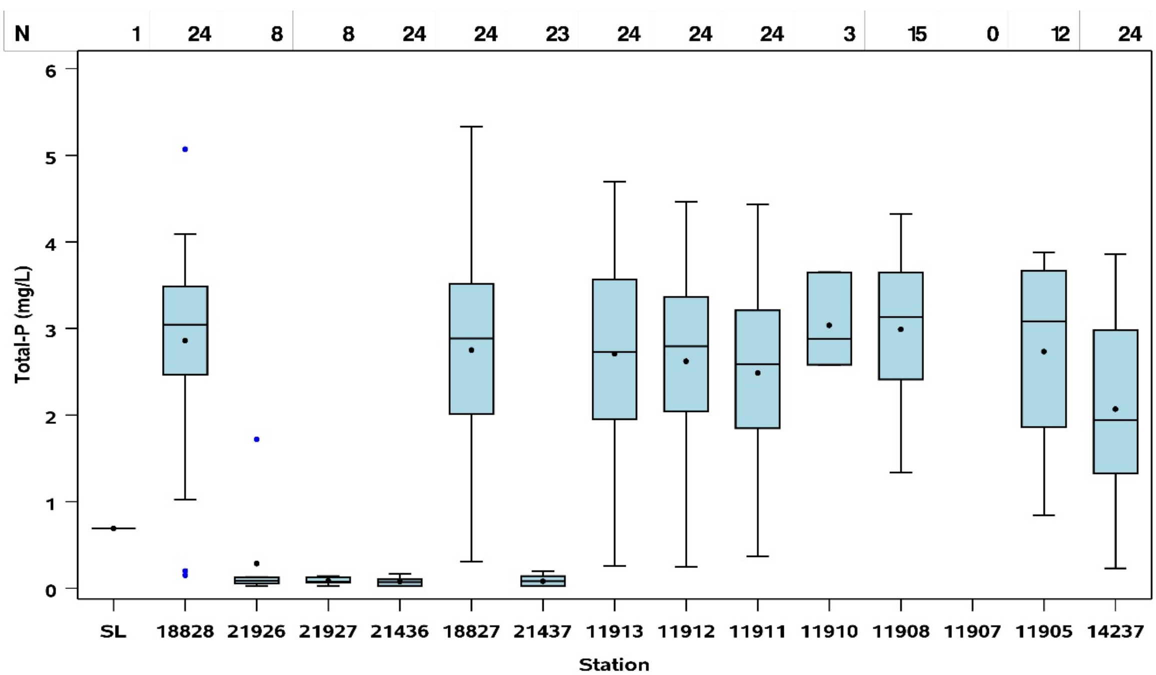

Figure 16 Box-and-whisker plots of total-P results for all monitoring events.

SL represents the nutrient screening level used by TCEQ for assessment of nutrient concerns for total-P (TCEQ, 2015b).

WWTFs

There are eight permitted point source outfalls along Nolan Creek/South Nolan Creek providing discharges from WWTFs (Table 10). These effluent discharges, along with some groundwater discharge, provide a continuous source of baseflow to the creek (Figure 8 and Table 10). In the upper portion of South Nolan Creek, average discharges from the Bell County WCID No. 1 Main Plant and Plant 2 of 17 cfs represent about 85 percent of baseflow based on median monthly field measurements of 20 cfs at station 18828. All eight WWTFs have an average daily discharge limit for *E. coli* of 126 MPN/100 mL and a daily maximum of 399 MPN/100 mL. Reporting data corresponding to the monitoring period indicated concentrations above permit limits on only a few occasions for the daily average or daily maximum (Figures 17 - 20). The timing of these elevated *E. coli* concentrations with WWTF discharges will be evaluated later in this report in relation to temporal trends in *E. coli* associated with monthly stream monitoring.

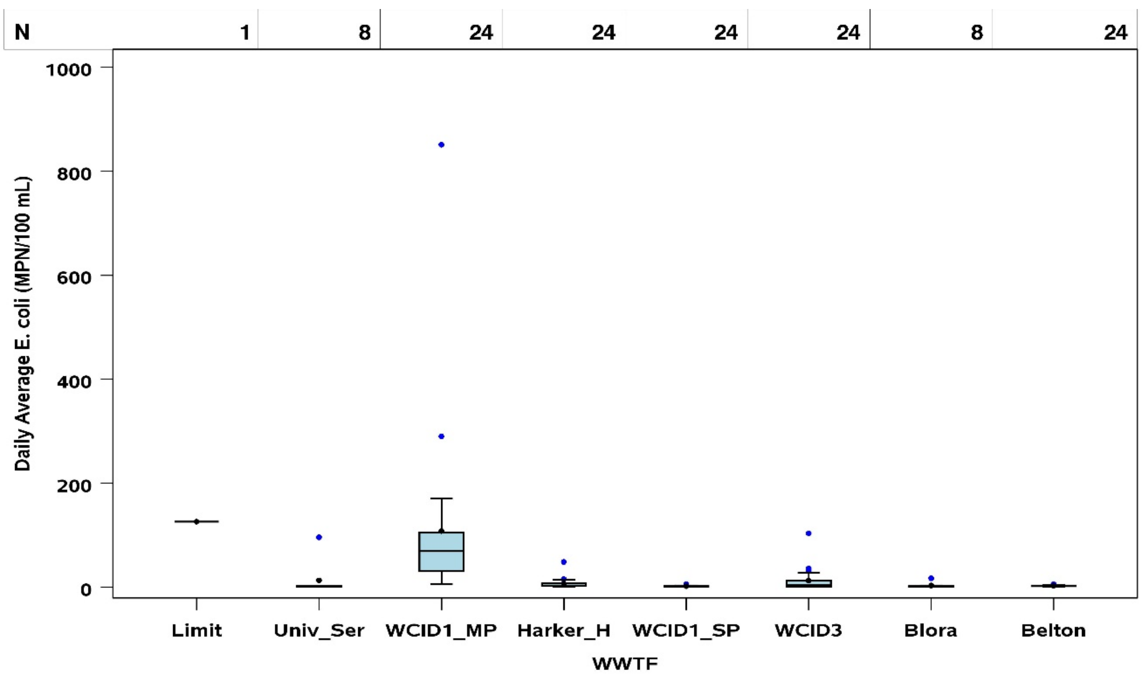

Figure 17 Box-and-whisker plots of daily average *E. coli* concentrations reported by permitted WWTFs.

Limit represents the permit limit for average *E. coli* of 126 MPN/100 mL. N represents the number of months with reporting data.

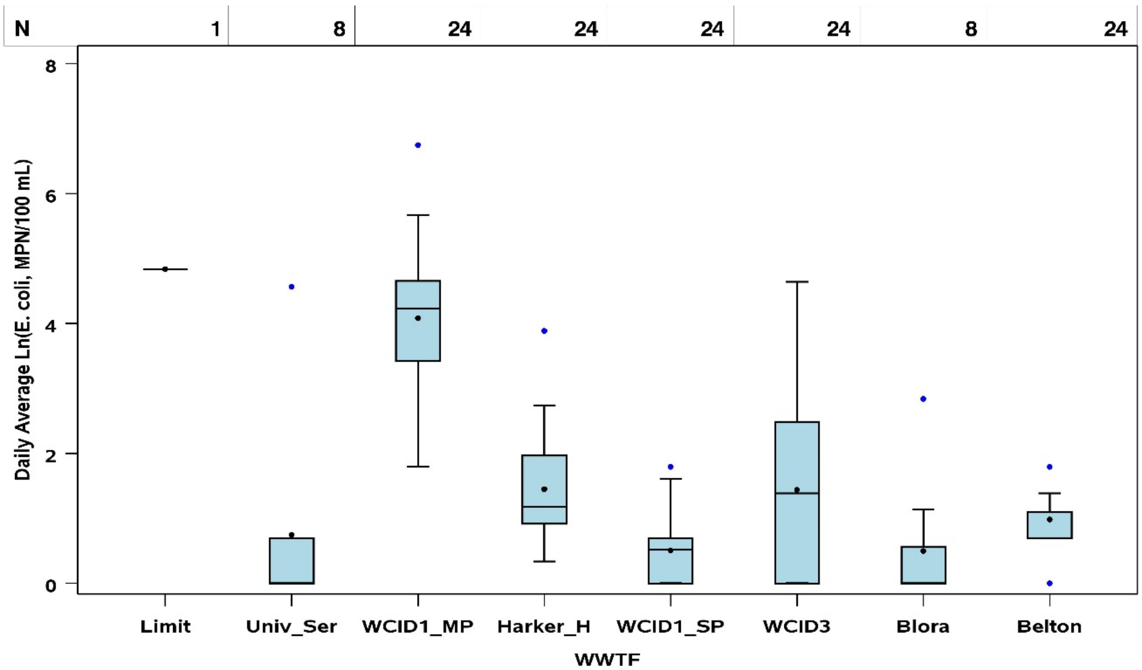

Figure 18 Box-and-whisker plots using a natural-log scale of daily average *E. coli* concentrations reported by permitted WWTFs.

Limit represents the permit limit for average *E. coli* of 126 MPN/100 mL. Ln represents the natural log scale. N represents the number of months with reporting data.

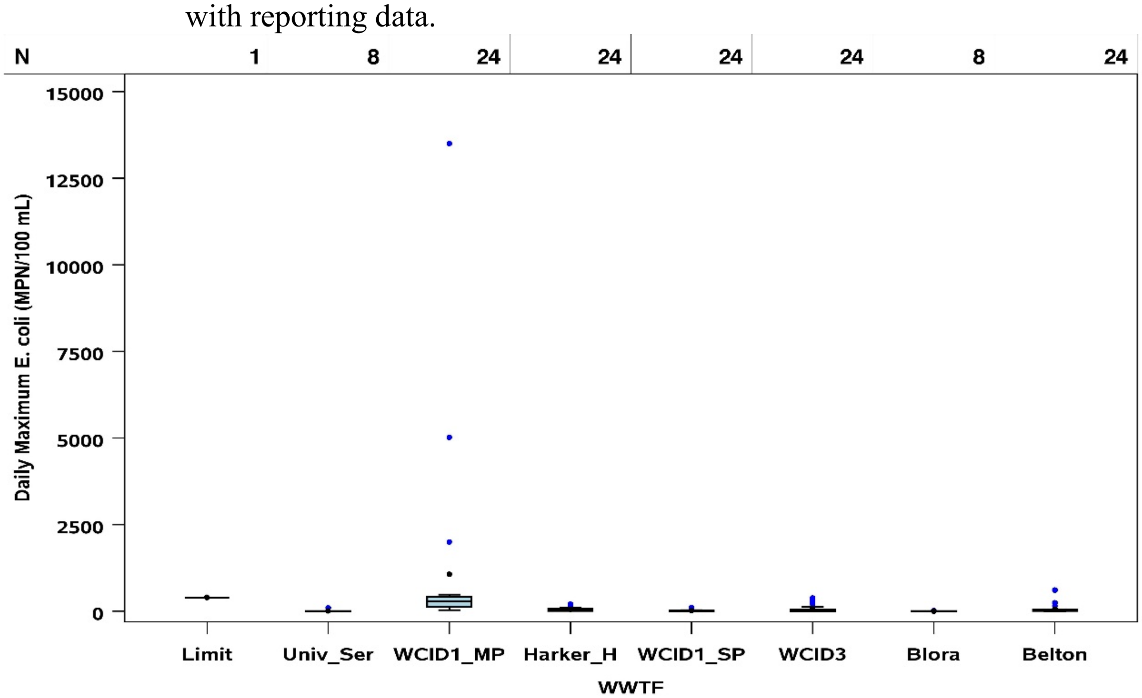

Figure 19 Box-and-whisker plots of daily maximum *E. coli* concentrations reported by permitted WWTFs.

Limit represents the permit limit for maximum *E. coli* of 399 MPN/100 mL. N represents the number of months with reporting data.

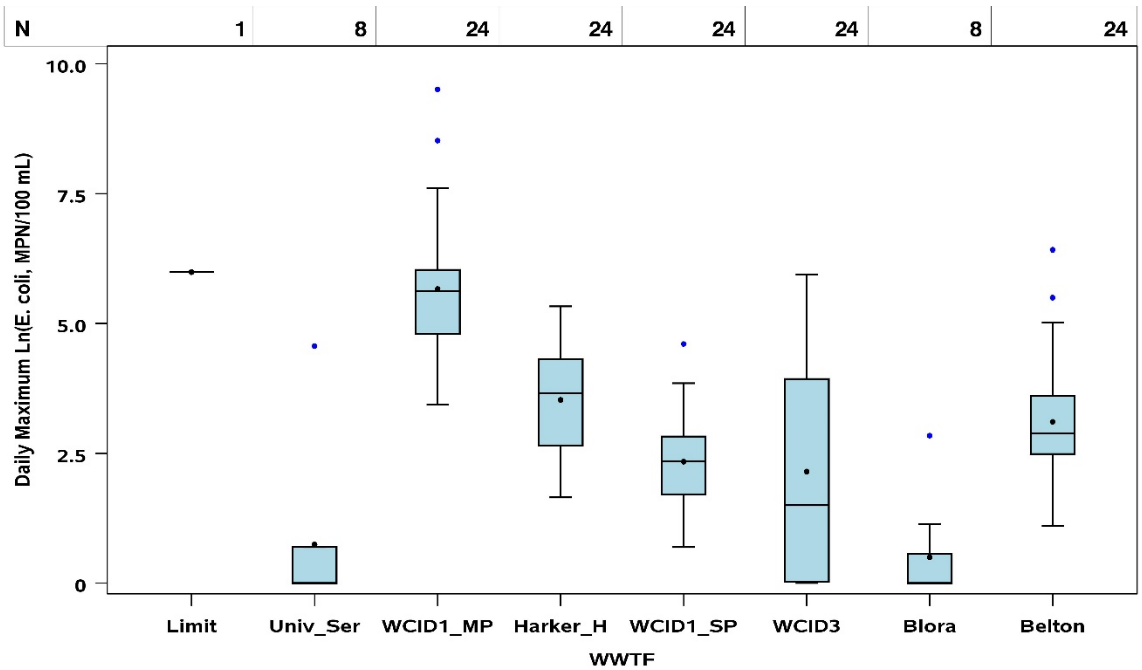

Figure 20 Box-and-whisker plots using a natural-log scale of daily maximum *E. coli* concentrations reported by permitted WWTFs.

The Limit represents the permit limit for maximum *E. coli* of 399 MPN/100 mL. Ln represents the natural log scale. N represents the number of months with reporting data.

Nutrient limitations for permitted discharges within the watershed exist only for ammonia. The Bell County WCID No. 1 (Plant 3, South Plant) as of August 27, 2015 amended its permit for a second discharge into Trimmier Creek, which is outside the watershed area. With discharges to Trimmier Creek, the Bell County WCID No. 1 (Plant 3, South Plant) has a total phosphorus limitation of 1 mg/L as a daily average, but as of September 2018 had not yet discharged any effluent to Trimmier Creek.

Comparisons between Stations and to Criterion and Screening Levels

Comparison of geometric mean *E. coli* concentrations were made using all data points and those with DSLP < 4 days removed (Figure 21). Removing data points associated with DSLP < 4 days notably decreased geometric mean *E. coli* concentrations (Figure 21), but even with observations associated with DSLP < 4 days removed, all stations still had geometric mean *E. coli* concentrations above the criterion on 126 MPN/100 mL. The station along the mainstem with geometric mean *E. coli* concentrations closest to the PCR criterion was the most upstream station, 18828, located along South Nolan Creek at 38th Street in Killeen (Figure 8).

Because Figure 21 summarizes data for all stations monitored, the number of observations and monitoring period varies (see Table 6). Limiting the graphic to just those stations monitored throughout the two-year period for events with a DSLP > 3 days provides a more informative chart for comparing *E. coli* concentrations between stations (Figure 22).

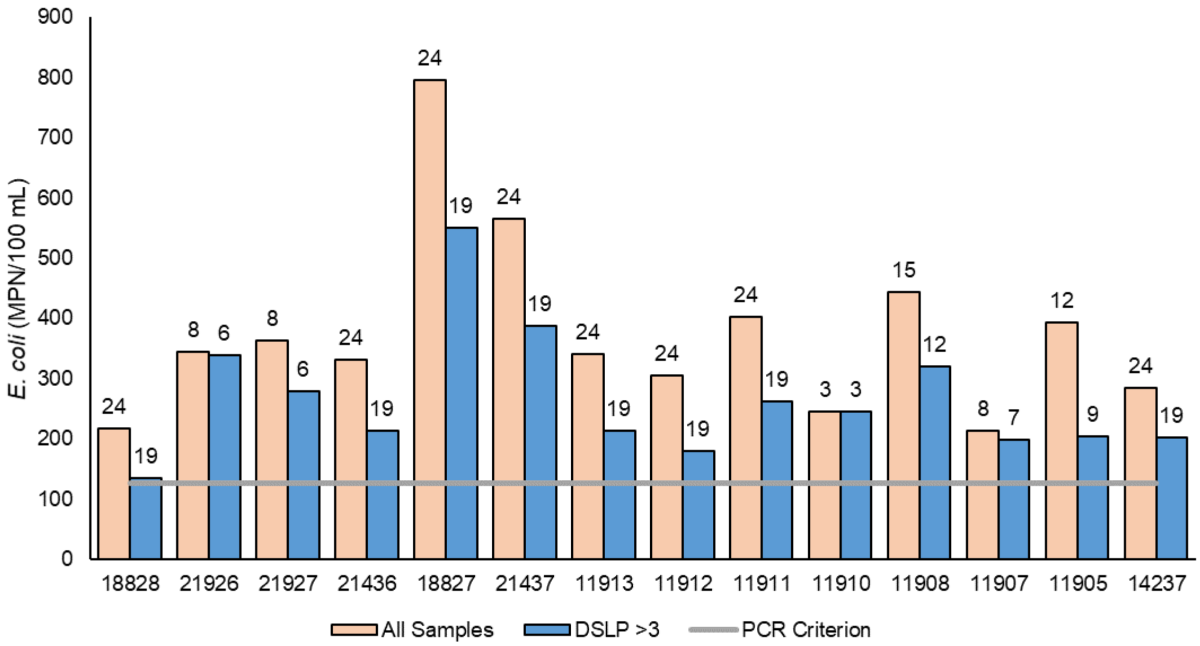

Figure 21 Comparison of geometric mean *E. coli* concentrations using all observations and only those associated with DSLP greater than 3 days.

Numbers above bars represent the number of observations.

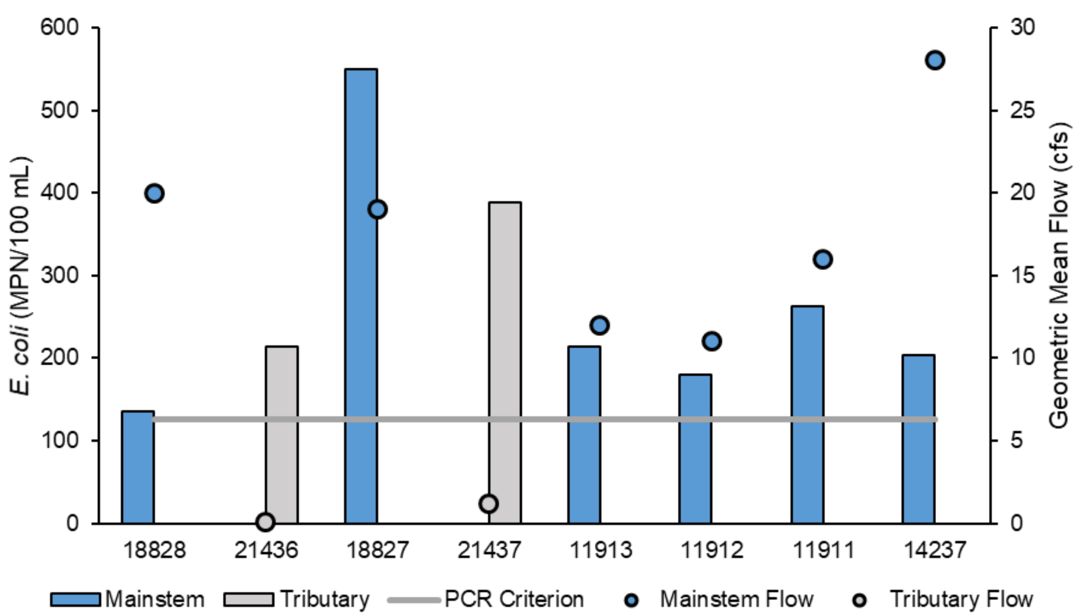

Figure 22 Comparison of geometric mean *E. coli* concentrations for selected stations with a DSLP greater than 3 days.

Selected stations were those consistently monitored over the two-year period to represent similar environmental conditions (n=19).

While station 21437 on Little Nolan Creek had some of the highest measured concentrations for *E. coli* (see Figure 12), station 18827 on the mainstem of South Nolan Creek at the crossing of Twin Creek Road had the highest geometric mean *E. coli* concentration (Figures 21 and 22). The geometric mean concentration at station 18827 was more than double that of many of the other mainstem stations (Figures 21 and 22). While only a little over a mile downstream, the geometric mean *E. coli* concentration at station 11913 at Roy Reynolds Road was less than half the geometric mean concentration at station 18827. Of the two major tributaries monitored, higher concentrations were generally found along Little Nolan Creek, which flows into South Nolan Creek below station 18827 than on Long Branch, which flows in above station 18827. This contradicts previous study findings where higher *E. coli* concentrations were generally measured along Long Branch than Little Nolan Creek (see Figure 4 and McFarland and Adams, 2015b).

With the large variability in *E. coli* concentrations as shown in Figures 12 through 14 and the interdependence of downstream on upstream water quality, it is difficult to make clear statistical comparisons between stations, although *E. coli* concentrations at station 18827 appeared to stand out as greater than most other stations. To evaluate for differences in *E. coli* between stations, a nonparametric Kruskal-Wallis test was applied. The Kruskal-Wallis test compares median values, which are more similar to the geometric means than averages. To avoid differences in environmental conditions and the number of samples collected, only the eight stations that were consistently monitored throughout the two-year period were compared using the Kruskal-Wallis test (see Table 6). The Kruskal-Wallis indicated statistically significant differences ($p = 0.0155$, $n=24$) when all eight stations were evaluated, but no statistical differences in *E. coli* between stations when station 18827 was removed from the dataset ($p = 0.4841$, $n=24$).

Station 21436 on Long Branch was monitored all 24 months of the project, and as noted earlier, had a geometric mean *E. coli* concentration for all 24 months of 331 MPN/100 mL and for monitoring events with DSLP >3 days, only 206 MPN/100 mL (Figure 21). Along Long Branch, which flows in between mainstem stations 18828 and 18827, three stations were monitored monthly between October 2016 and May 2017. This monitoring was conducted to see if contributions of bacteria along Long Branch could be more clearly isolated as previous monitoring had indicated that the higher *E. coli* concentrations observed at station 18827 might be associated with high contributions from Long Branch (Figure 4). For samples collected between October 2016 and May 2017, geometric mean *E. coli* concentrations showed little difference between the most upstream station 21926 at Tripp Trail in Killeen and station 21927 at Lake Road in Killeen (Figure 23). At the most downstream station on Long Branch (21436) located at Twin Creek Road in Killeen, a dilution of *E. coli* concentrations appeared to occur with an associated increase in flow as noted for samples with a DSLP >3 days. The one month with a DSLP <4 days occurred in February 2017, when flooding conditions were monitored and flow could not be measured due to unsafe water levels for wading.

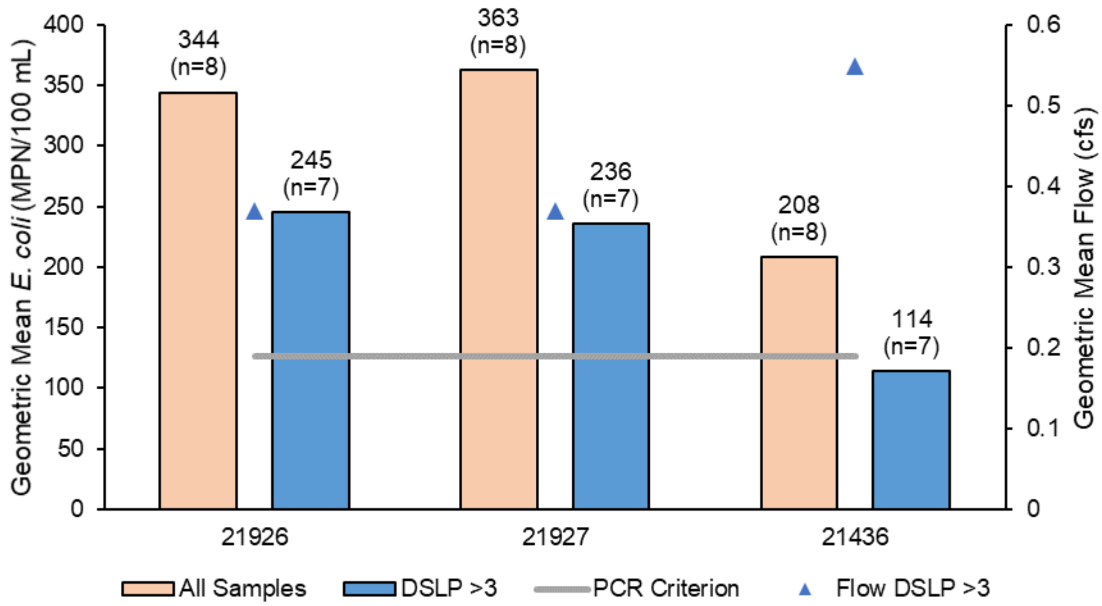

Figure 23 Comparison of geometric mean *E. coli* concentrations along Long Branch.

Data collected between October 2016 and May 2017 for all observations and only those associated with DSLP greater than 3 days. Numbers above bars represents geometric mean values and "n" the number of observations.

For nutrients in comparison to screening levels, average concentrations were elevated at all mainstem stations but not at tributary stations (Figures 24 and 25). Because much of the flow within the mainstem of Nolan Creek/South Nolan Creek at baseflow is associated with WWTF discharges, it is assumed that these WWTF discharges are the primarily contributing source of these elevated nutrient levels. Previous monitoring that included storm events, showed a decrease or dilution of concentrations when stormwater runoff events were considered (see McFarland and Adams, 2015b). It is important to note that for nutrients, all WWTFs are within their permit limits and that except at Bell County WCID No. 1 (Plant 3, South Plant) when it discharges into Trimmier Creek, there are no total-P or NO_2-N+NO_3-N permit limits required for these facilities. As noted previously, the Bell County WCID No. 1 (Plant 3, South Plant) has a total-P limitation of 1 mg/L as a daily average for discharges into Trimmier Creek, which flows into Stillhouse Hollow Lake outside the Nolan Creek watershed.

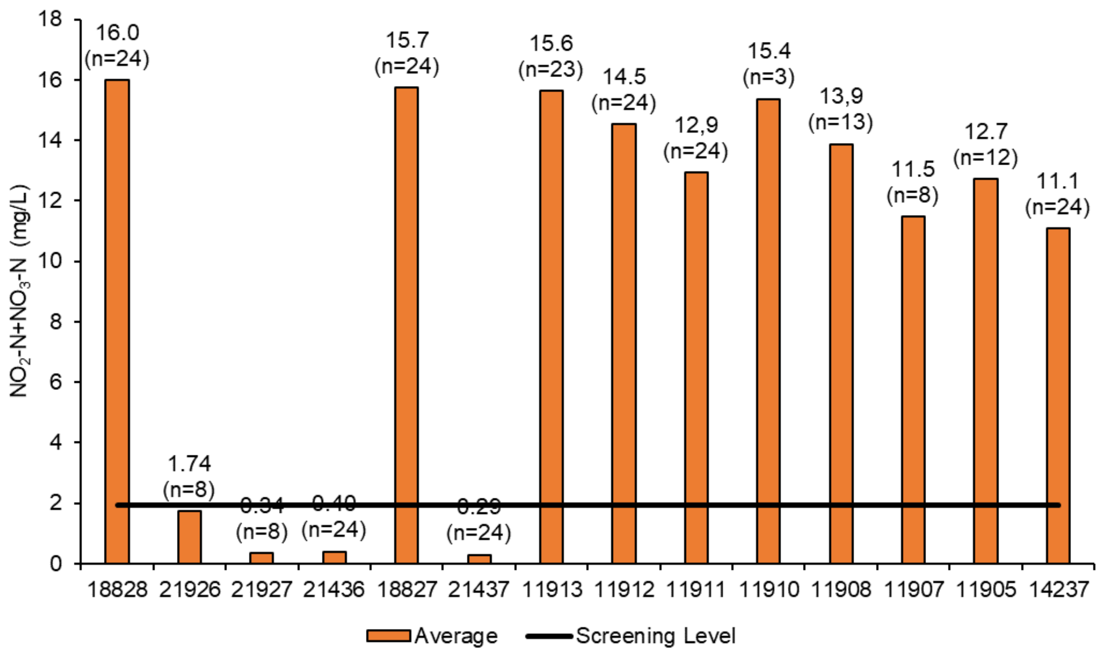

Figure 24 Comparison of average NO_2-N+NO_3-N to screening level of 1.95 mg/L.

Numbers above bars represents the average and "n" the number of observations between September 2016 and August 2018.

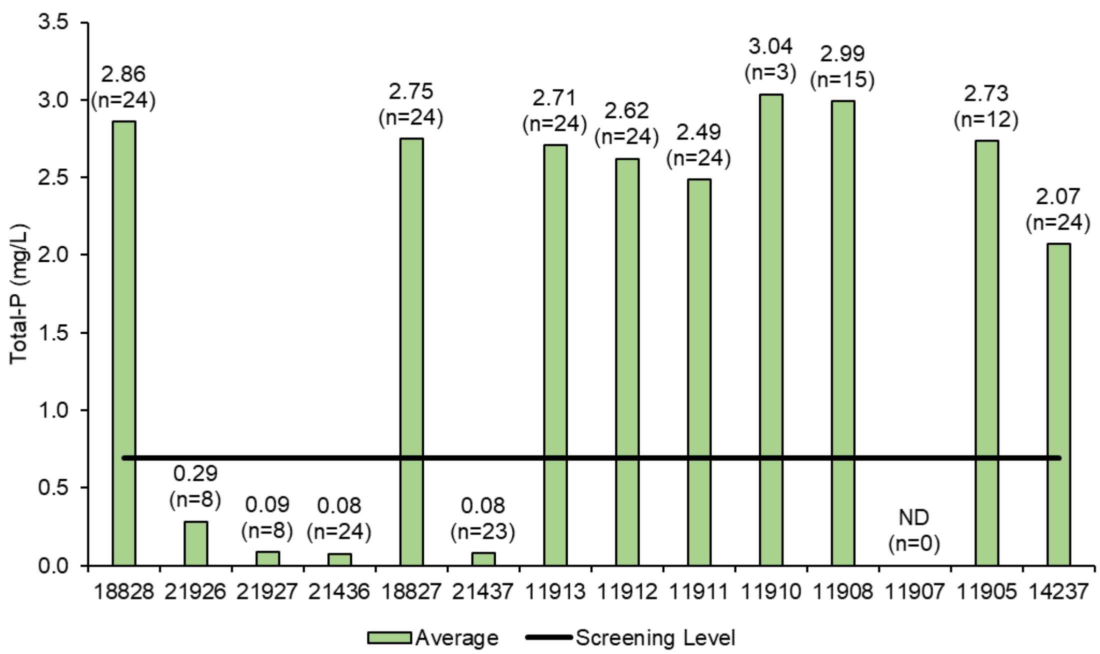

Figure 25 Comparison of average total-P to screening level of 0.69 mg/L.

Numbers above bars represents the average and "n" the number of observations between September 2016 and August 2018. ND indicated no data. Samples at station 11907 were not analyzed for total-P.

Comparisons over Time

Time series plots of *E. coli* concentrations were developed for stations that had historical data from the previous characterization project (see Table 2) or were monitored for all 24 months under the current project (Figures 26-35). Visually differences in *E. coli* concentration over time were difficult to assess, but it was clear that more storm influenced events occurred during more recent monitoring (T2: Sep2016 – Aug2018) than during the previous characterization project monitoring (T1: May2013-Jun2015).

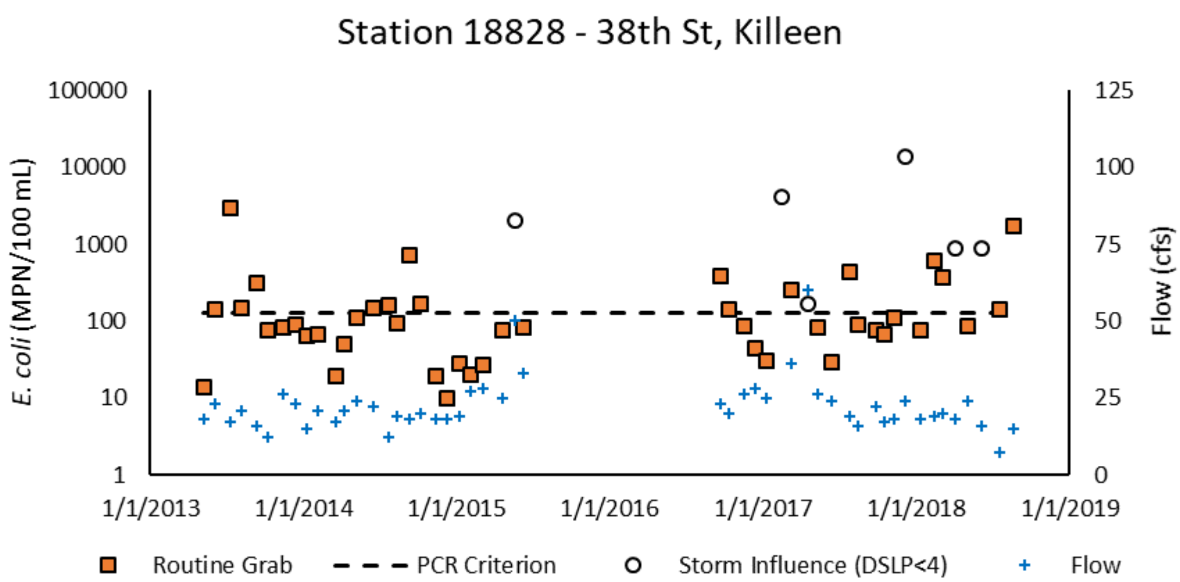

Figure 26 Monthly measurements of *E. coli* and flow over time for station 18828.

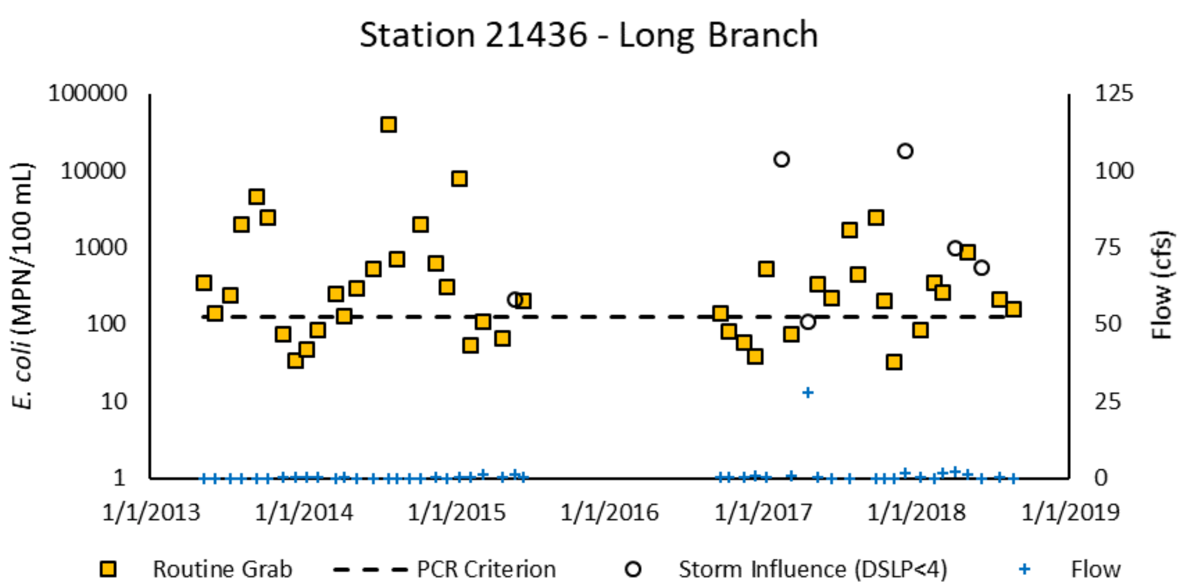

Figure 27 Monthly measurements of *E. coli* and flow over time for station 21436.

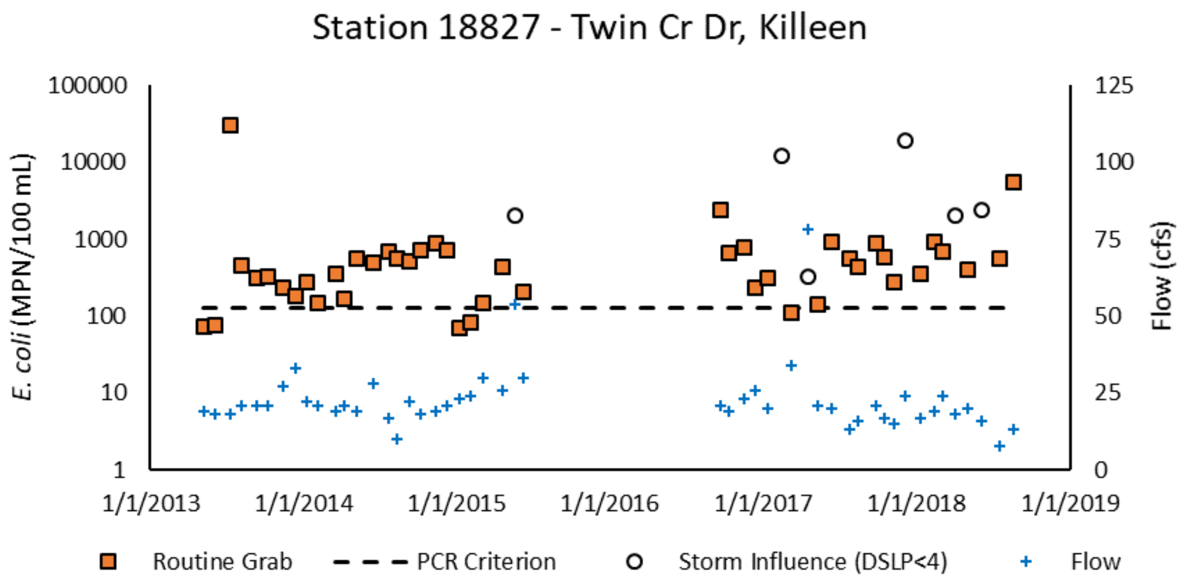

Figure 28 Monthly measurements of *E. coli* and flow over time for station 18827.

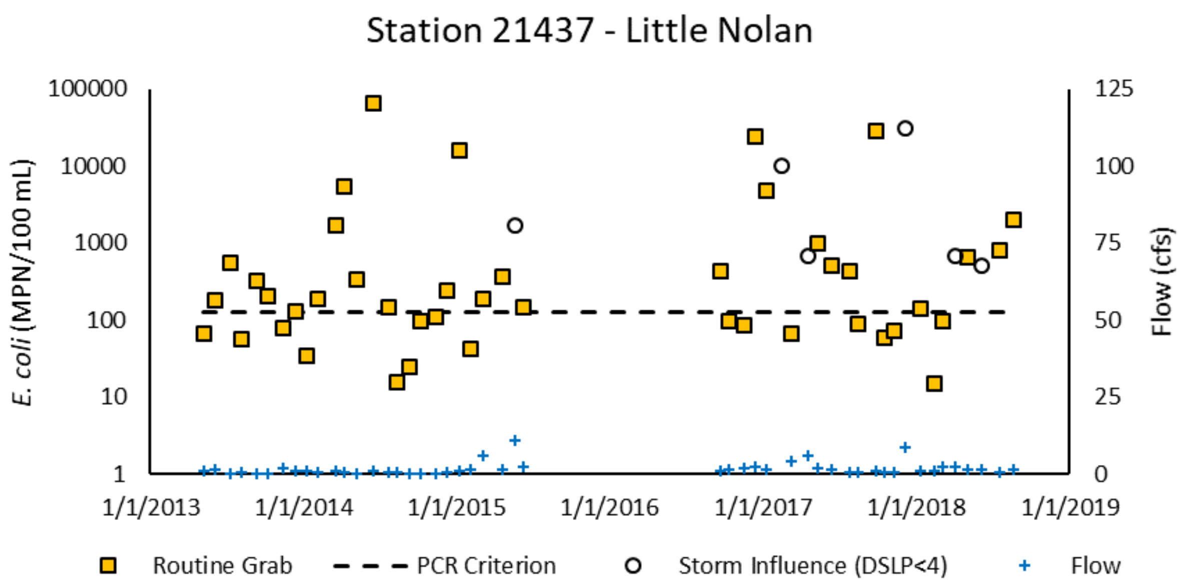

Figure 29 Monthly measurements of *E. coli* and flow over time for station 21437.

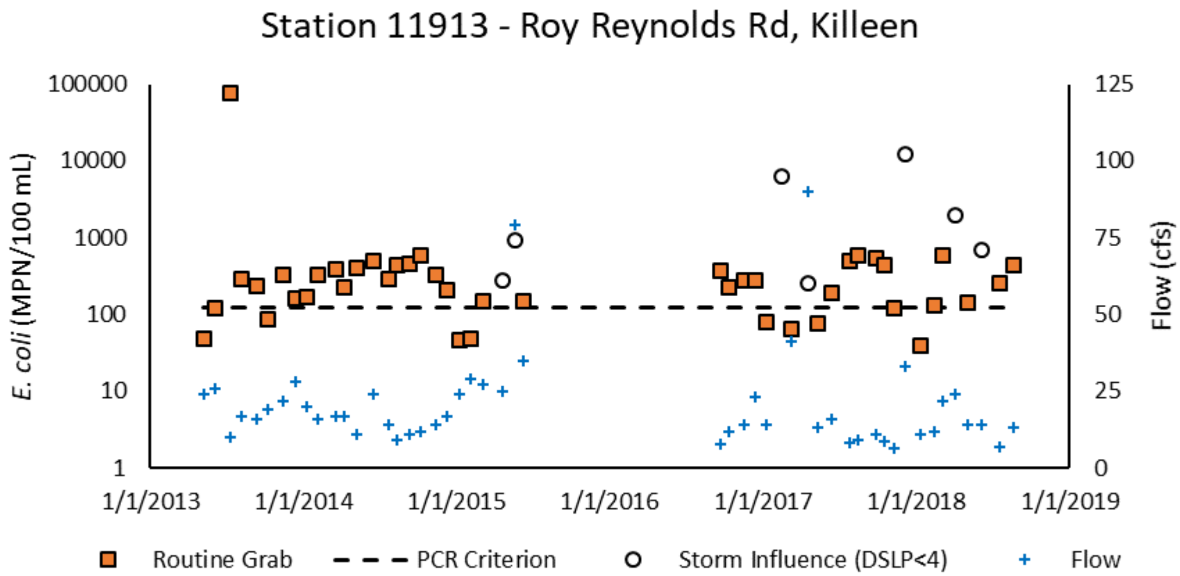

Figure 30 Monthly measurements of *E. coli* and flow over time for station 11913.

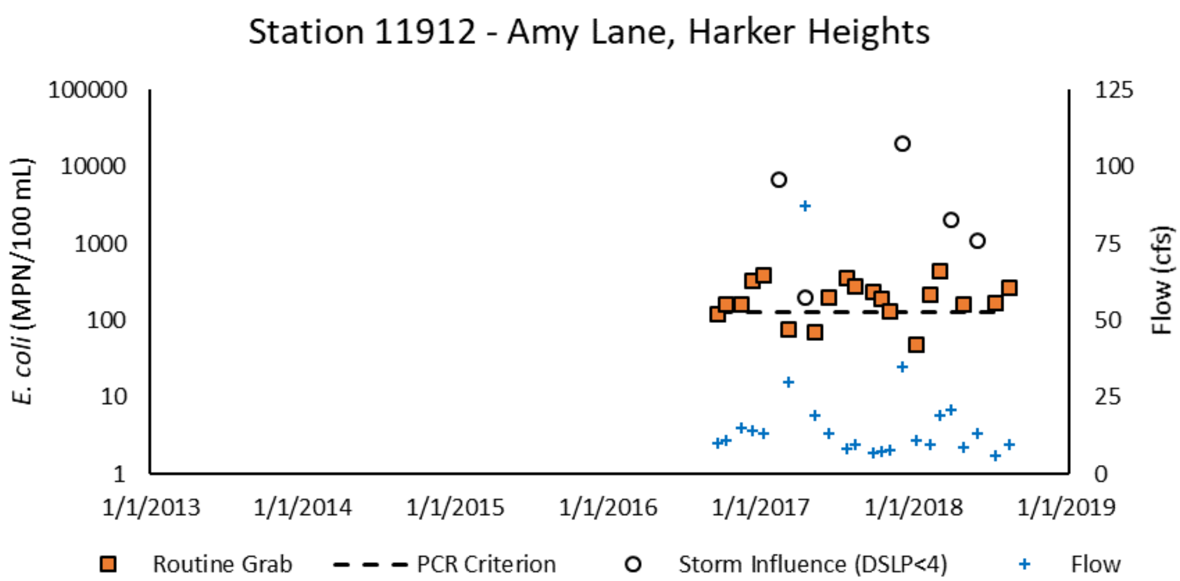

Figure 31 Monthly measurements of *E. coli* and flow over time for station 11912.

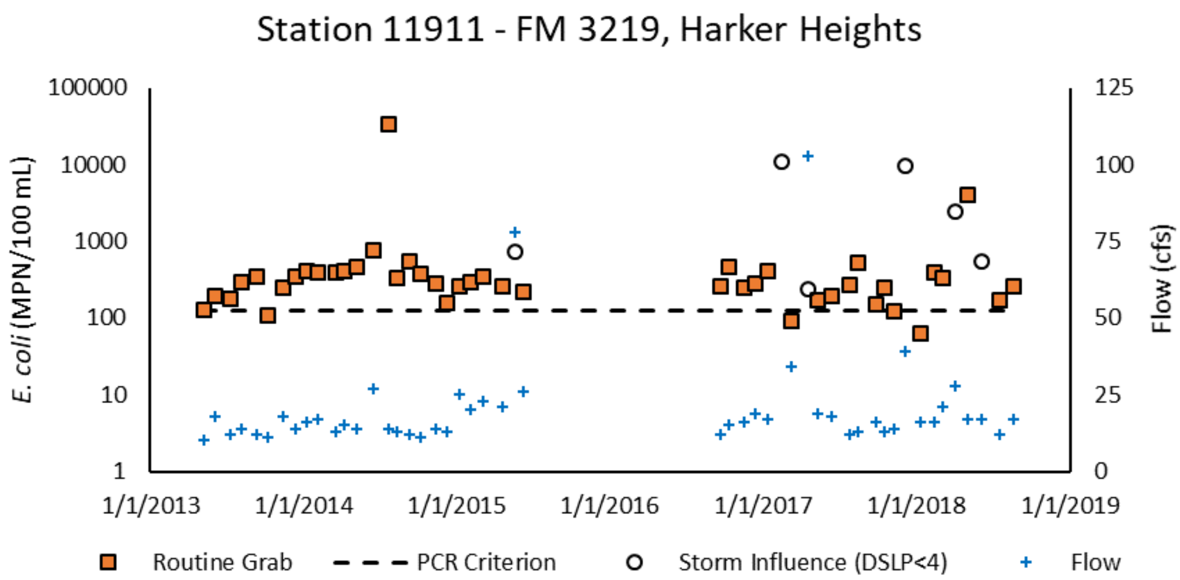

Figure 32 Monthly measurements of *E. coli* and flow over time for station 11911.

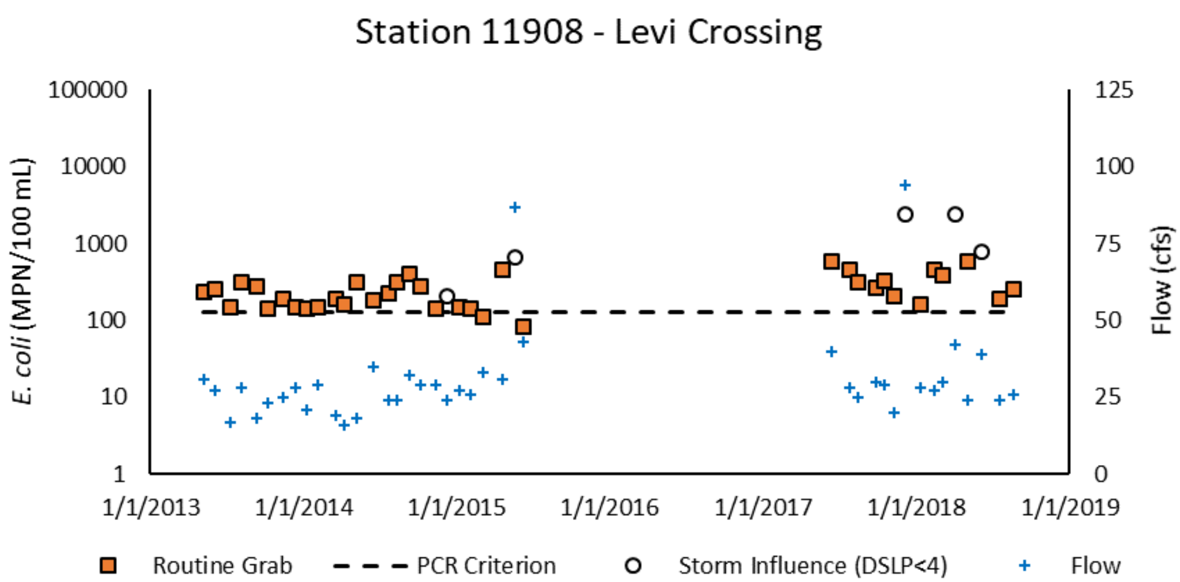

Figure 33 Monthly measurements of *E. coli* and flow over time for station 11908.

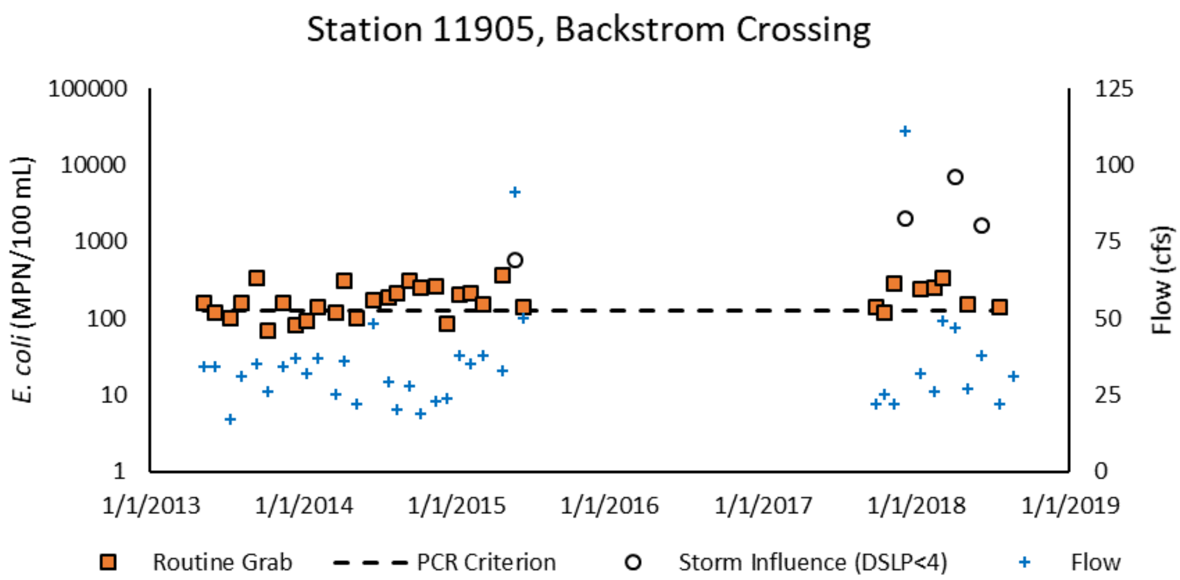

Figure 34 Monthly measurements of *E. coli* and flow over time for station 11905.

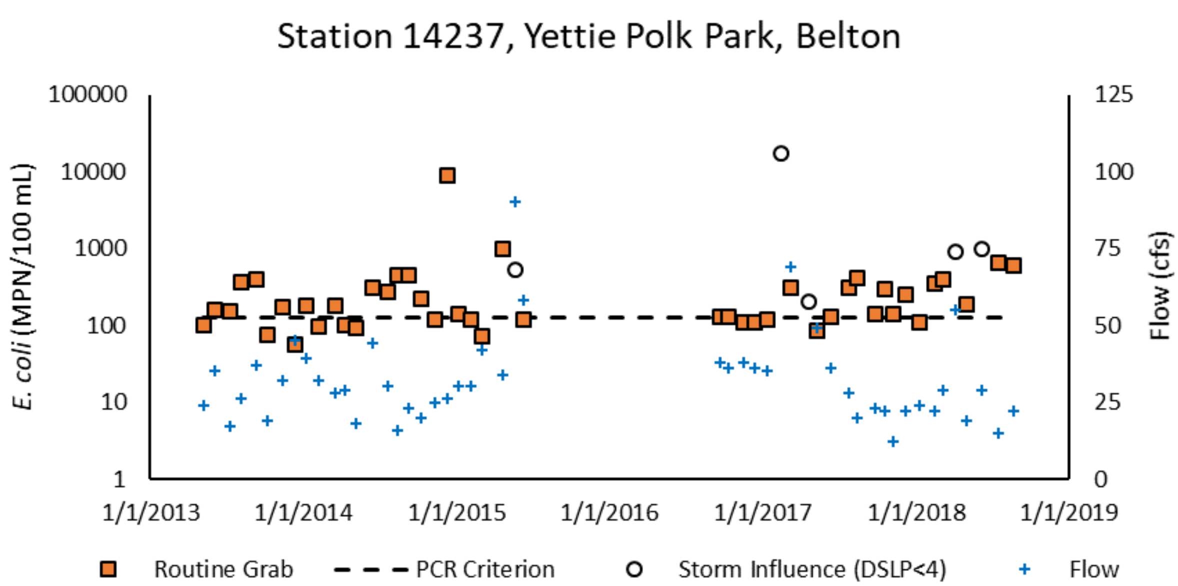

Figure 35 Monthly measurements of *E. coli* and flow over time for station 14237.

Influence of Flow and Season on Temporal Variations

Variability in environmental factors can potentially mask trends or make trends apparent if not considered. Two of the most prominent environmental factors are flow and seasonality. Stream flow can greatly influence *E. coli* concentrations as it increases runoff and, thus, increases contributions from nonpoint sources off the landscape. Direct correlations with flow measurements had previously shown significant increases in *E. coli* concentrations with increases in flow, but only when targeted storm monitoring was included of high flow events (see McFarland and Adams, 2015b). In data collected between May 2013 and June 2015 (T1), some storm monitoring was conducted at stations 18828, 11913, 11910, and 11905. When just routine monitoring was considered at these four stations, flow did not show a significant relationship with *E. coli* concentrations. With the current dataset, some marginally significant relationships were indicated between flow and *E. coli* at a couple of stations when both were transformed on natural log scale, but no significant correlations were indicated at any station between flow and *E. coli* concentrations when events with a DSLP > 3 days were removed.

While flow with routine grab samples appeared to be a factor only when storm influenced, seasonality based on water temperature including both routine monthly historical monitoring (T1: May2013-Jun2015) and more recent monitoring (T2: Sep2016-Aug2018) was a significant factor at most stations (Table 11). Samples collected with measured water temperature greater than 20ºC (68ºF) were considered warm season samples and samples collected with a water temperature of 20ºC (68ºF) or less were grouped as cool season samples. A Kruskal-Wallis nonparametric test was applied to compare median *E. coli* concentrations between seasons. As might be expected, *E. coli* concentrations of samples collected when water temperatures were warmer (greater than 20ºC) were greater than for samples collected when water temperatures were cooler (water temperature less than or equal to 20ºC) at most sampling stations (Table 11).

To evaluate for trends or changes in *E. coli* concentrations between the two monitoring periods, seasonality and DSLP needed to be taken into account, so “false” trends were not indicated due to variations in these environmental factors. To determine if a step-trend had occurred between T1 (May2013 - Jun2015) and T2 (Sep 2016 – Aug2018), data sets were limited to routine grabs with a DSLP greater than 3 days. Data sets were also divided and compared by season (warm and cool) based on measured water temperature, if seasonality was considered a significant factor (see Table 11). Only stations that were monitored for the full 24-month period in T2 were included in the step-trend analysis to allow a comparable number of samples for comparison between the two periods. Step-trend analyses were not conducted for stations 11908 or 11905 due to more limited sampling in T2 at these locations (see Table 6). A Kruskal-Wallis nonparametric test was implemented to compare median concentrations between periods by station and by season, when indicated. Statistically comparing more recent monitoring (T2) to past monitoring (T1), no significant differences were indicated (results not presented as no significant differences were found).

Table 11 Comparison of *E. coli* concentrations by season.

Cool season represented by water temperatures of 20ºC or less, while warm season represented by water temperature equal to or greater than 20ºC. Kruskal-Wallis p-value less than 0.05 indicates statistically significant differences (*) and less than 0.01 indicates highly significant difference (**) in median values.

Station	Season	Mean *E. coli* (MPN/ 100 mL)	Median *E. coli* (MPN/ 100 mL)	Kruskal-Wallis p-value	Significance	Minimum *E. coli* (MPN/ 100 mL)	Max. *E. coli* (MPN/ 100 mL)	# of Obs.
11905	cool	182	160	0.5344	NS	70	330	17
11905	warm	197	160			99	370	17
11908	cool	201	155	0.0047	**	110	460	16
11908	warm	305	280			84	580	20
11911	cool	286	285	0.8999	NS	64	410	20
11911	warm	1760	260			110	33000	25
11912	cool	232	210	0.7209	NS	48	440	7
11912	warm	196	190			71	350	13
11913	cool	210	170	0.0393	*	39	580	17
11913	warm	3047	285			48	77000	28
14237	cool	557	125	0.0272	*	55	8800	24
14237	warm	280	260			84	650	21
18827	cool	345	230	0.0217	*	70	920	17
18827	warm	1926	535			73	34000	28
18828	cool	111	65	0.0299	*	19	610	9
18828	warm	267	102			10	2900	36
21436	cool	588	98	0.0024	**	32	7900	24
21436	warm	2808	385			110	39000	20
21437	cool	2262	120	0.1087	NS	15	24000	24
21437	warm	4882	440			16	65000	21

WWTFs *E. coli* Concentrations over Time

While direct causes for *E. coli* concentrations cannot be pinpointed as they often are from nonpoint sources, WWTFs are a known point source and for comparison purposes, monthly WWTF reporting data for average and maximum *E. coli* concentrations for all WWTF discharges are presented (Figures 36 and 37). In plotting reported data from January 2013 through August 2018, most values were below permit limits. Only the Bell County WCID1 Main Plant reported daily average *E. coli* concentrations above the permit limit (Figure 36), while the WCID1 Main Plant, Harker Heights, and WCID3 WWTFs indicated maximum values on occasion exceeding the permit limit (Figure 37). Numeric values for average and maximum *E. coli* concentrations as presented in Figure 36 and 37 are presented in Appendix B for reference.

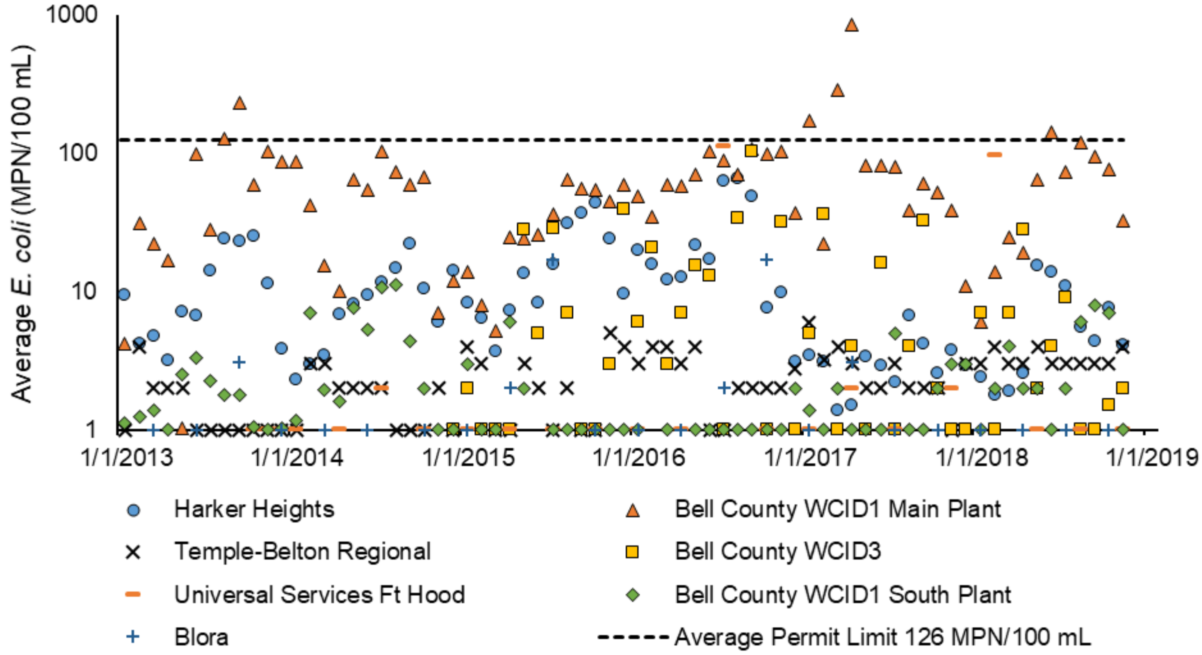

Figure 36 Monthly average *E. coli* as reported by WWTFs.

Discharges for Bell County WCID1 Plant 2 are combined with Bell County WCID1 Main Plant and reported under the Main Plant. Data presented are monthly values for January 2013 through August 2018.

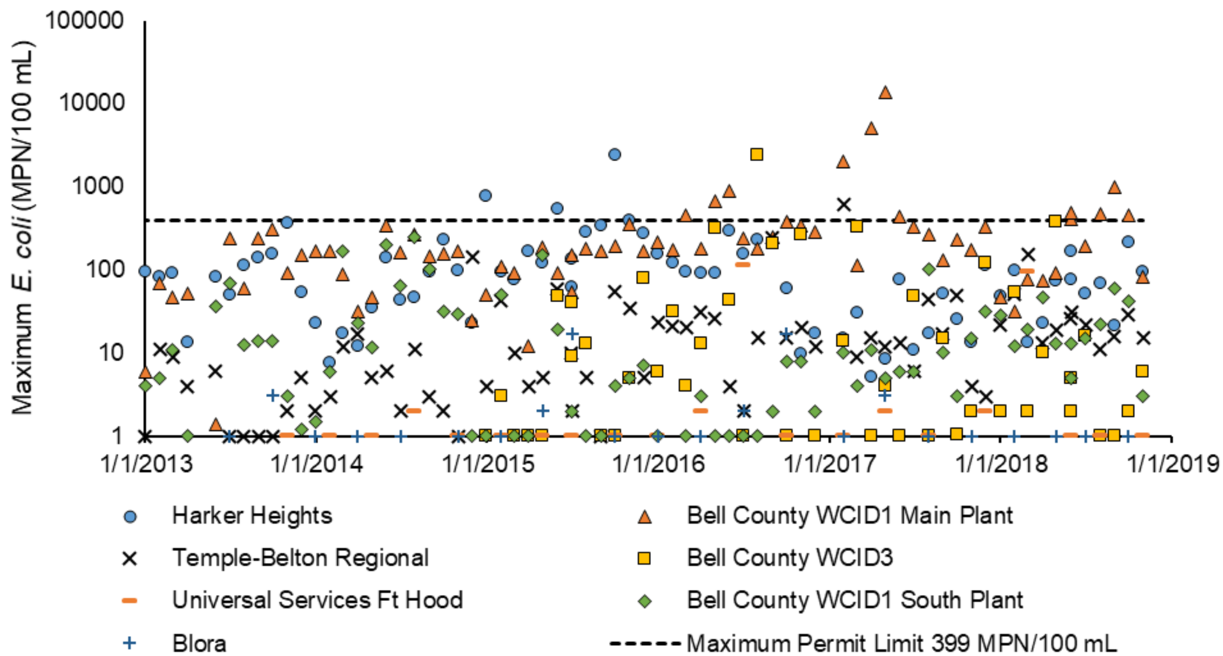

Figure 37 Monthly maximum *E. coli* as reported by WWTFs.

Discharges for Bell County WCID1 Plant 2 are combined with Bell County WCID1 Main Plant and reported under the Main Plant. Data presented are monthly values for January 2013 through August 2018.

Comparison with LDC Plots

Because LDCs were used to estimate *E. coli* load reductions needed at locations along South Nolan Creek within the WPP, data collected at associated stations were compared to these curves as an indicator of potential changes by flow regime. These LDCs were initially developed from data collected between May 2013 and June 2015 and included routine monthly monitoring as well as the sampling of nine storm events. Details regarding this previous monitoring are outlined in McFarland and Adams (2015b) and development of these LDCs in McFarland and Adams (2016). The four stations for which LDCs were developed included the following (see Figure 12):

- 18828, South Nolan Creek at 38th Street in Killeen
- 11913, South Nolan Creek at Roy Reynolds Road in Killeen
- 11910, South Nolan Creek at US 190 in Nolanville
- 11905, South Nolan Creek at Backstrom Crossing

Data collected between September 2016 and August 2018 were overlaid on these LDCs along with estimates of measured geometric mean loads for moderate and low flow conditions (Figures 38-41). Because storm events were not targeted for monitoring for the 2016-2018 data set, very few events fell within the high flow category, so geometric means were not calculated. Stations 18828 and 11913 had 23 data points with flow and bacteria data in the 2016-2018 data set, while station 11910 had only three and station 11905 12 data points (see Table 6).

For station 18828, the most upstream location (see Figure 12), estimated *E. coli* loads (MPN/day) generally fell within the range of previously collected data (Figure 38). There was a slightly higher frequency of values for 2016-2018 data above the allowable loading based on the assessment criterion of 126 MPN/100 mL for *E. coli* than for 2013-2015 data leading to an increased geometric mean loading during both moderate and low flow conditions.

At station 11913 off Roy Reynold Road in Killeen, the geometric mean loading for *E. coli* increased during moderate flows but decreased for low flow conditions comparing the two period (Figure 39).

For station 11910, all three *E. coli* measurements in the 2016-2018 data set fell within low flow category and showed a negligible difference compared to 2013-2018 data (Figure 40).

At station 11905 at Backstorm Crossing, some slight increases were shown under moderate and low flow conditions based on a comparison of geometric mean *E. coli* load (Figure 41). Of note, these comparisons are based on limited data as only 12 routine grab samples were collected at station 11905 during the 2016-2018 period.

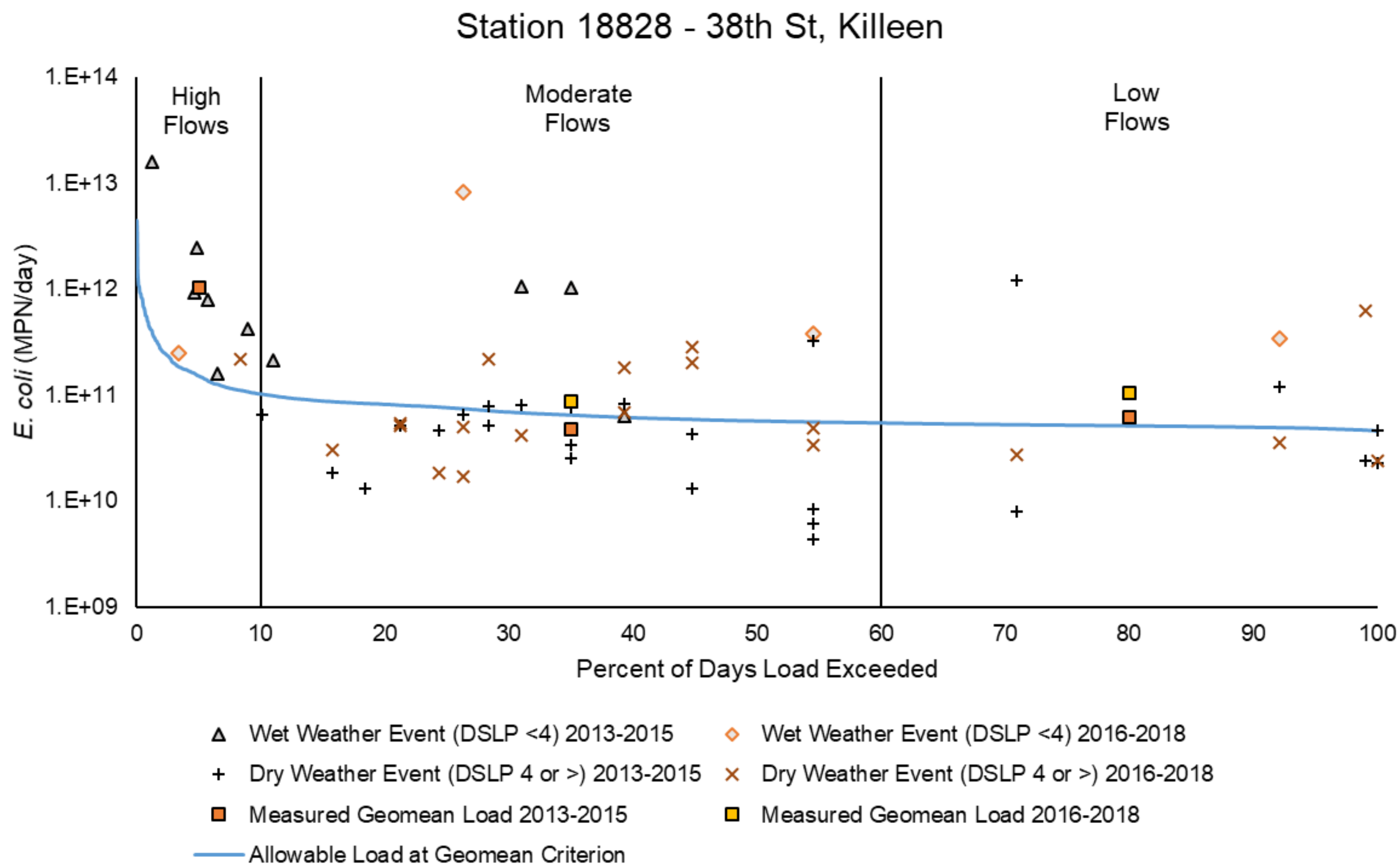

Figure 38 Load duration curve of estimated *E. coli* loadings for South Nolan Creek at station 18828 located at 38th St. in Killeen.

Compares data collected in 2013-2015 with more recent data collected in 2016-2018. Load duration curve development based on 2013-2015 data outlined in McFarland and Adams (2016). Of note for station 18828, the geometric mean loading for moderate and low flows was miscalculated and the y-axis was constricted so some lower data points were obscured in McFarland and Adams (2016). The above graph corrects for these two issues in the previous presentation of the *E. coli* LDC for station 18828.

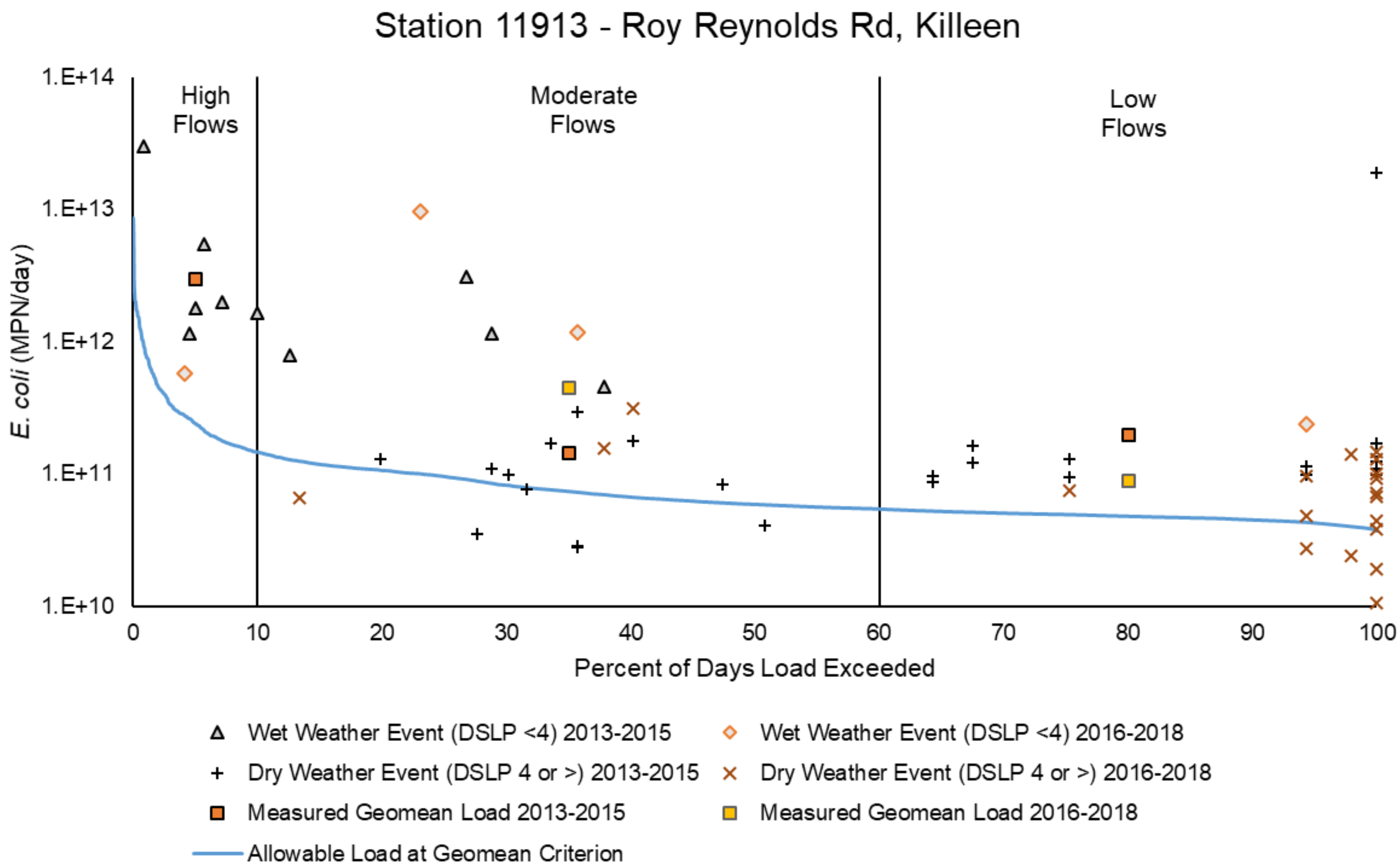

Figure 39 Load duration curve of estimated *E. coli* loadings for South Nolan Creek at station 11913 located at Roy Reynolds Road in Killeen.

Compares data collected in 2013-2015 with more recent data collected in 2016-20. Load duration curve development based on 2013-2015 data outlined in McFarland and Adams (2016).

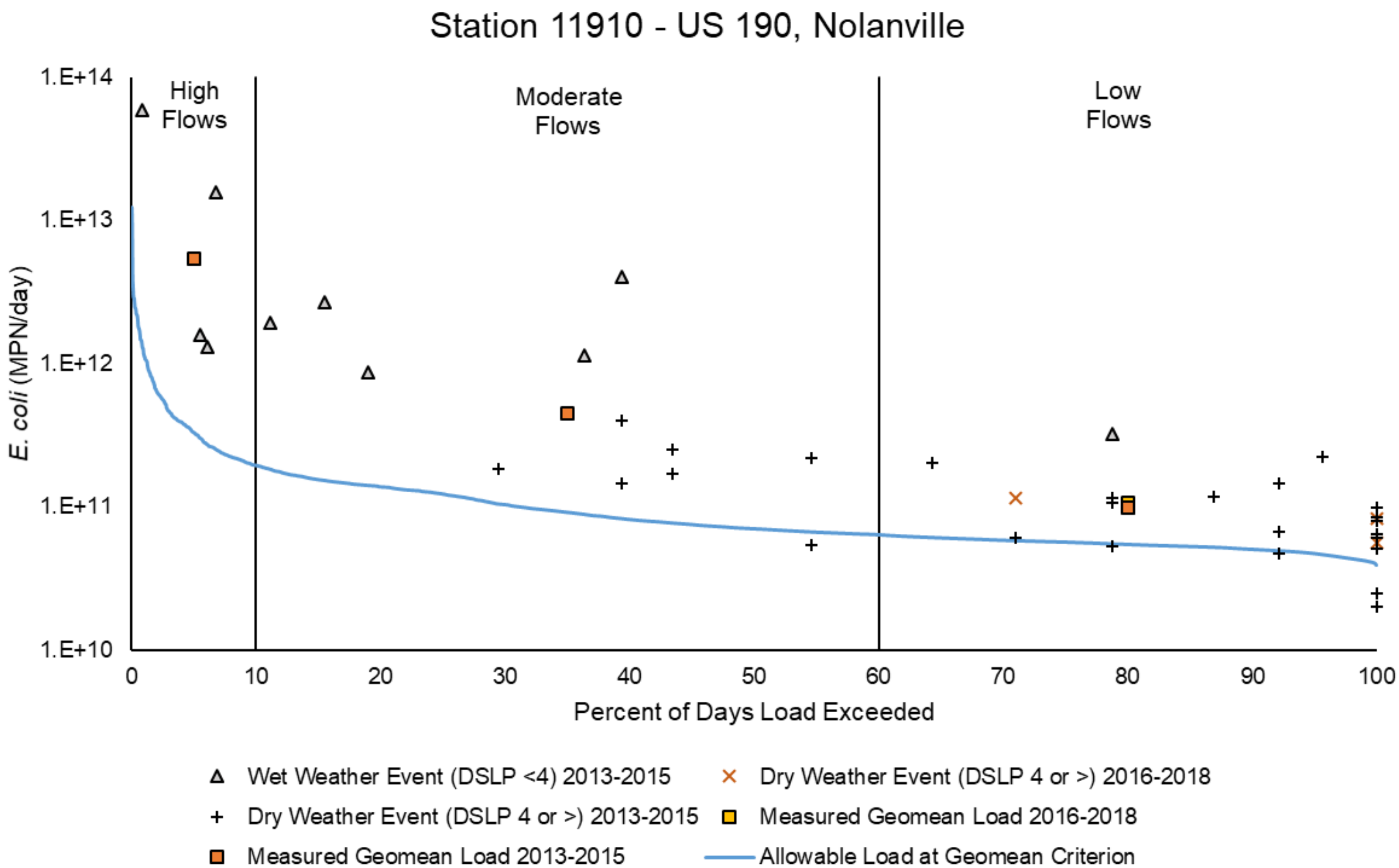

Figure 40 Load duration curve of estimated *E. coli* loadings for South Nolan Creek at station 11910 located at US 190 in Nolanville.

Compared data collected in 2013-2015 with more recent data collected in 2016-2018. Load duration curve development based on 2013-2015 data outlined in McFarland and Adams (2016).

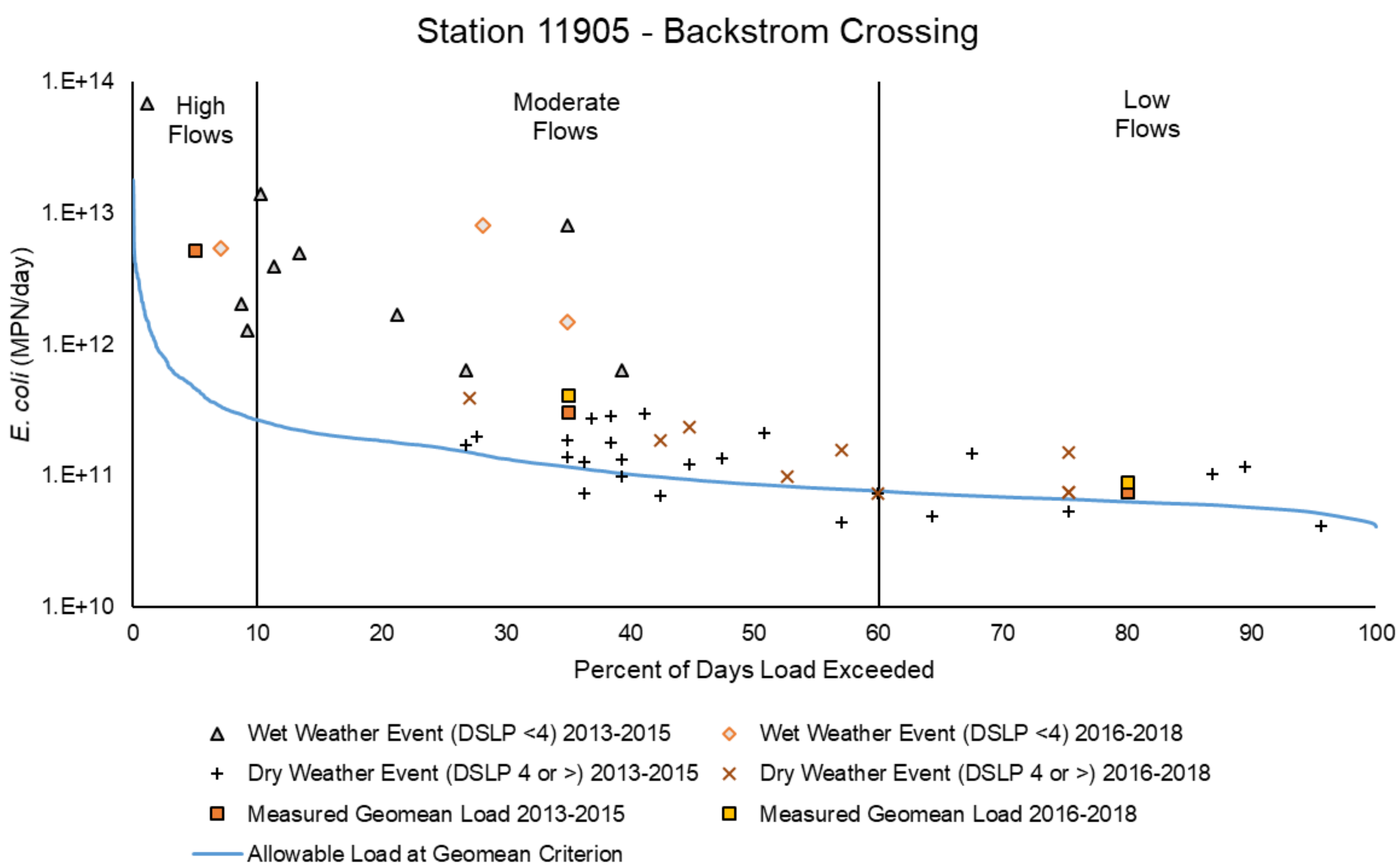

Figure 41 Load duration curve of estimated *E. coli* loadings for South Nolan Creek at station 11905 located at Backstrom Crossing.

Compares data collected in 2013-2015 with more recent data collected in 2016-2018. Load duration curve development based on 2013-2015 data outlined in McFarland and Adams (2016).

Summary

A wide variability in *E. coli* concentrations occurred in the two years of monitoring with results ranging from 15 MPN/100 mL to a high of 29,000 MPN/100 mL. A large amount of the variability in *E. coli* concentrations was related to storm water influences based on DSLP. When data were limited to more dry-weather conditions (DSLP greater than 3 days), a very notable decrease in variability of *E. coli* results was observed (Figures 13 and 14). In comparing *E. coli* concentrations to the criterion of 126 MPN/100 mL, results showed all stations with geometric mean concentrations above criterion, even when the data set was limited to events with DSLP >3 days (Figure 21).

To limit the influence of different monitoring frequencies and environmental influences, the eight stations monitored throughout the two-year period were compared with the data set limited to events with a DSLP >3 days. Comparisons using a Kruskal-Wallis nonparametric test indicated higher median concentrations at station 18827 (located at the crossing of South Nolan Creek at Twin Creek Dr in Killeen) than at the other seven stations. This difference was only marginally significant and no significant difference in median *E. coli* concentrations were indicated between stations when station 18827 was removed from the data set.

Seasonality was significant for *E. coli* concentrations with most stations indicating higher *E. coli* concentrations during monitoring events with warmer water temperatures (greater than 20ºC) than cooler water temperatures. In evaluating for step-trends over time by station and by season (where applicable), no significant differences were found in median *E. coli* concentrations. This step-trend analysis evaluated the seven stations that were monitored through the most recent period (T2: Sep2016-Aug2018) compared to samples collected as part of a previous project (T1: May2013-Jun2015).

For evaluating differences that might be related to flow conditions, *E. coli* concentrations from the current monitoring were overlaid on previously developed LDCs associated with stations 18828, 11913, 11910, and 11905 (Figures 38-41). While some numeric differences in geometric means for moderate and low flows were apparent, estimated *E. coli* loads (MPN/day) generally fell within the range of previously collected data.

While nutrients (nitrates and total-P) are a concern in this watershed, only a very limited evaluation was done of the nutrient data collected with comparison made to TCEQ screening levels (Figures 24 and 25). Along the mainstem of Nolan Creek/South Nolan Creek, nitrate and total-P concentrations were well above screening levels of concern for these two parameters. The mainstem of Nolan Creek/South Nolan Creek has discharges from several WWTFs, which are a contributing source of nutrients. Currently, only the Bell County WCID1 South Plant has limits beyond ammonia for any other nutrient parameter with a limit of 1 mg/L for total-P as a daily average when it discharges into Trimmier Creek. Nutrients, beyond ammonia, are generally not limited within WWTF permits. Other sources of nutrients include nonpoint source runoff often associated with fertilizer and animal waste.

The focus of the WPP within the Nolan Creek/South Nolan Creek watershed is on bacteria as measured by *E. coli* concentrations. The more recent monitoring conducted shows that concentrations are still above the target criterion supporting the need for the WPP. Implementation of the WPP focuses primarily on nonpoint source contributions of bacteria, which should also aid partially in addressing concerns related to nutrients.

References

American Public Health Association, American Water Works Association and Water Environment Federation. 2016. *Standard Methods for the Examination of Water and Wastewater*, latest online edition.

EPA, 1983. *Methods for Chemical Analysis of Water and Wastewater*, United States Environmental Protection Agency, Office of Research and Development, Washington, D.C. EPA-600/4-79-020.

City of Killeen and Jacobs. 2008. Final Report: Assessment and Targeting of Bacterial Sources in the South Nolan Creek Watershed. Prepared for the TCEQ.

McFarland, A., and T. Adams. 2015a. Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218 (TR1409). Prepared by the Texas Institute for Applied Environmental Research at Tarleton State University with assistance from the City of Killeen for the Texas Commission on Environmental Quality Nonpoint Source Program CWA §319(h), Contract No. 582-13-3006. Online at: http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan_Data_Inventory_Report(revDec2015)FINAL.pdf (link verified August 22, 2017).

McFarland, A., and T. Adams. 2015b. Characterizing Water Quality within Nolan Creek/South Nolan Creek (TR1508). Prepared by the Texas Institute for Applied Environmental Research at Tarleton State University with assistance from the City of Killeen for the Texas Commission on Environmental Quality Nonpoint Source Program CWA §319(h), Contract No. 582-13-3006. Online at: http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan_Monitoring_Report(revDec2015)FINAL.pdf (link verified August 22, 2017).

McFarland, A., and T. Adams. 2016. Characterizing Potential Pollutant Loads to Nolan Creek/South Nolan Creek. Prepared by the Texas Institute for Applied Environmental Research at Tarleton State University with assistance from the City of Killeen for the Texas Commission on Environmental Quality Nonpoint Source Program CWA §319(h), Contract No. 582-13-3006. Online at: http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan_LDC_SELECT_Report(18Feb2016)FINAL.pdf (link verified August 22, 2017).

TCEQ, Texas Commission on Environmental Quality. 2018. Chapter 307 – Texas Surface Water Quality Standards. Texas Administrative Code, Title 30, Part 1, Chapter 307. Online at: https://www.tceq.texas.gov/waterquality/standards/2018-surface-water-quality-standards (link verified October 25, 2018).

TCEQ, Texas Commission on Environmental Quality. 2015a. 2014 Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d). TCEQ, Austin, TX (November 19, 2015) Online at: https://www.tceq.texas.gov/waterquality/assessment/14twqi/14txir (link verified August 22, 2017).

TCEQ, Texas Commission on Environmental Quality. 2015b. 2014 Guidance for Assessing and Reporting Surface Water Quality in Texas. TCEQ, Austin, TX (June, 2015) Online at: https://www.tceq.texas.gov/assets/public/waterquality/swqm/assess/14txir/2014_guidance.pdf (link verified October 25, 2018).

TCEQ, Texas Commission on Environmental Quality. 2012. *Surface Water Quality Monitoring Procedures*, Volume 1, TCEQ, Austin, TX (RG-415, revised August 2012).

Appendix A Water Quality Monitoring Data

Table A-1 Monthly water quality data for Station 11905 September 2017 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
27-Sep-17	7:21	>7	757	6.3	7.9	25.3	22	17.5	3.39	0.28	3.77	<3	140	< 4
17-Oct-17	7:41	>7	754	8.4	8.1	17.0	25	19.9	3.35	0.60	3.88	<3	120	< 4
8-Nov-17	8:09	>7	732	7.4	8.0	17.5	22	14.9	3.03	0.81	3.16	<3	280	< 4
6-Dec-17	7:47	<1	725	7.8	8.1	13.8	111	17.2	3.07	2.15	3.56	312	2000	170
10-Jan-18	9:01	>7	725	9.9	8.2	11.6	32	13.2	2.20	0.53	2.28	<3	240	< 4
13-Feb-18	8:29	>7	750	10.4	8.1	8.3	26	13.7	2.63	1.06	2.75	7.1	250	< 4
6-Mar-18	8:23	>7	570	8.6	8.2	15.8	49	6.91	1.40	0.77	1.44	<3	330	< 4
4-Apr-18	7:28	1	395	8.0	7.9	16.5	47	2.86	no data	0.45	0.84	<3	7100	8
2-May-18	7:22	>7	742	6.8	7.9	21.8	27	14.2	3.14	0.37	3.37	<3	150	< 4
5-Jun-18	7:15	1	293	5.8	7.8	25.9	38	1.97	0.833	0.35	0.95	<3	1600	< 4
17-Jul-18	7:28	>7	792	6.0	7.9	27.3	22	15.9	3.47	0.73	3.80	<3	140	< 4
21-Aug-18	7:35	>7	716	6.2	7.9	28.0	31	14.5	2.85	0.93	3.00	<3	310	< 4

Table A-2 Monthly water quality data for Station 11908 June 2017 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
13-Jun-17	7:08	>7	726	6.8	8.0	25.6	40	14.6	2.58	0.65	2.72	<3	580	6
26-Jul-17	8:25	>7	833	6.7	8.2	27.3	28	15.7	3.31	0.57	3.54	<3	460	6

15-Aug-17	7:51	>7	733	6.6	8.0	27.4	25	17.1	3.58	1.63	3.65	<3	310	< 4
27-Sep-17	7:44	>7	746	6.5	7.9	25.7	30	16.6	3.77	0.49	4.24	<3	260	< 4
17-Oct-17	8:03	>7	748	8.4	8.0	17.4	29	21.9	3.73	1.75	4.32	<3	330	< 4
8-Nov-17	8:25	>7	717	7.9	8.1	17.5	20	13.1	3.00	0.78	3.13	<3	210	< 4
6-Dec-17	8:06	<1	653	8.4	8.2	15.6	94	15.8	2.64	0.73	2.87	25.2	2400	31
10-Jan-18	9:19	>7	722	9.7	8.1	13.1	28	13.7	2.27	0.72	2.41	<3	160	< 4
13-Feb-18	8:51	>7	742	10.2	8.1	9.8	27	15.2	2.87	1.48	3.07	<3	460	< 4
6-Mar-18	8:45	>7	628	8.9	8.1	16.0	30	7.05	1.42	1.22	1.49	<3	390	< 4
4-Apr-18	7:47	1	443	8.3	7.9	16.8	42	4.91	no data	0.49	1.34	<3	2400	< 4
2-May-18	7:39	>7	732	7.0	7.8	22.2	24	17.0	2.92	0.67	3.19	<3	580	< 4
5-Jun-18	7:36	1	509	6.4	7.9	25.7	39	5.37	1.37	0.55	1.55	<3	770	< 4
17-Jul-18	7:56	>7	782	6.1	7.8	27.4	24	15.6	3.55	0.99	4.10	6.2	190	7
21-Aug-18	8:01	>7	723	6.2	7.8	28.0	26	15.6	2.99	1.04	3.23	3.7	250	< 4

Table A-3 Monthly water quality data for Station 11910 June 2017 through August 2017.

Date	**Time**	**DSLP**	**Specific Conductance (uS/cm)**	**DO (mg/L)**	**pH (standard units)**	**Water Temp (C)**	**Flow (cfs)**	**NO_2-N +NO_3-N (mg/L)**	**PO_4-P (mg/L)**	**TKN (mg/L)**	**TP (mg/L)**	**CHLA (µg/L)**	***E. coli* (MPN/ 100mL)**	**TSS (mg/L)**
13-Jun-17	7:27	>7	710	7.0	8.1	26.2	19	12.8	2.37	0.82	2.58	3.6	250	< 4
26-Jul-17	8:38	>7	845	7.5	8.3	27.7	12	19.1	3.33	0.63	3.65	<3	190	< 4
15-Aug-17	8:12	>7	708	6.7	8.0	27.8	11	14.2	2.86	1.46	2.88	7.9	310	< 4

Table A-4 Monthly water quality data for Station 11911 September 2016 through August 2018.

Date	**Time**	**DSLP**	**Specific Conductance (µS/cm)**	**DO (mg/L)**	**pH (standard units)**	**Water Temp (C)**	**Flow (cfs)**	**NO_2-N +NO_3-N (mg/L)**	**PO_4-P (mg/L)**	**TKN (mg/L)**	**TP (mg/L)**	**CHLA (µg/L)**	***E. coli* (MPN/ 100mL)**	**TSS (mg/L)**
21-Sep-16	7:23	>7	745	5.7	7.7	27.8	12	13.2	2.77	0.79	2.99	<3	260	< 4
11-Oct-16	7:18	>7	693	7.1	8.0	20.8	15	13.7	2.54	0.47	2.74	<3	460	< 4

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
16-Nov-16	8:32	>7	709	7.1	7.8	19.8	16	14.4	2.33	1.36	2.46	<3	250	15
13-Dec-16	8:53	>7	685	7.1	7.7	17.0	19	12.6	1.92	0.85	2.03	<3	280	< 4
10-Jan-17	8:48	>7	701	7.6	8.0	16.0	17	9.86	2.01	1.28	2.19	<3	410	< 4
14-Feb-17	9:04	<1	186	10.7	8.4	12.0	flood flows, no data	0.907	0.176	1.68	0.37	8.0	11000	145
8-Mar-17	9:01	>7	668	7.8	7.9	18.5	34	9.64	1.46	0.46	1.56	5.8	91	< 4
19-Apr-17	7:43	1	440	7.7	7.9	22.1	103	3.63	0.521	0.72	0.55	3.0	240	< 4
10-May-17	7:49	>7	742	6.2	7.8	23.2	19	13.4	2.21	0.28	2.42	<3	170	5
13-Jun-17	7:41	>7	715	6.0	8.0	26.5	18	14.1	2.56	0.70	2.71	<3	190	< 4
26-Jul-17	8:50	>7	833	6.3	8.2	28.1	12	17.8	3.30	0.57	3.56	<3	270	< 4
15-Aug-17	8:27	>7	704	5.8	8.0	28.3	13	14.8	2.90	1.66	3.00	7.0	520	< 4
27-Sep-17	8:06	>7	739	5.7	7.7	26.6	16	20.3	3.40	0.61	3.71	<3	150	< 4
17-Oct-17	8:26	>7	719	7.1	8.0	19.6	13	17.0	3.15	1.30	3.66	3.4	250	< 4
8-Nov-17	8:40	>7	720	6.8	8.0	19.5	14	14.9	3.01	1.03	3.16	<3	120	< 4
6-Dec-17	8:22	<1	391	9.2	8.4	13.4	39	4.24	0.716	0.84	0.73	6.5	9600	31
10-Jan-18	9:39	>7	718	8.8	8.0	15.3	16	16.8	2.65	0.67	2.81	<3	64	< 4
13-Feb-18	9:12	>7	711	8.7	8.0	12.7	16	12.9	2.34	1.41	2.40	3.4	390	< 4
6-Mar-18	9:06	>7	623	8.7	8.1	16.5	21	8.67	1.66	0.97	1.71	<3	330	< 4
4-Apr-18	8:04	1	499	7.6	7.9	17.5	28	9.86	no data	0.60	1.60	<3	2400	6
2-May-18	7:58	>7	716	3.9	7.7	23.0	17	17.0	2.83	0.94	3.26	<3	4100	11
5-Jun-18	7:58	1	525	6.0	7.8	26.2	17	9.02	1.73	0.37	1.98	3.2	550	< 4
17-Jul-18	8:16	>7	755	5.7	7.8	27.6	12	22.4	3.98	0.77	4.43	3.6	170	6
21-Aug-18	8:21	>7	685	6.2	7.7	28.2	17	19.4	3.34	0.84	3.62	<3	260	< 4

Table A-5 Monthly water quality data for Station 11912 September 2016 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
21-Sep-16	7:36	>7	752	5.5	7.6	28.0	10	16.2	2.99	0.87	3.25	<3	120	< 4
11-Oct-16	7:33	>7	707	6.4	7.9	21.2	11	15.4	2.70	0.44	2.95	<3	160	< 4
16-Nov-16	8:45	>7	714	6.6	7.7	20.1	15	16.5	2.40	1.17	2.69	<3	160	< 4
13-Dec-16	9:09	>7	686	6.7	7.7	17.1	14	14.2	2.02	1.06	2.15	<3	330	< 4
10-Jan-17	9:03	>7	707	6.8	7.7	16.3	13	10.9	2.17	1.60	2.29	<3	390	< 4
14-Feb-17	9:24	<1	189	10.6	8.3	12.0	flood flows, no data	0.965	0.187	1.27	0.25	5.5	6800	124
8-Mar-17	9:13	>7	654	7.2	7.8	18.5	30	9.78	1.41	0.97	1.52	<3	75	< 4
19-Apr-17	7:52	1	411	6.9	7.8	22.0	87	3.02	0.412	0.73	0.45	3.2	200	8
10-May-17	8:02	>7	745	5.5	7.7	23.2	19	15.3	2.36	0.24	2.62	<3	71	7
13-Jun-17	7:54	>7	723	5.8	7.8	26.4	13	17.0	2.82	0.88	3.10	<3	200	< 4
26-Jul-17	9:00	>7	847	5.9	8.0	28.2	8.0	22.2	3.57	0.67	3.88	<3	350	5
15-Aug-17	8:44	>7	711	5.4	7.8	28.3	9.3	17.8	3.26	1.88	3.42	4.4	280	< 4
27-Sep-17	8:22	>7	745	5.3	7.5	26.7	6.9	22.7	3.64	0.60	4.06	<3	230	< 4
17-Oct-17	8:45	>7	727	6.8	7.8	20.1	7.3	19.8	3.41	1.11	3.74	<3	190	< 4
8-Nov-17	8:52	>7	729	6.1	7.8	19.9	7.6	17.5	3.27	1.24	3.31	<3	130	< 4
6-Dec-17	8:35	<1	334	9.2	8.2	12.6	35	2.79	0.501	0.79	0.56	4.7	20000	47
10-Jan-18	9:54	>7	723	7.8	7.9	15.5	11	18.8	2.73	1.27	2.90	<3	48	< 4
13-Feb-18	9:28	>7	720	8.0	7.8	13.2	9.3	13.7	2.36	1.17	2.52	<3	210	< 4
6-Mar-18	9:23	>7	626	8.2	8.0	16.5	19	10.1	1.85	0.69	1.93	<3	440	< 4
4-Apr-18	8:12	1	520	7.3	7.7	17.6	21	11.4	no data	0.72	1.74	<3	2000	< 4
2-May-18	8:13	>7	721	6.0	7.6	23.1	8.4	19.2	2.94	0.76	3.31	<3	160	< 4
5-Jun-18	8:14	1	544	5.8	7.7	26.3	13	11.3	2.02	0.70	2.26	<3	1100	< 4
17-Jul-18	8:31	>7	747	5.7	7.6	28.0	6.0	22.3	4.07	0.74	4.46	<3	170	< 4
21-Aug-18	8:34	>7	670	5.7	7.6	28.4	9.7	20.2	3.37	0.79	3.55	<3	260	< 4

Table A-6 Monthly water quality data for Station 11913 September 2016 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
21-Sep-16	7:51	>7	757	5.4	7.5	27.7	7.9	17.9	3.20	0.28	3.46	<3	370	< 4
11-Oct-16	7:51	>7	711	6.0	7.9	21.6	12	17.1	2.81	0.66	3.12	<3	230	< 4
16-Nov-16	8:59	>7	709	6.3	7.6	20.2	14	15.9	2.51	0.97	2.68	<3	280	< 4
13-Dec-16	9:40	>7	683	6.4	7.6	17.4	23	13.4	1.90	0.82	2.08	<3	280	< 4
10-Jan-17	9:18	>7	712	6.2	7.8	16.4	14	10.5	2.16	2.03	2.26	<3	79	< 4
14-Feb-17	9:44	<1	197	10.4	8.1	12.0	flood flows, no data	1.12	0.209	1.00	0.26	4.0	6300	101
8-Mar-17	9:26	>7	633	7.1	7.8	18.6	41	8.49	1.28	0.67	1.37	<3	66	< 4
19-Apr-17	8:13	1	443	7.0	7.8	22.0	90	3.53	0.445	0.64	0.50	3.6	260	5
10-May-17	8:15	>7	722	5.4	7.7	23.3	13	16.3	2.39	< 0.2	2.62	<3	75	< 4
13-Jun-17	8:09	>7	711	5.5	7.8	26.2	16	18.7	3.06	0.79	3.13	<3	190	< 4
26-Jul-17	9:12	>7	859	5.4	8.0	28.0	8.2	24.6	4.00	0.55	4.26	<3	500	< 4
15-Aug-17	8:59	>7	731	5.2	7.8	28.2	9.1	21.4	3.62	1.49	3.86	<3	580	4
27-Sep-17	8:41	>7	753	5.1	7.4	27.1	11	25.5	3.94	0.53	4.47	<3	550	< 4
17-Oct-17	9:02	>7	733	6.5	7.8	20.8	8.6	21.7	3.51	1.12	4.08	<3	440	< 4
8-Nov-17	9:05	>7	735	5.7	7.8	20.6	6.5	20.2	3.56	1.04	3.67	<3	120	< 4
6-Dec-17	8:48	<1	334	9.3	8.2	12.5	33	3.44	0.525	0.90	0.59	3.5	12000	31
10-Jan-18	10:10	>7	725	7.4	7.9	16.0	11	19.8	2.88	0.70	3.02	<3	39	< 4
13-Feb-18	9:45	>7	729	7.4	7.9	14.1	12	15.2	2.57	1.94	2.73	3.6	130	< 4
6-Mar-18	9:37	>7	619	8.2	8.0	16.4	22	11.6	1.83	0.38	1.82	<3	580	< 4
4-Apr-18	8:32	1	524	7.4	7.7	17.4	24	11.1	no data	0.77	1.74	<3	2000	< 4
2-May-18	8:28	>7	719	5.3	7.5	23.1	14	20.6	3.06	0.76	3.36	<3	140	< 4
5-Jun-18	8:30	1	573	5.6	7.6	26.3	14	13.2	2.22	0.87	2.47	<3	690	< 4
17-Jul-18	8:46	>7	753	5.4	7.6	27.7	6.9	23.5	4.41	1.25	4.69	<3	260	< 4
21-Aug-18	8:50	>7	610	5.5	7.5	28.1	13	16.8	2.73	0.81	2.73	<3	440	< 4

Table A-7 Monthly water quality data for Station 14237 September 2016 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
21-Sep-16	6:56	>7	758	6.4	8.0	26.6	38	9.39	1.74	< 0.2	1.88	5.0	130	5
11-Oct-16	6:48	>7	650	8.3	8.0	17.9	36	10.4	1.47	0.27	1.55	<3	130	< 4
16-Nov-16	8:04	>7	688	8.9	8.1	16.7	38	11.2	1.55	0.53	1.58	<3	110	< 4
13-Dec-16	8:26	>7	685	9.7	8.0	13.1	36	10.6	1.37	0.52	1.40	3.1	110	< 4
10-Jan-17	8:22	>7	722	10.2	8.1	11.3	35	11.6	1.85	0.56	1.91	<3	120	< 4
14-Feb-17	8:35	<1	213	9.3	8.4	14.7	flood flows, no data	0.993	0.214	2.57	0.78	79.7	17000	1360
8-Mar-17	8:36	>7	632	9.2	8.2	17.2	69	5.12	0.930	< 0.2	1.01	7.1	310	< 4
19-Apr-17	7:15	1	399	8.3	8.1	21.0	174	1.56	0.185	0.21	0.23	<3	206	10
10-May-17	7:25	>7	733	7.5	8.1	21.9	49	9.17	1.11	< 0.2	1.15	6.6	84	5
13-Jun-17	6:46	>7	707	6.7	8.2	25.8	36	10.0	1.21	0.44	1.31	<3	130	< 4
26-Jul-17	8:03	>7	865	7.0	8.3	27.0	28	16.5	2.80	< 0.2	3.01	<3	310	6
15-Aug-17	7:23	>7	721	7.2	8.1	27.1	20	15.1	2.09	1.13	2.13	<3	410	5
27-Sep-17	7:00	>7	769	6.1	7.9	25.0	23	18.3	3.19	0.24	3.40	<3	140	< 4
17-Oct-17	7:20	>7	747	8.7	8.1	16.5	22	17.8	2.92	0.39	3.28	<3	300	< 4
8-Nov-17	7:46	>7	750	7.4	8.1	16.9	12	14.6	2.90	0.88	3.00	<3	140	< 4
6-Dec-17	7:28	>7	723	8.1	8.2	13.3	22	15.2	2.90	0.44	3.16	<3	250	< 4
10-Jan-18	8:42	>7	725	10.6	8.2	10.6	24	14.4	2.13	0.56	2.21	3.1	110	< 4
13-Feb-18	8:03	>7	740	10.6	8.1	7.2	22	13.8	2.49	0.96	2.58	<3	350	< 4
6-Mar-18	7:53	>7	586	8.9	8.2	15.8	29	5.80	1.33	0.86	1.34	3.5	390	4
4-Apr-18	7:06	1	661	8.7	8.1	16.8	55	11.6	no data	0.52	1.97	<3	920	5
2-May-18	7:04	>7	743	6.7	7.9	21.5	19	13.1	2.70	0.33	2.95	<3	190	< 4
5-Jun-18	6:54	1	297	6.4	7.8	25.7	29	2.00	0.947	0.36	1.18	4.0	1000	< 4
17-Jul-18	7:08	>7	799	6.7	7.9	26.6	15	14.5	3.48	0.90	3.86	5.4	650	< 4
21-Aug-18	7:14	>7	707	6.7	8.0	27.4	22	13.1	2.59	0.83	2.80	4.5	610	< 4

Table A-8 Monthly water quality data for Station 18827 September 2016 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
21-Sep-16	8:16	>7	757	5.6	7.4	28.2	21	17.5	3.08	0.49	3.45	3.3	2400	< 4
11-Oct-16	8:19	>7	703	6.2	7.8	22.8	19	15.8	2.66	1.25	2.96	<3	650	< 4
16-Nov-16	9:23	>7	705	6.4	7.5	21.5	23	16.9	2.45	1.20	2.68	<3	770	< 4
13-Dec-16	10:04	>7	686	6.8	7.5	19.0	26	13.4	1.93	1.69	2.08	<3	230	< 4
10-Jan-17	9:43	>7	719	6.4	7.7	17.7	20	9.40	2.11	2.95	2.26	<3	310	< 4
14-Feb-17	10:15	<1	226	10.1	8.0	12.5	flood flows, no data	1.37	0.263	1.18	0.32	3.5	12000	92
8-Mar-17	9:49	>7	648	7.5	7.7	19.4	34	9.72	1.42	0.95	1.59	<3	110	< 4
19-Apr-17	8:38	1	432	7.2	7.7	22.2	78	2.35	0.270	0.66	0.31	5.5	330	7
10-May-17	8:38	>7	747	5.4	7.7	23.6	21	15.6	2.41	0.56	2.70	<3	140	< 4
13-Jun-17	8:32	>7	726	5.7	7.7	26.4	20	18.8	2.99	1.10	3.27	3.3	920	< 4
26-Jul-17	9:31	>7	869	6.1	7.8	28.3	13	25.1	3.98	0.91	4.45	<3	550	< 4
15-Aug-17	9:29	>7	698	5.9	7.6	28.7	16	20.5	3.44	1.00	3.58	6.1	440	< 4
27-Sep-17	9:12	>7	744	5.4	7.2	27.7	21	25.3	3.81	0.41	4.24	<3	870	< 4
17-Oct-17	9:36	>7	733	6.7	7.6	22.2	17	21.5	3.36	1.18	3.89	<3	580	< 4
8-Nov-17	9:28	>7	757	6.1	7.7	21.4	15	20.0	3.49	1.03	3.70	<3	280	< 4
6-Dec-17	9:17	<1	374	8.7	8.1	14.0	24	6.51	1.01	1.16	1.18	3.5	19000	30
10-Jan-18	10:34	>7	730	7.7	7.8	17.2	17	19.6	2.80	1.40	3.00	<3	350	< 4
13-Feb-18	10:18	>7	743	8.3	7.8	15.6	19	16.5	2.64	1.01	2.81	7.7	920	< 4
6-Mar-18	10:07	>7	626	8.8	7.9	17.9	24	9.85	1.74	0.50	1.94	3.9	690	< 4
4-Apr-18	8:58	1	536	7.8	7.5	18.0	18	12.7	no data	0.56	1.89	3.0	2000	< 4
2-May-18	8:57	>7	724	5.6	7.4	23.3	20	18.2	2.76	1.09	3.08	<3	410	< 4
5-Jun-18	9:02	1	540	6.0	7.6	26.6	16	16.0	1.96	0.92	2.28	8.6	2400	5
17-Jul-18	9:12	>7	774	6.2	7.5	27.8	7.9	26.7	4.57	0.86	5.33	<3	550	< 4
21-Aug-18	9:17	>7	615	6.1	7.4	28.8	13	18.5	2.84	1.00	3.04	4.3	5600	< 4

Table A-9 Monthly water quality data for Station 18828 September 2016 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
21-Sep-16	8:46	>7	769	6.9	7.0	29.7	23	17.4	3.14	1.33	3.52	<3	390	< 4
11-Oct-16	9:19	>7	722	7.0	7.5	26.3	20	16.0	2.80	0.78	3.01	<3	140	< 4
16-Nov-16	10:08	>7	750	7.2	7.2	24.7	26	19.1	2.61	1.65	2.92	<3	85	< 4
13-Dec-16	10:53	>7	696	7.7	7.3	21.3	28	14.6	2.15	2.42	2.42	<3	44	< 4
10-Jan-17	10:31	>7	721	7.9	7.5	20.2	25	11.2	2.19	2.37	2.43	<3	30	< 4
14-Feb-17	11:17	<1	197	10.5	8.2	11.8	flood flows, no data	0.556	0.0477	1.03	0.15	<3	4100	53
8-Mar-17	10:49	>7	661	8.4	7.5	20.6	36	0.395	< 0.005	0.94	0.20	<3	250	9
19-Apr-17	9:31	1	621	7.5	7.5	23.1	60	7.91	0.894	1.33	1.02	<3	170	< 4
10-May-17	9:30	>7	747	6.8	7.6	24.7	26	16.4	2.51	0.50	2.82	<3	81	< 4
13-Jun-17	8:56	>7	740	7.1	7.5	27.2	24	18.4	3.03	0.95	3.34	<3	29	< 4
26-Jul-17	9:49	>7	851	7.4	7.6	29.5	19	23.7	3.57	0.99	4.09	3.5	440	< 4
15-Aug-17	9:56	>7	705	7.2	7.6	29.8	16	19.7	3.35	1.50	3.46	3.0	91	6
27-Sep-17	9:42	>7	738	7.0	7.0	29.1	22	25.1	3.77	1.27	4.02	<3	77	< 4
17-Oct-17	9:58	>7	742	7.6	7.3	26.2	17	21.8	3.44	1.17	3.58	<3	66	< 4
8-Nov-17	9:49	>7	748	7.1	7.3	24.8	18	19.1	3.28	1.32	3.51	<3	110	< 4
6-Dec-17	9:45	<1	560	8.0	7.5	19.1	24	14.5	2.35	0.62	2.71	3.3	14000	5
10-Jan-18	10:58	>7	723	8.2	7.5	19.8	18	19.7	2.84	0.75	3.08	<3	77	< 4
13-Feb-18	10:43	>7	743	8.3	7.5	18.8	19	15.9	2.62	1.40	2.81	4.1	610	< 4
6-Mar-18	10:29	>7	657	8.6	7.8	20.2	20	11.2	2.11	1.49	2.24	<3	370	< 4
4-Apr-18	9:21	1	623	7.9	7.4	20.6	18	15.0	no data	1.20	2.50	<3	870	< 4
2-May-18	9:12	>7	746	7.0	7.2	24.2	24	19.5	2.93	1.40	3.43	<3	86	< 4
5-Jun-18	9:25	1	638	7.4	7.3	27.6	16	11.4	2.72	0.82	3.11	3.5	870	< 4
17-Jul-18	9:37	>7	782	7.7	7.1	29.3	7.1	25.8	4.43	1.16	5.07	<3	140	< 4
21-Aug-18	9:43	>7	638	8.7	7.0	30.2	15	19.4	2.94	0.75	3.20	3.2	1700	< 4

Table A-10 Monthly water quality data for Station 21436 September 2016 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
21-Sep-16	8:27	>7	736	6.8	7.9	24.4	0.10	0.331	0.0472	< 0.2	0.07	<3	140	< 4
11-Oct-16	8:32	>7	536	8.6	8.0	15.9	0.10	0.288	0.0065	0.31	< 0.06	5.5	80	< 4
16-Nov-16	9:30	>7	648	9.0	7.9	14.9	0.30	0.453	0.0066	0.29	< 0.06	<3	57	< 4
13-Dec-16	10:13	>7	583	9.6	7.9	13.0	0.55	0.558	0.0143	0.29	0.09	<3	39	< 4
10-Jan-17	9:53	>7	676	10.2	8.0	12.3	0.40	0.452	< 0.005	< 0.2	0.11	<3	520	6
14-Feb-17	10:31	<1	224	10.2	8.2	12.2	flood flows, no data	0.624	0.105	1.06	0.16	4.1	14000	88
8-Mar-17	10:05	>7	495	9.6	8.0	16.3	0.90	0.480	0.0234	< 0.2	0.09	<3	73	< 4
19-Apr-17	8:50	1	229	7.7	7.9	21.7	28	0.088	0.0071	0.55	0.12	<3	110	9
10-May-17	8:48	>7	735	7.4	7.9	20.6	0.08	0.793	0.0648	< 0.2	< 0.06	<3	330	< 4
13-Jun-17	8:41	>7	709	6.8	7.9	23.9	0.01	0.453	0.0384	0.22	< 0.06	4.6	220	< 4
26-Jul-17	9:38	>7	655	6.2	8.1	26.2	0.01	0.280	0.0336	0.23	< 0.06	<3	1700	< 4
15-Aug-17	9:42	>7	641	6.8	8.0	25.9	<0.10	0.108	0.0124	0.39	0.09	<3	440	9
27-Sep-17	9:24	>7	684	6.5	7.9	23.8	0.01	0.415	0.0477	< 0.2	0.09	<3	2400	< 4
17-Oct-17	9:44	>7	741	9.3	8.0	14.1	0.01	0.708	0.0380	0.54	0.17	<3	200	< 4
8-Nov-17	9:36	>7	743	8.2	8.1	14.2	0.01	0.524	0.0617	< 0.2	0.07	<3	32	< 4
6-Dec-17	9:30	<1	372	9.1	8.1	10.7	1.5	0.612	0.0401	0.41	< 0.06	<3	18000	6
10-Jan-18	10:45	>7	737	10.4	8.0	10.2	0.20	0.688	0.0270	< 0.2	0.08	<3	86	< 4
13-Feb-18	10:26	>7	615	10.5	8.0	7.4	0.01	0.439	0.0089	0.44	0.06	<3	350	< 4
6-Mar-18	10:15	>7	447	10.0	8.1	14.0	1.4	0.173	0.0100	< 0.2	0.14	4.7	260	< 4
4-Apr-18	9:07	1	376	9.0	7.9	14.7	2.2	0.306	no data	0.43	0.06	5.5	1000	< 4
2-May-18	9:00	>7	482	7.7	8.0	21.1	1.0	0.430	0.0187	0.32	< 0.06	1.5	870	12
5-Jun-18	9:08	1	467	4.6	7.8	24.2	0.01	0.090	0.0123	0.37	< 0.06	8.7	550	5
17-Jul-18	9:21	>7	610	6.5	7.9	25.2	0.01	0.068	0.0083	0.24	0.15	.	210	< 4
21-Aug-18	9:28	>7	637	6.5	8.0	25.5	0.01	0.337	0.0446	0.50	0.07	<3	160	< 4

Table A-11 Monthly water quality data for Station 21437 September 2016 through August 2018.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
21-Sep-16	8:04	>7	570	5.8	7.9	25.7	1.0	0.169	0.0271	< 0.2	0.09	<3	440	< 4
11-Oct-16	8:06	>7	504	8.6	8.1	16.3	1.7	0.074	0.0074	< 0.2	< 0.06	<3	99	< 4
16-Nov-16	9:12	>7	580	9.6	8.1	15.1	1.9	0.129	< 0.005	0.35	< 0.06	<3	86	< 4
13-Dec-16	9:52	>7	608	10.9	8.1	12.2	2.2	0.376	0.0170	< 0.2	0.07	<3	24000	< 4
10-Jan-17	9:32	>7	607	10.9	8.2	11.6	1.5	0.223	0.0057	0.36	0.15	<3	4900	< 4
14-Feb-17	10:00	<1	207	10.6	8.3	11.8	flood flows, no data	0.695	0.0937	0.82	0.14	<3	10000	72
8-Mar-17	9:38	>7	551	11.1	8.2	15.6	4.1	0.360	0.0182	0.53	0.20	<3	66	< 4
19-Apr-17	8:27	1	555	9.4	8.1	20.7	5.9	0.765	0.0104	< 0.2	0.10	<3	690	< 4
10-May-17	8:28	>7	581	7.7	8.0	21.6	1.9	0.489	0.0401	< 0.2	< 0.06	<3	980	< 4
13-Jun-17	8:21	>7	469	7.0	8.2	25.1	1.7	0.401	0.0576	0.42	< 0.06	<3	520	< 4
26-Jul-17	9:22	>7	518	5.2	8.3	26.9	0.39	0.053	0.0124	0.49	< 0.06	<3	440	< 4
15-Aug-17	9:16	>7	446	6.2	8.1	26.4	0.58	< 0.05	0.0076	0.30	0.07	<3	88	< 4
27-Sep-17	8:56	>7	521	7.5	8.1	24.9	1.0	0.478	0.0702	0.27	0.14	<3	29000	< 4
17-Oct-17	9:19	>7	504	9.3	8.2	13.8	0.64	0.432	0.0642	0.75	0.16	<3	60	< 4
8-Nov-17	9:17	>7	506	9.1	8.3	13.8	0.85	0.473	0.0695	0.43	0.08	<3	72	8
6-Dec-17	9:04	<1	328	10.4	8.4	10.5	8.5	0.484	0.0459	0.29	< 0.06	<3	31000	5
10-Jan-18	10:23	>7	561	11.0	8.3	9.7	1.2	0.515	0.0629	< 0.2	0.08	<3	140	< 4
13-Feb-18	10:04	>7	551	11.5	8.2	6.8	0.94	< 0.05	0.0089	0.29	0.12	19.5	15	< 4
6-Mar-18	9:53	>7	491	11.5	8.3	11.5	2.2	< 0.05	0.0054	< 0.2	0.09	<3	96	< 4
4-Apr-18	8:46	1	485	10.7	8.2	11.8	2.6	< 0.05	no data	0.30	< 0.06	<3	690	< 4
2-May-18	8:41	>7	500	7.2	8.0	21.7	1.3	< 0.05	0.0088	< 0.2	< 0.06	<3	650	< 4
5-Jun-18	8:48	1	433	7.2	8.3	24.9	1.4	< 0.05	< 0.005	< 0.2	< 0.06	<3	520	< 4
17-Jul-18	9:01	>7	473	4.9	7.8	26.2	0.35	0.318	0.0057	0.43	0.14	<3	820	16
21-Aug-18	9:04	>7	454	7.1	8.1	26.4	1.4	0.374	0.0560	0.48	< 0.06	<3	2000	< 4

Table A-12 Monthly water quality data for Station 21926 October 2016 through May 2017.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
11-Oct-16	9:03	>7	367	8.1	8.1	16.5	<0.10	0.470	< 0.005	0.52	0.08	9.8	1400	< 4
16-Nov-16	9:54	>7	407	8.4	7.8	15.2	0.10	0.473	< 0.005	0.57	< 0.06	3.7	93	< 4
13-Dec-16	10:39	>7	388	9.4	7.8	12.0	0.26	0.279	< 0.005	0.57	0.13	<3	68	< 4
10-Jan-17	10:17	>7	454	10.1	8.1	11.8	0.33	0.329	< 0.005	< 0.2	0.10	<3	350	< 4
14-Feb-17	11:02	<1	316	9.5	8.2	14.7	33	0.143	0.0216	0.55	0.08	3.7	3700	18
8-Mar-17	10:32	>7	430	9.3	8.0	16.3	0.84	10.2	1.49	0.79	1.72	<3	190	4
19-Apr-17	9:18	1	201	6.2	7.8	22.1	37	< 0.05	< 0.005	0.38	0.11	10.0	35	5
10-May-17	9:14	>7	705	6.4	7.9	20.8	0.01	1.96	0.0065	< 0.2	< 0.06	5.4	2400	24

Table A-13 Monthly water quality data for Station 21927 October 2016 through May 2017.

Date	Time	DSLP	Specific Conductance (µS/cm)	DO (mg/L)	pH (standard units)	Water Temp (C)	Flow (cfs)	NO_2-N +NO_3-N (mg/L)	PO_4-P (mg/L)	TKN (mg/L)	TP (mg/L)	CHLA (µg/L)	*E. coli* (MPN/ 100mL)	TSS (mg/L)
11-Oct-16	8:48	>7	350	6.6	8.1	16.2	<0.10	0.064	0.0051	0.32	< 0.06	5.3	580	< 4
16-Nov-16	9:43	>7	467	7.5	7.9	14.7	0.20	0.152	< 0.005	0.60	0.06	<3	730	< 4
13-Dec-16	10:26	>7	400	10.1	8.0	12.2	0.41	0.321	< 0.005	0.49	0.13	<3	99	< 4
10-Jan-17	10:06	>7	542	10.7	8.2	11.7	0.12	0.382	< 0.005	0.30	0.12	<3	410	< 4
14-Feb-17	10:47	<1	261	10.1	8.3	12.9	flood flows, no data	0.424	0.0619	0.84	0.07	3.1	7500	45
8-Mar-17	10:20	>7	494	13.1	8.4	15.5	1.1	0.473	< 0.005	0.31	0.14	<3	160	< 4
19-Apr-17	9:05	1	218	7.2	7.9	22.0	29	0.075	< 0.005	< 0.2	0.07	10.4	86	13
10-May-17	9:02	>7	594	4.9	7.9	21.1	0.01	0.851	0.0142	< 0.2	0.08	<3	170	< 4

Appendix B Reported *E. coli* Data for WWTFs

Table B-1 Monthly reported daily average *E. coli* for WWTF discharges January 2013 through August 2018.

Permit limit for daily average *E. coli* 126 MPN/100 mL.

End Date	Universal Services Ft Hood	Bell County WCID1 Main Plant	Harker Heights	Bell County WCID1 South Plant	Bell County WCID3	Blora	Temple-Belton Regional
Jan-13		4.2	9.5	1.13			1
Feb-13		31	4.2	1.25			4
Mar-13		22.2	4.8	1.4		1	2
Apr-13		17	3.2	1			2
May-13		1.02	7.2	2.52			2
Jun-13		99	6.7	3.3		1	1
Jul-13		28	14.1	2.29			1
Aug-13		127	24.3	1.79			1
Sep-13		233	23.4	1.79		3.1	1
Oct-13	1	59	25.2	1.06			1
Nov-13	1	103	11.5	1			1
Dec-13	1	86.3	3.9	1.02		1	1
Jan-14	1	88	2.3	1.16			1
Feb-14		42	3	7.04			3
Mar-14		15.4	3.5	1.94		1	3
Apr-14	1	10	6.9	1.62			2
May-14		64	8.2	7.66			2
Jun-14		54	9.5	5.3		1	2
Jul-14	2	103	11.7	10.85			2
Aug-14		73	14.7	11.24			1
Sep-14		59	22.3	4.43			1
Oct-14	1	68	10.5	2		1	1
Nov-14		7	6.1	1			2
Dec-14		12	14.2	1	1		1
Jan-15	1	14	8.4	3	2	1	4
Feb-15		8	6.5	1	1		3
Mar-15		5.24	3.7	1	1		1
Apr-15	1	25	7.4	6	1	2	1
May-15		24	13.6	2	28		3
Jun-15		26	8.3		5		2

End Date	Universal Services Ft Hood	Bell County WCID1 Main Plant	Harker Heights	Bell County WCID1 South Plant	Bell County WCID3	Blora	Temple-Belton Regional
Jul-15	1	36	15.7	1	28.5	17.1	1
Aug-15		64	31	1	7		2
Sep-15		56	37.1	1	1		1
Oct-15	1	55	44.1	1	1	1	1
Nov-15		45.45	24	1	3		5
Dec-15		59	9.7	1	40		4
Jan-16	1	49	19.8	1	6	1	3
Feb-16		35	15.9		21		4
Mar-16		59	12.3	1	3		4
Apr-16	1	58	12.8		7	1	3
May-16		71	22	1	15.6		4
Jun-16		103	17.3	1	13		1
Jul-16	113	89	63.3	1	1	2	1
Aug-16		71	65.8	1	34		2
Sep-16		107	48.7	1	103.5		2
Oct-16	1	100	7.6	1	1	17.1	2
Nov-16		103	9.8	1	32		2
Dec-16		37	3.1	2	1		2.8
Jan-17	1	171	3.5	1.4	5	1	6
Feb-17		22.3	3.1	1	36		3.2
Mar-17		290	1.4	2	1		4
Apr-17	2	851	1.5	1	4	3.1	3
May-17		81	3.4	1	1		2
Jun-17		82	2.9	1	16		2
Jul-17	1	80	2.2	5	1	1	3
Aug-17		39	6.7	1	4		2
Sep-17		61	4.2	1	33		2
Oct-17		52	2.6	2	2	1	2
Nov-17	2	39	3.8	3	1		1
Dec-17		11	2.9	3	1		3
Jan-18		6	2.4	1	7	1	3
Feb-18	96	14	1.8	2	1		4
Mar-18		25	1.9	4	7		3
Apr-18		19	2.6	2	28	1	3
May-18	1	65	15.4	2	2		4
Jun-18		141	14	1	4		3

End Date	Universal Services Ft Hood	Bell County WCID1 Main Plant	Harker Heights	Bell County WCID1 South Plant	Bell County WCID3	Blora	Temple-Belton Regional
Jul-18		73	10.9	2	9	1	3
Aug-18	1	120	5.5	6	1		3

Table B-2 Monthly reported maximum *E. coli* for WWTF discharges January 2013 through August 2018.

Permit limit for maximum *E. coli* 399 MPN/100 mL.

End Date	Universal Services Ft Hood	Bell County WCID1 Main Plant	Harker Heights	Bell County WCID1 South Plant	Bell County WCID3	Blora	Temple-Belton Regional
Jan-13		6	95.9	4			1
Feb-13		69	82.3	5			11
Mar-13		47	90.5	11			9
Apr-13		51	13.5	1			4
May-13		1.37	81.3	36			6
Jun-13		236	49.6	70		1	1
Jul-13		60	114.5	12.5			1
Aug-13		238	141.4	14			1
Sep-13		308	155.3	14		3.1	1
Oct-13	1	91	365.4	3			2
Nov-13		152	53.7	1.2			5
Dec-13		167	22.8	1.5		1	2
Jan-14	1	168	7.5	6			3
Feb-14		88	17.1	170			12
Mar-14		32	12	23		1	17
Apr-14	1	46	34.5	11.5			5
May-14		342	141.4	200			6
Jun-14		161	43.9	65		1	2
Jul-14	2	270	47.1	250			11
Aug-14		147	93.3	100			3
Sep-14		156	231	32			2
Oct-14	1	170	98.8	29		1	1
Nov-14		25	23.1	1			142
Dec-14		50	770.1	1	1		4

End Date	Universal Services Ft Hood	Bell County WCID1 Main Plant	Harker Heights	Bell County WCID1 South Plant	Bell County WCID3	Blora	Temple-Belton Regional
Jan-15	1	111	93.4	50	3	1	42
Feb-15		92	77.6	1	1		10
Mar-15		12	167	1	1		4
Apr-15	1	187	121.7	150	1	2	5
May-15		90	547.5	19	49		59
Jun-15		53	135.4	0	9		10
Jul-15	1	150	61.8	2	41	17.1	2
Aug-15		180	287.8	1	13		5
Sep-15		165	344	1	1		1
Oct-15	1	195	2419.8	4	1	1	55
Nov-15		355	387.3	5	5		34
Dec-15		169	275.5	7	78		5
Jan-16	1	216	156.5	1	6	1	23
Feb-16		172	121.1	0	31		21
Mar-16		446	95.9	1	4		20
Apr-16	2	180	90.6	3	13	1	31
May-16		660	90.8	1	317		26
Jun-16		888	290.9	1	43		4
Jul-16	113	239	156.5	1	1	2	2
Aug-16		179	231	1	2420		15
Sep-16		250	206.4	2	206		244
Oct-16	1	378	59.4	8	1	17.1	15
Nov-16		344	9.8	8	261		20
Dec-16		287	17.5	2	1		12
Jan-17	1	2000	14.8	10	14	1	613
Feb-17		112	30.5	4	326		9
Mar-17		5020	5.2	11	1		15
Apr-17	2	13500	8.5	5	4	3.1	12
May-17		431	75.8	6	1		13
Jun-17		325	11	6	49		6
Jul-17	1	267	17.5	100	1	1	44
Aug-17		131	52	10	15		17
Sep-17		227	25.9	3	1.05		49
Oct-17		171	13.5	15	2	1	4
Nov-17	2	330	111.9	31	123		3
Dec-17		47	48.7	28	2		22

End Date	Universal Services Ft Hood	Bell County WCID1 Main Plant	Harker Heights	Bell County WCID1 South Plant	Bell County WCID3	Blora	Temple-Belton Regional
Jan-18		31	97.1	12	53	1	50
Feb-18	96	76	13.4	19	2		151
Mar-18		75	23.1	47	10		13
Apr-18		90	73.3	13	381	1	19
May-18	1	406	77.1	13	2		26
Jun-18		480	166	5	5		31
Jul-18		191	52	15	16	1	22
Aug-18	1	477	68.3	22	1		11