NOLAN CREEK

Assessment of Water Quality and Watershed Based Planning for Nolan Creek/South Nolan Creek – Final Project Report

Prepared for:

Texas Commission on Environmental Quality
Nonpoint Source Program CWA §319(h)
Contract No. 582-13-30061

Prepared by:

Texas Institute for Applied Environmental Research

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For more information about this document or any other document TIAER produces, send email to info@tiaer.tarleton.edu. More information about the Nolan Creek/South Nolan Creek project can be accessed from the project website at: http://www.killeentexas.gov/nolancreekwatershed.

Cover photograph is South Nolan Creek at Twin Creek Drive in Killeen (station 18827) taken on October 8, 2013.

Table of Contents

Executive Summary 1
Introduction 1
General Project Description 1
Project Area 1
Project Significance and Background 4
Project Significance 4
Background 4
Methods 6
Goals and Objectives 6
Project Tasks 6
Results and Observations 24
Task 1: Project Administration 24
Task 2: Quality Assurance 26
Task 3: Building Partnerships 27
Task 4: Watershed Characterization – Data Inventory 28
Task 5: Watershed Characterization – Data Collection and Analysis 33
Task 6: Watershed Characterization – Identification of Causes, Sources and Pollutant Load Reductions 41
Task 7: Information and Education Component 49
Discussion 53
Summary 55
References 56

List of Figures

Figure 1 Watershed and subwatersheds associated with Segment 1218, Nolan Creek/South Nolan Creek 2
Figure 2 Project monitoring locations in the Nolan Creek/South Nolan Creek watershed 34
Figure 3 Geometric mean *E. coli* concentrations for routine grab samples compared to assessment criteria 36
Figure 4 Geometric mean *E. coli* concentrations for routine grab and storm samples compared to assessment criteria 36
Figure 5 Average flow compared to geometric mean *E. coli* concentrations for routine grab and storm samples 37
Figure 6 Relationship of drainage area size with geometric mean bacteria concentrations for routine grabs 38
Figure 7 Time history of bacteria concentrations at station 18827, South Nolan Creek at Twin Creek Dr in Killeen 38
Figure 8 Median NO_2-N+NO_3-N concentrations from routine grab and storm compared to screening level of 1.95 mg/L. 39
Figure 9 Load duration curve for station 18828, South Nolan Creek at 38th Street 42
Figure 10 Load duration curve for station 11913, South Nolan Creek at Roy Reynolds Road 42
Figure 11 Load duration curve for station 11910, Nolan Creek at US 190 43
Figure 12 Load duration curve for station 11910, Nolan Creek at Backstrom Crossing 43
Figure 13 Land Use/Land Cover for the Nolan Creek/South Nolan Creek watershed showing developed subcategories 45
Figure 14 Distribution of potential *E. coli* loads from all SELECT sources by subbasin within the Nolan Creek/South Nolan Creek watershed 47

List of Tables

Table 1 Watershed identification information 2
Table 2 Schedule of project deliverables 18
Table 3 Summary of data needs for running SELECT 30
Table 4 Summary of data needs for developing FDCs and LDCs 32
Table 5 Geometric mean concentrations of measured bacteria values by flow regime and estimated percent reductions needed to meet the primary contact recreation criterion of 126 MPN/100 mL for four stations along Nolan Creek/South Nolan Creek 44
Table 6 Production rates of *E. coli* by source. 46
Table 7 Proposed outline of education and outreach activities 50

Executive Summary

Project Title: Assessment of Water Quality and Watershed Based Planning for Nolan Creek/South Nolan Creek

TCEQ Contract Number: 582-13-30061

EPA ID Number: 99614617

Project Start Date: September 18, 2012

Project Completion Date: February 29, 2016

Funding:

Total Budget	**$459,418**
Total EPA Grant	$275,651
Total Expenditures of EPA Funds	*To Be Determined*
Total Section 319 Match Accrued	*To Be Determined*
Total Budget Expenditures	*To Be Determined*

Summary of Accomplishments:

The goals of this project were to identify causes and sources of pollution in Nolan Creek/South Nolan Creek watershed and to develop an Information/Education Strategy that provided stakeholders and agencies with sufficient information to address the bacteria impairment through future development of a watershed protection plan (WPP) or total maximum daily load (TMDL). The project was successful in characterizing the watershed and producing the information needed by stakeholders to determine how best to address the bacteria impairment within the Nolan Creek/South Nolan Creek watershed. The public participation plan (PPP) developed early in the project provided the background for forming the stakeholder group for the Nolan Creek Partnership, and stakeholder input has led to an information/educational strategy that will be evaluated for future effectiveness. The characterization of the watershed through acquisition of historical and direct monitoring data as well as a thorough compilation of land use characteristics have allowed an assessment of potential sources both spatially and under varying flow conditions. This information has allowed stakeholders to better target sources and areas within the watershed needing remediation. Stakeholders will be moving forward toward development of a WPP. Facilitation of this WPP will be conducted by TIAER through a Clean Water Act (CWA) 319(h) grant entitled, *Nolan Creek/South Nolan Creek Watershed Protection Plan (WPP).* This new project is contract number 582-16-60281 with TCEQ and EPA Federal Grant number C9-99614620. The data and information gathered under the current CWA 319(h) project will provide the foundation for the Nolan Creek/South Nolan Creek WPP.

Introduction

General Project Description

Nolan Creek/South Nolan Creek (Segment 1218) is listed as impaired for bacteria and, thus, the use of primary contact recreation (Figure 1). To aid in addressing this impairment, this grant proposal builds upon a previous CWA 319(h) grant project (FY04, *Assessment and Targeting of Bacterial Sources in the South Nolan Creek Watershed*), which focused primarily on the upper third of the watershed on an area largely within the City of Killeen. The current project, FY12 *Assessment of Water Quality and Watershed Based Planning for Nolan Creek/South Nolan Creek*, expanded the focus to the entire watershed area, while targeting impaired assessment units (AUs). Within the 2010 303(d) List for Texas, which was in place when this project was initiated, AUs 1218_02 and 1218C were listed as impaired for bacteria. The most recent 303(d) List for 2014 continues to list these two AUs as impaired for bacteria. Concerns for nutrients were also noted in 2010 and continue in the 2014 assessment of Texas surface water quality.

The overall goal of this project was to characterize the watershed well enough to provide stakeholders and agencies sufficient information to address the bacteria impairments on Nolan Creek/South Nolan Creek through, if needed, the development of a watershed protection plan (WPP) or total maximum daily load (TMDL). To provide sufficient water quality data to characterize bacteria loadings, ambient monitoring was conducted in conjunction with some biased flow monitoring to capture storm flows at mainstem and tributary sites. A comprehensive Geographic Information Systems (GIS) inventory was developed as well as a source survey for the watershed. Modeling tools were then used to aid in better characterizing possible sources and loadings of bacteria in the study area.

Project goals, activities, and findings were communicated to stakeholders through meetings to ensure that decision-making regarding the water body was stakeholder-driven. Affected stakeholders included municipalities, counties, groundwater conservation districts, and soil and water conservation districts as well as the general public. During the project, project information was disseminated to watershed stakeholders at public meetings as well as via an internet site hosted by the City of Killeen (http://www.killeentexas.gov/nolancreekwatershed).

Project Area

The Nolan Creek/South Nolan Creek watershed comprises 72,800 acres and is located almost completely within Bell County with a small, northwest portion extending into Coryell County (Figure 1, Table 1). South Nolan Creek has its headwaters near the City of Killeen and converges with North Nolan Creek to the west of Belton to form Nolan Creek. Municipalities within the watershed include Killeen, Harker Heights, Nolanville, and Belton. The Fort Hood Military Reservation also covers much of the northern portion of the watershed. Several small lakes and reservoirs exist throughout the watershed, although none are directly on the mainstem of Nolan or South Nolan Creek. Nolan Creek passes through the City of Belton and then converges with the Leon River as part of the Brazos River Basin.

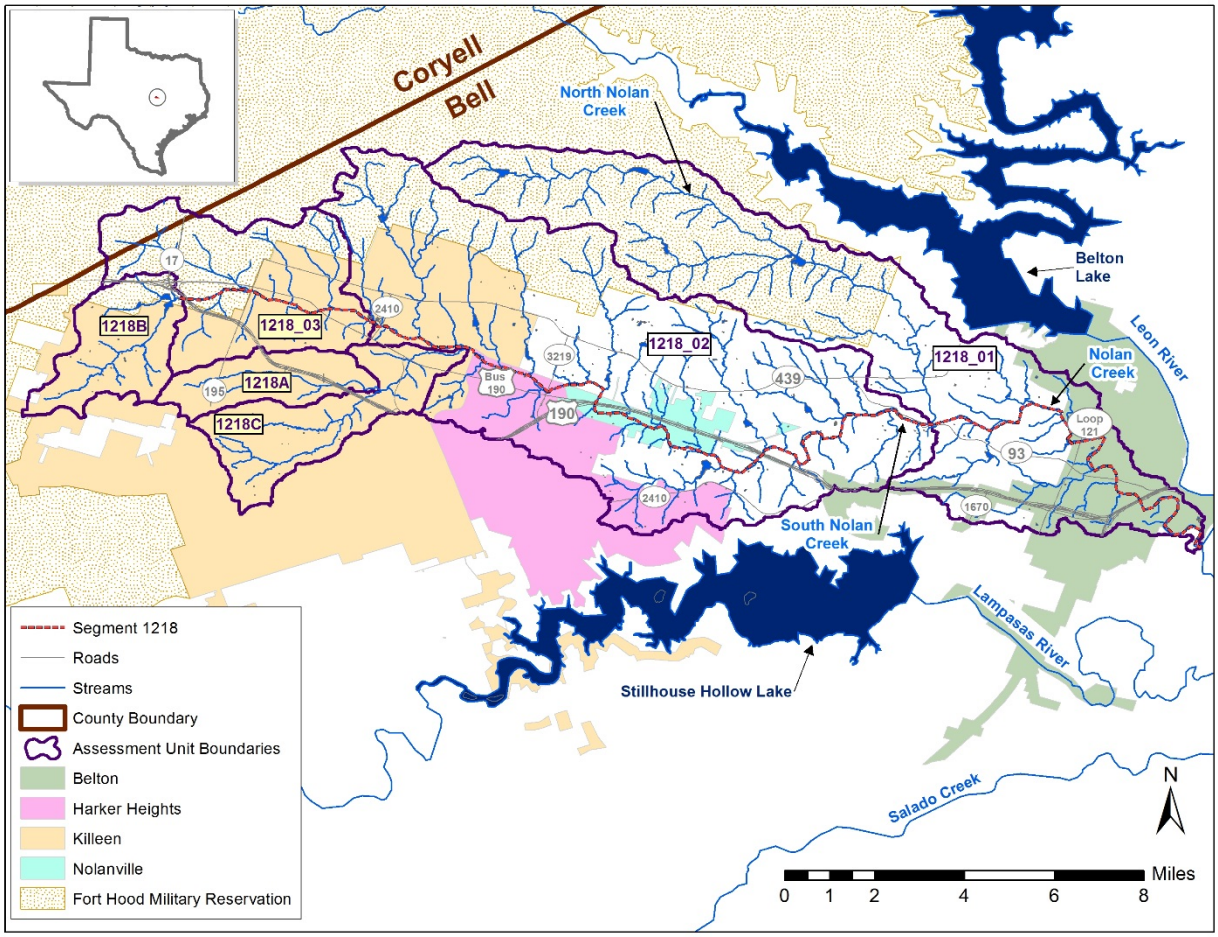

Figure 1 Watershed and assessment units associated with Segment 1218, Nolan Creek/South Nolan Creek. Insert shows the watershed location within the State of Texas.

Table 1 Watershed identification information.

Watershed	Segment	Hydrologic Unit Code	Size
Nolan Creek/South Nolan Creek Watershed	1218	1207020111	72,800 acres

Segments and assessment units (AUs) identified by the Texas Commission on Environmental Quality (TCEQ) in Figure 1 include the following:

- 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.

Project Significance and Background

Project Significance

Segment 1218 was first listed on the 303(d) List for elevated bacteria concentrations in 1996. The 2010 303(d) list identifies AU 1218_02 (portion of South Nolan Creek from confluence with North Nolan/Nolan Creek fork upstream to confluence with Liberty Ditch in the TIAER in Bell County) and 1218C (Little Nolan Creek from confluence with Nolan Creek/South Nolan Creek upstream to headwaters in the TIAER, Bell County) as impaired for elevated bacteria concentrations. Both AUs are classified as 5b, indicating that a review of the water quality standards for the water body will be conducted before a total maximum daily load (TMDL) will be scheduled. In addition, the 2010 Texas Water Quality Inventory identified nitrate, total phosphorus, and orthophosphorus as concerns for Segment 1218.

More recently, the 303(d) List within the 2012 and 2014 Texas Water Quality Inventory continues to include bacteria as an impairment for AUs 1218_02 and 1218C for primary contract recreation (TCEQ, 2013a; 2015a). In addition to the bacteria impairment, concerns for elevated nitrate, total phosphorus, and orthophosphorus concentrations are noted for AU 1281_02 in the 2012 Texas Integrated Report (TCEQ, 2013b), but only for elevated nitrate and total phosphorus in the 2014 Texas Integrated Report (TCEQ, 2015b).

Background

The current project builds upon a FY04 319(h) grant project conducted by the City of Killeen entitled, *Assessment and Targeting of Bacterial Sources in the South Nolan Creek Watershed*, which assessed water quality conditions and impairments within the upper 6.9 miles of the South Nolan Creek watershed (Nett and Flowers, 2008). This previous 319 project focused on the uppermost portion of Segment 1218 including AUs 1218A, 1218B, 1218C, 1218_03, and the upper most portion of 1218_02, all which contain portions of the City of Killeen (Figure 1).

The goal of this previous project was to confirm whether the City of Killeen was contributing to the elevated bacteria concentrations, and if so, to what degree, and to identify priority subbasins for implementation of control practices. As part of City of Killeen's project, monthly monitoring was conducted at nine stations for bacteria from October 2006 through February 2008. On three occasions about six months apart, nutrients, metals, dissolved oxygen, biological oxygen demand, temperature, pH, conductivity, flow, and water clarity were monitored at five sites. Storm monitoring was conducted at one station (11913 off Roy Reynolds Rd) with wet-weather samples from nine events analyzed for nutrients, total suspended solids, biological oxygen demand, and oil and grease. In conjunction with the water quality monitoring, potential sources of bacteria were examined. The monitoring results found low bacteria levels for South Nolan Creek above 38th Street and confirmed a bacteria impairment downstream between Twin Creek Drive and Ann Boulevard within the City of Killeen. Elevated bacteria concentrations were also noted along Long Branch and Little Nolan Creek. These findings led to the partitioning of Nolan Creek/South Nolan Creek into three main AUs, and three additional water bodies for assessment purposes noted in Figure 1. The study indicated that bacteria were not a problem in much of the headwaters as defined by AU 1218_03 allowing future efforts to focus on the impaired areas now defined by AUs 1218_02 and 1218C.

In comparing results from the City of Killeen monitoring with information regarding potential sources, a significant positive correlation was found between the number of septic tanks in the drainage area above sampling stations and bacteria concentrations (Nett and Flowers, 2008). Control practices were recommended for target areas along Long Branch and Little Nolan Creek that included a Septic Tank Elimination Program (STEP) and public education regarding septic tank maintenance. Dry weather screening for illicit discharges was also recommended as well as public education throughout the watershed regarding appropriate disposal of pet waste. Implementation of these control practices has become part of the City of Killeen's storm water management program, and the stakeholder group developed helped advance the current project, which extends the examination of elevated bacteria concentrations to more downstream portions of Nolan Creek/South Nolan Creek.

The current project focuses on impaired AUs 1218_02 along South Nolan Creek and 1218C along Little Nolan Creek, but also includes data gathering efforts throughout the Nolan Creek/South Nolan Creek watershed. The objective of this project was to build on previous monitoring and source identification efforts conducted by the City of Killeen focusing on impaired sections and extending efforts downstream to include the cities of Harker Heights, Nolanville, and Belton. The Fort Hood Military Reservation also covers large portions of the watershed to the north. Almost the entire watershed is within Bell County. The goal of this project was to provide watershed stakeholders and affected agencies with enough information to determine how to address these bacteria impairments.

Methods

Goals and Objectives

The goals of this project were to identify causes and sources of pollution in Nolan Creek/South Nolan Creek watershed and to develop an Information/Education Strategy that provided stakeholders and agencies with sufficient information to address the bacteria impairment through future development of a watershed protection plan (WPP) or total maximum daily load (TMDL). Specific objectives included:

- collecting water quality data for evaluation of bacteria and nutrient concentrations and assessment of source identification;
- merging water quality monitoring, source survey and land use information with modeling tools to provide an evaluation of loading and sources throughout the watershed;
- developing a comprehensive GIS inventory and conducting a source survey; and
- facilitating public education and outreach through meeting with stakeholders to provide the information and knowledge to make informed decisions about the future of the watershed.

The specific tasks and subtasks to accomplish these objectives are outlined below from the project workplan.

Project Tasks

Task 1: Project Administration

Objective: TIAER will effectively administer, coordinate, and monitor all work performed under this project including technical and financial supervision.

Subtask 1.1: Project Oversight – TIAER will provide technical and fiscal oversight of the staff and/or subgrantee(s)/subcontractor(s) to ensure Tasks and Deliverables are acceptable and completed as scheduled and within budget. With TCEQ Project Manager authorization, TIAER may secure the services of subgrantee(s)/subcontractor(s) as necessary for technical support, repairs, and training. Project oversight status will be provided to TCEQ with the Quarterly Progress Reports (QPRs).

Subtask 1.2: QPRs – TIAER will submit QPRs to TCEQ by the 15th of the month following each state fiscal quarter for incorporation by TCEQ into the Grant Reporting and Tracking System (GRTS). The QPRs are to include the following:

- A status of deliverables for each task; and
- A brief narrative description in QPR format.

Subtask 1.3: Contract Communication – TIAER will participate in a post-award orientation meeting with TCEQ within 30 days of Contract execution. TIAER will provide minutes from

the meeting.

TIAER will maintain regular telephone and/or email communication with the TCEQ Project Manager regarding the status and progress of the project in regard to any matters that require attention between QPRs.

Matters that must be communicated to the TCEQ Project Manager include, but are not limited to:

- notification a minimum of 14 days before the event or activity that TIAER has scheduled public meetings or events, initiated construction, or any other major task activities; and
- notification within 48 hours regarding events or circumstances that may require changes to the budget, Grant Activities, or Schedule of Deliverables.

Subtask 1.4: Annual Report Article – TIAER will provide an article for the *Nonpoint Source Annual Report* upon request by TCEQ. The article will include a brief summary of the project and describe the activities of the past fiscal year.

Subtask 1.5: Coordination Meeting with EPA – TIAER will attend a project update and coordination meeting with EPA in Dallas to share progress on goals, measures of success, challenges, and opportunities, mid-way through the project. Items discussed at the meeting will be documented in meeting minutes.

Deliverables:

- QPRs;
- Meeting minutes from the post-award orientation meeting;
- An Annual Report Article; and
- A Coordination Meeting with EPA and meeting minutes.

Task 2: Quality Assurance (QA)

Objective: TIAER will refine and document data quality objectives (DQOs) and QA/quality control (QC) activities that ensure data of known and acceptable quality are generated by this project.

Subtask 2.1: QA Project Plan (QAPP) Planning Meeting – TIAER will schedule a QAPP planning meeting with the TCEQ Project Manager, QA staff, technical staff, management, and contractors, to implement a systematic planning process based on the elements in the TCEQ NPS QAPP shell. The information developed during this meeting will be incorporated into a QAPP. The storage location of data records, and how data should be coded, will also be determined during these meetings. TIAER may conduct additional meetings to determine whether changes to an existing QAPP are needed.

Subtask 2.2: QAPP – TIAER will develop and submit to TCEQ a QAPP with project-specific DQOs and other components, as applicable, consistent with *EPA Requirements for Quality Assurance Project Plans (QA/R5), EPA Guidance for Geospatial Data Quality Assurance Project Plans (QA/G-5G),* and the TCEQ *NPS QAPP Shell* within 60 days of Contract execution. All of the monitoring procedures and methods prescribed in the QAPP

will be consistent, where applicable, with the guidelines detailed in the *TCEQ Surface Water Quality Monitoring Procedures, Volume 1 and 2*. Unless authorized by TCEQ, monitoring projects that include *E. coli* sampling are required to have samples processed by a laboratory that is accredited by TCEQ and whose accreditation at the time the analysis are performed include the matrices, methods, and parameters of analysis within an 8 hour time-frame for regulatory samples and 24 hour time-frame for non-regulatory samples. TIAER will develop the QAPP in consultation with the TCEQ Project Manager, QA staff, technical staff, management, and contractors. The QAPP must be approved by TCEQ.

Activities covered under this QAPP:

- Data Acquisition;
- GIS and map development; and
- Data collection.

Tasks/Subtasks covered under this QAPP:

- Tasks 2, 4, 5, and 8.

Tasks/Subtasks not covered under this QAPP:

- Tasks 1, 3, and 7.

Subtask 2.3: QAPP for Modeling – TIAER will develop and submit to TCEQ a QAPP with project specific DQOs consistent with the *EPA Requirements for Quality Assurance Project Plans for Modeling* QA/G-5M format within 60 days of Contract execution. The QAPP will be developed by TIAER in consultation with the TCEQ Project Manager, QA staff, technical staff, management, and contractors. The QAPP must be approved by TCEQ.

Activities covered under this QAPP:

- Data Acquisition;
- GIS and map development; and
- Modeling.

Tasks/Subtasks covered under this QAPP:

- Tasks 2, 6, and 8.

Tasks/Subtasks not covered under this QAPP:

- Tasks 1, 3, and 7.

Subtask 2.4: QAPP Update – TIAER will develop annual QAPP revisions no less than 60 days prior to the end of the effective period of the QAPP.

Subtask 2.5: **QAPP Amendments –** TIAER will review, approve, and incorporate all Amendments into a revised QAPP during the annual revision process, or will submit an

Amendment to the QAPP 90 days prior to the scheduled initiation of changes or additions to activities listed in the current QAPP. TIAER will document all Amendments to the QAPP and the reasons for the changes. TIAER's QA Officer will forward the revised pages to all people on the QAPP distribution list.

Subtask 2.6: Data Submittals – TIAER will review, verify, and validate water quality monitoring data before it is submitted to TCEQ. TIAER will submit:

- Water quality monitoring data once every six months after initiation of monitoring that is consistent with TCEQ formatting requirements for upload into the Surface Water Quality Monitoring Information System (SWQMIS); and
- Data reports and presentations for review and approval at least two weeks prior to the scheduled public release.

Deliverables:

- A QAPP Planning Meeting;
- Draft and Final QAPPs;
- Draft and Final QAPP Annual Updates;
- Draft and Final QAPP Amendments; and
- Data Submittals.

Task 3: Building Partnerships – Element E, Part A

Objective: TIAER will satisfy a portion of Element E of the EPA 2004 Guidelines; and conduct Step 1, and the stakeholder portions of Steps 2 through 4 of the Watershed Planning and Implementation Process as outlined in the EPA Handbook.

Subtask 3.1: Public Participation Plan (PPP) – TIAER will develop a draft PPP prior to initial Stakeholder Group development. The PPP will support public outreach throughout the entire watershed area to include stakeholders from Harker Heights, Nolanville, Belton, and Fort Hood, as well as, throughout the rural areas of Bell County. The PPP will establish Stakeholder Group membership, the ground rules for meetings, and public participation in the project beyond the Stakeholder Group. The PPP must be approved by the TCEQ Project Manager and be presented to stakeholders for feedback.

Subtask 3.2: Stakeholder Group Development – TIAER will develop a Stakeholder Group, which includes representatives of local, state and federal government; landowners and facility operators in all major land use categories present in the watershed; environmental groups, developers and other special interest groups active in the watershed; and other local residents.

Subtask 3.3: Stakeholder Group Activities – TIAER will ensure facilitation of the Stakeholder Group's work in accordance with the PPP, including:

- Formation of the Stakeholder Group;
- Meetings;

- Identification of issues of concern and address significant issues where possible;
- Presentation and solicitation of feedback of all deliverable reports; and
- Gaining community acceptance of the project.

Subtask 3.4: Stakeholder Group Meetings – TIAER will hold stakeholder group meetings to establish priorities and focus work efforts. Meetings will be held on a regular basis to provide status of work progress to the group and obtain input on subsequent steps. Meeting agenda and minutes will be submitted to the TCEQ Project Manager for approval before distribution.

Subtask 3.5: Dissemination of Project Information – TIAER will use Stakeholder Group meetings and the project webpage, to disseminate project information in accordance with the PPP. Project information will be submitted to the TCEQ Project Manager for approval before dissemination.

Activities will include:

- Presentation of all deliverable reports :
  - solicit input from stakeholders upon initiation of Task activities;
  - present draft reports to stakeholders;
  - solicit input/comments from stakeholders regarding each draft report;
  - hosting a Project webpage;
  - track input/comments provided by stakeholders and the responses by the project team to comments; and
  - present final report to stakeholders.

- Additional activities may include:
  - communicating via media sources;
  - Texas Watershed Steward training;
  - Texas Stream Team education events and trainings;
  - a LID Workshop; and
  - holding and/or participating in public education and outreach events.

Subtask 3.6: PPP Progress Reports – Biannual updates and a final document will be submitted by TIAER documenting the status of:

- the completion of objectives and tasks of the PPP;
- the strategy for achieving the remaining objectives and goals of the PPP through the completion of the project; and
- activities and input provided by the Stakeholder Group.

Deliverables:

- Draft and Final PPPs;
- A Project webpage and updates;
- Stakeholder group and public meeting agendas, minutes, sign in sheets, and other available documentation; and
- Draft and Final Building Partnership Reports – Element E, Part A.

Task 4: Watershed Characterization -Element A – Phase 1: Data Inventory

Objective: TIAER will satisfy a portion of Element A of the EPA Handbook by developing a comprehensive GIS inventory for the study area that will include classifying current land use for the watershed.

Subtask 4.1: Summarize Existing Data and Create a Watershed Inventory – TIAER will develop a summary of available data on physical and natural features, land use and population characteristics, water body and watershed conditions and pollutant sources, and water body monitoring data into a comprehensive inventory for the watershed. The data summary will be updated during the course of the watershed planning effort so that a complete summary is available to stakeholders. The data inventory will include, though is not limited to, information relevant to the watershed regarding the following topics from existing sources:

- Physical and Natural Features;
- Watershed Boundaries;
- Hydrology (Stream Networks and Reservoirs);
- Topography;
- Soils;
- Climate;
- Ecoregion;
- Wildlife;
- Land Use and Population Characteristics;
- Land Use and Land Cover;
- Existing Land Management Practices;
- Water Body and Watershed Conditions;
    - 305(b) Report
    - 303(d) List
    - Existing TMDL Reports
    - Source Water Assessments (if applicable)
- Point Sources;
- NPS Sources;
- Water Body Monitoring Data;
    - Water Quality and Flow
- Septic Tank Locations (where available);
- Municipalities;
- Surface Water Quality Monitoring (SWQM) Stations;
- U.S. Geological Survey (USGS) Gages;
- Floodwater Retarding Structures;
- Wetlands;
- Roads;
- Public Parks;
- Texas Pollutant Discharge Elimination System (TPDES) Permittees (Including Concentrated Animal Feeding Operations (CAFOs), Waste Water Treatment Facilities (WWTF) and Municipal Separate Storm Sewer Systems (MS4s)); and

- Sites Permitted for Land Application of Sewage Sludge and Septage.

Subtask 4.2: Geographic Representation – TIAER will develop a compilation of data from Task 4.1 to characterize the watershed to the subwatershed level using GIS software and existing data to:

- Create maps for hydrology, soils and land use data;
- Create data tables providing statistics and other relevant information including hydrologic, soils and land use data;
- Create maps that display general locations of point sources and potential NPS of pollution by
  groups; and
- Create tables of data detailing point sources and potential NPS of pollution. The tables will provide statistics on sources of pollution and water quality parameters affected.

Subtask 4.3: Watershed Characterization – Element A – Phase 1: Data Inventory Report – TIAER will develop a report providing a data inventory, land use surveys, maps, and modeling recommendations for stakeholders. The document will identify spatial, temporal, and other data gaps that need to be filled for modeling to be conducted and the completion of the Watershed Characterization.

Deliverables:

- Draft and Final Watershed Characterization -Element A -Phase 1: Data Inventory Reports; and
- GIS data for the watershed in shapefile or ArcGIS grid format.

Task 5: Element A: Watershed Characterization -Phase 2: Data Collection and Analysis

Objective: TIAER will provide baseline information to aid in determining the spatial distribution of existing nonpoint and point source contributions of bacteria and nutrients to better assess the bacterial impairments and nutrient concerns currently noted in the 2010 Texas Water Quality Inventory, and to provide monitoring data to allow a spatial characterization of potential sources of bacteria and nutrients in conjunction with the comprehensive GIS inventory conducted under Task 4 and modeling activities under Task 6. By meeting these DQOs, stakeholders within the watershed will be in a position to determine the next phase for addressing these impairments or concerns through a WPP or a TMDL.

Subtask 5.1: Conduct a Data Review – TIAER will conduct a data review to identify data gaps, and to determine the types of data needed to identify causes, sources, and acceptability of data.

Subtask 5.2: Develop a Water Quality Monitoring Plan – TIAER will summarize the specific objectives of the project's monitoring effort and the preliminary locations, times, and other details of planned monitoring activities, to demonstrate how the planned activities support the DQOs.

Subtask 5.3: Source Survey Development – TIAER will facilitate a meeting (by Month 5) of local stakeholders and technical experts to design and apply a source survey to better characterize possible sources of bacteria and nutrient loadings in the watershed. The source survey should consider sources such as WWTFs, central sewage collection systems, on-site sewage facilities (OSSFs), and MS4s. TPDES compliance issues should be examined. Wildlife, livestock and non-domestic animal populations should be considered.

Technical experts to be surveyed should include at least one representative, as appropriate to their jurisdiction and interest, from Texas Parks and Wildlife Department, Texas Department of Agriculture, TCEQ, Texas AgriLife Extension Service, Texas Forest Service, U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS), Texas Wildlife Services, USGS, U.S. Fish and Wildlife Service, USDA Natural Resources Conservation Service, USDA Agricultural Research Service,

U.S. Army Corps of Engineers, affected municipalities, counties, Groundwater Conservation Districts (GCDs) and Soil and Water Conservation Districts (SWCDs).

Subtask 5.4: Data Collection – TIAER will develop a monitoring program and will conduct monitoring, as outlined in the QAPP, to achieve DQOs.

Monthly monitoring will include 11 stations for 26 months. Monthly monitoring parameters will include *E. coli*, nitrite-nitrate-nitrogen, orthophosphate-phosphorus, total phosphorus, total Kjeldahl nitrogen and total suspended solids. Sonde data including dissolved oxygen, specific conductance, and water temperature will also be collected with monthly grabs samples. Instantaneous flow will be measured the same day as each grab sample, if conditions allow. During elevated flows, safety and access issues may preclude the measurement of flow at some locations.

Storm monitoring will be conducted at four stations with up to four events monitored per year for a total of 12 events. Storm sampling stations will include an automated sampler set to initiate upon a selected rise in water level and a flow meter to continuously record stream water levels. Storm samples will focus on the first flush of an event and will include storm grabs for analysis of *E. coli*. Storm samples will be flow composited over the first portion of each event and analyzed for the same nutrient parameters as routine grab samples, as well as, total suspended solids.

The specific location of routine and storm monitoring stations will be developed with input from TCEQ, selected stakeholders, and the project partners as the monitoring plan for the QAPP is developed.

Subtask 5.5: Watershed Characterization -Phase 2: Data Collection and Analysis Report – TIAER will provide a report that describes the results of sampling activities, and recommendation for future monitoring efforts to TCEQ and stakeholders.

Deliverables:

- Draft and Final Sampling Plans, including DQOs and data review;
- A Technical Report describing results from the source survey; and

- Draft and Final Watershed Characterization -Phase 2: Data Collection and Analysis Reports.

Task 6: Element A: Watershed Characterization -Phase 3: Identification of Causes, Sources of Pollution, Estimation of Pollutant Loads and parts of Element B: Estimate Load Reductions

Objective: TIAER will identify the causes and sources of pollution, or groups of similar sources. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed.

Subtask 6.1: Identify Causes and Sources of Pollution – TIAER will analyze data to identify the causes and sources of water quality problems in the watershed. The analysis will:

- identify pollutant sources and causes of impairments or water quality concerns including:
  - Point Sources;
  - NPS;
  - Stakeholders' concerns and observations; and
  - Effects on water quality and overall watershed functions.
- compare available monitoring data to water quality standards, and to the current 303(d) list and 305(b) assessments.

TIAER will complete an evaluation to assess the relative magnitude of sources (major or minor), location of sources, and timing of source loading based on GIS mapping, monitoring data, and information collected from the source survey.

Subtask 6.2: Geographic Representation – TIAER will provide maps of the watershed and sub watersheds that identify the major causes and source of the water quality problems.

Subtask 6.3: Load Duration Curves (LDC) Analysis – TIAER will conduct a LDC analysis for bacteria for at least four sites within the project area. LDCs shall be consistent with 1) EPA's *An Approach for Using Load Duration Curves in the Development of TMDLs*, 2) EPA's *Options for Expressing Daily Loads in TMDLs*, and 3) EPA's *Development of Duration-Curve Based Methods for Quantifying Variability and Change in Watershed Hydrology and Water Quality*. LDC development will be completed using a drainage area ratio approach. Data collected under Task 5.4, where appropriate, will be integrated into the LDCs. LDCs will be used to help estimate load reductions under varying flow regimes.

Subtask 6.4: Spatially Explicit Load Enrichment Calculation Tool (SELECT) Modeling – TIAER will conduct watershed modeling for the study area. Utilizing information from the watershed inventory (subtask 4.1), the GIS inventory (subtask 4.2) and the source survey (subtask 5.4), TIAER will develop a spatially explicit model, such as SELECT, for the study area. Modeling will be conducted on Nolan Creek/South Nolan Creek watershed to estimate loadings from various sources, and to identify critical loading areas within the watershed.

Subtask 6.5: Watershed Characterization -Phase 3: Identification of Causes and Sources of Pollutant Loads Report including parts of Element B addressing Load Reductions Report – TIAER will develop a report using data developed in this phase to identify causes and sources of pollution that need to be controlled. Pollutant load data and associated maps developed under this objective will be included in the report. The document will identify additional gaps in data, and methods to deal with these gaps will be recommended. This report will address loads by source and load reductions identified through LDCs and SELECT modeling associated with Element B of the planning process.

Deliverables:

- Watershed Maps that identify potential causes and sources of water quality problems; and
- Draft and Final Watershed Characterization Reports -Phase 3: Identification of Causes and Sources of Pollution Report including parts of Element B addressing loads by source and load reductions as identified through LDCs and SELECT modeling.

Task 7: Information and Education Component – Element E, Part B

Objective: TIAER will satisfy a portion of Element E of the EPA 2004 Guidelines by conducting portions of Steps 1 and 4 in the Watershed Planning and Implementation Process as outlined in the EPA Handbook.

Subtask 7.1: Define Education and Outreach Goals and Objectives – TIAER, with input from project partners, will identify education and outreach goals for the "Assessment of Water Quality and Watershed Based Planning for the Nolan Creek/South Nolan Creek" project. The outreach goals will be specific, measurable, action-oriented, and time-focused by:

- developing general strategies to reach targeted audiences that include specific outreach activities, workshops, trainings and social marketing techniques; and
- developing an evaluation component that measures success qualitatively and quantitatively to ensure the needed impact is generated through the education and outreach program, and that the education and outreach goals of the project are met.

Subtask 7.2: Identify and Analyze the Target Audience – TIAER will identify the audience which needs to be reached in order to meet the goals and objectives identified in Task 7.1.

Subtask 7.3: Design the Education and Outreach Implementation Measures – An effective plan will be created to reach the target audiences with specific information and social marketing solutions that will inform the public, garner support, and change behaviors throughout the watershed. Project information will be submitted to the TCEQ Project Manager for approval before dissemination.

Activities may include:

- partnerships with schools to conduct outreach water quality education;
- campaigns to distribute water protection brochures and market the outreach plan;

- urban growth workshops;
- septic system workshops ;
- campaigns regarding illegal dumping and litter; and
- agricultural waste collection days.

Subtask 7.4: Evaluate the Education and Outreach Program – An evaluation component will be developed in the plan that measures success qualitatively and quantitatively to ensure the needed impact is generated through the education and outreach program and that the education and outreach goals of the project are met.

Subtask 7.5: Information and Education Plan Report – Element E, Part B Report – TIAER will develop a report summarizing information developed under Task 7. The report will satisfy portions of Element E pertaining to the information/education component used to enhance public understanding of the project and encourage their continued participation throughout the project. The report will be approved by the TCEQ Project Manager and be presented to stakeholders for feedback.

Deliverables:

- Draft and Final Information and Education Component – Element E Reports.

Task 8: Project Report

Objective: TIAER will produce a Project Report that summarizes all activities completed, and conclusions reached, during the project. The Project Report must summarize all the Task Reports in either the text or as appendixes.

Subtask 8.1: Draft Project Report – TIAER will provide a Draft Project Report summarizing all project activities, findings, and the contents of all previous deliverables, referencing and/or attaching them as web links or appendices. This comprehensive, technical report will provide analysis of all Grant Activities and Deliverables under this Scope of Work. The Draft Project Report should be structured per the following outline:

- Title;
- Table of Contents;
- Executive Summary;
- Introduction;
- Project Significance and Background;
- Methods;
- Results and Observations;
- Discussion;
- Summary;
- References; and
- Appendices.

Subtask 8.2: Final Project Report – TIAER will revise the Draft Project Report to address comments provided by the TCEQ Project Manager and EPA, and will submit the Final

Project Report to the TCEQ Project Manager, who will subsequently submit it to EPA. The Final Project Report must describe project activities, and identify and discuss the extent to which project goals and purposes have been achieved, and the amount of funds actually spent on the project. The Final Project Report should emphasize successes, failures, lessons learned, and should include specific water quality data demonstrating water quality improvements. The Final Project Report should address how TIAER will utilize the information in future endeavors.

Deliverables:

- A Draft Project Report; and
- A Final Project Report.

Table 2 Schedule of project deliverables. Strikethrough indicates changes in due dates.

TASK	DELIVERABLE	DUE DATE	DATE SUBMITTED OR WHEN EVENT OCCURRED
Note: Due Dates reflect approved 6-month extension of project through February 28, 2016.			
Contract Executed September 18, 2012			
1.2	Quarterly Progress Report FY13 Q-1 No. 1 Quarterly Progress Report FY13 Q-2 No. 2 Quarterly Progress Report FY13 Q-3 No. 3 Quarterly Progress Report FY13 Q-4 No. 4 Quarterly Progress Report FY14 Q-1 No. 5 Quarterly Progress Report FY14 Q-2 No. 6 Quarterly Progress Report FY14 Q-3 No. 7 Quarterly Progress Report FY14 Q-4 No. 8 Quarterly Progress Report FY15 Q-1 No. 9 Quarterly Progress Report FY15 Q-2 No. 10 Quarterly Progress Report FY15 Q-3 No. 11 Quarterly Progress Report FY15 Q-4 No. 12 Quarterly Progress Report FY16 Q-1 No. 13	Dec. 15, 2012 Mar. 15, 2013 Jun. 15, 2013 Sep. 15, 2013 Dec. 15, 2013 Mar. 15, 2014 Jun. 15, 2014 Sep. 15, 2014 Dec. 15, 2014 Mar. 15, 2015 Jun. 15, 2015 Sep. 15, 2015 Dec. 15, 2015	Dec. 14, 2012 Mar. 15, 2013 Jun. 14, 2013 Sep. 13, 2013 Dec. 13, 2013 Mar. 18, 2014 Jun. 11, 2014 Sep. 12, 2014 Dec. 15, 2015 Mar. 13, 2015 Jun. 11, 2015 Sep. 11, 2015 Dec. 11, 2015
1.3	Contract Communication Post-Award Meeting Post Award Meeting Minutes Quarterly Communication Minutes	 Oct., 18, 2012 Dec. 15, 2012 Quarterly with QPR	 Held Sep. 21, 2012 at TCEQ Offices in Austin Submitted with Dec. 2012 QPR Submitted with QPRs
1.4	Annual NPS Report Article FY13 Annual NPS Report Article FY14 Annual NPS Report Article FY15	Upon Request Upon Request Upon Request	None requested of TIAER by TCEQ None requested of TIAER by TCEQ None requested of TIAER by TCEQ
1.5	Project Coordination Meeting with EPA	Sep 30, 2014	Occurred between TCEQ and EPA in fall 2014.
2.1	QAPP Planning Meeting with City of Killeen	Oct. 18, 2012	Held in conjunction with post-award meeting on Sep. 21, 2012. Additional meeting held Feb. 11, 2013 between TIAER and City of Killeen to discuss the QAPP and Monitoring plan drafts. Task Completed.

TASK	DELIVERABLE	DUE DATE	DATE SUBMITTED OR WHEN EVENT OCCURRED
2.2	Draft QAPP for Monitoring	~~Nov. 16, 2012~~ Jan. 15, 2013	Delayed due to delays in securing subcontract with the City of Killeen, anticipated submittal Jan. 15, 2013 noted in 1st Quarter QPR. Feb. 22, 2013 - Draft Monitoring QAPP sent to TCEQ for review. Received comments Mar. 28 and responded with final revision dated Apr. 17, 2013 and QAPP approved May 2, 2013..
2.3	Draft QAPP for Modeling	~~Nov. 16, 2012~~ Jan. 15, 2013	Delayed due to delays in securing subcontract with the City of Killeen, anticipated submittal Jan. 15, 2013 noted in 1st Quarter QPR. Feb. 22, 2013 – Draft Modeling QAPP sent to TCEQ for review. Received comment Apr. 4 and responded with final revision dated May 13, 2013 approved May 16, 2013.
2.4	QAPP Updates FY14 FY15	No less than 60 days prior to end of effective period	FY14 Annual revision to Monitoring QAPP approved Mar. 6, 2014. FY14 Annual certification for Modeling QAPP approved Feb. 12, 2014. FY15 Annual certification for Monitoring and Modeling QAPPs approved Feb. 6, 2015.
2.5	QAPP Amendments Draft QAPP Amendments Final	As needed As needed	All revisions minor and handled as part of annual revision or certifications.
2.6	Data Submittals (quarterly data submittals requested by TCEQ PM) Note: Data collection completed in June 2015, so final data submittal in July 2015.	Mar. 15, 2013 Jun. 15, 2013 Sep. 15, 2013 Dec. 15, 2013 Mar. 15, 2014 Jun. 15, 2014	Data collection started in May 2013 with approval of monitoring QAPP. First data submittal sent Sep. 13, 2013. Second submittal sent Dec. 16, 2013 Third submittal sent Mar. 12, 2014 Forth submittal Jun. 13, 2014

TASK	DELIVERABLE	DUE DATE	DATE SUBMITTED OR WHEN EVENT OCCURRED
		Sep. 15, 2014 Dec. 15, 2014 Mar. 15, 2015 Jun. 15, 2015 Aug. 15, 2015	Fifth submittal Sep. 10, 2014 Sixth submittal Dec. 11, 2014 Seventh submittal Mar. 9, 2015 Eighth submittal Jun. 11, 2015 Final Data submittal Jul. 22, 2015
3.1	Draft Public Participation Plan (PPP) Final PPP	~~Dec. 15, 2012~~ Jan. 15, 2013 Mar. 15, 2013	Delayed due to delays in securing subcontract with City of Killeen Feb. 25, 2013 – Submitted to TCEQ Mar. 4, 2013 – PPP approved by TCEQ Mar. 5, 2013 – Distributed final PPP to project partners and TCEQ
3.2–3.5	Stakeholder Group Development, Activities, Meetings and Project Dissemination	Bi-annually	Meeting with Administrative Stakeholders - April 29, 2013 (Killeen Utility Collections Building) Public Meetings - July 31, 2013 (Killeen Utility Collections Building) Sep. 5, 2013 (Harker Heights Activity Center) Jan. 16, 2014 (Killeen Civic Center) Sep. 25, 2014 (Killeen Transportation Services Building) Oct. 8, 2015 (Killeen Transportation Services Building) Jan 20, 2016 (Harker Heights Activity Center)
3.6	Draft Building Partnerships – Element E, Part A Report Final Building Partnerships – Element E, Part A Report	Mar. 15, 2013 ~~Aug. 15, 2015~~ Jan. 29, 2016	Mar. 4, 2013 – TCEQ PM gave final approval of PPP and approved document was sent in PDF form to project partners. To be updated as needed. Final revision due date revised with project extension.
4.1-4.2	Inventory of existing data and GIS representation for watershed in shapefile or ArcGIS grid format	~~Dec. 15, 2013~~ Revised due date Dec. 5, 2014	Maps included in Data Inventory Report delivered to TCEQ Dec. 5, 2014.

TASK	DELIVERABLE	DUE DATE	DATE SUBMITTED OR WHEN EVENT OCCURRED
4.3	Draft Watershed Characterization Report (Data Inventory Report)	~~Dec. 15, 2013~~ Dec. 5, 2014	Due date revised as substantially more time needed than originally envisioned to pull together all historical watershed data and land use information. Draft completed and delivered to TCEQ Dec. 5, 2014. Comments received from TCEQ Jan. 12, 2015.
	Final Watershed Characterization Report (Data Inventory Report)	~~Mar. 14, 2014~~ ~~Apr. 15, 2015~~ May 28, 2015	Extension requested for final report to address extensive comments. Revisions submitted 28May2015 to TCEQ with response to comments. Further revisions requested based on comments to Source Survey Report received June 16, 2015. Modified version sent July 14, 2015 and approved by TCEQ July 17, 2015.
5.2	Draft Water Quality Monitoring Plan	~~Nov. 16, 2012~~ Jan. 15, 2013	Extension requested due to delays in securing subcontract with City of Killeen. Reconnaissance and planning meeting held between TIAER and CoK Jan. 18, 2013. Draft submitted to TCEQ PM for review Feb. 22, 2013.
	Final Water Quality Monitoring Plan	~~Dec. 15, 2012~~ Within two weeks of receipt of comments from TCEQ	Draft approved by TCEQ without revision Mar. 8, 2013.
5.3	Source Survey Technical Report	Dec. 15, 2014	Draft completed and delivered to TCEQ Dec. 15, 2014. Comments received from TCEQ Jan. 28, 2015. Revisions and response to comments submitted to TCEQ May 28, 2015. Further comments received June 16, 2015. Modified version sent July 3,

TASK	DELIVERABLE	DUE DATE	DATE SUBMITTED OR WHEN EVENT OCCURRED
			2015 and approved by TCEQ July 7, 2015.
5.5	Draft Watershed Characterization – Phase 2 Report (Monitoring Report) Final Watershed Characterization – Phase 2 Report (Monitoring Report)	~~Apr. 15, 2015~~ Aug. 31, 2015 ~~Jun. 15, 2015~~ Nov.30, 2015	Extension requested as initial date was set prior to when monitoring for the project would be completed. Draft submitted to TCEQ Sep. 10, 2015 Accepted by TCEQ without comment Sep. 17, 2015.
6.2	Watershed maps that identify potential cause and sources of water quality problems	~~Jun. 15, 2015~~ Aug. 31, 2015	Extension requested to better time use of all monitoring data with report.
6.5	Draft Watershed Characterization Phase 3 Report with Loadings Final Watershed Characterization Phase 3 Report with Loadings	~~June 15, 2015~~ Aug. 31, 2015 ~~Jul. 15, 2015~~ Nov. 30, 2015	Extension requested to allow use of all monitoring data in draft report and work within 6-month extension of the project. Draft submitted Aug. 31, 2015 to TCEQ. Revisions and response to comments submitted to TCEQ Nov. 23, 2015 with approval received Dec. 1, 2015.
7.1	Define Education Goals	Mar. 15, 2013	Strategies for reaching targeted audience outlined in PPP
7.2	Identify Target Audience	Mar. 15, 2013	Target audience identified in PPP
7.3	Design Implementation Measures	Mar. 15, 2013	Identified in PPP
7.4	Evaluate Education and Outreach Program FY13 FY14 FY15	 Sep. 15, 2013 Sep. 15, 2014 Sep. 15, 2015	 Review of PPP
7.5	Draft Information & Education Plan Report Final Information & Education Plan Report	~~Jun. 15, 2015~~ Oct. 30, 2015 ~~Jul. 15, 2015~~ Nov. 30 2015	Due dates revised with 6-month extension of project. Draft submitted Nov. 18, 2015 to TCEQ. Comments received from TCEQ Nov. 19, 2015. Revisions and response to comments submitted to TCEQ Dec. 8, 2015 and approved by

TASK	DELIVERABLE	DUE DATE	DATE SUBMITTED OR WHEN EVENT OCCURRED
			TCEQ same day.
8.1- 8.2	Draft Project Report Final Project Report	~~Jul. 15, 2015~~ Dec. 18, 2015 ~~Aug. 15, 2015~~ Feb. 28, 2015	Due dates revised with 6-month extension of project.

Results and Observations

Task 1: Project Administration

Results:

Overall the project was effectively administered by TIAER with deliverables, due dates, and submittals summarized in Table 2. Communication between the TCEQ and TIAER project managers occurred on a regular basis without prompting. The majority of deliverables were on time or prior approval was received to move due dates. Many of the shifts in deliverable due dates were due to a six-month extension for the project requested in February 2015 due to a change in the workload for the TIAER project manager as she took on the role of interim executive director for TIAER. The quality of reports was considered exceptional by TCEQ with the details provided to meet project goals.

Thirteen quarterly progress reports (QPRs) were developed over the course of the project outlining progress on tasks, details of monitoring activities, minutes from project communications meetings, stakeholder sign in sheets and other appropriate items. These QPRs can be found on TIAER's website with the following links:

Q1 documenting work completed September 1, 2012 – November 30, 2012[1]

Q2 documenting work completed December 1, 2012 – February 28, 2013[2]

Q3 documenting work completed March 1, 2012 – May 31, 2012[3]

Q4 documenting work completed June 1, 2013 – August 31, 2013[4]

Q5 documenting work completed September 1, 2013 – November 30, 2013[5]

Q6 documenting work completed December 1, 2013 – February 29, 2014[6]

Q7 documenting work completed March 1, 2014 – May 31, 2014[7]

Q8 documenting work completed June 1, 2014 – August 31, 2014[8]

Q9 documenting work completed September 1, 2014 – November 30, 2014[9]

Q10 documenting work completed December 1, 2014 – February 28, 2015[10]

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[1] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q1_No1_Final.pdf
[2] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q2_No2_Final.pdf
[3] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q3_No3_Final.pdf
[4] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q4_No4_Final.pdf
[5] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q5_No5_Final.pdf
[6] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q6_No6_Final.pdf
[7] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q7_No7_Final.pdf
[8] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q8_No8_Final.pdf
[9] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q9_No9_Final.pdf

Q11 documenting work completed March 1, 2015 – May 31, 2015[11]

Q12 documenting work completed June 1, 2015 – August 31, 2015[12]

Q13 documenting work completed September 1, 2015 – November 30, 2015[13]

Observations:

The project has had several changes in management at TCEQ and TIAER over the three and half year timespan. In May 2014, Nikki Jackson, the initial project manager for TIAER, left TIAER and Anne McFarland became the project manager with Leah Taylor picking up the outreach and educational role that Ms. Jackson had been fulfilling. Anne McFarland had previously been in primarily a technical oversight role for the project. In June 2014, Anju Chalise took another job within TCEQ and Arthur Talley became the TCEQ project manager. Then in January 2015, Megan Wilson was named the TCEQ project manager with mentoring guidance and technical review still provided by Arthur Talley. Despite all these changes in project personnel and oversight the project continued to be successfully managed throughout due to continuity of at least some personnel at TIAER, and the management background provided by personnel at TCEQ.

Also, in the fall of 2014, TIAER shifted from doing its contract management and invoicing internally to using Sponsored Research Services (SRS) of the Texas A&M System. In dealing with invoicing, there were some issues between SRS and TCEQ in the interpretation of how to handle the required 60/40 split and other invoicing nuances. Both entities worked productively to resolve these issues.

The subcontract that TIAER had with the City of Killeen for the project also lead to some delays in initiation of some project work as it took about three months to establish once the contract between TCEQ and TIAER was approved. The subcontract with the City of Killeen also took some special care, particularly when amended, to deal with differences in contracting needs associated with SRS and Killeen. One special consideration in partnering with a city is to make sure additional time is considered for setting up contract to deal with approvals needed from city council. This alone can take a couple of months to go through the appropriate procedures for agendas and approvals. Also, for close out of the contract budget, the largest item left during the last quarter of the project was the subcontracted portion by the City of Killeen. This occurred because the city needed to wait until the project was almost over to invoice to make their match portion for associated with work by city personnel, which included review of a draft of the final project report.

[10] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q10_No10_Final.pdf
[11] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q11_No11_Final.pdf
[12] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q12_No12_Final.pdf
[13] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek_Q13_No13_Final.pdf

Task 2: Quality Assurance

Results:

Two quality assurance project plans (QAPPs) were established for this project. The first, a monitoring QAPP, addressed data collection, data acquisition and map development activities under the following tasks:

- Task 2 – Quality Assurance,
- Task 4 – Data Inventory,
- Task 5 – Data Collection and Analysis, and
- Task 8 – Final Project Reporting.

The monitoring QAPP was consistent with EPA Requirements for *Quality Assurance Project Plans (QA/R5)*, *EPA Guidance for Geospatial Data Quality Assurance Project Plans (QA/G-5G)*, and the *TCEQ NPS QAPP Shell*. All of the monitoring procedures and methods prescribed in the QAPP were also consistent where applicable with the guidelines detailed in the *TCEQ Surface Water Quality Monitoring Procedures, Volume 1 and 2* (TCEQ, 2012a; 2014). The monitoring QAPP was developed by TIAER with the City of Killeen in consultation with the TCEQ Project Manager, QA and technical staff. The original QAPP, revisions, and annual certifications can be found at the following links:

Nolan Monitoring QAPP Revision 0[14]

Monitoring QAPP Revision Year 1[15]

Monitoring QAPP Certification Year 2[16]

As outlined in the monitoring QAPP, data submittals occurred quarterly after the initiation of monitoring and were consistent with TCEQ formatting requirements for upload into TCEQ's SWQMIS.

The second, a modeling QAPP, address modeling, data acquisition and map development activities under the following tasks:

- Tasks 2 – Quality Assurance,
- Task 6 – Identification of Causes and Estimation of Pollutant Load Reductions, and
- Task 8 – Final Project Reporting.

The modeling QAPP was consistent with the EPA Requirements for *Quality Assurance Project Plans for Modeling (QA/G-5M)* and was developed by TIAER and the City of Killeen in consultation with the TCEQ Project Manager, Quality Assurance and technical staff. The original QAPP, revisions, and annual certifications can be found at the following links:

[14] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan_Monitoring_QAPP_Revision0.pdf
[15] http://t-nn.tarleton.edu/docs/nolan_creek/Monitoring%20QAPP%20Revision_Year%201.pdf
[16] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek%20Monitoring%20QAPP%20Certification_Year%202.pdf

Nolan Modeling QAPP Revision 0[17]

Modeling QAPP Certification Year 1[18]

Modeling QAPP Certification Year 2[19]

As any changes were minor, mainly addressing changes in personnel and the six-month extension of the project, no amendments were required during the project to either of these QAPPs, but were handled via annual revisions or certifications.

Observations:

Completion of the initial monitoring and modeling QAPPs was delayed a few months due to unanticipated delays in setting up the initial subcontract between TIAER and the City of Killeen. This partnership between TIAER and the City of Killeen was very important to the success of the project in that it involved a key watershed stakeholder. Of note for future projects when partnering with a city, time needs to be considered in the project timeline to contractually get the partnership established, particularly if part of the budget relies on a subcontract.

Task 3: Building Partnerships

Results:

As the Building Partnerships Report for the project, a Public Participation Plan (PPP) was developed early on to define stakeholders and potential agencies to reach out to for involvement in the project. The PPP also outlined project goals, avenues of communication between project partners and stakeholders, and how stakeholders would be notified of meetings and the distribution of project materials. The PPP as approved by TCEQ in March 2013 can be found at the following link:

Public Participation Plan for Nolan Creek/South Nolan Creek Watershed Based Planning[20]

Throughout the project, the City of Killeen has hosted a website for the Nolan Creek Partnership where meeting notifications and material were made available at http://www.killeentexas.gov/nolancreekwatershed

As this project continues into development of a watershed protection plan (WPP), either a public domain will be found to continue this website as a place of stakeholders to obtain current project information. TIAER also plans to host a website archiving project activities and reports for the Nolan Creek/South Nolan Creek watershed.

Six public meetings were held over the course of the project and the agenda and information presented at each meeting can be found on the website hosted by the City of Killen

[17] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan_Modeling_QAPP_Revision0.pdf
[18] http://t-nn.tarleton.edu/docs/nolan_creek/Modeling%20QAPP%20Certification_Year%201.pdf
[19] http://t-nn.tarleton.edu/docs/nolan_creek/Nolan%20Creek%20Modeling%20QAPP%20Certification_Year%202.pdf
[20] http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan%20Creek%20PPP%20-%2002252013_Final.pdf

(http://www.killeentexas.gov/nolancreekwatershed) as well as TIAER's project website using the following link: http://tiaer.tarleton.edu/nolan-creek-watershed.html. Meeting material is organized by meeting date.

July 31, 2013 – Nolan Creek Partnership Meeting (Killeen Utility Collections Building)

Sep. 5, 2013 – Nolan Creek Partnership Meeting (Harker Heights Activity Center)

Jan. 16, 204 – Nolan Creek Partnership Meeting (Killeen Civic Center), originally scheduled for Dec. 5, 2013 but postponed due to icy weather

Sep. 25, 2014 – Nolan Creek Partnership Meeting (Killeen Transportation Services Building)

Oct. 8, 2015 – Nolan Creek Partnership Meeting (Killeen Transportation Services Building)

Jan. 20, 2016 - Nolan Creek Partnership Meeting (Harker Heights Activity Center) (*meeting date is set but meeting has not yet occurred, so no materials yet).*

At these meetings, as well as via the project website, project findings were presented, draft reports distributed, and input from stakeholders was solicited. Additional activities included hosting of a Texas Watershed Steward workshop conducted during the first year of the project to increase stakeholder knowledge of nonpoint source pollution issues and promotion of Texas Stream Team training events to encourage volunteer monitoring in the watershed.

Observations:

While the City of Killeen has done a wonderful job of hosting the project's website, there is need as the project continues into a WPP to obtain a public domain for the website, so this task can be transferred to a watershed coordinator, who likely will not be directly associated with the City. Obtaining a public domain website is being coordinated by the City of Killeen website manager.

Task 4: Watershed Characterization – Data Inventory

Results:

An outcome of this task was development of the report can be found at the following link:

Data Inventory for the Nolan Creek/South Nolan Creek Watershed Segment 1218[21]

This report provides a building block towards meeting the project goal of identifying causes and sources of pollution in the Nolan Creek/South Nolan Creek watershed by providing an inventory of existing data to aid in watershed planning efforts. Because bacteria is the impairment, this report focused primarily on data related to bacteria and potential bacteria sources within the watershed, but also considers the nutrient concerns as noted in the 2012 Texas Water Quality Inventory.

[21] http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan_Data_Inventory_Report(revDec2015)FINAL.pdf

This Data Inventory Report was prepared as a first step in satisfying Element A of the EPA *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (EPA, 2008). Element A involves identification of causes and sources of pollution within a watershed that will need to be controlled to achieve estimated load reductions. Within this project, Element A is being addressed in three phases: Phase 1 involves creation of the data inventory and identification of data gaps, Phase 2 involves direct data collection needed to evaluate loadings sources and loadings throughout the watershed, and Phase 3 will provide loading estimates by source at the sub-watershed level as well as estimates of needed load reductions.

To develop estimates of loadings and sources for Phase 3, the Spatially Explicit Load Enrichment Calculation Tool (SELECT) was used in Task 6. This tool was developed jointly by the Spatial Sciences Laboratory (SSL) and Department of Biological and Agricultural Engineering at Texas A&M University as a screening model to spatially depict and estimate potential bacteria loads from various sources within a watershed (see Teague et al., 2009). Use of SELECT involves developing an inventory of potential bacterial sources (e.g., point discharges, septic systems, livestock, deer, feral hogs, and pets) and then distributing the potential loads from these sources across the watershed based on land use and source type (Table 3). Combining land use and source loading data, SELECT then generates a spatial display by subwatershed of potential bacteria loadings that can be used to target potential “hot spots” and identify dominant sources.

Also under Task 6, load duration curves (LDCs) were also developed for four locations within the watershed to aid in the identification of sources and needed load reductions. Load duration curves are a simple method for obtaining an estimate of loadings under varying flow regimes (EPA, 2007; Cleland, 2003). The data needed for developing LDCs for the Nolan Creek/South Nolan Creek includes information on long-term flows and measurements of bacteria under varying flow conditions (Table 4). For evaluating load reductions needed, part of the contributing load includes the permitted load from WWTFs, as well as estimates of the load associated with MS4 areas. For MS4 areas, loadings are generally based on the percent land area associated with the urbanized area defined within the 2010 Census data (e.g., TCEQ, 2012b).

A goal of the data inventory report was to collect and summarize existing data needed for identifying sources and estimating loadings for Phase 3 of this project under Task 6. Phase 2 of this project involves direct monitoring under Task 5, which addresses some data gaps previously identified through prior efforts in the watershed.

Table 3 Summary of data needs for running SELECT.

Type of Data	Units	Use	Data Source
Spatial GIS data, Land use and cover	30-m resolution, 16 categories	Land use and cover categories for associating with bacteria loadings from various sources	Multi-Resolution Landuse Consortium National Land Cover Database
Spatial GIS data, Soils	Soil mapping units	Used in conjunction with the location of rural households to estimate risk of septic system failures	Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database
Location permitted discharge facilities, average monthly discharge	Location (latitude/longitude) & permitted average monthly discharge (MGD)	Used to define potential point sources of bacteria and nutrients	TCEQ Information Resources Division Central Registry or USEPA Enforcement & Compliance History Online (ECHO) website or directly from permitted facilities
Spatial GIS, Population data at various scales	Density down to blocks, as needed	Used to indicate population density in urban and rural areas	U.S. Census Bureau
Spatial GIS, Urbanized Areas	Spatial boundaries	Used to indicate municipal boundaries	U.S. Census Bureau
Spatial boundaries for counties and cities	Spatial boundaries	Used to indicate county boundaries and aid with city boundaries	Texas Natural Resources Information System (TNRIS) StratMap Boundaries with modifications, as provided, from municipalities
MS4 boundaries	Spatial boundaries	Used to indicate MS4 permit boundaries for urbanized areas	U.S. Census Bureau
Spatial GIS, point data	Household locations	Used to define rural population density with regard to on-site sewage facilities (OSSFs) and potential failure rates in conjunction with sewer service boundaries	U.S. Census Bureau
Spatial GIS, Stream layer	Line data	To define location of stream segments	National Hydrography Dataset (NHD)

Type of Data	Units	Use	Data Source
Spatial data, livestock density	County level estimates adjusted to watershed area for major livestock groups	Used to estimate livestock density throughout the watershed	USDA Census of Agriculture (USDA-NASS, 2014)
Spatial wildlife density	Deer density and other pertinent species, as available	Used to estimate deer density throughout the watershed	Texas Parks & Wildlife Department (TPWD, 2012) surveys and/or information from biologists
Spatial, pet density	Dog density per household	Used to estimate dog density throughout the watershed	American Veterinary Medical Association (AVMA, 2012) and stakeholder input
Spatial, feral hog density	Feral hog density	Used to estimate feral density throughout the watershed	TPWD (TPWD, 2012), literature values and stakeholder input
Rates of fecal production	cfu/day	Used to estimate potential bacteria loads for various sources (i.e., feral hogs, deer, dogs, cattle or other livestock, and WWTF discharges)	EPA and literature values
Wastewater treatment facility (WWTF) discharges	Discharge rates and bacteria concentration data	Used to estimate bacteria loadings associated with WWTF discharges	TCEQ Information Resources Division Central Registry, USEPA Enforcement & Compliance History Online (ECHO), or directly from permitted facilities
Spatial, boundaries for sewer service areas	Spatial boundaries	Used to define areas on sewer based on sewer Certificates of Convenience and Necessity (CCNs) and municipal boundaries	Public Utility Commission of Texas & Municipal boundaries (TNRIS)
Spatial GIS data, Digital Elevation Models (DEMs)	30 meter resolution	Delineation of watershed and subwatershed boundaries	National Elevation Dataset from USGS

Table 4 Summary of data needs for developing FDCs and LDCs.

Type of Data	Units	Use	Source
Time series, daily streamflow	Average daily (cfs)	Ranking of daily flow conditions for stream sites used for LDCs	USGS and direct project data
Concentration at various points in time	mg/L for nutrients and MPN/100mL or colonies/100mL for bacteria	Concentration of nitrates, orthophosphorus, total phosphorus and bacteria for LDCs.	TCEQ SWQMIS and direct project data
Instantaneous flow measurements collected with concentration data	cfs	Flow data to relate concentrations LDCs.	TCEQ SWQMIS and direct project data
Spatial data, location of existing SWQM stations	Latitude/ longitude	Define location of stations within the watershed with existing water quality monitoring data in SWQMIS	TCEQ SWQM Clean Rivers Program
Spatial GIS data, Digital Elevation Models (DEMs)	30 meter resolution	Delineation of watershed and subwatershed boundaries	National Elevation Dataset from USGS (USGS, 2014)
Wastewater treatment facility (WWTF) discharges	Permitted discharge rates	Used to estimate bacteria loadings associated with WWTF discharges	TCEQ Information Resources Division Central Registry, USEPA Enforcement & Compliance History Online (ECHO), or directly from permitted facilities
MS4 Areas	Percent land area above LDC sites	Used to estimate bacteria loadings associated with MS4 areas	U.S. Census Bureau urbanized areas

Observations:

One of the purposes of creating a data inventory is to identify data gaps that need to be filled to allow adequate assessment of sources and loadings associated with water quality impairments and concerns in the watershed. In assessing data gaps with regard to data needs associated with running SELECT and developing LDCs for bacteria, there were a few identified. For SELECT, the main data gap was in information available regarding the distribution of OSSFs. Detailed OSSF information is available for the portion of the watershed within the boundaries of the City of Killeen, but will need to be estimated for the rest of the watershed. The distribution of OSSFs for other areas within the watershed can be estimated by overlaying census block data with sewer service areas and assuming all households outside the sewer area are on septic. This likely will underestimate this source, as there are likely households within the sewer areas of the other municipalities also still on septic.

With regard to the water quality data available, some spatial and temporal gaps occur that would hinder the estimation of loadings if based on just these historical data. Most of the water quality data with any temporal consistency has occurred at only a limited number of stations. Although multiple stations have monitoring data within each AU, often individual stations were only monitored for relatively brief time periods. The flow conditions under which monitoring has occurred also has generally favored baseflow conditions limiting the evaluation of point versus nonpoint source conditions. Another item hindering the evaluation of loadings is the limited timeframe of continuous flow data available. The one USGS station provides historical data for almost 10 years from 1974 to 1982, but to derive flow conditions representative of more recent years for loading calculations, hydrologic estimation techniques may be needed, which could involve use of USGS flow gaging stations near but outside the watershed.

To assist in filling the water quality data gaps, Phase 2 of this project under Task 5 addresses direct data collection activities. The direct data collected along with historical data identified in this data inventory as will provide the information needed to estimate loadings and sources in Phase 3 under Task 6, completing the watershed characterization effort for watershed based planning (EPA, 2008).

Task 5: Watershed Characterization – Data Collection and Analysis

Results:

In conjunction with stakeholders in the watershed, a monitoring plan was developed to assess data gaps previously identified with regard to sources of bacteria as well as extending the monitoring to cover the entire span of Segment 1218, but focusing on the impaired AUs of 1218_02 and 1218C. The monitoring plan included routine monthly monitoring at 11 locations and quarterly storm monitoring at 4 locations to allow a better characterization of watershed conditions (Figure 2). The monitoring plan and rationale is outlined in the following report and can also be found as an appendix in the monitoring QAPP under Task 2:

Monitoring Plan for Nolan Creek/South Nolan Creek[22]

[22] http://t-nn.tarleton.edu/docs/nolan_creek/publications/FINAL_Monitoring_Plan_08Apr2013.pdf

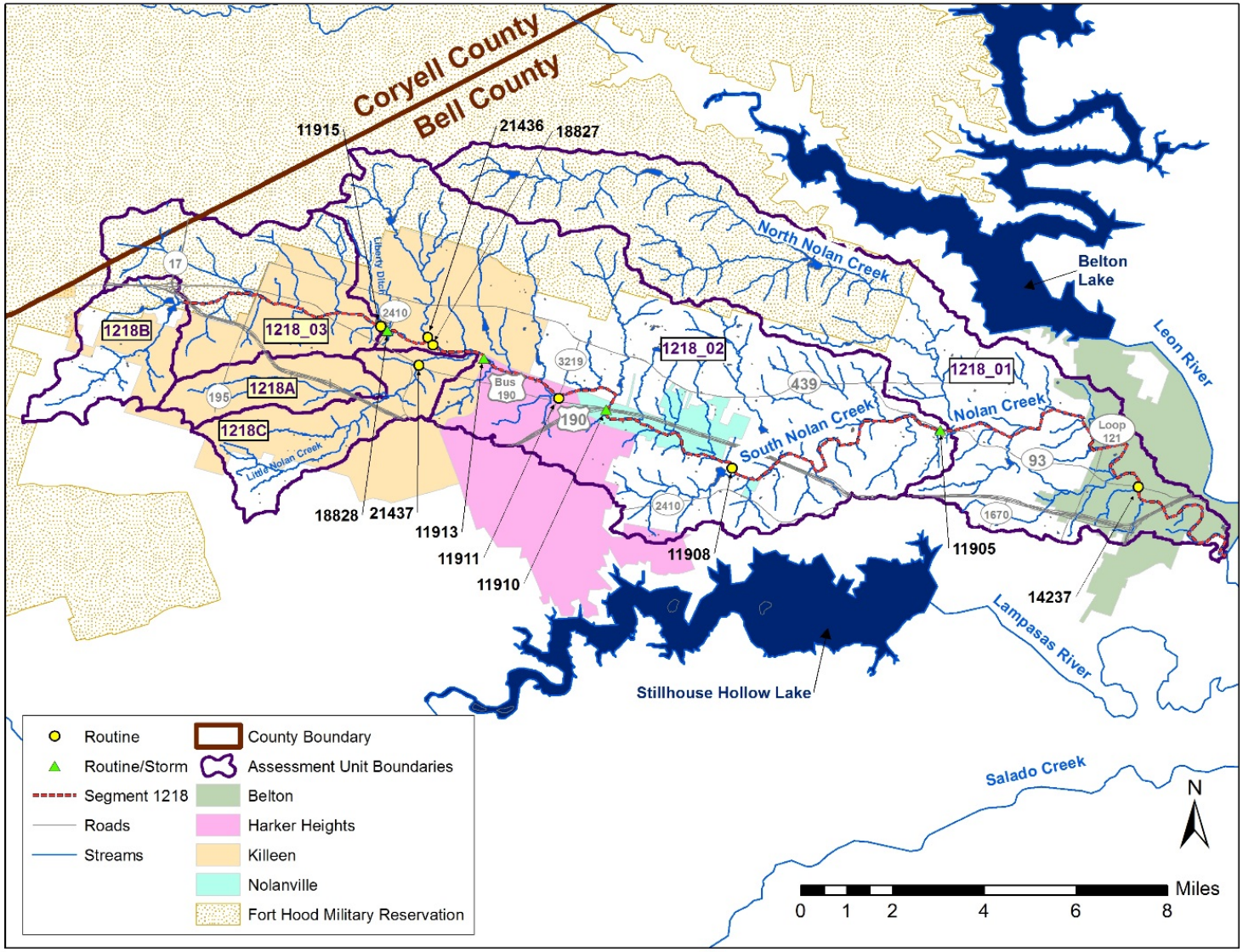

Figure 2 Project monitoring locations in the Nolan Creek/South Nolan Creek watershed.

As part of Task 5, a source survey report was developed that included much of the information from the data inventory conducted under Task 4, but also included a visual assessment and stakeholder evaluation of potential sources. While few direct sources were noted in the visual assessment, perceived sources indicated by stakeholders as noted from a meeting held on September 25, 2014 included:

- Stormwater, pets, grackles/pigeons, septic systems
- Sanitary sewer leaks, OSSF (*on-site sewage facility*) failures
- Domestic animals, wildlife, farms, SSOs (*sanitary sewer overflows*), Ft Hood land disturbance
- Residential septic system, municipal sanitary sewer overflows
- Street/yard/ag runoff, livestock
- Stormwater runoff from small feeder lines in east Killeen
- Unsure
- Wastewater plant emissions, sewage drainage during storms

The full source survey report can be accessed at the following link:

Survey of Potential Bacteria and Nutrient Sources in the Nolan Creek/South Nolan Creek Watershed[23]

The direct monitoring data were evaluated spatially and temporally to assess the distribution and sources of bacteria and nutrient contributions to the watershed. The details of this evaluation as well as the results of all the direct monitoring data collected are presented in the following report:

Characterizing Water Quality within Nolan Creek/South Nolan Creek[24]

As a summary of the findings, bacteria contributions exceeded the geometric mean criterion for bacteria at all but two most upstream stations (Figure 3). Bacteria contributions from tributaries to South Nolan Creek associated with Long Branch (station 21436) and Little Nolan Creek (station 21437) appeared to contribute to the higher bacteria concentrations noted at stations 18827 and 11913 each below the confluence of these two tributaries (see Figure 2 for map of station locations). Much higher concentrations of bacteria were noted with storm events than during routine monitoring indicating a large nonpoint source contribution with rainfall runoff (Figure 4). Bacteria concentrations overall for the watershed indicated increasing concentrations with increasing flows above baseflow conditions (Figure 5).

[23] http://t-nn.tarleton.edu/docs/nolan_creek/publications/SourceSurvey_Report_(revDec2015)FINAL.pdf
[24] http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan_Monitoring_Report(revDec2015)FINAL.pdf

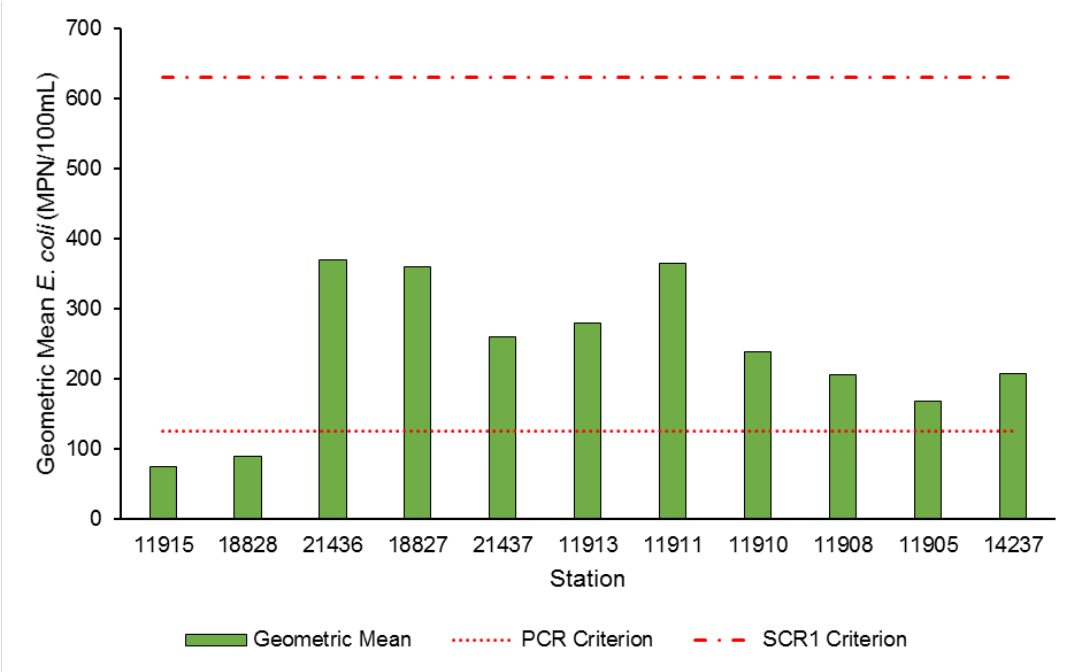

Figure 3 Geometric mean *E. coli* concentrations for routine grab samples compared to assessment criteria. PCR = primary contact recreation and SCR1 = secondary contact recreation 1.

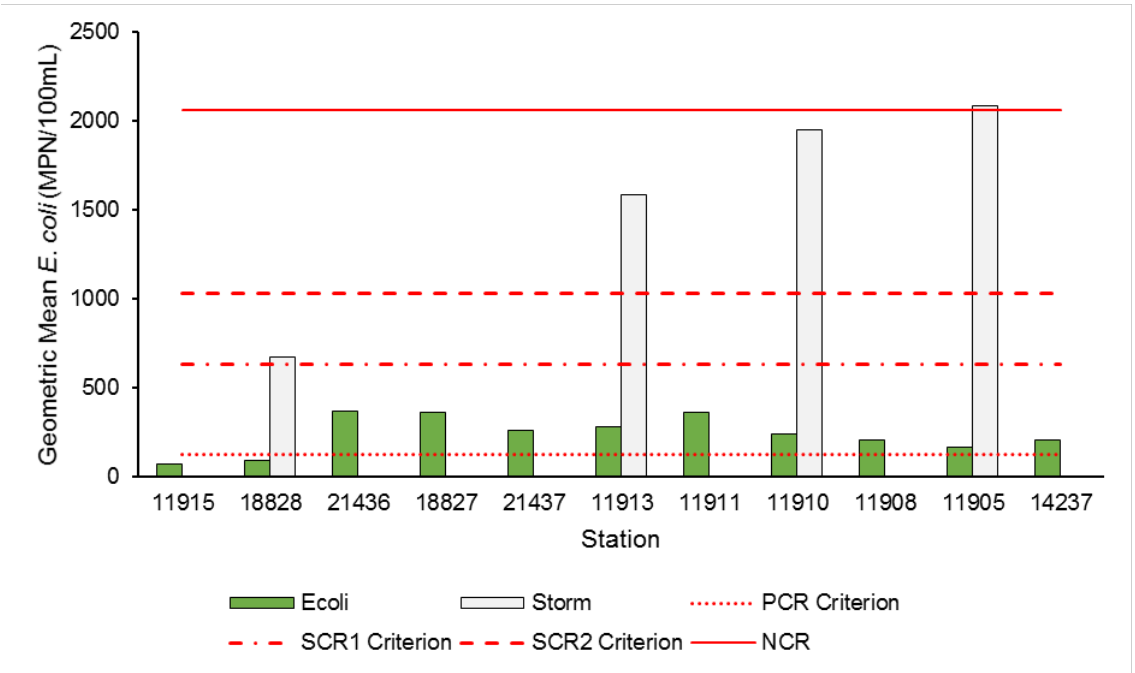

Figure 4 Geometric mean *E. coli* concentrations for routine grab and storm samples compared to assessment criteria. PCR = primary contact recreation, SCR1 = secondary contact recreation 1, SCR2 = secondary contract recreation 2, and NCR = noncontact recreation.

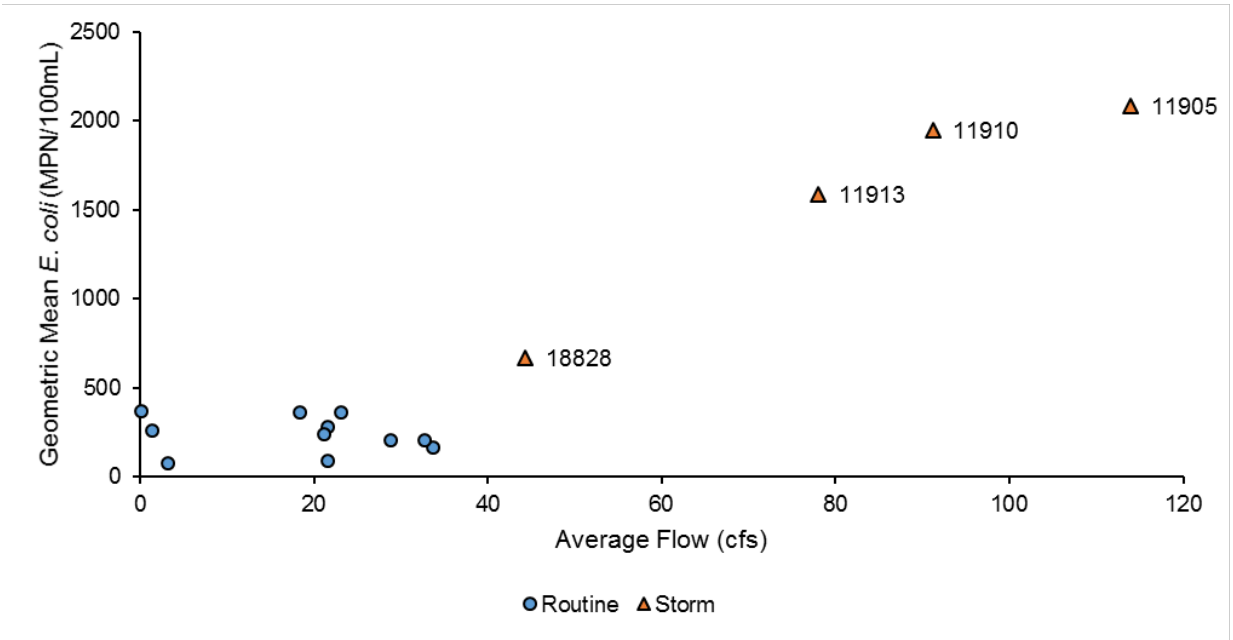

Figure 5 Average flow compared to geometric mean *E. coli* concentrations for routine grab and storm samples. Storm stations labeled.

Besides flow, potential relationships were explored between drainage area characteristics, such as land use and drainage area, and the geometric mean *E. coli* concentrations for each station. In contrast to storm samples, which indicated increasing flow with drainage area, and thus, increasing bacteria concentrations; bacteria concentrations appeared to decrease for routine grab samples with increasing drainage area, but this decrease was only apparent if the two most upstream stations, 11915 an18828, were excluded (Figure 6). No significant correlations were indicated when geometric mean bacteria concentrations were related to percent land use above monitoring stations. This included correlation analyses conducted with and without stations 18828 and 11915, as these two stations appeared to respond differently than the other stations monitored with regard to their bacteria levels.

In evaluating time history plots of bacteria at specific locations, point sources in the form of sewer system overflows (SSOs) did occasionally cause spikes in bacteria concentrations that were apparent in the monthly routine monitoring. For example, the relatively high *E. coli* concentrations noted on July 10, 2013 at station 18827 appeared to be related to a large sewage discharge upstream of this location, which was reported on July 2, 2013 (Figure 7).

For nutrients, concentrations observed were well above screening levels during routine monitoring, but showed a diluting effect of stormwater runoff during elevated flows indicating a strong point source signature as shown in Figure 8 for nitrates. Similar figures are presented in *Characterizing Water Quality within Nolan Creek/South Nolan Creek* in Appendix C.

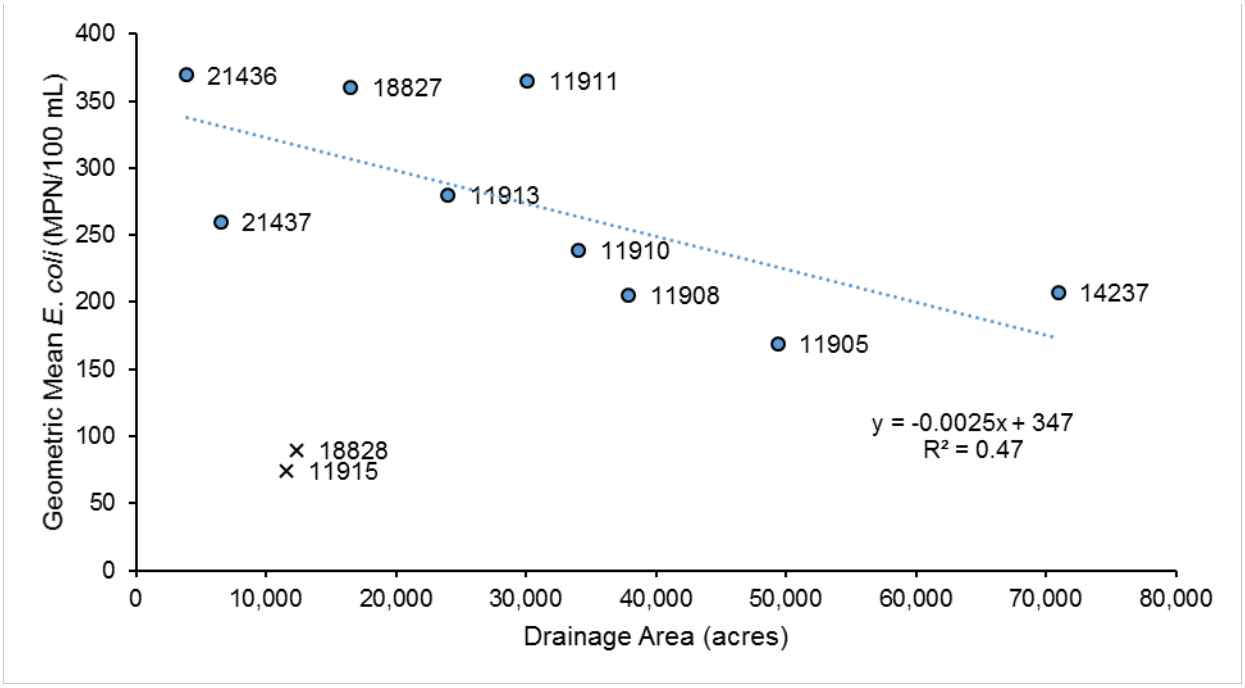

Figure 6 Relationship of drainage area size with geometric mean bacteria concentrations for routine grabs. Values are labeled by station. Values for stations 18828 and 11915 were not included in regression analysis and are noted with "x's".

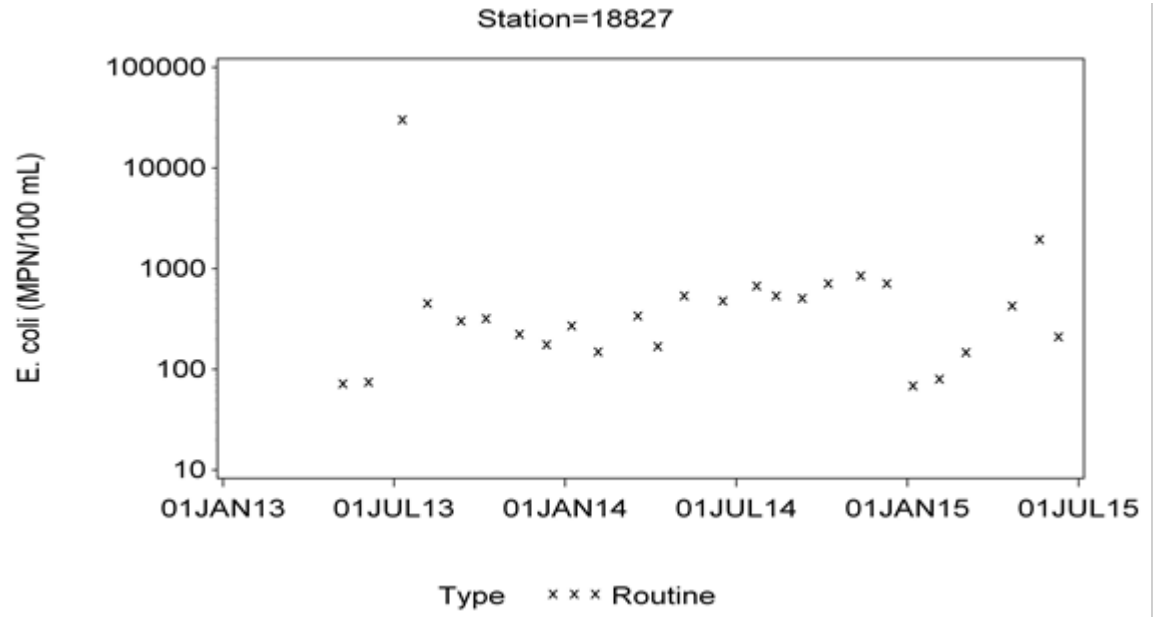

Figure 7 Time history of bacteria concentrations at station 18827, South Nolan Creek at Twin Creek Dr in Killeen.

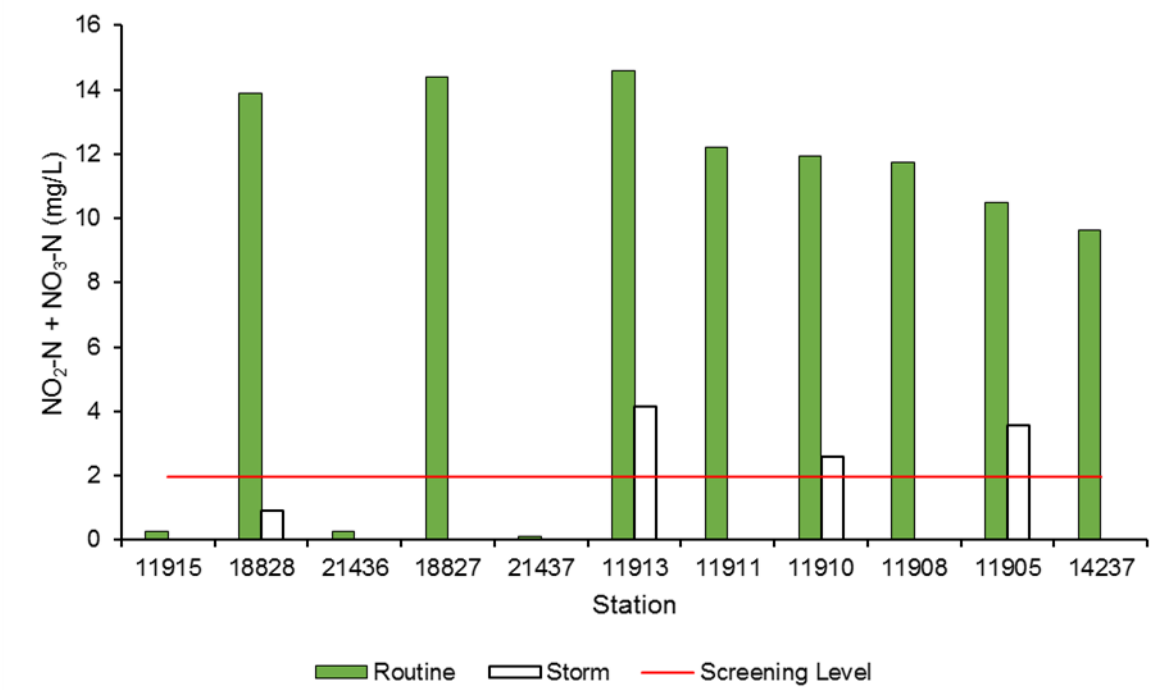

Figure 8 Median NO_2-N+NO_3-N concentrations from routine grab and storm compared to screening level of 1.95 mg/L. Stations ordered from most upstream to downstream.

Observations:

Controlling bacteria concentrations during dry-weather conditions or baseflow can be challenging, as the source in many areas may not be readily apparent. Within the Nolan Creek/South Nolan Creek watershed, the lowest bacteria concentrations for routine grabs consistently occurred at the two most upstream stations (see Figure 3). These were stations 11915 (just upstream of the discharge from the Bell County WCID1 Main Plant WWTF discharge) and 18828 (located at 38th St in Killeen, just below the WCID1 Main Plant WWTF discharge). Only stations 11915 and 18828 indicated geometric mean of *E. coli* concentrations for routine grab samples below the criterion level of 126 MPN/100 mL for primary contact recreation (Figure 3). It was unclear why bacteria concentrations were so low at these two stations and higher at other monitored stations with similar land uses. One possibility is that the water near station 18828 is largely from groundwater. Groundwater is often associated with lower bacteria concentrations as the water is filtered through the ground. While fairly high up in the drainage above these two stations, there is also an instream reservoir, which would also aid in filtering bacteria (see Figure 2 within AU 1218B). More elevated concentrations of bacteria at station 18828 in stormwater runoff were indicated during wet-weather conditions reflecting higher bacteria contributions with surface runoff. The bacteria concentrations at station 18828 were slightly higher than those at station 11915 and did appear to correspond with average daily concentrations reported by the Bell County WCID1 Main Plant for *E. coli* reflecting then this contribution in conjunction with upstream contributions. The average daily concentrations from

the Bell County WCID1 Main Plant were also below the 126 MPN/100 mL criterion except on a couple of occasions in the late summer and fall of 2013.

From station 18828 at 38th St in Killeen to station 18827 at Twin Creek Dr in Killeen, a very notable increase in *E. coli* concentrations occurred for routine grab samples (Figure 3). This increase in concentration appeared to be related to inflows for Long Branch, which was monitoring at station 21436. Geometric mean *E. coli* concentrations for stations 18828 and 21436 were very similar. It is not clear what the contributing source along Long Branch, although SSOs are suspected as well as fairly high density of OSSFs in this drainage area.

Between stations 18827 at Twin Creek Dr and station 11913 at Roy Reynolds Road, there is an apparent decrease in concentrations of *E. coli* (Figure 3). Little Nolan Creek, which flows into South Nolan Creek just prior to station 11913 shows very similar geometric mean concentrations of E. coli to station 11913. Within Little Nolan Creek, as with Long Branch, SSOs and OSSFs are suspected as the major contributing sources, although this connection cannot be clearly made. Within the Little Nolan Creek watershed, only a few SSOs have been reported, although one did lead to a fish kill in October 2013. Little Nolan Creek does have the highest density of OSSFs within the city limits of Killeen and seepage from these OSSFs may also be contributing to some of the higher *E. coli* concentrations along Little Nolan Creek, and, thus, to South Nolan Creek.

From station 11913 at Roy Reynolds Road in Killeen to station 11911 at US 190 in Harker Heights, a notable increase in E. coli concentrations. This indicates some contributing bacteria source between these two locations. Of the available information, a high frequency of SSO events within Harker Heights appear to be a likely source for this increase in bacteria loading.

From station 11911 to station 11905 at Backstrom Crossing near the end of AU 1218_02, the geometric mean *E. coli* concentrations with routine monitoring appear to generally decrease with increasing flows associated with increasing drainage area (Figure 6). There are still contributing sources between these stations, but largely dilution with increasing drainage area appears to largely explain the decreasing in *E. coli* concentrations observed.

At station 14237 in Belton, there is a slight increase seen in *E. coli* concentrations compared to station 11905 at Backstrom Crossing. At station 14237, which is located within the Yettie Polk Park, birds were noted as nesting near the bridge at this location and ducks and geese were often seen when sampling. While water quality samples were located upstream of the bridge at this location, studies have shown that bridge nesting by birds can have a localized impact of increasing bacteria concentrations (Pendergrass et al., 2015).

While sources of bacteria cannot be clearly defined as causing elevated bacteria concentrations, it appears that during dry-weather conditions or baseflow that SSOs and OSSFs may be notable sources, particularly along Long Branch and Little Nolan Creek and the area near station 11911 within Harker Heights. It is speculated that unseen sewage seepage, whether from OSSFs or leaking sewer lines, may be things to consider if seen sources above ground do not appear to be the apparent cause. During wet-weather conditions, bacteria concentrations increase quite notably with rainfall runoff. Contributing sources of bacteria to the land surface, thus, need to be a focus for controlling bacteria concentrations during wet-weather conditions.

Task 6: Watershed Characterization – Identification of Causes, Sources and Estimation of Pollutant Load Reductions

Results:

Load duration curves and use of SELECT were modeling tools applied to aid in estimating needed load reductions and targeting potential sources within the watershed. The full finding from Task 6 are presented in the following report:

Characterizing Potential Pollutant Loads to Nolan Creek/South Nolan Creek[25] (Note: This report is currently part of a 30 day public review period. The report will be finalized prior to the public review period).

A summary of the major results within this report are presented below.

For the Nolan Creek/South Nolan Creek watershed, LDCs were developed for four location at which direct monitoring data. These were stations (see Figure 2)

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

The geometric mean criterion for *E. coli* of 126 MPN/100 mL from the Texas State Water Quality Standards (TSWQS) was used as the target level for LDCs. To further inform, measured data were categorized as influenced by wet or dry weather conditions based on the parameter days since last significant precipitation (DSLP, parameter code 72053). If DSLP was recorded as less than 4 days, the sample was considered to be wet-weather influenced.

For all four stations, measured bacteria loadings for high flows were associated with wet-weather events with all values exceeding the allowable loading based on the 126 MPN/100 mL criterion (Figures 9-12). For moderate flows, loadings during wet and dry events at all stations generally exceeded criterion loadings, except at station 18828. At station 18828, the most upstream station located along South Nolan Creek at 38th Street in the City of Killeen, most dry event samples collected under moderate flow conditions led to loadings below the criterion load. In almost all cases, loadings associated with wet-weather events lead to higher loadings than dry-weather events monitored under similar flow conditions. Similar to moderate flows, all stations, but 18828, indicated geometric mean loadings above the criterion loading level.

[25] http://t-nn.tarleton.edu/docs/nolan_creek/publications/Nolan_LDC_SELECT_Report(23Nov2015)public_review.pdf

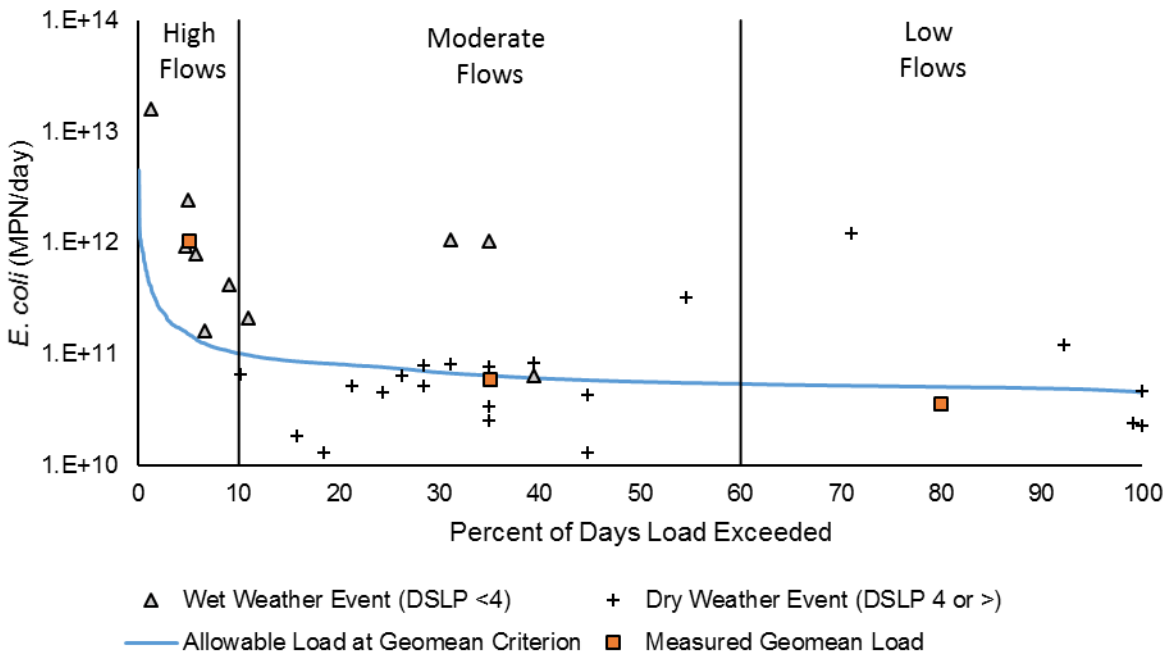

Figure 9 Load duration curve for station 18828, South Nolan Creek at 38th Street.

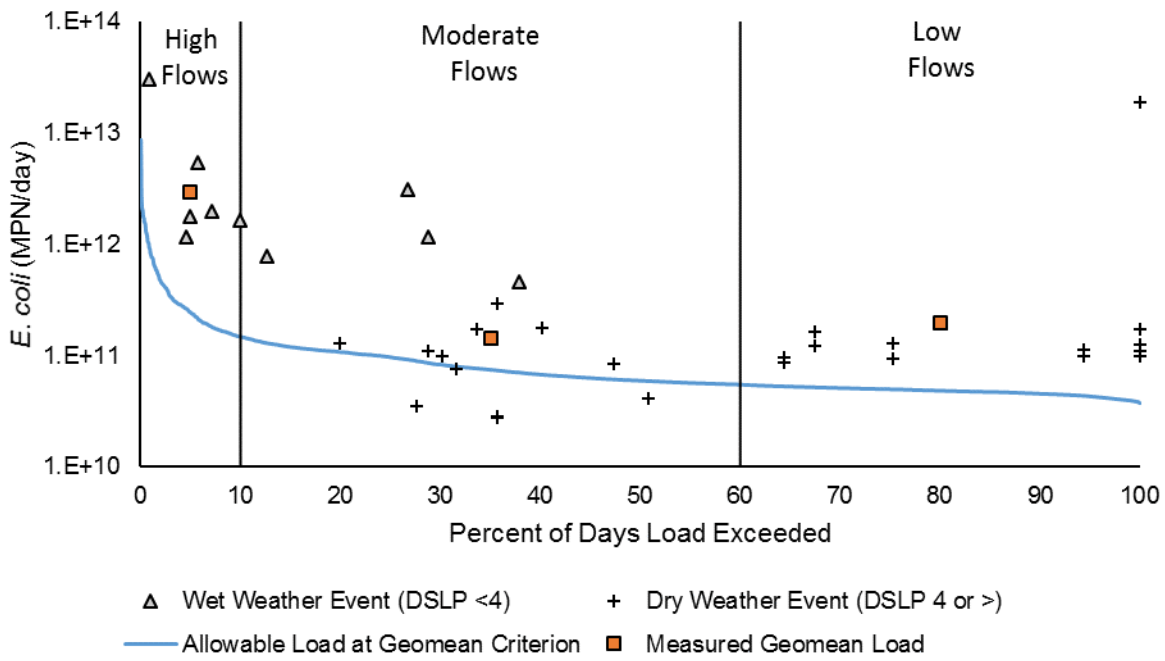

Figure 10 Load duration curve for station 11913, South Nolan Creek at Roy Reynolds Road.

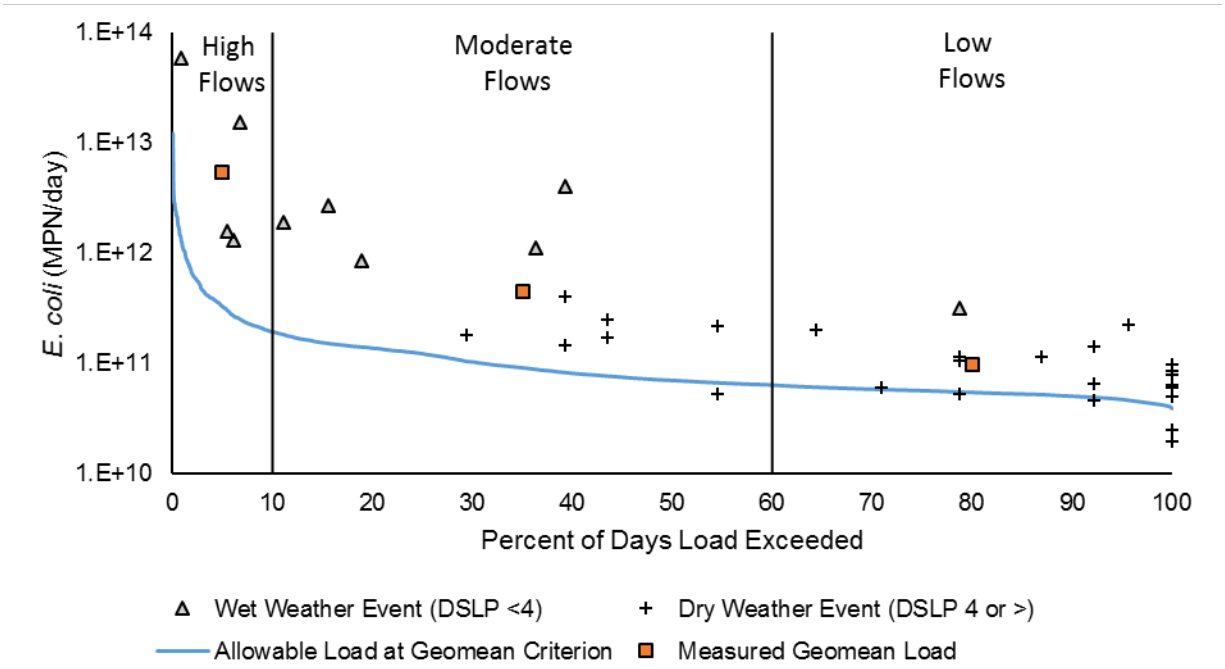

Figure 11 Load duration curve for station 11910, Nolan Creek at US 190.

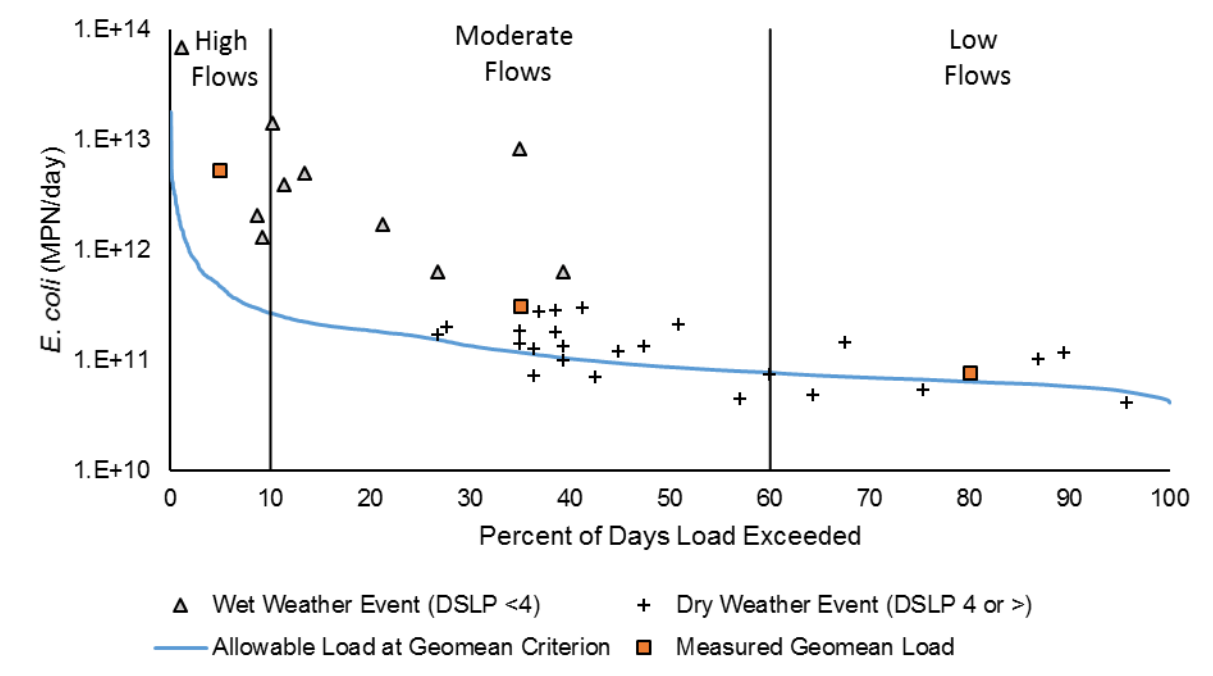

Figure 12 Load duration curve for station 11905, Nolan Creek at Backstrom Crossing.

To satisfy part of EPA's nine elements for watershed plans (EPA, 2008), estimates of percent reductions were calculated within each flow regime and are presented in Table 5. The highest estimated load reductions were noted during high flows as over 90 percent at all four stations. For moderate and low flows, no reductions were noted for station 18828 with negative reduction percentages. The highest percent reduction during moderate flows was noted at station 11910 for Nolan Creek at US 190. The highest percent reduction during low flows was noted at station 11913 on South Nolan Creek at Roy Reynolds Road between the City of Killeen and the City of Harker Heights.

Table 5 Geometric mean concentrations of measured bacteria values by flow regime and estimated percent reductions needed to meet the primary contact recreation criterion of 126 MPN/100 mL for four stations along Nolan Creek/South Nolan Creek. Negative percent reductions indicate the criterion is already met and reductions are not necessary.

Station	High Flows (0-10%)		Moderate Flows (10-60%)		Low Flows 60-100%)	
	Geometric Mean *E. coli* (MPN/100 mL)	Estimated Percent Reduction	Geometric Mean *E. coli* (MPN/100 mL)	Estimated Percent Reduction	Geometric Mean *E. coli* (MPN/100 mL)	Estimated Percent Reduction
18828	865	85%	116	-8%	88	-44%
11913	1521	92%	243	48%	509	75%
11910	2049	94%	616	80%	227	44%
11905	1405	91%	326	61%	149	16%

Use of SELECT, divided the watershed into subbasins and largely used information about density characteristics and land use to develop a summary of potential loadings from various sources. The land use of the watershed is depicted in Figure 13 and the major sources considered for bacteria are outlined in Table 6.

While the methods used for estimating various potential loadings from regulated and non-regulated sources differed using SELECT, combining them presents an overall picture of potential "hot spots" within the watershed (Figure 14). Of note, even subbasins with low potential loadings (those in dark green in Figure 14) still may have loadings exceeding the criterion. For example, the lowest total potential loading was estimated in subbasin 5 as 2.85E+12 cfu/day. Under moderate flow conditions for the LDCs, allowable loads were 2.69E+11 cfu/day or less (see Figures 9 - 12).

Potential loading by source and subbasin are shown in a tabular format in Appendix B of the report, *Characterizing Potential Pollutant Loads to Nolan Creek/South Nolan Creek*, along with the percent comprised by each source within subbasin. This aids in identifying potential impairment sources by subbasin for bacteria that need to be controlled, an important element in watershed based planning (EPA, 2008). In the more western portion of the watershed, urban stormwater and pet waste appeared to be the dominant potential sources, while in the mid-portion of the watershed in the yellow-colored subbasins, cattle appeared as the dominant potential source.

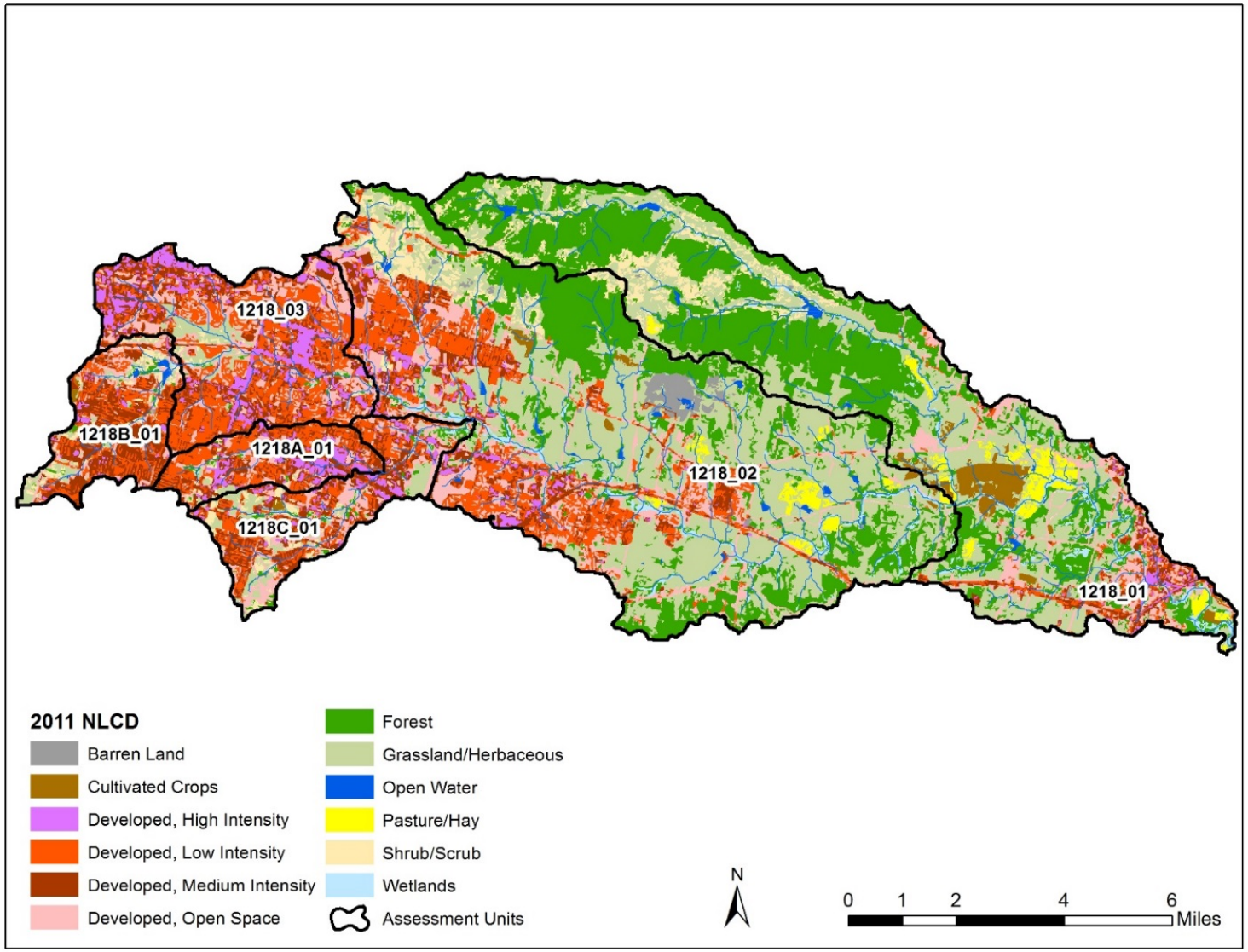

Figure 13 Land use/land cover for the Nolan Creek/South Nolan Creek watershed showing developed subcategories. Source: 2011 National Land Cover Database (USGS, 2014a).

Table 6 Production rates of *E. coli* by source. Production rates generally based on values for raw waste unless otherwise specified. Production rates are in colony forming units (cfu) per day. Source: EPA (2001) unless otherwise noted.

Source	Production Rate, *E. coli* (cfu/day) [a]	Load Calculation (cfu/day)
Municipal Wastewater Discharges	126 cfu/100 mL[b]	Production rate times permitted discharge in milliliters
Urban Stormwater	2.87×10^2 to 1.04×10^6 [c]	Estimated runoff volume times *E. coli* loading associated with impervious cover from 1 to 100 percent of land area
Cattle	10×10^9 cfu/day * 0.5	Production rate times number of cattle
Sheep/Goats	1.2×10^{10} cfu/day * 0.5	Production rate times number of sheep & goats
Horses	4.2×10^8 cfu/day * 0.5	Production rate times number of horses
Feral Hogs	1.1×10^{10} cfu/day * 0.5	Production rate times number of hogs
Deer	3.5×10^8 cfu/day * 0.5	Production rate times number deer
Dogs	5×10^9 cfu/day * 0.5	Production rate times number of dogs
On-Site Sewage Facilities	10×10^6 cfu/100 mL * 0.5	Production rate times potential failure discharge amount

a. Production rate values multiplied by 0.5 are in units of fecal coliform original and converted to *E. coli* using a conversion factor suggested by Doyle and Erikson (2006).

b. For permitted dischargers, the criterion of 126 cfu/100 mL associated with primarily contact recreation was used as the maximum potential production rate for bacteria in potential load calculations.

c. Production rates for urban stormwater runoff based on estimates from a study by PBS&J (2000) with the curve adjusted for a zero intercept as the percent impervious cover reaches zero.

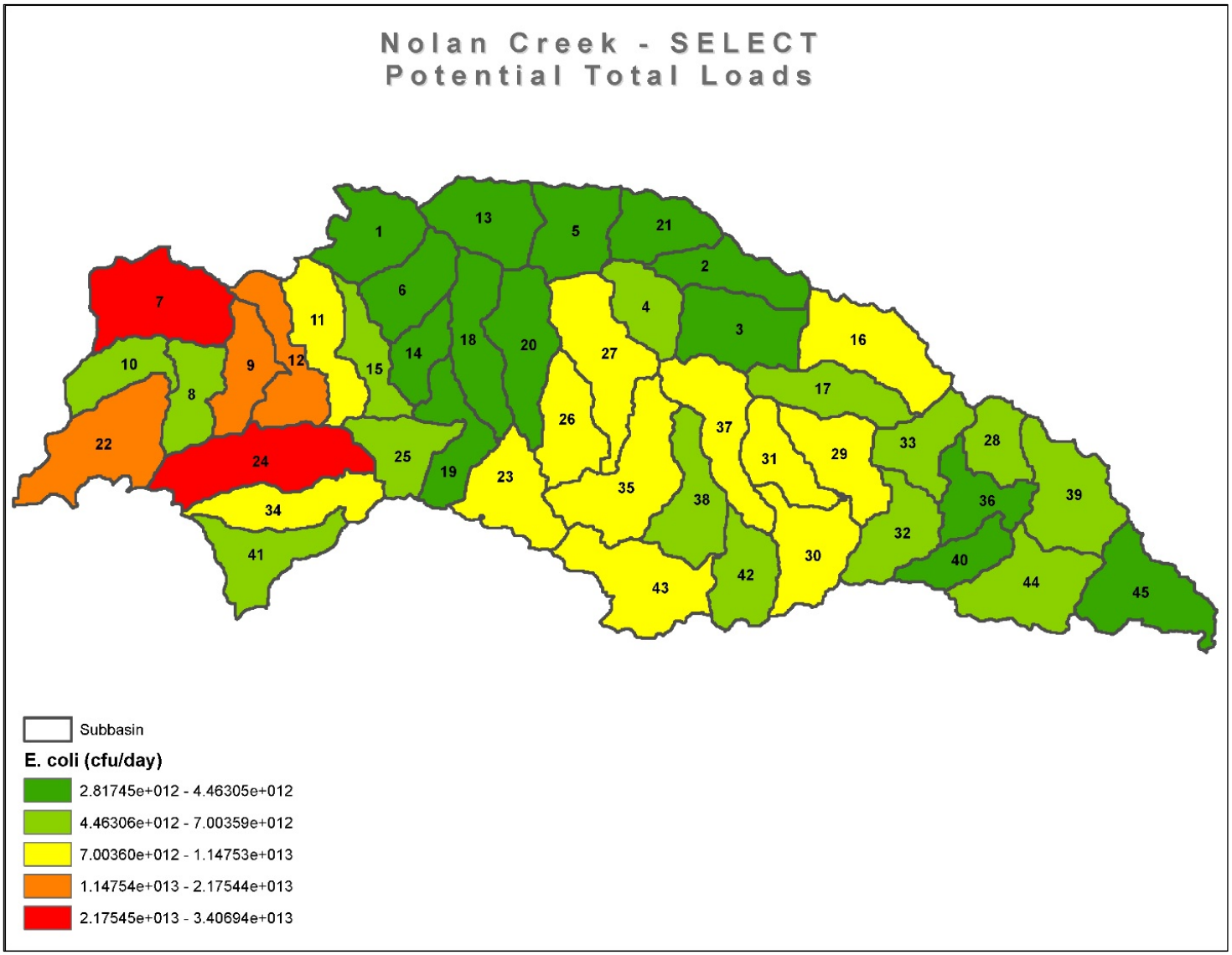

Figure 14 Distribution of potential *E. coli* loads from all SELECT sources by subbasin within the Nolan Creek/South Nolan Creek watershed.

Observations:

Use of LDCs and SELECT help highlight flow conditions and potential sources of bacteria loadings in the Nolan Creek/South Nolan Creek watershed. The LDCs indicate that wet-weather events generally associated with nonpoint sources lead to the highest loadings during high and moderate flows, but that some excursions above criterion occur during low flow conditions indicating a need to control some dry weather contributions. The SELECT maps provide a spatial representation of the potential major sources, which for the Nolan Creek/South Nolan Creek watershed include urban stormwater and pets in the western portion of the watershed and cattle predominately in the mid-portion of the watershed. A focus then is to match up what these two tools tell us about actual and potential loadings in the watershed with what we know about instream water quality.

Of note, LDCs match assessment data in indicating bacteria concentrations below assessment levels during low and moderate flows at the most upstream station, 18828 (Figure 9). Some subbasins from SELECT above station 18828 (subbasins 7, 9, 12 and 22; see Figure 14) in contrast indicated some of the highest potential loadings, primarily from urban stormwater runoff (Figure 14). This is a case where potential loadings may already be adequately controlled in that water quality is already meeting target levels. The same appears to be apparent for SELECT subbasin 24, which represents assessment unit 1218A. Based on results presented in the TCEQ 2012 Texas Integrated Report, AU 1218A is in compliance for bacteria (TCEQ, 2013a), even though some of the highest potential bacteria loadings are associated with this subbasin.

The areas of the watershed noted as impaired for bacteria are AU 1218C, Little Nolan Creek, and 1218_02, portions of South Nolan Creek (see Figure 1). Station 11913 is located on South Nolan Creek below the confluence with of Little Nolan Creek. The SELECT subbasins associated with the area between monitoring stations 18828 and 11913 not associated with Little Nolan Creek (subbasins 1, 6, 14, 15, 18, and 19) show potential loadings primarily from urban stormwater and pets, but also cattle (see Appendix B of the report). Along Little Nolan Creek (subbasins 25, 34, and 41), urban stormwater and pets were the dominant potential sources, although OSSFs were also a minor but notable potential contributor.

Further along South Nolan Creek at station 11910, bacteria loads are generally higher compared to those at station 11913 using the LDC analysis (Figures 10 and 11). The SELECT subbasins do not break exactly between stations 11913 and 11910, but are mainly subbasins 18, 20, 23, 26, and 27. Of these five subbasins, cattle is the dominant potential source in subbasins 20, 26, and 27; urban stormwater is the dominant potential source in subbasin 23; and within subbasin 18, cattle and pets are dominant followed by urban stormwater as potential loading sources. While urban land is prominent in the watershed, it appears in the area between stations 11913 and 11910 a focus on both urban and agricultural sources is needed to target reduction efforts.

Moving further downstream to station 11905, loadings are still above target levels based on the LDCs for low and moderate flows, but much closer to compliance levels than those noted at station 11913. Between stations 11910 and 11905, SELECT output indicates cattle as the dominant potential source. Other prominent sources in this area include urban stormwater with subbasin 35, but then pets, sheep/goats, and feral hogs in the more rural subbasins (29-32, 37, 38, and 43).

Overall, SELECT indicates a mix of urban and rural land uses contributing to the potential bacteria loading within the Nolan Creek/South Nolan Creek watershed. SELECT also shows that in relation to instream water quality data, some areas, such as above station 18828 the most upstream station monitored, that what is indicated as potential sources may not be a problem, at least not during baseflow conditions associated with most assessment monitoring. The SELECT methodology enables a pictorial presentation of the potential bacterial loadings from what are considered common sources within a watershed. It should be emphasized that SELECT does not depict all sources nor actual loadings. The purpose of applying SELECT, as well as LDCs, is to engage stakeholders in identifying sources within impaired waterbodies, and also to help them determine cost-effective restoration efforts to reduce bacteria loadings in the watershed, thus, preserving its use for primary contact recreation.

Task 7: Information and Education Component

Results:

For Task 7, an educational and outreach plan was developed and fully presented in the following report:

Outreach and Education Strategy for the Nolan Creek/South Nolan Creek Watershed[26] (Note: This report is currently part of a 30 day public review period. The report will be finalized prior to the public review period).

The Nolan Creek Watershed Partnership will provide or help facilitate workshops, outreach initiatives, and educational material with the goal to engage stakeholders and educate them on the importance of proper watershed stewardship. Table 7 summarizes activities within the watershed that the Partnership plans to develop or help facilitate. Of note, many of the urban programs are already addressed within the stormwater management plans associated with MS4 permits, but the Partnership can help advertise these programs as part of a broader watershed-wide effort to improve water quality. For the rural or agricultural programs, the Partnership plans to partner with AgriLife and other agencies to facilitate programs and workshops already developed.

[26] http://t-nn.tarleton.edu/docs/nolan_creek/publications/Outreach%20and%20Education%20Strategy_(08Dec2015)_Reviewforpubliccomment.pdf

Table 7 Proposed outline of education and outreach activities.

Outreach Activity	Host &/or Delivery Agency	Proposed Number of Programs or Items		
		Years 1-3	Years 4-6	Years 7-10
Nolan Creek Partnership Outreach - Awareness & Informational Materials				
Website	Nolan Creek Partnership	1	1	1
Fact Sheet		1	1	1
Newsletters		3	3	3
Brochures		1	1	1
Fliers		4	4	4
Signage			3	3
Displays at Local Events		8	12	12
Regional Nonpoint Source Pollution Educational Programs				
Texas Watershed Steward Training	Nolan Creek Partnership & Cities (host) with Texas AgriLife with TWRI (delivery agency)	1		
Texas Stream Team Training	Nolan Creek Partnership & Cities (host) with Texas Stream Team (delivery agency)	2	2	2
Septic System Workshops	Nolan Creek Partnership & Cities (host) with Texas AgriLife with TWRI (delivery agency)		1	1
Riparian Proper Functioning Condition Training	Nolan Creek Partnership & Cities (host) with Texas Riparian Association (delivery agency)		1	1
Public School Educational Program	Nolan Creek Partnership & Cities (host & delivery agency)		2	2
Agricultural Nonpoint Source Pollution Educational Programs				
Nutrient Management	Nolan Creek Partnership (advertising & supporting) with Texas AgriLife (delivery agency)		2	2
Soil & Water Testing			2	2
Livestock Grazing Management Education			2	2

Outreach Activity	Host &/or Delivery Agency	Proposed Number of Programs or Items		
		Years 1-3	Years 4-6	Years 7-10
Agricultural Waste Pesticide Collection Events	Nolan Creek Partnership (hosting) with TCEQ (delivery agency)		1	1
Lonestar Healthy Streams	Nolan Creek Partnership (hosting) with Texas AgriLife (delivery agency)		1	1
Feral Hog Management Workshop	Nolan Creek Partnership (hosting) with Texas AgriLife (delivery agency)		1	2
Whitetail Deer Management Workshop	Nolan Creek Partnership (hosting) with Texas AgriLife (delivery agency)		1	2
Urban Nonpoint Source Pollution Educational Programs				
Pet Waste	Nolan Creek Partnership (advertising & supporting) with Cities, Texas AgriLife, Centex Sustainable Communities Partnership (hosting)		1	1
Illegal Dumping			1	1
Fats, Oil, Grease			1	1
Sports & Athletic Field Education			1	1
Low Impact Development			1	1
Urban Nutrient Management			1	1
Stormwater BMP Demonstrations			1	1
Local Government Maintenance Education			1	1
Stream Cleanup Events	Nolan Creek Partnership & Cities (advertising & supporting) with Keep Texas Beautiful (hosting)		1	1
Recreationalist Anti-Litter Campaign	Cities & County (Hosting)		1	1
Storm Drain Inlet Marking Events	Cities (Hosting)		1	1

Observations:

Outreach and education are powerful and effective tools in watershed protection efforts. Both help develop an awareness of the value of our water resources, educate people on what is threatening those resources, and encourage protection and restoration action. When done efficiently, outreach can educate stakeholders on the causes of water pollution and provide solutions. However, most importantly, outreach and education can help to change behaviors and promote responsible attitudes and actions within the Nolan/South Nolan Creek watershed.

Outreach programs can involve a tremendous amount of effort and resources. To make sure resources are being effectively used, the time involved, cost, and stakeholder participation will be tracked. A planning evaluation will be conducted at least once every three years to assess whether objectives are being met, the effectiveness of materials distributed, and if appropriate target audiences are being reached. On an annual basis, a process evaluation will be conducted logging the cost of activities and the timing and frequency with which materials were distributed, so adjustments can be made in the frequency and message being delivered. Evaluating the impact of these efforts will provide a feedback mechanism for ongoing improvement of the outreach effort. Impact evaluations will occur at least annually and may be applied at various workshops or other gatherings of stakeholders. The proposed impact evaluation tool is further described in the project report, *Outreach and Education Strategy for the Nolan Creek/South Nolan Creek Watershed*.

Discussion

The goals of this project were to identify causes and sources of pollution in Nolan Creek/South Nolan Creek watershed and to develop an Information/Education Strategy that provided stakeholders and agencies with sufficient information to address the bacteria impairment through future development of a watershed protection plan (WPP) or total maximum daily load (TMDL). To meet these goals, 11 measures of success were outlined in the project workplan, which were met within the project timeframe. These 11 measures of success are discussed below.

1. Adherence to TCEQ's administrative requirements

   Satisfactory performance – Some issues occurred with regard to compliance to the required financial reporting and invoicing, but these issues were worked out with TCEQ. All other administrative requirements were handled well between TIAER and TCEQ.

2. Timely submittal of QPRs and deliverables

   Satisfactory performance – The majority of deliverables were on time or prior approval was received to move due dates.

3. Acceptance of the original QAPP and annual updates by TCEQ

   Satisfactory performance – There were some delays in development of the original QAPPs, but once developed, they were updated on timely basis.

4. Conformance to QAPP revisions

   Satisfactory performance – Conformance to the QAPPs was followed and any nonconformance issues were documented in with corrective actions reports to TCEQ as noted in QPRs.

5. TCEQ and Stakeholder approval of the PPP, a community-based Stakeholder Group process where problems are identified, awareness and education are promoted, information is disseminated, dialogue and discussion of issues occurs, feedback is exchanged with the community, and the decision making process is facilitated by stakeholder input.

   Completed – The PPP was approved by stakeholders and a community-based approach was used in the project with biannual stakeholder meetings. All reports disseminated and findings were presented at stakeholder meetings for review and comments. Input from stakeholders was encouraged and an evaluation tool used to gage stakeholder knowledge, concerns, and areas of focus for future engagement. Communication with stakeholders was facilitated through a project website and through media sources. The project hosted a Texas Watershed Steward workshop to increase stakeholder knowledge of nonpoint source water quality issues and promoted Texas Stream Team trainings to encourage volunteer monitoring in the watershed.

6. Publication of a data inventory and map, or series of maps, which shows point and nonpoint sources of pollution by group and provides tables of data regarding existing point and NPS of pollution, TCEQ and stakeholder approval of the Watershed Characterization -Phase 1 Report.

Completed –There were some delays in getting the Phase 1 Watershed Characterization report developed in that it took longer than expected to get compile and understand the large inventory of data comprised within this report.

7. Collection and submittal of monitoring data.

   Excellent performance – Monitoring data were collected according to QAPP guidance and all data submittals occurred in a timely fashion in the appropriate format.

8. TCEQ and Stakeholder acceptance of the Watershed Characterization -Phase 2 Report;

   Completed – Report very detailed and well received. Considered very informative by stakeholders.

9. Identification of the causes and sources of water quality problems and estimation of pollutant loadings at a subcategory level and subwatershed level within the watershed;

   Good performance – Potential sources by subbasin identified and load reductions estimated using LDCs and SELECT.

10. TCEQ and stakeholder approval of the Watershed Characterization -Phase 3 Report; and

    Completed – The identification of causes and sources using the modeling tools outlined for the project (LDCs and SELECT), still left some unknowns with regard to specific sources. While the stakeholders approved the report, they also voiced a desire for bacteria source tracking to be implemented in the watershed to better identify contributing sources.

11. Development of Education and Outreach Component in the Plan with an evaluation component that measures success qualitatively and quantitatively ensuring the needed impact was generated and that the education and outreach goals of the project were met.

    Completed – Education and outreach strategy has been developed including an evaluation tool that was implemented within the project and will be used to evaluated the success of future education and outreach efforts.

Summary

The project was successful in characterizing the watershed and producing the information needed by stakeholders to determine how best to address the bacteria impairment within the Nolan Creek/South Nolan Creek watershed. Stakeholders will be moving forward toward development of a WPP. Facilitation of this WPP will be conducted by TIAER through a CWA 319(h) grant entitled, *Nolan Creek/South Nolan Creek Watershed Protection Plan (WPP)*. This new project is contract number 582-16-60281 with TCEQ and EPA Federal Grant number C9-99614620. The data and information gathered under the current CWA 319(h) project will provide the foundation for the Nolan Creek/South Nolan Creek WPP.

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