Clean Water Act Section 319(h) Nonpoint Source Pollution Control Program Project

Bacterial Monitoring for the Buck Creek Watershed

Quality Assurance Project Plan

Texas State Soil and Water Conservation Board

prepared by

Texas Water Resources Institute
Texas A&M Vernon Agricultural Research and Extension Center

Effective Period: November 1, 2003 to September 30, 2007

Questions concerning this quality assurance project plan should be directed to:

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Section A1: Approval Sheet

Bacterial Monitoring for the Buck Creek Watershed

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Name: Donna Miller
Title: Chief; State/Tribal Programs Section

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Signature: _____ Date:_____

Texas State Soil and Water Conservation Board (TSSWCB)

Name: Thomas J Helton
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Signature: _____ Date:_____

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Name: George D. Di Giovanni, Ph.D.
Title: Associate Professor, Environmental Microbiology; Project Advisor

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Name: C. Allan Jones, Ph.D.
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Name: Kevin Wagner
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Section A2: Table of Contents

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List of Acronyms and Abbreviations

ACS	American Chemical Society
AREC	Agricultural Research and Extension Center
BMP	best management practices
BST	bacterial source tracking
CAR	corrective action report
CR	county road
CFU	colony forming units of bacteria
COC	chain of custody
CWA	Clean Water Act
DO	dissolved oxygen
DQO	data quality objectives
EP AREC	Texas A&M El Paso Agricultural Research and Extension Center
EPA	United States Environmental Protection Agency
FM	Farm to Market Road
GPS	global positioning system
ID	identification
LIMS	laboratory information management system
MAL	minimum analytical level
MDL	minimum detection limit
NIST	National Institute of Standards and Technology
NPS	nonpoint source
PM	project manager
QA	quality assurance
QAO	quality assurance officer
QAPP	quality assurance project plan
QC	quality control
RPD	relative percent deviation
RRA	Red River Authority
SOP	standard operating procedure
SH	state highway
SM	Standard Methods for the Examination of Water and Wastewater
SWCD	Soil and Water Conservation District
TAMU	Texas A&M University (College Station campus implied)
TCE	Texas Cooperative Extension
TCEQ	Texas Commission on Environmental Quality
TMDL	total maximum daily load
TSSWCB	Texas State Soil and Water Conservation Board
TWRI	Texas Water Resources Institute
USEPA	United States Environmental Protection Agency
USGS	United States Geological Service

Section A3: Distribution List

Organizations, and individuals within, which will receive copies of the approved QAPP and any subsequent revisions include:

United States Environmental Protection Agency, Region VI

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Title: Associate Professor, Environmental Microbiology; Project Advisor

Section A4: Project/Task Organization

The following is a list of individuals and organizations participating in the project with their specific roles and responsibilities:

USEPA – Provides project overview and funding at the Federal level.

Ellen Caldwell, USEPA Texas Nonpoint Source Project Manager
Responsible for overall performance and direction of the project at the Federal level. Ensures that the project assists in achieving the goals of the federal Clean Water Act (CWA). Reviews and approves the quality assurance project plan (QAPP), project progress, and deliverables.

TSSWCB - Provides project overview and funding at the state level.

Thomas J Helton, TSSWCB Project Lead
Responsible for ensuring that the project delivers data of known quality, quantity, and type on schedule to achieve project objectives. Tracks and reviews deliverables to ensure that tasks in the work plan are completed as specified.

Donna Long, TSSWCB Quality Assurance Officer
Reviews and approves QAPP and any amendments or revisions and ensures distribution of approved/revised QAPPs to TSSWCB and USEPA participants. Responsible for verifying that the QAPP is followed by project participants. Determines that the project meets the requirements for planning, quality assessment (QA), quality control (QC), and reporting under the CWA Section 319 program. Monitors implementation of corrective actions. Coordinates or conducts audits of field and laboratory systems and procedures.

TWRI – Provides the primary point of contact between the Texas State Soil and Water Conservation Board (TSSWCB) and the project contractors. Tracks and reviews deliverables to ensure that tasks in the work plan are completed as specified. Responsible for coordination, review, and delivery of quarterly reports and the final project report.

Dr. C. Allan Jones, TWRI Director; Project Coordinator
Responsible for ensuring that tasks and other requirements in the contract are executed on time and as defined by the grant work plan; assessing the quality of work by participants; submitting accurate and timely deliverables and costs to the TSSWCB Project Lead; and coordinating attendance at conference calls, meetings, and related project activities.

Kevin Wagner, TWRI Quality Assurance (QA) Officer
Responsible for determining that the Quality Assurance Project Plan (QAPP) meets the requirements for planning, quality control, quality assessment, and reporting for activities conducted by TWRI.

EP AREC – Provides technical advice and direction concerning water sample collection, laboratory procedures and data analysis.

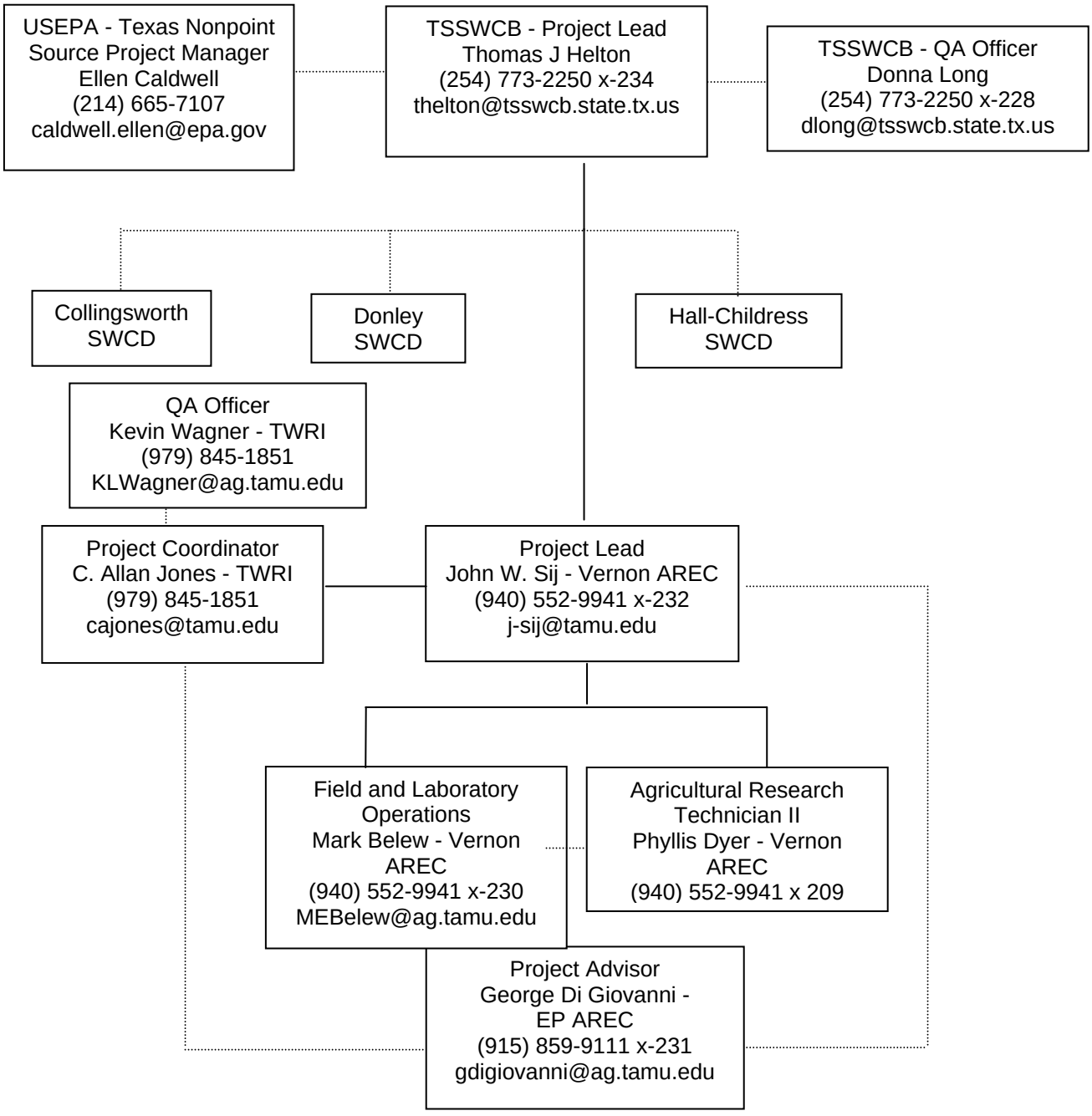
Dr. George D. Di Giovanni, Associate Professor, Env. Microbiology; Project Advisor
Responsible for technical oversight of activities involved in generating analytical data by the Vernon AREC laboratory. Responsible for general facilitation of audits and reporting of corrective actions.

Vernon AREC – Responsible for collection of ambient and storm water samples Responsible for the data analysis and interpretation in ambient and storm water samples. Vernon AREC will contribute to the development of quarterly reports and the final project report.

Dr. John W. Sij, Professor; Research and Extension Agronomist; Project Leader
Responsible for coordinating and supervising field sampling activities. Responsible for ensuring that field personnel have adequate training and a thorough knowledge of standard operating procedures (SOPs) specific to the analysis or task performed and/or supervised. Responsible for ensuring that tasks and other requirements in the contract are executed on time and with the QA/QC requirements in the system as defined by the contract work plan and in the QAPP. Responsible for verifying that the data produced are of known and acceptable quality. Responsible for ensuring adequate training and supervision of all activities involved in generating analytical data for this project. Responsible for the facilitation of audits and the implementation, documentation, verification, and reporting of corrective actions. Responsible for submitting accurate and timely data analyses and other materials for progress and final reports to TWRI.

Field Cod

Figure A.4-1 Project Organization Chart



Section A5: Problem Definition/Background

The Red River Basin includes 29 classified segments and 11 major reservoirs covering 145,169 acres. Buck Creek, also known as Spiller Creek, is a small waterbody situated within the Red River Basin and is located within a subwatershed to the Lower Prairie Dog Town Fork of the Red River (segment 207). This stream segment is located within Ecoregion 27, Central Great Plains. Small streams within this region are typically characterized by widely varying flows and high levels of dissolved salts, generally originating from saltwater seeps and springs. Buck Creek (segment 207A) is situated within a predominantly rural and agricultural landscape in the panhandle region of Texas.

Land use in the watershed is predominantly row crops and grasslands (Figure A.5-1, below). Temperatures in the region range from 25ºF to 93ºF and rainfall averages approximately 21 inches annually. During periods of rainfall, bacteria (*E. coli*, specifically) originating from aquatic birds and mammals, livestock, inadequately treated sewage, and/or failing septic systems may be washed into the streams and have the potential to impede recreational use of this waterbody. Bacterial indicators, such as *E. coli*, may remain in the streams in levels exceeding established criteria and can be measured well after a rain event has occurred. These organisms are normally found in feces of warm-blooded animals and are generally not harmful to human health, but may indicate the presence of pathogens that can cause disease.

The State of Texas requires that water quality in Buck Creek be suitable for fishing, swimming, wading, and a healthy aquatic ecosystem. However, data obtained from water quality monitoring indicates that bacteria levels are sometimes elevated in the creek. Although these data points provide an indicator of a potential water quality problem, the data do not provide conclusive evidence of persistent impairment; rather, it suggests a temporal recurring phenomenon.

Like most states, Texas does not directly monitor pathogens because of the difficulty and expense of measuring them. Instead, it tests for the presence of organisms that indicate the likely presence of pathogens—for example, *E. coli* is typically used as the indicator in the assessment of fresh water. These indicators are used to estimate the relative risk of swimming or other recreational activities involving direct contact with the water because the probability of becoming ill is greater when the bacteria counts are elevated.

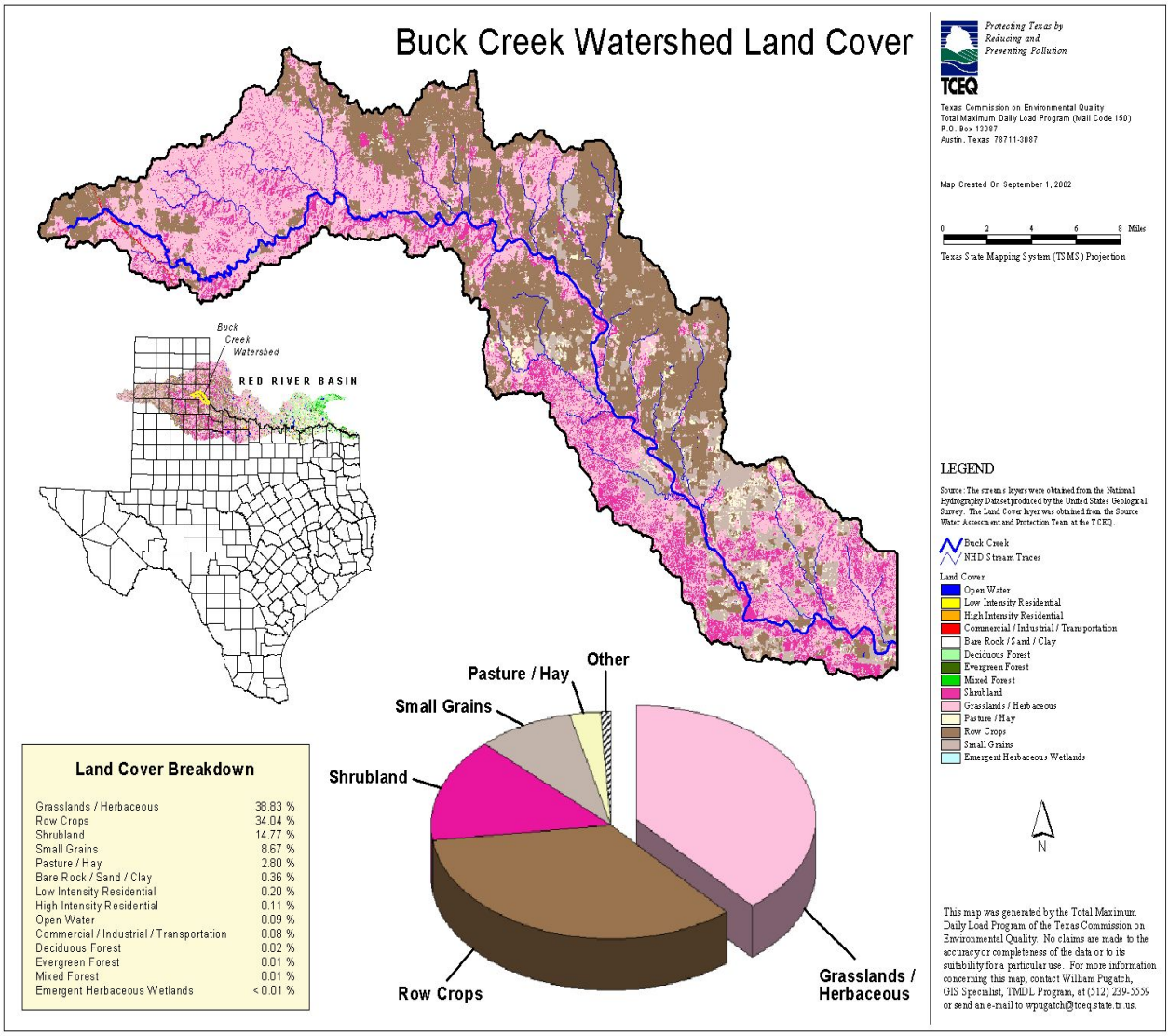
The data used to establish current bacterial loadings in the majority of classified waterbodies across the State is the result of quarterly sampling conducted through the Texas Commission on Environmental Quality (TCEQ)—Clean Rivers Program. Buck Creek is an unclassified waterbody and as such, has not been sampled at the same quarterly intervals as the classified waterbody into which it flows. Since Buck Creek has been on an intermittent sampling regime, only 20 fecal coliform samples and 14 *E. coli* samples have been collected from one designated sampling site within a five-year period.

It has been suggested that a total maximum daily load (TMDL) for bacteria can be done on several impaired segments across the state by using simple, established statistical methods to identify the timing and magnitude of observed exceedances of water quality criteria.

While this may be acceptable for waterbody segments that have sufficient data; this waterbody would be better served with the encouragement of public participation, establishment of targeted monitoring, and an educational outreach program.

The main objective of this project will be to obtain a sufficient amount of data in order to make a scientifically sound decision concerning the bacterical impairment of this waterbody segment. The secondary objective will be the establishment of community awareness, participation, and a feeling of ownership for their watershed.

Figure A.5-1. Buck Creek Watershed Land Cover



Section A6: Project/Task Description

General Project Description:

As the lead agency for the State of Texas in abating agricultural/silvicultural NPS pollution, the TSSWCB works closely with Soil and Water Conservation Districts (SWCDs), in addition to working cooperatively with various state agencies and universities to reduce NPS pollution from various agricultural activities. This project will expand the efforts and activities of TSSWCB; Hall-Childress, Donley, and Salt Fork SWCDs; Texas Water Resources Institute (TWRI), Vernon Agricultural Research and Extension Center (AREC), and Texas Cooperative Extension (TCE)**.**

In this project in Phase 1, TWRI and Vernon AREC will work with the Texas State Soil and Water Conservation Board and cooperating districts in the collection and analysis of water samples in accordance with an approved Quality Assurance Project Plan (QAPP). Vernon AREC will be responsible for collection, analysis, and compilation of water quality data as well as producing reports on project activities. All sites will be monitored for *E. coli* using modified mTEC medium and one site will also be monitored for fecal coliform bacteria using mFC medium.

The Vernon AREC will be responsible for composing the QAPP, analyzing samples in accordance with the QAPP, and composition of quarterly and final reports for this project. The Hall-Childress SWCD and TCE will collaborate in disseminating information and educational efforts related to project activities. Both the SWCD and TCE will also aid in contributing to, and reviewing of the final report as deemed necessary.

Table A.6-1. Project Plan Milestones

TASK	PROJECT MILESTONES	AGENCY	START	END
1.1	Quarterly meetings (when necessary) including project participants, landowners and other interested parties.	Vernon AREC, TWRI	Apr 04	Oct 06
1.2	Prepare quarterly reports submitted electronically to TSSWCB and distributed to project cooperators and participants.	Vernon AREC, TWRI	Apr 04	July 07
1.3	Conduct educational programs about water pollution and project findings.	TCE, SWCDs	Apr 04	Jan 07
1.4a	Develop draft final report for review by TSSWCB.	Vernon AREC, TWRI	May 06	July 07
1.4b	Submit final report to TSSWCB.	Vernon AREC, TWRI	--------	Sept 07
2.1a	Develop DQOs and QAPP for review by EPA.	Vernon AREC, TWRI	Jan 04	Feb 04
2.1b	Approve QAPP.	EPA	Feb 04	May 04
2.2	Select 12 or 13 sites to conduct water quality sampling.	SWCDs, NRCS, Vernon AREC, RRA TSSWCB	Jan 04	Feb 04
2.3	Obtain sampling locations and establish sampling process for routine and high rainfall sampling events.	Vernon AREC	Jan 04	Feb 04
2.4	Conduct routine grab sampling at selected sites within watershed.	Vernon AREC	May 04	July 07
2.5	Collect a minimum of 8 rain event grab samples (or , if less than 8, the maximum number of events for project duration)	Vernon AREC	May 04	July 06
2.6a	Analyze routine grab samples on a bi-weekly basis and high rainfall grab samples as necessary.	Vernon AREC	May 04	July 06
2.6b	Compile and analyze the sampling data.	Vernon AREC	May 04	July 06

Section A7: Quality Objectives And Criteria For Measurement Data

The objective of this section is to ensure that data collected meets the data quality objectives (DQOs) of the project. One objective is to organize an integrated team among the multiple agencies and groups involved with the project to efficiently and effectively achieve project goals and to summarize activities and achievements made throughout the course of the project. A second objective is to monitor micro-watersheds through data collection and analysis, and provide data to inform district and landowners of any potential or existing water quality issues and/or problems. Achievement of these objectives will support decisions for implementation of appropriate BMPs in order to reduce fecal bacteria levels in the Buck Creek watershed.

Following are actions that will be undertaken by this project to assess bacterial nonpoint source pollution within Buck Creek Watershed:

- Monitor water quality as related to bacterial nonpoint source pollution in Buck Creek by in-stream water sampling
- Composition of final report for Phase 1
- If monitoring data from Phase 1 studies demonstrate the need for a TMDL, appropriate follow-up (Phase 2) will be planned and implemented. Experts in bacterial source tracking will be involved and advisory to Phase 1 efforts to facilitate TMDL definitions and guidance if needed.

The measurement performance criteria to support the project objective are specified in Table A.7-1.

When sufficient flow is present, routine manual grab samples with be collected on a biweekly basis. During routine sampling, measurements of dissolved oxygen (DO), conductivity, pH, and water temperature will be obtained *in situ*. Bacteria samples will be analyzed for *Escherichia coli.* Fecal coliform will also be analyzed at the established Clean Rivers Progam site.

Table A.7-1. Data Quality Objectives for Measurement Data

NA = Not applicable; mg/L = milligrams per liter; col = colonies; mL = milliliters; in/hr = inches per hour; fps = feet per second; µS/cm = microsiemens per centimeter; ft = feet; m = meters; °C = degrees Celsius

Parameter	Units	Method Type	Method	Method Description	Storet	MDL[1] / MAL	Precision of Laboratory Duplicates	Accuracy[2]	Precision of Field Duplicates	Percent Complete[3]
Field Parameters										
Days Since Last Significant Precipitation	Days	Observation	TCEQ SOP	Field observation	72053	NA	NA	NA	NA	90
Flow Severity	1-no flow 2-low 3-normal 4-flood 5-high 6-dry	Observation	TCEQ SOP	Field observation	01351	NA	NA	NA	NA	90
Water Temperature	˚C	Meter	EPA 170.2	Automated Instrument	00020	0.2	NA	±0.25	NA	90
Specific Conductance	µS/cm	Meter	Std. Method 2510-B	Automated Instrument	00094	20 µS/cm	NA	±2% of range	NA	90
Dissolved Oxygen	mg/L (ppm)	Meter	EPA 360.1	Automated Instrument	00300	2.0	NA	±0.2	NA	90
pH	pH units	Meter	EPA 150.1	Automated Instrument	00400	0.2	NA	±0.2	NA	90
Lab Parameters										
E. coli in water	CFU/ 100 mL	Membrane filter culture on modified mTEC agar	EPA 1603	Membrane Filter	31648	1	3.27* ΣRlog/n	NA	NA	90
Fecal coliform in water	CFU/ 100 mL	Membrane filter culture on mFC agar	Std. Method 9222-D	Membrane Filter	31616	40	3.27* ΣRlog/n	NA	NA	90

[1] MDLs for field parameters represent manufacturer specifications.
[2] Manufacturer specifications are presented for accuracy limits and method detection limits for field parameters.
[3] The objective is for 90% of the data to be collected.

Precision

The precision of laboratory data is a measure of the reproducibility of a result from an analysis repeated. It is strictly defined as a measure of the closeness with which multiple analyses of a given sample agree with each other. Precision is assessed by repeated analyses of a sample. For quantitative microbiological analyses, the method to be used for calculating precision is the one outlined in Standard Methods for the Examination of Water and Wastewater, 20th Edition, section 9020 B.8.b.

$$RPD_{bacteria} = (\log X_1 - \log X_2)$$

The RPDbacteria should be lower than 3.27 ΣRlog/n, where Rlog is the difference in the natural log of duplicates for the first 15 positive samples.

Accuracy

Accuracy is a statistical measurement of correctness and includes components of systemic error. A measurement is considered accurate when the result reported does not differ from the true situation. Performance limits are specified in Table A.7-1.

An additional element of accuracy is the absence of contamination. This is determined through the analysis of field blank samples of sterile water taken to the field and processed in a manner identical to the sample. Requirements for field blank samples are discussed in Section B5.

Representativeness

Data collected under this project will be considered representative of ambient water quality conditions. Representativeness is a measure of how accurately a monitoring program reflects the actual water quality conditions typical of a receiving water. The representativeness of the data is dependent on 1) the sampling locations, 2) the number of samples collected, 3) the number of years and seasons when sampling is performed, 4) the number of depths sampled, and 5) the sampling procedures. Site selection procedures will assure that the measurement data represent the conditions at the site. The goal for meeting total representation of the water body and watershed is tempered by the availability of time and funding. Representativeness will be measured with the completion of sample collection in accordance with the approved QAPP.

Comparability

The comparability of the data produced is predetermined by the commitment of the staff to use only approved procedures as described in this QAPP. Comparability is also guaranteed by reporting all ambient, high flow, and QC data for evaluation by others.

Completeness

The completeness of the data is a measure of how much of the data is available for use compared with the total potential data. Ideally, 100% of the data would be available. However, the possibility of unavailable data due to accidents, weather, insufficient sample volume, broken or lost samples, etc. is to be expected. Therefore, it will be a general goal of the project(s) that 90 percent data completion is achieved.

Section A8: Special Training Requirements/Certifications

All personnel involved in sampling, sample analyses, and statistical analyses have received the appropriate education and training required to adequately perform their duties. No special certifications are required. Vernon AREC personnel involved in the use of Global Positioning System (GPS) instruments, for this project, have been trained in the appropriate use of GPS, in the use of field equipment, laboratory equipment and all applicable standard operating procedures (SOPs).

Section A9: Documentation and Records

Hard copies of general maintenance records, all field data sheets, chain of custody forms (COCs), laboratory data entry sheets, calibration logs, and corrective action reports (CARs) will be archived by each laboratory for at least five years. In addition, Vernon AREC will archive electronic forms of all project data for at least five years. A blank CAR form is presented in Appendix A, a blank COC form is presented in Appendix B, and blank field data reporting forms are presented in Appendix C.

Quarterly progress reports will note activities conducted in connection with the water quality monitoring program, items or areas identified as potential problems, and any variations or supplements to the QAPP. CARs will be utilized when necessary. CARs that result in any changes or variations from the QAPP will be made known to pertinent project personnel and documented in an update or amendment to the QAPP. All quarterly progress reports and QAPP revisions wil be distributed to personnel listed in Section A3.

The TSSWCB may elect to take possession of records at the conclusion of the specified retention period.

Section B1: Sampling Process Design (Experimental Design)

One goal of this project is to organize an integrated team among the multiple agencies and groups involved with the project to efficiently and effectively achieve project goals and to summarize activities and achievements made throughout the course of the project. However, the primary goal of this project is to monitor micro-watersheds through data collection and analysis, and provide data to inform district and landowners of any potential or existing water quality issues and/or problems. Achievement of these objectives will support decisions on how to best target management measures to reduce fecal bacteria levels in the Buck Creek watershed.

This project is primarily designed to evaluate water quality parameters that indicate bacterial contamination. This project will also be used as an opportunity to educate area landowners concerning associated BMPs focused on reducing potential contamination sources within Buck Creek and it's tributaries. The waterborne constituents that will be measured are shown in Table B1-1.

Table B1-1. Waterborne Constituents

Parameter	Status	Reporting Units
Laboratory Parameters		
Fecal Coliform Bacteria	Critical	colonies per 100 milliliters (col/100ml)
Escherichia coli	Critical	colonies per 100 milliliters (col/100ml)
Field Parameters		
Dissolved Oxygen	Non-critical	milligrams per liter (mg/L)
Potential Hydrogen (pH)	Non-critical	pH standard units
Specific Conductance	Non-critical	microsiemens per centimeter (µS/cm)
Water Temperature	Non-critical	degrees Celsius (°C)
Flow Severity	Critical	1-no flow,2-low,3-normal,4-flood,5-high, 6-dry
Water level	Critical	feet (ft)

The sampling program is designed to characterize water quality of both base and high flow conditions in Buck Creek and it's tributaries. Water quality grab samples will be collected at biweekly intervals for all constituents. Routine grab samples will be scheduled for collection on a biweekly basis but will only be taken if water is flowing. Physical parameters that will be measured *in situ* during routine sampling include specific conductance, dissolved oxygen, pH, and water temperature. If a site is not flowing but pooled or dry, that will be noted on the field data sheet. Water quality samples collected as part of the routine sampling schedule will be analyzed for bacteria.

In order to obtain temporally representative results, including wet and dry conditions and seasonal variation, the ambient water sampling will occur on a routine schedule over the course of eighteen months, and capture dry and runoff-influenced events at their natural frequency, as they occur. There will be no prejudice against rainfall or high flow events, except that the safety of the sampling crew will not be compromised in case of lightning or flooding.

In the instance that a sampling site is inaccessible, no sample will be taken and will be documented in the field notebook. If, near the end of the study, the TSSWCB PM/QAO agrees that the sampling has not achieved good representativeness of typical conditions, they may restrict the final sampling event(s) to target a particular condition (e.g., rainfall).

Table B.1-2. Buck Creek Sampling Sites

CR = County Road; FM = Farm to Market Road; SH = State Highway

Site	Subwatershed & General Location	Latitude	North	Longitude	West
BC-01	Buck Creek at CR 28; *Donely County*	34	50' 07.71"	100	36' 38.67"
BC-02	Buck Creek at CR Z and CR 29; *Donely County*	34	48' 54.43"	100	35' 01.58"
BC-03	Buck Creek at CR 40; *Collingsworth County*	34	51' 25.47"	100	28' 00.93"
BC-04	Buck Creek at SH 1547; *Collingsworth County*	34	50' 47.33"	100	23' 57.71"
BC-05	Unnamed Tributary at SH 1056; *Collingsworth County*	34	51' 50.0"	100	22' 48.1"
BC-06	Buck Creek at CR 110; *Collingsworth County*	34	50' 33.04"	100	20' 46.70"
BC-07	Buck Creek at SH 338; *Collingsworth County*	34	49' 08.32"	100	16' 39.24"
BC-08	Buck Creek at CR SA; *Collingsworth County*	34	47' 27.4"	100	14' 44.6"
BC-09	House Log Creek at CR SA; *Collingsworth County*	34	47' 26.8"	100	14' 21.0"
BC-10a	Buck Creek at Scrivner Ranch (SH 256); *Childress County*	34	43' 46.4"	100	13' 41.0"
BC-10b	Buck Creek at Scrivner Ranch (SH 256); *Childress County*	34	43’ 46.4”	100	13’ 40.9”
BC-10c	Buck Creek at Scrivner Ranch (SH 256); *Childress County*	34	43’ 07.8”	100	12’ 27.2”
BC-11	Buck Creek at SH 83; *Childress County*	34	42' 08.6"	100	11' 19.5"
BC-12	Buck Creek at SH 62; *Childress County*	34	40' 09.6"	100	9' 25.1"
BC-13	Buck Creek at CR 19; *Childress County*	34	36' 39.9"	100	06' 39.4"

Section B2: Sampling Method Requirements

Typically, water samples will be collected directly from the stream (approximately one foot below the surface) into sterile wide-mouthed polypropylene bottles or bags. All sample containers will be labeled with the following information:

- collection date,
- collection time,
- sample location,
- and sampler's initials.

Care will be exercised to avoid the surface microlayer of water, which may be enriched in bacteria and not be representative of the water column. In cases where, for safety reasons, it is inadvisable to enter the stream bed, and boat access is not practical, staff will use a clean bucket and rope from a bridge to collect the samples from the stream, and pour the water into the sample bottles. If a bucket is used, care will be taken to avoid contaminating the sample. Specifically, they must exert care to ensure that the bucket and rope do not come into contact with the bridge. The bucket must be thoroughly rinsed between stations. Buckets are also to be sanitized between sampling stations with a bleach- or isopropyl alcohol-soaked wipe. The first bucketful of water collected from a bridge is used to rinse the bucket. Samples are collected from subsequent buckets of water.

Water temperature, pH, specific conductivity, and dissolved oxygen will be measured and recorded *in situ* with a multiprobe whenever samples are collected. All field measurements will be conducted in accordance with the methods listed in Table B 4-1. Measurements will only be taken if water is flowing. If a site is not flowing but pooled or dry, that will be noted on the field data sheet.

Upon collection, all samples will be transported in an iced container to the laboratory for analysis. All filtration and preservation will be performed in the laboratory.

Table B.2-1. Sample Volume, Container Types, Minimum Sample Volume, Preservation Requirements, and Holding Time Requirements.

Parameter	Matrix	Container	Preservation	Temperature	Sample Volume	Holding Time
E. coli	water	sterile plastic bottle or bag	none	4°C	125 ml	6 hours[1]
Fecal Coliform	water	sterile plastic bottle or bag	none	4°C	125 ml	6 hours[1]

[1] 6 hours to deliver to laboratory. In the case that this 6-hour holding time is not met, the *E. coli* quantitative count will be flagged, though the non-quantitative source identification will still be valid.

Documentation of Field Sampling Activities

Field sampling activities are documented on field data reporting forms as presented in Appendix C. Field observations (flow severity and days since last significant precipitation) are based on SOPs in the TCEQ's Surface Water Quality Monitoring Procedures Manual (1999). All sample information will be logged into a field log.The following will be recorded for all ambient water sampling:

- station ID
- location
- sampling time
- date
- water depth
- sample collector's name/signature

Detailed observational data are recorded including water appearance, weather, biological activity, stream uses, unusual odors, specific sample information, days since last significant rainfall, estimated hours since rainfall began (if applicable), and flow severity.

Recording Data

For the purposes of this section and subsequent sections, all field and laboratory personnel follow the basic rules for recording information as documented below:

- Legible writing with no modifications, write-overs or cross-outs;
- Correction of errors with a single line followed by an initial and date;
- Close-outs on incomplete pages with an initialed and dated diagonal line.

Failures in Sampling Methods Requirements and/or Deviations from Sample Design and Corrective Action

Examples of failures in sampling methods and/or deviations from sample design requirements include but are not limited to such things as sample container problems, sample site considerations, etc. Failures or deviations from the QAPP are documented on the field data reporting form and reported to the sampling agency Project Leader. The sampling agency Project Leader will determine if the deviation from the QAPP compromises the validity of the resulting data. The sampling agency Project Leader, in consultation with the TSSWCB QAO will decide to accept or reject data associated with the sampling event, based on best professional judgment. The resolution of the situation will be reported to the TSSWCB in the quarterly report.

Section B3: Sample Handling and Custody Requirements

Chain-of -Custody

Proper sample handling and custody procedures ensure the custody and integrity of samples beginning at the time of sampling and continuing through transport, sample receipt, preparation, and analysis. The COC form is used to document sample handling during transfer from the field to the laboratory. The sample number, location, date, changes in possession and other pertinent data will be recorded in indelible ink on the COC. The sample collector will sign the COC and transport it with the sample to the laboratory. At the laboratory, samples are inventoried against the accompanying COC. Any discrepancies will be noted at that time and the COC will be signed for acceptance of custody. (In the instance that the field sample collector and laboratory sample processor are one in the same, a field-to-lab COC will be unnecessary.) Sample numbers will then be recorded into a laboratory sample log, where the laboratory staff member who receives the sample will sign it. A copy of a blank COC form used on this project is included as Appendix B.

Sample Labeling

Samples are labeled on the container with an indelible, waterproof marker. Label information includes the site identification, the date, the sampler's initials, and time of sampling. The COC form will accompany all sets of sample containers.

Sample Handling

Following collection, samples are placed on ice in an insulated cooler for transport to the laboratory. At the laboratory, samples are placed in a refrigerated cooler dedicated to sample storage. The Laboratory Supervisor has the responsibility to ensure that holding times are met with water samples. The holding time is documented on the COC. Any problems will be documented with a corrective action report.

In the case of *E. coli* cultures:
Following the 24-hour culture incubation and subsequent enumeration, one Petri dish per sample containing a membrane filter on modified mTEC medium with 1 – 100 (preferably 10 – 40) *E. coli* colonies is labeled appropriately, placed in a sealable bag, and transferred to an insulated DOT-approved shipping container with blue ice for cooling. The laboratory sample custodian will then enclose the sample COC in the shipping container and send it via overnight courier to the EP AREC laboratory for storage, in the instance that a Bacterial Source Tracking (BST) phase (Phase II) is necessary.

Failures in Chain-of-Custody and Corrective Action

All failures associated with chain-of-custody procedures are immediately reported to the TSSWCB PM. These include such items as delays in transfer, resulting in holding time violations; violations of sample preservation requirements; incomplete documentation, including

signatures; possible tampering of samples; broken or spilled samples, etc. The Project Leader and the TSSWCB PM/QAO will determine if the procedural violation may have compromised the validity of the resulting data. Any failures that potentially compromise data validity will invalidate data, and the sampling event should be repeated. The resolution of the situation will be reported to the TSSWCB in the quarterly progress report. Corrective action reports will be maintained by the TSSWCB PM.

Section B4: Analytical Methods Requirements

E. coli in water samples will be isolated and enumerated by the laboratory using modified mTEC agar, EPA Method 1603 (*EPA/821/R-02/023. September 2002. Escherichia coli in Water by Membrane Filtration Using Modified Membrane-Thermotolerant Escherichia coli (modified m-TEC) Agar*). The modified mTEC method is a single-step method that uses one medium and does not require testing using any other substrate. The modified medium contains a chromogen, 5-bromo-6-chloro-3-indolyl-ß-D-glucuronide, which is catabolized to glucuronic acid and a red- or magenta-colored compound by *E. coli* that produce the enzyme ß-D-glucuronidase. This enzyme is the same enzyme tested for using other substrates such as MUG and UV fluorescence as used in other *E. coli* assays (e.g. IDEXX QuantiTray).

All laboratory sampling areas and equipment will be sterilized with at least one or in any combination of the following methods--ethyl alcohol, bleach, UV light, or by autoclave. All disposables will be placed in a heat-resistant biohazard bag and autoclaved prior to disposal.

One site will require fecal coliform analysis in addition to the *E. coli* enumeration. Fecal coliform in water samples will be isolated and enumerated by the laboratory using mFC agar, as describe in Standard Methods for the Examination of Water and Wastewater, 20th edition.

Table B.4-1. Laboratory Analytical Methods

Parameter	Method	Equipment Used
Laboratory Parameters		
Fecal Coliform Bacteria	SM 9222-D	Incubator, filtering apparatus
Escherichia coli	EPA 1603	Incubator, filtering apparatus
Field Parameters		
Dissolved Oxygen	EPA 360.1	YSI Multiprobe
Potential Hydrogen	EPA 150.1	YSI Multiprobe
Specific Conductance	SM 2510 B2.c	YSI Multiprobe
Water Temperature	EPA 170.1	YSI Multiprobe
Flow Severity	TCEQ SOP	Field observation
Water level	USGS	Meter stick

EPA = Methods for Chemical Analysis of Water and Wastes, March 1983
SM = Standard Methods for Examination of Water and Wastewater, 20th edition
SOP = Standard Operating Procedure
USGS = Techniques of Water Resources Investigations, Book 3, Chapter A8, 1980

Section B5: Quality Control Requirements

Table A.7-1 in Section A7 lists the required accuracy, precision, and completeness limits for the parameters of interest. It is the responsibility of the Project Leader to verify that the data are representative. The Project Leader also has the responsibility of determining that the 90 percent completeness criteria is met, or will justify acceptance of a lesser percentage. All incidents requiring corrective action will be documented through use of Corrective Action Reports (Appendix A). Annual laboratory audits, sampling site audits, and quality assurance of field sampling methods will be conducted by the TSSWCB QAO or their designee.

Field Blanks

Field blanks consist of sterile distilled water that is taken to the field and transferred to the appropriate container in precisely the same manner as a sample during the course of a sampling event. They are used to assess the contamination from field sources such as air borne materials, carryover from prior sampling sites, and containers. A field blank should be included for each sampling event. The analysis of field blanks should yield a value of no colonies detected.

Laboratory Blanks

Laboratory blanks consist of 100mL aliquots of sterile distilled water, that are processed in the same manner as a sample, at the beginning and the end of a sample set. They are used to assess the sterilization techniques employed throughout the sample process. Laboratory blanks will be included at the beginning and the end of the sample set for each sampling event. The analysis of laboratory blanks should yield a value of no colonies detected.

Failures in Quality Control and Corrective Action

Notations of blank contamination will be noted in the quarterly report and the final QA/QC Report. Corrective action will involve identification of the possible cause of the contamination failure where possible. Any failures that have potential to compromise data validity will invalidate data, and the sampling event should be repeated. The resolution of the situation will be reported to the TSSWCB in the quarterly progress report. Corrective action reports will be maintained by the Project Leader and the TSSWCB PM.

Section B6: Equipment Testing, Inspection, & Maintenance Requirements

To minimize downtime of all measurement systems, spare parts for field and loaboratory equipment will be kept in the laboratory, and all field measurement and sampling equipment, in addition to all laboratory equipment, must be maintained in a working condition. All field and laboratory equipment will be tested, maintained, and inspected in accordance with manufacturer's instructions and recommendation in Standard Methods for the Examination of Water and Wastewater, 20th Edition. Maintenance and inspection logs will be kept on each piece of laboratory equipment and general maintenance checklists will be filled out for field sampling equipment, by the field technician, prior to each sampling event.

Records of all tests, inspections, and maintenance will be maintained and log sheets kept showing time, date, and analyst signature. These records will be available for inspection by the TSSWCB.

Failures in any testing, inspections, or calibration of equipment will result in a CAR and resolution of the situation will be reported to the TSSWCB in the quarterly report. Corrective action reports will be maintained by the Project Leader and the TSSWCB PM.

Table B.6-1. Equipment Inspection and Maintenance Requirements

Equipment	**Relevant Testing, Inspection and Maintenance Requirement**
D.O. meter	SM 9020 B 3.a
Conductivity meter	SM 2510 B 2.c
pH meter	SM 4500-H^+ B 2 b
Thermometers	SM 9020 B 3.a
Water deionization units	SM 9020 B 3.d
Media dispensing apparatus	SM 9020 B 3.f
Autoclaves	SM 9020 B 3.h
Refrigerator	SM 9020 B 3.i
Freezer	SM 9020 B 3.j
Membrane filter equipment	SM 9020 B 3.k
Ultraviolet sterilization lamps	SM 9020 B 3.l
Biological safety cabinet	SM 9020 B 3.m
Incubators	SM 9020 B 3.o
Glassware and plasticware	SM 9020 B 4.a
Utensils and containers	SM 9020 B 4.b
Dilution water bottles	SM 9020 B 4.c

Section B7: Instrument Calibration and Frequency

All instruments or devices used in obtaining environmental measurement data will be calibrated prior to use. Each instrument has a specialized procedure for calibration and a specific type of standard used to verify calibration. The instruments requiring calibration are listed below in Table B.7-1.

All calibration procedures will meet the requirements specified in the USEPA-approved methods of analysis. The frequency of calibration recommended by the equipment manufacturer, as well as any instructions specified by applicable analytical methods, will be followed. All information concerning calibration will be recorded in a calibration logbook by the person performing the calibration and will be accessible for verification during either a laboratory or field audit.

All instruments or devices used in obtaining environmental measurement data will be used according to appropriate laboratory or field practices. Written copies of standard operating procedures (SOPs) are available for review upon request.

Standards used for instrument or method calibrations shall be of known purity and be NIST traceable whenever possible. When NIST traceability is not available, standards shall be of American Chemical Society (ACS) or reagent grade quality, or of the best attainable grade. All certified standards will be maintained traceable with certificates on file in the laboratory. Dilutions from all standards will be recorded in the standards log book and given unique identification numbers. The date, analyst initials, stock sources with lot number and manufacturer, and how dilutions were prepared will also be recorded in the standards log book.

Failures in any testing, inspections, or calibration of equipment will result in a CAR and resolution of the situation will be reported to the TSSWCB in the quarterly report. Corrective action reports will be maintained by the Project Leader and the TSSWCB PM.

Table B.7-1. Instrument Calibration Requirements

Equipment	Relevant Calibration Requirement
D.O. meter	SM 4500-O G 3.c
Conductivity meter	SM 2510 B 4.a
pH meter	SM 4500-H^+ B 2 b

Section B8: Inspection / Acceptance Requirements for Supplies and Consumables

All standards, reagents, media, plates, filters, and other consumable supplies are purchased from manufacturers with performance guarantees, and are inspected upon receipt for damage, missing parts, expiration date, and storage and handling requirements. Labels on reagents, chemicals, and standards are examined to ensure they are of appropriate quality, initialed by staff member and marked with receipt date. Volumetric glassware is inspected to ensure class "A" classification, where required. Media will be checked as described in quality control procedures. All supplies will be stored as per manufacturer labeling and discarded past expiration date. In general, supplies for microbiological analysis are received pre-sterilized, used as received, and not re-used.

Section B9: Data Acquisition Requirements (Non-direct Measurements)

The data used to establish current bacterial loadings in The Buck Creek watershed is the result of quarterly sampling conducted through the Texas Commission on Environmental Quality (TCEQ)—Clean Rivers Program. Buck Creek is an unclassified waterbody and as such, has not been sampled at the same quarterly intervals as the classified waterbody into which it flows. Since Buck Creek has been on an intermittent sampling regime, only 20 fecal coliform samples and 14 *E. coli* samples have been collected from one designated sampling site, on a 44-mile waterbody segment, within a five-year period. Therefore, all required data to be used for this project will be collected in accordance with this QAPP.

The historical data will be considered, however, the amount of data collected in the course of this project will provide the basis for a more sound scientific decision concerning a bacterial impairment of the Buck Creek watershed.

Section B10: Data Management

Field Collection and Management of Routine Samples

Field staff will visit sampling sites on a biweekly basis to collect grab water samples and measure field water quality parameters. Site identification, date, time, personnel, water depth, measurements of field parameters, and any comments concerning weather or conditions at the site are noted on a field data sheet. One field data sheet is filled out in the field for each site visited. An example of a field data sheet is shown in Appendix C. If no flow is observed at a site, samples are not collected, information about the site visit is recorded on the field data sheet and the site is noted as pooled with no flow or dry. Information on the dates that sites were visited when no flow was occurring is recorded into a separate database maintained in an Excel workbook.

Field staff will measure dissolved oxygen, pH, water temperature, and specific conductance at each stream site, using calibrated multisonde equipment. Measurements read from the instrument are recorded on the field data sheet. Grab samples are then collected at the site, and an identification number (either a sample identification number or a site code) is written in marker on the outside of the sterile polypropylene sample bags. The bags are placed in an iced chest for transportation to the laboratory.

Unique sample identification numbers are obtained from a book of numbers located in the laboratory office. If the number of samples to be obtained is known ahead of time, sample identification (ID) numbers can be obtained before leaving the office and marked on bottles in the field. If sample ID numbers are not obtained prior to sample collection, site codes are marked on sample bottles in the field. After sample ID numbers are obtained, each sample bottle (or bag) is labeled with the appropriate ID number by marking the number on each bottle (or bag). Sample ID numbers are recorded on the COC forms. Sample bottles being processed are typically placed in order of collection time, so the order of the sample bottles matches the order of the field data and the COC sample ID numbers, reducing transcription errors. Site name, time of collection, comments, and other pertinent data are copied from the field data sheets to the COC. The COC and accompanying sample bottles (or bags) are submitted to laboratory analysts, with relinquishing and receiving personnel both signing and dating the COC.

All COC and field observations data will be manually entered into an electronic database. The electronic database will be created in Microsoft Access software on an IBM-compatible microcomputer with the Windows 2000 Operating System. The project database will be maintained on a Windows NT network drive, which is backed up to tape media every night.

Original data recorded on paper files will be stored for at least five years in a locked, restricted-access, fire-resistant storage area. Electronic data files will be archived to CD-ROM after approximately one year, then maintained in the above storage area.

Laboratory Data

All field samples will be logged upon receipt, COC's (if applicable) will be checked for number of samples, proper and exact I.D. number, signatures, dates, and type of analysis specified. TSSWCB will be notified if any discrepancies are found and laboratory analysis will not occur until proper corrections are made. All samples will be stored at 4ºC until analysis. Bacteriological samples will be given a unique identification number and logged into an electronic database. Enumerated bacteriological data will be manually entered into the database system for electronic storage. The electronic database will be created in Microsoft Access software on an IBM-compatible microcomputer with the Windows 2000 Operating System. The project database will be maintained on a Windows NT network drive, which is backed up to tape media every night. At least 10% of all data manually entered in the database will be reviewed for accuracy by the Project Leader to ensure that there are not any transcription errors. Hard copies of data will be printed and housed in the laboratory for a period of five years. Any COC's and bacteriological records related to QA/QC of bacteriological procedures will be housed at Vernon AREC.

Data Validation

Using the review of laboratory data, any parameters that are not representative of environmental conditions because they were generated through poor field or laboratory practices will not be submitted to the TSSWCB. This determination will be made by the Project Leader, TSSWCB QAO, and other personnel having direct experience with the data collection effort. This coordination is essential for the identification of valid data and the proper evaluation of that data. The validation will include the following checks specified in Table D.2-1.

Data Reporting

Data will be reported according to the standards of the TSSWCB.

Data Dissemination

At the conclusion of the project, the Project Leader will provide a copy of the complete project electronic database via recordable CD-ROM media to the TSSWCB PM, along with the final report. The TSSWCB may elect to take possession of all project records. However, summaries of the data will be presented in the final project report.

Section C1: Assessments and Response Actions

The following table presents the types of assessments and response action for activities applicable to this QAPP.

Table C.1-1. Assessments and Response Actions

Assessment Activity	Approximate Schedule	Responsible Party	Scope	Response Requirements
Status Monitoring Oversight, etc.	Continuous	TWRI and Vernon AREC	Monitoring of the project status and records to ensure requirements are being fulfilled. Monitoring and review of contract laboratory performance and data quality	Vernon AREC and TWRI will report to TSSWCB PM via quarterly report.
Laboratory Inspections	Once per course of the project	TSSWCB QAO	Analytical and QC procedures employed at the laboratory	Vernon AREC has 30 days to respond in writing to the TSSWCB QAO to address corrective actions
Monitoring Systems Audit	Once per course of the project	TSSWCB QAO	The assessment will be tailored in accordance with objectives needed to assure compliance with the QAPP. Field sampling, handling and measurement; facility review; and data management as they relate to the project	Vernon AREC has 30 days to respond in writing to the TSSWCB QAO to address corrective actions

Corrective Action

The Vernon AREC Project Leader is responsible for implementing and tracking corrective action procedures as a result of audit findings. Records of audit findings and corrective actions are maintained by the TSSWCB QAO.

If audit findings and corrective actions cannot be resolved, then the authority and responsibility for terminating work is specified in agreements or contracts between participating organizations.

Section C2: Reports to Management

Quarterly progress reports will be generated by TWRI personnel and will note activities conducted in connection with the water quality monitoring program, items or areas identified as potential problems, and any variations or supplements to the QAPP. Corrective action report forms will be utilized when necessary (Appendix A). CARs will be maintained in an accessible location for reference at Vernon AREC. CARs that result in any changes or variations from the QAPP will be made known to pertinent project personnel, documented in an update or amendment to the QAPP and distributed to personnel listed in Section A3.

The field measurement and sampling for the project will be done according to the QAPP. However, if the procedures and guidelines established in this QAPP are not successful, corrective action is required to ensure that conditions adverse to quality data are identified promptly and corrected as soon as possible. Corrective actions include identification of root causes of problems and successful correction of identified problem. Corrective Action Reports will be filled out to document the problems and the remedial action taken.

Section D1: Data Review, Validation, and Verification

All data obtained from field and laboratory measurements will be reviewed and verified for integrity, continuity, reasonableness, and conformance to project requirements, and then validated against the data quality objects outlined in Section A7. Only those data that are supported by appropriate QC data and meet the DQOs defined for this project will be considered acceptable for use.

The procedures for verification and validation of data are described in Section D2, below. The Project Leader is responsible for ensuring that field and laboratory data collected by staff is properly reviewed, verified, and submitted in the required format for the project database. The TSSWCB QAO is responsible for validating that all data collected meet the data quality objectives of the project.

Section D2: Validation and Verification Methods

All data will be verified to ensure they are representative of the samples analyzed and locations where measurements were made, and that the data and associated QC data conform to project specifications. The Project Leader is responsible for the integrity, validation and verification of the data each field and laboratory task generates or handles throughout each process. The field and laboratory QA tasks ensure the verification of field data, electronically generated data, and data on chain-of-custody forms and hard copy output from instruments.

Verification, validation and integrity review of data will be performed using self-assessments and peer review, as appropriate to the project task, followed by technical review by the manager of the task. The data to be verified are evaluated against project specifications (Section A7 and Section B5) and are checked to ensure the verification of raw data for errors, especially errors in transcription, calculations, and data input. Potential outliers are identified by examination for unreasonable data, or identified using computer-based statistical software. If a question arises or an error or potential outlier is identified, the manager of the task responsible for generating the data is contacted to resolve the issue. Issues that can be corrected are corrected and documented electronically or by initialing and dating the associated paperwork. If an issue cannot be corrected, the task manager consults with the TSSWCB QAO to establish the appropriate course of action, or the data associated with the issue are rejected.

The Vernon AREC Project Leader and TSSWCB QAO, as appropriate, are responsible for validating that the verified data are scientifically valid, defensible, of known precision, accuracy, integrity, meet the data quality objectives of the project, and are reportable to the TSSWCB.

Table D.2-1. Data Review, Verification, and Validation Procedures

Data to be Verified	Field Supervisor and Staff	Laboratory Supervisor and Staff	PM/QAO Task *
Collection and analysis techniques consistent with SOPs and QAPP	X	X	X
Field QC samples collected for all parameters as prescribed in the QAPP	X		X
Field documentation complete	X		X
Instrument calibration data complete	X	X	X
Bacteriological records complete		X	X
Sample documentation complete	X	X	X
Field QC results within acceptance limits	X		X
Sample identifications	X	X	X
Chain of custody complete/acceptable	X	X	X
Sample preservation and handling	X	X	X
Holding times	X	X	X
Instrument calibration data	X	X	X
QC samples analyzed at required frequencies		X	X
QC samples within acceptance limits		X	X
Internal/external standards	X		X
Instrument readings/printouts	X	X	X
Calculations	X	X	X
Laboratory data verification for integrity, precision, accuracy and validation		X	X
Laboratory data reports		X	X
Data entered in required format	X	X	X
Site ID number assigned			X
Valid STORET codes			X
Absence of transcription error	X	X	X
Reasonableness of data	X	X	X
Electronic submittal errors	X	X	X
Sampling and analytical data gaps	X	X	X

* TSSWCB PM / QAO will monitor data for QA/QC purposes as needed.
All other entities are required to inspect 100% of the data prior to approval

Section D3: Reconciliation with Data Quality Objectives

Data that have been reviewed, verified, and validated will be summarized for each station individually, as well as all stations together, for their ability to meet the data quality objectives of the project and the informational needs of water quality agency decision-makers. These summaries will be included in the final report.

Appendix A
Corrective Action Report
CAR #:_____

Date:_____ Area/Location:_____

Reported by:_____ Activity:_____

State the nature of the problem, nonconformance or out-of-control situation:
_____
_____
_____
_____
_____

Possible causes:
_____
_____
_____

Recommended Corrective Actions:
_____
_____
_____

CAR routed to:_____
Received by:_____

Corrective Actions taken:
_____
_____
_____
_____

Has problem been corrected?: YES NO

Immediate Supervisor:_____

Project Leader:_____

Quality Assurance Officer:_____

Appendix B

CHAIN OF CUSTODY RECORD

Project: ***Bacterial Monitoring for the Buck Creek Watershed***							Remarks:					
Name and signature of collector:							Air bill #					
Station ID	Sample ID	Media Code	Sample Type	Preserv-ation	Collection Date:	Time:	Num containers	Analyses			Remarks	Tag ID:
								EC	TSS	Other		
Relinquished by: (Signature):					Date:	Time:	Received for lab by:				Date:	Time:
Project Leader (Signature):												

Appendix C

Field Data Reporting Form

Station ID	**Date**	**Time**	**Depth (ft)**
Sample ID	**COC Number**		

Collector Name(s)

Collecting Agency

Station Description

Circle one:
Flow Severity: 1-no flow 2-low 3-normal 4-flood 5-high 6-dry

Days since last significant rainfall:

Weather Observations (use codes from back**)**

Field Parameters

Dissolved Oxygen (DO) . ppm

pH

Specific Conductance µS/cm

Temperature ˚C

Other Observations:

00: No significant weather observed
01: Clouds generally dissolving or becoming less developed
02: State of sky on the whole unchanged during the past hour
03: Clouds generally forming or developing during the past hour
04: Haze, smoke, or dust in suspension in the air, visibility equal to or greater than 1km
05: Smoke
10: Mist
12: Distant lightning
18: Squalls
20: Fog during previous hour,
21: Precipitation during previous hour
22: Drizzle (not freezing) or snow grains during previous hour
23: Rain (not freezing) during previous hour
25: Freezing drizzle or freezing rain during previous hour,
26: Thunderstorm (with or without precipitation) during previous hour,
27: Blowing or drifting snow or sand
28: Blowing or drifting snow or sand, visibility equal to or greater than 1 km
29: Blowing or drifting snow or sand, visibility less than 1 km
30: Fog
31: Fog or ice fog in patches
32: Fog or ice fog, has become thinner during the past hour
33: Fog or ice fog, no appreciable change during the past hour
34: Fog or ice fog, has begun or become thicker during the past hour
35: Fog, depositing rime
40: Precipitation
41: Precipitation, slight or moderate
42: Precipitation, heavy
43: Liquid precipitation, slight or moderate
44: Liquid precipitation, heavy
45: Solid precipitation, slight or moderate
46: Solid precipitation, heavy
50: Drizzle
51: Drizzle, not freezing, slight
52: Drizzle, not freezing, moderate
53: Drizzle, not freezing, heavy
54: Drizzle, freezing, slight
55: Drizzle, freezing, moderate
56: Drizzle, freezing, heavy
57: Drizzle and rain, slight
58: Drizzle and rain, moderate or heavy
60: Rain
61: Rain, not freezing, slight
62: Rain, not freezing, moderate
63: Rain, not freezing, heavy
64: Rain, freezing, slight
65: Rain, freezing, moderate
66: Rain, freezing, heavy
67: Rain or drizzle and snow, slight
68: Rain or drizzle and snow, moderate or heavy
80: Showers or intermittent precipitation
81: Rain showers or intermittent rain, slight
82: Rain showers or intermittent rain, moderate
83: Rain showers or intermittent rain, heavy
84: Rain showers or intermittent rain, violent
90: Thunderstorm
91: Thunderstorm, slight or moderate, with no precipitation
92: Thunderstorm, slight or moderate, with rain showers and/or snow showers
93: Thunderstorm, slight or moderate, with hail
94: Thunderstorm, heavy, with no precipitation
95: Thunderstorm, heavy, with rain showers and/or snow
96: Thunderstorm, heavy, with hail