Semiannual Water Quality Report for the Bosque River Watershed

Monitoring Period: July 1, 2007 - June 30, 2014

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TR1502

February 2015

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Acknowledgements

Financial support of the monitoring presented in this report was provided through the Lake Waco-Bosque River Initiative funded by United States Department of Agriculture, Section 319(h) Clean Water Act funding via the Texas State Soil and Water Conservation Board and the Texas Commission on Environmental Quality in cooperation with Region 6 of the United States Environmental Protection Agency, and funding provided by the State of Texas through the Texas Institute for Applied Environmental Research at Tarleton State University.

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Abstract

The intent of this report is to provide the Texas Commission on Environmental Quality (TCEQ) with a semiannual update on water quality data collected by the Texas Institute for Applied Environmental Research (TIAER) in the Bosque River watershed. The current report covers water quality samples collected from July 1, 2007 through June 30, 2014 for sites active during the last six months of the reporting period and focuses just on current monitoring sites within the North Bosque River watershed.

In this report, TCEQ water quality criteria or screening levels for dissolved oxygen (DO), water temperature, pH, chloride (Cl), sulfate (SO_4), total dissolved solids (TDS), *Escherichia coli (E. coli)*, nutrients, and chlorophyll-α (CHLA) were compared to routine grab sample data representing stations on the North Bosque River and its major tributaries. In addition, screening levels for nutrients were compared to storm sample data collected by automated samplers for these same stations. Data from microwatershed sites were not compared to water quality criteria or screening levels due to the highly intermittent nature of streamflow in these smaller watersheds.

Water quality criteria for pH, water temperature, DO, Cl, SO_4, TDS, and bacteria serve to protect designated uses associated with classified Segments 1226 (North Bosque River) and 1255 (Upper North Bosque River). Screening levels for nutrients and CHLA were based on general TCEQ assessment guidelines for freshwater streams. Basic statistics (mean, median, standard deviation, minimum, maximum, and number of observations) are also provided for each constituent (excluding TDS) by site and sampling type. Values for TDS were calculated from specific conductance (conductivity), and basic statistics are presented for conductivity. For these analyses, sites were categorized according to drainage area or location within the watershed.

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CHAPTER 1

Introduction

The Bosque River watershed encompasses about 4,300 square kilometers (1,660 square miles) in north central Texas, all draining into Lake Waco. Lake Waco provides flood control for the area and supplies drinking water to about 150,000 people. Major tributaries within the Bosque River watershed include the North Bosque River, Hog Creek, Middle Bosque River, and South Bosque River, of which the North Bosque River basin comprises about 74 percent of the total drainage area.

For the North Bosque River watershed, the classified segments are 1226, North Bosque River, and 1255, Upper North Bosque River (Figure 1). Segment 1226 includes the North Bosque River from Lake Waco, up to a point immediately above the confluence of Indian Creek. Segment 1255 includes the North Bosque River from Indian Creek to the confluence of the North Fork and South Fork above Stephenville. Segment 1246 includes the Middle and South Bosque Rivers located in McLennan County, as well as a small portion of the Middle Bosque River in Coryell County up to the confluence of Cave Creek and has been the focus of past monitoring by TIAER (e.g., McFarland and Millican, 2012) but is currently not part of TIAER's monitoring network.

The designated uses for Segments 1226, 1246, and 1255 are quite similar, although differences are indicated for aquatic life and domestic water supply (Tables 1 and 2). Aquatic life use levels and DO criteria designated for these classified segments are, thus, slightly different (Table 2).

Table 1. Designated uses for TCEQ classified segments. Source: TCEQ (2010).

Segment	Aquatic Life	Primary Contact Recreation	Domestic Water Supply
1226	x	x	x
1246	x	x	
1255	x	x	

Table 2. Aquatic life uses and DO criteria for TCEQ classified stream segments. Source: 307 TAC §307.10(1) and TCEQ (2012a).

Segment	Segment Name	Aquatic Life [a]	24-hr DO Mean (mg/L)	DO Minimum (mg/L)
1226	North Bosque River	H	5	3
1246	Middle Bosque - South Bosque River	H	5	3
1255	Upper North Bosque River	I	4	3

[a.] Aquatic life uses are high (H), intermediate (I), limited (L), and minimal (M).

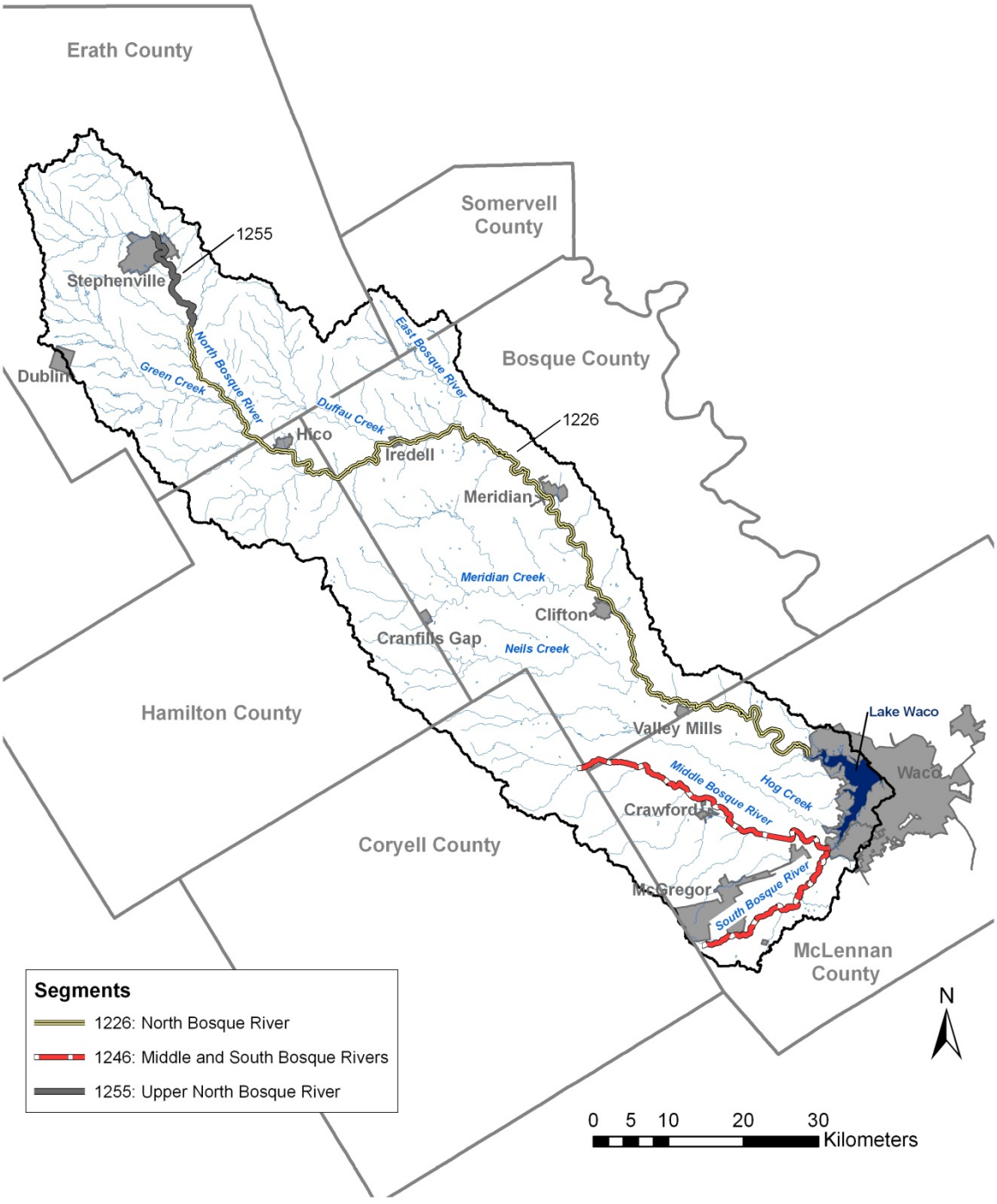

Figure 1. TCEQ classified stream segments in the Bosque River watershed.

Other prominent hydrologic features in the Bosque River watershed, besides Lake Waco, include 42 flood retardation reservoirs built in the 1950s and 1960s under Public Law 566. These PL-566 reservoirs are found primarily in the upper portion of the North Bosque River watershed with two located in the lower portion of the Hog Creek watershed. These small reservoirs are designed to control flooding by reducing peak streamflows, and, thus, have a direct impact on the hydrology of area streams. No PL-566 reservoirs are currently monitored but previously up to eight PL-566 reservoirs were routinely monitored on about a monthly basis through much of the 1990s until early 2003 (see previous semiannual reports for further information). One reservoir, NF030 (TCEQ identification number 17224) on the North Fork of the North Bosque River, was monitored monthly until April 2008, when monitoring was suspended due to a change in project priorities.

Statewide attention has focused on the Bosque River watershed largely due to the prominence of the dairy industry in the northern portion. The headwaters of the North Bosque River are located in Erath County. Erath County has been the number one milk producing county in Texas for a number of years, but for most months starting in 2011, Castro or Palmer County has often edged out Erath County for the number one spot based on milk production records (e.g., USDA-AMS, 2013). The 1996 State of Texas Water Quality Inventory indicated that nonpoint source loadings associated with elevated nutrient and fecal coliform levels were the most serious threat to meeting designated uses within Segments 1226 and 1255 (TNRCC, 1996). Elevated nitrogen levels were also indicated in 1996 as a concern within Segment 1246, the Middle Bosque-South Bosque River. In 1998, Segments 1226 and 1255 were included in the Clean Water Act Section 303(d) list for Texas as impaired water bodies under narrative water quality criteria related to nutrients and aquatic plant growth with concentrated animal feeding operations identified as the major nonpoint source of nutrients (TNRCC & TSSWCB, 1999). Nutrients have been the focus of TIAER monitoring efforts due to the role of nutrients in promoting excessive growth of algae as indicated by elevated chlorophyll-a levels throughout Segments 1226 and 1255 (TNRCC, 1999).

In February 2001, the Texas Commission on Environmental Quality (TCEQ) adopted a total maximum daily load (TMDL) for soluble reactive phosphorus in Segments 1226 and 1255 that was approved by EPA in December 2001. This TMDL requires about a 50 percent reduction in loading and concentration of soluble reactive phosphorus, depending on the location along the river (TNRCC, 2001). Phosphorus was identified as the nutrient limiting algal growth in the North Bosque River, and, thus, a reduction in soluble reactive phosphorus should reduce algal abundance in the North Bosque River.

The 2012 Texas Water Quality Inventory evaluates water bodies based on assessment units (AUs) describing specific areas within each segment (TCEQ, 2013). Four AUs are defined for Segment 1226 and two AUs each for Segments 1255 and 1246 as follows:

- 1226_01 Portion of North Bosque River from confluence with Lake Waco in McLennan County upstream to confluence with Neils Creek in Bosque County
- 1226_02 Portion of North Bosque River from confluence with Neils Creek upstream to confluence with Meridian Creek in Bosque County
- 1226_03 Portion of North Bosque River from confluence with Meridian Creek upstream to confluence with Duffau Creek in Bosque County
- 1226_04 Portion of North Bosque River from confluence with Duffau Creek in Bosque County upstream to a point immediately upstream of Indian Creek confluence (end of segment) in Erath County
- 1246_01 Entire Middle Bosque River
- 1246_02 Entire South Bosque River
- 1255_01 Portion of North Bosque River from confluence with Indian Creek upstream to confluence with Dry Branch in Erath County
- 1255_02 Portion of North Bosque River from confluence with Dry Branch upstream to confluence with North/South Forks North Bosque River in Erath County

The 2012 Texas Water Quality Inventory uses the seven-year assessment period December 1, 2003 through November 30, 2010 (TCEQ, 2012a). The three more upstream AUs in Segment 1226 and both AUs in Segment 1255 are noted as impaired due to excessive algal growth as category 4a, indicating that a TMDL has already been completed and approved by EPA (Table 3). Additional impairments for Segment 1255 include elevated bacteria in both AUs and depressed dissolved oxygen (DO) in 1255_02. The depressed DO impairment is listed as category 5c, indicating that additional data and information need to be collected before a TMDL is scheduled. The bacteria impairment is categorized as 5b, indicating that a review of water quality standards for this water body will be conducted before a TMDL is scheduled. Concerns were indicated within Segments 1226 and 1255 for chlorophyll-a and nutrients in some AUs. Within Segment 1226, there was also concern noted regarding impairment of the macrobenthic community. For Segment 1246, no impairments were listed, but nitrate was noted as a concern in both AUs.

The intent of this report is to provide the TCEQ with a semiannual update on water quality data collected by the Texas Institute for Applied Environmental Research (TIAER) in the Bosque River watershed. The current report covers water quality samples collected between July 1, 2007 and June 30, 2014. A seven-year period of data was selected to resemble the length of time outlined in assessment methodology (TCEQ, 2012a).

This report includes only sampling stations monitored by TIAER that were active during the last six months of the seven-year period. In this report, TIAER grab and storm event water quality data collected from sites on mainstem or major tributaries of the North Bosque River were compared to TCEQ water quality criteria for classified segments (TCEQ, 2010) and TCEQ nutrient and chlorophyll-α screening levels (TCEQ, 2012a). Data from microwatershed sites were not included in

comparisons with water quality criteria and screening levels, due to the highly intermittent nature of these smaller streams.

Table 3. Summary of TCEQ assessment of use impairments and concerns for 2012. Source: 2012 Texas Water Quality Inventory (TCEQ, 2013).

	Segment 1226 - North Bosque River	Segment 1246 - Middle and South Bosque River	Segment 1255 - Upper North Bosque River
Assessment	Not Supporting: General use - nutrient enrichment	Supporting all uses	Not Supporting: Primary Contact Recreation use – bacteria; Aquatic life use - dissolved oxygen; General use - nutrient enrichment
Description of Impairment	Excessive algal growth (AUs 02, 03 & 04)	None	*E. coli* exceeding single sample and geometric criteria (AUs 01 & 02), depressed dissolved oxygen (AU 02), and excessive algal growth (AUs 01 & 02)
Concerns	Elevated chlorophyll-α (AUs 02, 03 & 04) and orthophosphorus (AU 04), depressed dissolved oxygen (AU 02) and impaired macrobenthic community (AU 04)	Elevated nitrate (AUs 01 & 02)	Elevated nitrate (AU 01), orthophosphorus (AUs 01 & 02), total phosphorus (AU 01), and chlorophyll-α (AUs 01 & 02)

Basic statistics (mean, median, standard deviation, minimum, maximum, and number of observations) were calculated for each constituent by site and sampling type. For these analyses, sites were categorized according to drainage area or location within the watershed.

CHAPTER 2

Current Water Quality Monitoring in the Bosque River Watershed

The locations of TIAER sampling sites within the Bosque River watershed are indicated in Figure 2. All sampling sites are labeled using a five character alphanumeric code. The first two letters specify the tributary or river (e.g., BO for North Bosque River) on which the site is located, while the last three digits indicate the relative location of the site. Lower numeric values indicate sites nearer the headwaters, while larger numeric values indicate sites further downstream. Sampling sites were grouped into categories based on drainage area or location within the watershed (Table 4).

Table 4. Description of sampling site categories

Category[a]	Description
Category 1	Sites on microwatersheds
Category 2	Sites on major tributaries to the North Bosque River
Category 3	Sites on the North Bosque River

a. Of note, recent semiannual reports also included a forth category of sites along other rivers and major tributaries to Lake Waco that included sites on the Middle and South Bosque River and Hog Creek. Sampling at these stations was discontinued in December 2010, so all data are presented in previous reports (see Adams and McFarland, 2011).

The general location of sampling sites within each category and monitoring histories are provided below (Table 5). General land-use descriptions are based on classification of satellite imagery from 2001 through 2003 conducted by the Spatial Sciences Laboratory of the Texas Agricultural Experiment Station (Narasimhan et al., 2005; Table 6). Information on animal waste application fields was compiled by TIAER from review of TCEQ permit information and used to supplement the satellite imagery classification.

A geospatial database (or GIS layer) was developed of animal waste application fields (WAFs) based on 2011 TCEQ records for permitted operations (see McFarland and Adams, 2013). For smaller nonpermitted operations or animal feeding operations (AFOs), dairy inspection and milk production records were used to identify the location of these operations. For nonpermitted facilities, the size of WAFs was estimated based on a maximum herd size of 199 head, and these fields were then located on land contiguous with the location of the AFO. This 2011 WAF geospatial information was then compared to WAF layers representing conditions in 2000 and 2005 to determine historical WAFs (see McFarland and Jones, 2006).

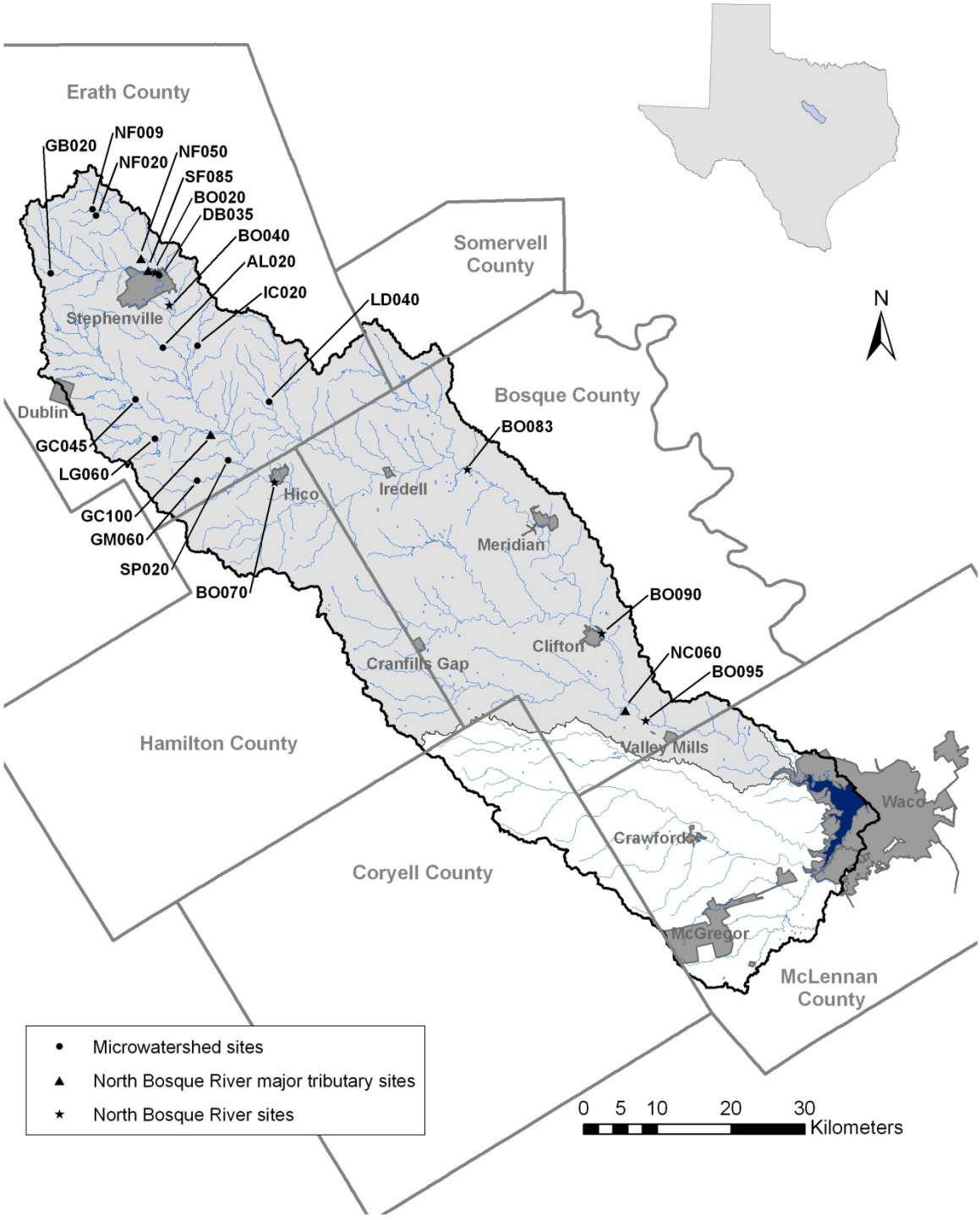

Figure 2. TIAER sampling sites within the Bosque River watershed. Map indicates sampling sites active between July and December 2013.

The updated information on WAFs includes milking operations and non-milking operations, although milking operations represent over 80 percent of the concentrated animal feeding operations (CAFOs) and animal feeding operations (AFOs) in the watershed. A biogas production facility that received dairy waste was active in the watershed roughly between late 2007 and 2010, and its WAFs are included in the historical WAFs.

Drainage areas above sampling sites were delineated using 30-meter digital elevation models created from United States Geological Survey 1:24,000 topographic maps (Table 6). Drainage areas for sampling sites were calculated using the AVSWAT 2000 extension in ArcView. The drainage area values presented in Table 6 may differ from those in reports prior to January 2002 due to changes in the GIS system and the calculation method used to determine these areas.

Table 5. Sampling history of monitoring sites in the Bosque River watershed.

Site	TCEQ ID	Watershed and General Location	Sample Type[a]	Date of First Grab Sample	Date of First Automatic Storm Sample
Category 1: Sites on microwatersheds					
AL020	17604	Alarm Creek at FM 914	C	14-May-01	05-Sep-01
DB035	17603	Dry Branch near FM 8	C	02-Apr-02	05-Feb-02
GB020	17214	Unnamed tributary to Goose Branch between CR 541 and CR 297	C	11-May-95	05-May-95
GC045	17609	Green Creek upstream of SH 6	C	16-Apr-01	26-May01
GM060	17610	Gilmore Creek at bend of CR 293	C	05-Feb-01	31-Aug-01
IC020	17235	Indian Creek downstream of US 281	C	08-Jun-94	18-Oct-93 [b]
LD040	17608	Little Duffau Creek at FM 1824	C	14-May-01	31-Aug-01
LG060	17606	Little Green Creek at FM 914	C	14-May-01	14-Jul-01
NF009	17223	Unnamed tributary of Scarborough Creek at CR 423	C	18-Apr-91	16-May-92 [c]
NF020	17222	North Fork North Bosque River Scarborough Creek at CR 423	C	30-Oct-91	19-May-92
SP020	17242	Spring Creek at CR 271	C	08-Jun-94	20-Oct-93 [b]
Category 2: Sites on major tributaries to the North Bosque River					
GC100	13486	Green Creek 1.8 km upstream of confluence with North Bosque River	C	06-Jan-93	01-Sep-92
NC060	11826	Neils Creek at SH 6, SE of Clifton	C	26-Sep-95	01-Nov-95
NF050	17413	North Fork North Bosque River at SH 108	C	04-Apr-91 [d]	07-Jun-91 [d]
SF085	17602	South Fork North Bosque River at SH 108	C	30-Apr-01	26-May-01
Category 3: Sites on the North Bosque River					
BO020	17226	North Bosque River at FM 8 above Stephenville	C	26-May-94	06-Feb-97
BO040	11963	North Bosque River at Erath CR 454 below Stephenville	C	04-Apr-91	25-Aug-93
BO070	11961	North Bosque River at US 281 near Hico	C	04-Apr-91	08-May-91
BO083	18003	North Bosque River at CR 2371	G	06-Nov-02	Not applicable
BO090	11956	North Bosque River at FM 219 at Clifton	C	26-Sep-95	04-Nov-95
BO095	11954	North Bosque River at CR 3310 off SH6 west of Valley Mills	C	02-May-01	03-Sep-01

a. G = grab sampling site and C=combined grab and storm sampling site.
b. Storm sampling suspended 03-Mar-98 to 03-May-2001 at IC020 and SP020.
c. Automated sampler at NF009 was offline from 25-Mar-98 through 12-Jun-98.
d. Storm sampling at NF050 suspended from 04-Feb-97 to 04-May-01 and grab sampling suspended 06-May-97 through April 2001. In April 2001, grab sampling was reinitiated, but no samples were collected until April 2002 due to dry conditions.

Data were analyzed in this report only for sampling stations that were monitored for water quality during at least the last six months of the seven-year reporting period. Previous editions of the Semiannual Report contain data summaries for many sites that are no longer active in TIAER's monitoring program. For example, monitoring at sites along the Middle and South Bosque Rivers and Hog Creek was discontinued in December 2010, so previous reports, such as Adams and McFarland (2011) should be referenced for analyses of data for these locations.

Table 6. Estimated land use and drainage area above sampling sites.

Site	Wood & Range (%)	Pasture (%)	Cropland (%)	Animal Waste App. Fields [a] (%)	Historical Animal Waste Appl. Fields [b] (%)	Urban (%)	Other (%)	Total Area (Hectares)
	Category 1: Sites on microwatersheds							
AL020	31.7%	44.9%	7.1%	4.4%	8.3%	2.8%	0.8%	4,720
DB035	22.8%	42.9%	10.5%	5.5%	12.9%	3.5%	1.9%	2,130
GB020	21.4%	22.6%	8.2%	41.4%	0.6%	4.0%	1.7%	440
GC045	31.1%	49.1%	8.4%	1.9%	6.2%	2.4%	0.9%	11,900
GM060	55.6%	33.7%	0.8%	5.0%	3.4%	1.1%	0.2%	4,410
IC020	36.3%	35.4%	6.5%	6.3%	13.4%	1.6%	0.4%	1,740
LD040	32.5%	25.2%	5.5%	21.3%	14.2%	0.3%	1.0%	2,960
LG060	38.9%	38.8%	8.2%	8.5%	3.7%	1.0%	0.9%	4,260
NF009	30.6%	49.6%	2.6%	0.2%	13.8%	2.8%	0.4%	520
NF020[c]	19.6%	33.7%	2.6%	9.4%	31.9%	1.7%	1.0%	800
SP020	65.0%	33.2%	1.3%	0.0%	0.0%	0.3%	0.2%	1,560
	Category 2: Sites on major tributaries to the North Bosque River							
GC100	39.1%	42.9%	6.9%	2.5%	5.8%	2.0%	0.8%	25,200
NC060	74.0%	17.9%	6.0%	0.0%	0.0%	1.3%	0.8%	35,300
NF050	23.1%	47.5%	7.3%	2.4%	16.0%	2.8%	0.8%	8,370
SF085	27.8%	36.7%	11.1%	9.1%	9.7%	4.5%	1.1%	13,000
	Category 3: Sites on the North Bosque River							
BO020	26.0%	41.1%	9.6%	6.3%	12.1%	3.9%	1.0%	21,700
BO040	25.7%	40.0%	9.5%	5.9%	11.3%	6.5%	1.1%	25,700
BO070	41.0%	38.6%	6.2%	3.2%	6.6%	3.5%	0.8%	93,100
BO083	53.4%	31.3%	4.6%	2.9%	4.4%	2.4%	1.0%	178,000
BO090	59.4%	27.5%	4.6%	2.0%	3.1%	2.4%	0.9%	253,000
BO095	61.5%	25.9%	5.0%	1.7%	2.6%	2.3%	0.9%	297,000

a. Animal waste application fields represent estimates from milking operations and non-milking operations.
b. Historical fields are previously permitted fields that are no longer permitted for animal waste application.
c. About 8 hectares (20 acres) or about 1 percent of the drainage area above site NF020 had been permitted for septic disposal, but permit was cancelled in 2004.

Sites on Microwatersheds

Eleven sampling stations are located in microwatersheds on creeks that discharge into the North Bosque River. All microwatershed sites represent primarily rural land uses (Table 6). Microwatershed sites, when active, were routinely monitored on a biweekly basis until September 2008. Starting in September 2008, microwatershed sites in the North Bosque River watershed were routinely monitored on only a monthly basis.

Alarm Creek

Site AL020 AL020 is an automated sampling site located on Alarm Creek at Farm-to-Market (FM) 914, 7.2 kilometers (4.5 miles) south of Stephenville. The dominant land uses above AL020 are improved pasture and wood and range, with a fair amount of land associated with WAFs and cropland. Alarm Creek has been routinely monitored since May 2001.

Dry Branch

Site DB035 DB035 is an automated sampling site located on Dry Branch near FM 8, about 0.8 kilometers (0.5 miles) upstream of the confluence with the North Bosque River. The dominant land use above DB035 is improved pasture followed by wood and range, WAFs, and cropland. Routine and storm sampling at DB035 was initiated in April 2002.

Goose Branch

Sites GB020 GB020 is an automated sampling site located in the Goose Branch microwatershed of the South Fork of the North Bosque River, northwest of Stephenville. Dairy WAFs are the predominant land use in the Goose Branch microwatershed. Much of the remaining land area is covered by native range and woodland or improved pasture. GB020 is located on an unnamed road off Erath County Road (CR) 297.

Gilmore Creek

Site GM060 GM060 is an automated sampling site located on Gilmore Creek, at the bend of Erath CR 293, approximately 330 meters (0.2 miles) downstream of the confluence with Wolf Prong Creek, north northeast of Carleton, Texas. Land uses above GM060 are predominantly wood and range and improved pasture.

Green Creek

Site GC045 Site GC045 is an automated site, located on Green Creek, 0.6 km (0.4 miles) upstream of SH 6, 3.3 km (2.0 miles) northwest of Alexander, Texas. The

majority of the land above GC045 is improved pasture followed by wood and range. Routine and storm sampling was initiated at GC045 in 2001.

Indian Creek

Site IC020 IC020 is located near U.S. Highway 281, on Indian Creek, which discharges into the upper North Bosque River between Stephenville and Hico, Texas. Automated sampling was suspended from March 3, 1998 to May 3, 2001, while routine sampling was continued. The majority of the land use above IC020 is characterized as wood or range and improved pasture with WAFs comprising a notable amount (almost 20 percent of the drainage area).

Little Duffau Creek

Site LD040 LD040 is an automated sampling site, located on Little Duffau Creek, at FM 1824, 2 km (1.2 miles) west of Duffau in Erath County. The largest land use category above LD040 is wood and range, although almost as much land (about 30 percent of the drainage basin) is associated with WAFs. Routine and storm sampling were initiated at LD040 in 2001.

Little Green Creek

Site LG060 LG060 is an automated sampling site, located on Little Green Creek, at FM 914, 3.2 kilometers (2.0 miles) south of Alexander. The land use above LG060 is characterized as mostly wood and range and improved pasture with a notable amount of land (about 10 percent) associated with WAFs. Routine and storm sampling were initiated at LG060 in 2001.

North Fork

Sites NF009 and NF020 These automated sites are located in a microwatershed of the North Fork of the North Bosque River. The North Fork joins the South Fork just north of Stephenville to form the North Bosque River. Sites NF009 and NF020 are located on separate tributaries flowing into the same PL-566 reservoir. Site NF020 is located on the Scarborough Creek tributary at CR 423. Site NF009 is located on an unnamed tributary of Scarborough Creek on CR 423. The dominant land use above NF020 is WAFs, while most of the land above NF009 is characterized as improved pasture.

Spring Creek

Site SP020 Site SP020 is located near CR 271, on Spring Creek, which discharges into the North Bosque River above Hico. Automated sampling was suspended from March 3, 1998 to May 3, 2001. Routine grab sampling continued throughout the monitoring period. Site SP020 is considered one of the least impacted sites within the watershed with most of its land designated as wood and range. Improved pasture

does comprise about a third of the SP020 watershed. No animal waste fields are located in this microwatershed.

Sites on Major Tributaries to the North Bosque River

Subwatershed sampling sites located on major tributaries to the North Bosque River are GC100 on Green Creek, NC060 on Neils Creek, NF050 on the North Fork of the North Bosque River, and SF085 on the South Fork of the North Bosque River. All four tributaries were monitored through the collection of manual grab samples on a biweekly basis until September 2008. Starting in September 2008, sites NF050 and SF085 were monitored routinely on only a monthly basis due to a change in project work plan, while biweekly monitoring continued at GC100 and NC060 under a separate project. Automated samplers for storm sampling were installed at sites NF050, and SF085 in May 2001, while storm sampling has occurred at NC060 since November 1995 and at GC100 since September 1992.

The land use above these sites varies considerably (Table 6). Wood and range comprise over 60 percent of the land area in the NC060 watersheds, while improved pasture dominates in the GC100, NF050 and SF085 watersheds comprising 38 to 48 percent of the land area. No WAFs are located in the drainage area above NC060 on Neils Creek, but 4 to 18 percent of the drainage area above GC100, NF050, and SF085 is associated with WAFs. Cropland also notably varies from 6 percent of the drainage area for NC060 to 12 percent of the drainage area for SF085.

Green Creek

Site GC100 Site GC100 is an automated sampling site on Green Creek, located about 1.8 kilometers (1.1 miles) upstream of the confluence with the North Bosque River. GC100 is located off CR 266 near Clairette, Texas. Land use within the GC100 watershed is closely divided between wood/range and improved pasture.

Neils Creek

Site NC060 Site NC060 is an automated sampling site located on Neils Creek, at SH 6, near the confluence of Neils Creek with the North Bosque River, and between Clifton and Valley Mills. The majority of the land above NC060 (>70 percent) is associated wood and range. No permitted WAFs are located in the Neils Creek drainage, although some poultry facilities reside in this drainage area.

North Fork

Site NF050 Site NF050, an automated sampling site, is located on the North Fork of the North Bosque River, at SH 108, approximately 1.6 km (1.0 mile) northwest of Stephenville. The dominant land use above NF050 is permanent pasture followed by

wood and range. Waste application fields are prominent above NF050 comprising about 18 percent of the watershed.

South Fork

Site SF085 Site SF085 is an automated sampling site located on the South Fork of the North Bosque River, at SH 108, 250 m (820 feet) upstream of the confluence with the North Fork of the North Bosque River, north of Stephenville. The land use above SF085 is mostly improved pasture or wood and range with much of the remaining land area associated with WAFs and cropland.

Sites on the North Bosque River

Sampling on the North Bosque River was conducted routinely during the reporting period at six sites, beginning upstream at BO020 above Stephenville and continuing downstream to BO095 near Valley Mills, TIAER's most downstream site on the North Bosque River (Figure 1). Routine grab samples were collected at all six North Bosque River sites, while storm event samples were collected at all but BO083. Of note in April 2008 TIAER started to collect routine grab samples at site 17500 on the North Bosque River at Clifton as part of a project for the TCEQ.

The land uses above North Bosque River sites indicate a general decrease from upstream to downstream sites in percentage of permanent pasture, WAFs, and cropland, and a general increase in percentage of land designated as wood and range (Table 6). About 4 percent of the drainage area above BO095 is designated as WAFs, almost all of which occurs in the upper portion of the North Bosque River watershed above site BO070 (McFarland and Hauck, 1998).

Six cities are located along the North Bosque River. These cities, listed upstream to downstream with population estimates, are Stephenville (17,833), Hico (1,379), Iredell (337), Meridian (1,523), Clifton (3,467), and Valley Mills (1,226). Population estimates are for January 1, 2012 provided by the Texas State Data Center (2013).

North Bosque River above Stephenville

Site BO020 Site BO020 is an automated sampling site located on the North Bosque River, at the crossing of FM 8, on the northeast boundary of Stephenville. BO020 is located just below the confluence of the North and South Forks of the North Bosque River. The drainage area for BO020 is primarily rural, but does contain a small portion of the City of Stephenville.

North Bosque River below Stephenville

Site BO040 Site BO040 is an automated sampling site located on the North Bosque River, approximately 0.4 river kilometers (0.25 river miles) downstream of the Stephenville wastewater treatment plant (WWTP), at the crossing of CR 454, and

about 8 river kilometers (5 river miles) below site BO020. Site BO040 is the only North Bosque River site located directly below a municipal WWTP discharge. Although the WWTP is a dominant influence on the water quality at BO040 during low flow conditions, the drainage area includes stormwater runoff from the City of Stephenville and from many of the rural land areas above and around Stephenville. Tributaries entering the river between sites BO020 and BO040 include Methodist Branch and Dry Branch.

North Bosque River at Hico

Site BO070 Site BO070, an automated sampler site, is located near U.S. Geological Survey (USGS) station 08094800, on the North Bosque River, at the crossing of U.S. Highway 281 in Hico, Texas. The drainage area of this site is often referred to as the upper North Bosque River watershed in TIAER reports that focus on monitoring within the upper third of the watershed (e.g., McFarland & Hauck, 1995; 1997a). BO070 is located about 1.6 river kilometers (1 river mile) upstream of the WWTP discharge for the City of Hico. Tributaries entering the river upstream of BO070 and below BO040 include Green and Spring Creeks.

North Bosque River at CR 2371

Site BO083 Site BO083 is a grab sampling site located on the North Bosque River, at Bosque CR 2371, about 10 kilometers east of the City of Iredell. The East Bosque River enters the North Bosque River upstream of BO083. Initial water quality samples were collected at BO083 as part of a periphyton study starting in November 2002. Water quality samples were not routinely collected at BO083 until March 31, 2003.

North Bosque River near Clifton

Site BO090 Site BO090 is an automated sampler site located near USGS station 08095000 on the North Bosque River, near the crossing of FM Road 219, about 0.8 km (0.5 miles) northeast of Clifton, Texas. Site BO090 is located upstream of the City of Clifton WWTP discharge. Meridian Creek enters the river between sites BO083 and BO090.

North Bosque River above Valley Mills

Site BO095 Site BO095 is located on the North Bosque River at CR 3310, off SH 6, west of Valley Mills, in Bosque County and is about three river miles upstream of USGS station 08095200 on the North Bosque River. Grab sampling was initiated at BO095 in May 2001. Site BO095 was installed as an automated sampling site in July 2001 to replace site BO100 (TCEQ 11953), which was removed as a sampling site location due to problems with stream bank stability. BO095 is located approximately 16 river kilometers (10 river miles) downstream of BO090. Neils Creek enters the river between sites BO090 and BO095.

CHAPTER 3

Collection and Analysis Methods

The TIAER monitoring program includes routine and storm event sampling at sites throughout the Bosque River watershed. Particular emphasis is given to analyzing waterborne nutrient constituents due to their potential impact on eutrophication.

Quality Assurance Procedures

Monitoring data collected by TIAER in the North Bosque River watershed during the reporting period was conducted under the following projects with the most recent revisions of Quality Assurance Project Plans (QAPPs) noted:

- The *Lake Waco-Bosque River Initiative* funded by the U.S. Department of Agriculture (e.g., TIAER, 2005a) and approved by TCEQ.
- Clean Water Act (CWA) Section 319(h) projects *Technical and Financial Assistance to Dairy Producers and Landowners of the North Bosque River Watershed within the Cross Timbers Soil and Water Conservation District* and *Technical and Financial Assistance to Dairy Producers and Landowners of the North Bosque River Watershed within the Upper Leon Soil and Water Conservation District* funded by the Texas State Soil and Water Conservation Board (e.g., TIAER, 2005b) and approved by the United States Environmental Protection Agency (USEPA).
- The CWA Section 319(h) project *Extending TMDL Efforts in the North Bosque River Watershed* funded through the TSSWCB (e.g., TIAER, 2007).
- The CWA Section 319(h) project *Assessment of Springtime Contributions of Nutrients and Bacteria to the North Bosque River Watershed* funded through the TSSWCB (e.g., TIAER, 2008).
- The *North Bosque River Watershed Water Quality Assessment* CWA Section 319(h) project funded through the TCEQ (e.g., TIAER, 2009a).
- The project *Microwatershed-Based Approach to Monitoring and Assessing Water Quality in the North Bosque River Watershed* funded through the TSSWCB and EPA (e.g., TIAER, 2009b).
- The CWA Section 319(h) project *Monitoring Effectiveness of Nonpoint Source Nutrient Management in the North Bosque River Watershed* funding through the TSSWCB (e.g., TIAER, 2013a).
- The *North Bosque River Watershed Monitoring Project* funded through the TCEQ (e.g., TIAER, 2010).
- The CWA Section 319(h) project *Evaluating Effectiveness of Implementation Activities within the North Bosque River Watershed* funding through the TCEQ (e.g., TIAER, 2013b).

General Collection Procedures for Grab Samples

Collection of routine grab samples consisted of a single representative sample. Grab samples were taken near the surface at depths of 0.3 m (1 ft) or less depending on total water depth, as recommended in TCEQ surface water quality monitoring procedures (TCEQ, 2003; 2008; 2012c). When grab samples were collected, water temperature, DO, pH, and specific conductance (conductivity) were measured in situ with a Hydrolab or YSI (multiprobe) field sampling instrument. Because stream sites within the Bosque River watershed are generally shallow and unlikely to stratify, multiprobe readings were taken only at the surface depth corresponding to routine grab samples.

Routine sampling at stream sites occurred on a biweekly schedule throughout most of the reporting period. Starting in September 2008, routine monitoring at all microwatershed sites within the North Bosque River watershed and at major tributary sites NF050 and SF085 was changed to monthly due to a change in the project work plan. Grab samples were not collected when a stream site was dry or when water at a site was pooled and not flowing. Appendix A indicates presence or absence of flow during each routine sampling period at stream sites. The percentage of routine sampling events at which flow was present at each stream site during the reporting period is shown on the last row of each table in Appendix A. In Appendices B-D, basic statistics are presented for grab and storm samples. Basic statistics for grab samples include routine grab as well as any additional grab samples collected for projects during the reporting period.

General Collection Procedures for Storm Samples

Each automated stormwater sampling site consists of an ISCO 4230 or 3230 bubbler-type flow meter and an ISCO 3700 or 6712 sampler. Both are enclosed in a sheet metal shelter. The ISCO flow meters operate by measuring the pressure required to force an air bubble through a 3 millimeter (0.125 inch) polypropylene tube, or bubbler line, then recording this pressure as the water level. The ISCO flow meters are programmed to record water level or stage and initiate sample retrieval by the ISCO 3700 samplers. Electrical power is provided by marine deep-cycle batteries, with recharge provided by solar cells.

The ISCO flow meters initiate preset sampling programs for the ISCO samplers when threshold water levels are exceeded. Each flow meter is programmed to record water level at 5-minute intervals and typically actuate the samplers when a designated stream rise, generally 4 to 8 centimeters (1.5 inches) above the bubbler datum, is registered. The actuation level was selected by trial-and-error as the lowest level that would actuate for rainfall-runoff events and avoid undesired actuation from

nonrainfall event causes such as waves. For some projects, higher activation levels may be implemented depending on project specific objectives.

Of note, prior to the spring of 2008, an attempt was made to monitor all storm events throughout the watershed. In 2008, objectives for monitoring within the North Bosque River watershed were changed due to decreased funding to monitor only selected events rather than all events. This modified monitoring frequency for storm events impacted sites along the mainstem of the North Bosque River and major tributary sites GC100 and NC060 starting in May 2008 and microwatershed sites and major tributary sites NF050, and SF085 starting in September 2008. Most storm events in 2008 and 2009 were monitored despite a reduction in storm monitoring resources. In 2010, no storm sampling occurred between January and August 2010 at most mainstem sites along the North Bosque River and major tributary sites on Neils Creek and Green Creek due to funding constraints. Some limited storm monitoring occurred between January and May 2010 at sites BO070 and BO095. Starting in September 2010, storm sampling was reinitiated at all storm sites along the mainstem of the North Bosque River and at GC100 and NC060 under new project funding, although still with the caveat of monitoring only selected, rather than all, events.

Once activated, samplers were programmed to retrieve one-liter sequential samples. The typical sampling sequence for microwatershed sites was:

- An initial sample
- Three samples taken at one-hour intervals
- Four samples taken at two-hour intervals
- All remaining samples taken at six-hour intervals

For most major tributary and mainstem sites, the typical sampling sequence was:

- An initial sample
- One sample taken at a one-hour interval
- One sample taken at a two-hour interval
- One sample taken at a three-hour interval
- All remaining samples taken at four-hour intervals

Most storm samples were composited on a daily basis using a flow-weighted strategy to decrease the overall number of storm samples submitted for laboratory analysis.

Measurement of Physical and Chemical Constituents

A variety of physical and chemical parameters were measured to evaluate water quality within the North Bosque River (Table 7). These parameters focused primarily on nutrients, but also included laboratory measurements of bacteria, CHLA, total suspended solids (TSS), chloride (Cl), and sulfate (SO_4). Field constituents measured in situ with a multiprobe included water temperature, DO, specific conductance, and pH. While not directly measured, total dissolved solids (TDS) was estimated by multiplying specific conductance by 0.65 for water quality evaluations. Field constituents were measured only when routine grab samples were collected.

Table 7. Descriptions, abbreviations, and units of water quality constituents.

Constituent	Abbreviation	Units	Description
Ammonia-nitrogen, dissolved	NH_3-N	mg/L	Inorganic form of nitrogen that is readily soluble and available for plant uptake. Elevated levels are toxic to many fish species.
Chlorophyll-a	CHLA	mg/L	Indicator of algae and phytoplankton biomass.
Chloride	Cl	mg/L	Measure of an inorganic salt compound in water that is produced by the combination of gaseous chlorine and metals (e.g. sodium chloride or magnesium chloride).
Specific conductance	Conductivity	µS/cm	Measure of the ability of water to carry an electric current and is used as an indicator of the salt content of the water.
Dissolved oxygen	DO	mg/L	Indicator of the amount of oxygen available in the water for biological activity and chemical reactions.
Escherichia coli	*E. coli*	colonies/100 mL [a]	Indicator of public health hazards from infectious microorganisms.
Nitrite-plus-nitrate nitrogen, dissolved	NO_2-N+ NO_3-N	mg/L	Inorganic forms of nitrogen. NO_2-N is generally a transitory phase in the nitrification of NH_3 to NO_3. NO_3-N is readily soluble and available for plant uptake. NO_3-N is considered the end product in the conversion of N from the ammonia form to nitrite then to nitrate under aerobic conditions.
Orthophosphate-phosphorus, dissolved	PO_4-P	mg/L	Inorganic form of phosphorus that is readily soluble and available for plant uptake. Soluble reactive phosphorus (SRP) is another name for this constituent.
pH	pH	standard units	Measures the hydrogen ion activity in a water sample.
Sulfate	SO_4	mg/L	An inorganic anion dissolved in water. When combined with Cl, elevated levels can become toxic.
Total Kjeldahl nitrogen	TKN	mg/L	Organic and ammonia forms of nitrogen are included in TKN.
Total phosphorus	Total-P	mg/L	Represents both organic and inorganic forms of phosphorus.
Total dissolved solids	TDS	mg/L	A measure of the amount of material dissolved in water, mostly inorganic salts. TDS is associated with water hardness and may be measured gravimetrically or via electric conductivity.
Total suspended solids	TSS	mg/L	Measures the solid materials, i.e., clay, silts, sand, and organic matter suspended in the water.
Water temperature	Water temp.	°C	Indicator of temperature conditions for aquatic life.

a. As of April 2004, the IDEXX method has been primarily used by TIAER for *E. coli* analysis within the Bosque River watershed. Results from the IDEXX method are reported as MPN/100 mL whereas plating technique results are reported as colonies/100 mL. In this report, data for all *E. coli* results are presented in units of colonies/100 mL regardless of the analysis method used. While there are some differences in the IDEXX and plating techniques for *E. coli* analysis, the results are considered synonymous for TCEQ assessment purposes for which *E. coli* criteria are expressed on colonies/100 mL.

All samples were routinely analyzed for ammonia-nitrogen (NH_3-N), nitrite-nitrogen plus nitrate-nitrogen (NO_2-N+NO_3-N), total Kjeldahl nitrogen (TKN), orthophosphate-phosphorus (PO_4-P), total phosphorus (total-P), and total suspended solids (TSS).

At mainstem and major tributary sites, CHLA was measured with routine samples, although CHLA was dropped from the analysis at sites NF050 and SF085 after August 2009 due to changes in monitoring priorities. Chlorophyll-α was not routinely measured at the microwatershed sites within the North Bosque River watershed, although some CHLA data occurs at sites AL020, GB020, GC045, IC020, NF020, and SP020 primarily between 2004 and 2005 as part of a project TIAER conducted with the BRA (see Adams and McFarland, 2010 or other earlier reports for a summary of these data). Of note, analysis of Cl and SO_4 was not initiated until November 2006 and is done quarterly at mainstem sites along the North Bosque River and at major tributary sites GC100 and NC060. Of note, most Cl and SO_4 analyses were conducted by the Trinity River Authority laboratory for TIAER rather than by the TIAER laboratory.

Bacteria monitoring by TIAER has generally occurred on a monthly basis at most sites. Biweekly bacteria analysis was initiated in February 2002 at microwatershed and several major tributaries to the North Bosque River and continued through September 2008 then switched back to monthly. From June 2003 to April 2005, some storm samples were analyzed for *E. coli* at sites AL020, GB020, GB040, and IC020 as part of a project with the Brazos River Authority (BRA). From April 2007 through May 2008, additional storm grabs were collected at microwatershed and some major tributary sites (NF050, and SF085) during selected events as part of a project with the TSSWCB. These storm bacteria data are reported in previous semiannual reports (e.g., Adams and McFarland, 2010) and, thus, not included in this report.

Reporting limits for the data presented are based on ambient water reporting limits (AWRLs) set by TCEQ (TCEQ, 2012b) or project specific reporting limits or limits of quantitation (LOQs). In most cases, the AWRL and LOQ are the same, unless the project requires a lower LOQ. TIAER continues to evaluate method detection limits (MDLs) as part of good laboratory practice, but also makes sure that appropriate analytical limits of quantitation are met for projects and that results are reported to project sponsors according to their specifications. For reference, the range of TCEQ AWRLs and project LOQs for the reporting period are presented in Table 8. As a data management procedure, TIAER uses half the reporting limit as the value for concentrations measured below the reporting limit.

Table 8. Analysis methods and method detection limits for water quality constituents.

Constituent	Method	Range of TCEQ AWRLs or Project LOQs[a]
Field Measurements [b]		
Conductivity	EPA[c] 120.1	not applicable
Dissolved oxygen	EPA 360.1	not applicable
pH	EPA 150.1	not applicable
Water temperature	EPA 170.1	not applicable
Laboratory Measurements		
Ammonia-nitrogen (dissolved)	EPA 350.1 or SM[d] 4500-NH3 G	0.02 - 0.1 mg/L
Chlorophyll-a	SM 10200-H	3.0 - 5.0 mg/L
Chloride	EPA 300.0 or SM 4500D	5 - 10 mg/L
Sulfate	EPA 300.0 or SM 426C	5 - 10 mg/L
Escherichia coli	IDEXX Colilert[e]	1 colonies/100 mL
Nitrite-nitrogen+nitrate-nitrogen (dissolved)	EPA 353.2 or SM 4500-NO3 F	0.04 - 0.05 mg/L
Total Kjeldahl nitrogen	EPA 351.2 or SM 4500-NH3 G	0.20 mg/L
Orthophosphate-phosphorus (dissolved)	EPA 365.2 or SM 4500P-E	0.005 mg/L[f]
Total phosphorus	EPA 365.4	0.06 mg/L
Total suspended solids	EPA 160.2 or SM 2540 D	4 mg/L

a. Source: *Appendix D, Surface Water Quality Monitoring Procedures Manual, Volume 1* (TCEQ, 2003; 2008; 2012c) and listing of *Ambient Water Quality Reporting Limits (AWRLs) for Texas Surface Water Quality Monitoring Programs* (TCEQ, 2012b). If the project LOQ is lower than the program AWRL, then the project LOQ is presented.

b. All field activities follow guidelines as outlined in the applicable version of TCEQ's *Surface Water Quality Monitoring Procedures Manual* (e.g., TCEQ, 2003; 2008; 2012c).

c. EPA refers to *Methods for Chemical Analysis of Water and Wastes* (EPA, 1983).

d. SM refers to the *Standard Methods for the Examination of Water and Wastewater*, 18th Edition (APHA, 1992) or most recent online edition.

e. Results from the IDEXX method are generally reported MPN/100 mL whereas plating technique results are reported as colonies/100 mL. In this report, data for all *E. coli* results using IDEXX are presented in units of colonies/100 mL for consistency with units used by TCEQ. For assessment purposes, MPN/100 mL and colonies/100 mL for *E. coli* are considered equivalent.

f. For PO_4-P the AWRL is 0.04 mg/L, but for the Bosque River a reporting limit of 0.005 mg/L has been established for TCEQ projects due to the TMDLs for soluble reactive phosphorus for Segments 1226 and 1255.

CHAPTER 4

Data Analysis Methods

Outliers

Values for each constituent were screened to detect questionable data points. Questionable data were then tracked through the chain of custody sheets and field data sheets and laboratory notebooks, as necessary, to ascertain whether these points represented transcription errors in the database. If a transcription error was found, the error was corrected prior to statistical analysis of the data.

Censored Data

Left censored data (values measured below the reporting limit, MDL or LOQ) for laboratory constituents were entered as one-half the reporting limit, as recommended by Gilliom and Helsel (1986) and Ward *et al.* (1988). Reporting limits for these variables are listed in Table 8 of the previous chapter. The number of samples with values measured below the reporting limit is presented for each constituent by site in Appendices B through D.

Methods for Assessment of Surface Water Quality

Numeric water quality criteria are designated for parameters such as water temperature, pH, *E. coli*, Cl, SO_4, TDS, and DO on a segment-by-segment basis in relation to specific uses (Table 9). Criteria for water temperature, pH, Cl, SO_4, and TDS are considered to protect the general use of a water body, while *E. coli* criteria are used to assess support of specific recreational use categories (i.e., primary contact recreation, secondary contact recreation 1, secondary contact recreation 2, and noncontact recreation). Dissolved oxygen criteria are generally associated with assessing the aquatic life use of a given segment.

Support of the general use of a water body also includes assessing nutrient concentrations and algal abundance as indicators of water quality problems associated with nutrient enrichment. Screening levels, rather than criteria, are set for nutrients and CHLA by TCEQ to help identify concerns and causes of nonsupport of narrative criteria for nutrient enrichment. Screening levels for nutrients and CHLA, unless specified in the Texas Surface Water Quality Standards, are statistically derived from long-term surface water quality monitoring data (TCEQ, 2012a). These screening levels represent the 85 percentile for each parameter for a given water body type (i.e., freshwater streams, tidal streams, reservoirs, and estuaries) generally

for a 10-year period (TCEQ, 2012a). These screening levels are updated periodically by TCEQ, and the most recent screening levels are shown for nutrients and CHLA for freshwater streams in Table 10.

Table 9. Water quality criteria for Segments 1226 and 1255 of the North Bosque River. Source: TCEQ (2012a).

Water Quality Parameter	Use Assessed	Segment 1226	Segment 1255
24-hour mean DO (mg/L)	Aquatic Life	5.0	4.0
Springtime mean DO (mg/L)	Aquatic Life	5.5	5.0
Absolute minimum DO (mg/L)	Aquatic Life	3.0	3.0
Springtime absolute minimum DO (mg/L)	Aquatic Life	4.5	4.0
E. coli (col/100 mL), long-term geometric average	Primary Contact Recreation	126	126
Cl (mg/L), long-term average	General	100	200
pH (standard units)	General	6.5 - 9.0	6.5 - 9.0
SO_4 (mg/L), long-term average	General	100	150
TDS (mg/L), long-term average	General	540	1000
Water temperature (ºC)	General	32.8	32.8

Table 10. Screening levels for streams in Texas.

Water Quality Parameter	Screening Level for Freshwater Streams (TCEQ, 2012a)
CHLA (µg/L)	14.1
NH_3-N (mg/L)	0.33
NO_2-N+NO_3-N (mg/L)	1.95
PO_4-P (mg/L)	0.37
Total-P (mg/L)	0.69

Assessments for aquatic life, recreation, and general uses normally are conducted by comparing individual or average constituent concentrations to the criterion or screening level. For the Bosque monitoring data, individual values were compared to segment specific criteria for DO, pH, and water temperature and screening levels for nutrients and CHLA (Tables 9 and 10). Averages over the seven-year period were compared to criteria for Cl, SO_4, and TDS, while the long-term geometric mean was compared for *E. coli* (Table 10). The mean TDS was calculated by multiplying the mean conductivity by 0.65. Assessments were made following the *2012 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2012a) with additional information provided from the *Texas Surface Water Quality Standards* (TCEQ, 2010) but with some modifications noted below.

Assessments were conducted by site for major tributary and mainstem sites to allow for the evaluation of water quality at specific sites within the Bosque watershed. This differs from the reporting of surface water quality for Texas conducted by TCEQ in which all data for sites within a segment or assessment unit are generally combined for assessment purposes. Criteria and screening levels for mainstem segments were applied to major tributary sites, unless specifically indicated. Although assessments are designed for routine grab samples, which are generally representative of

baseflow conditions, storm samples were also separately assessed to give a better indication of nonpoint source contributions. Data collected at microwatershed sites were not compared to criteria or screening levels due to the highly intermittent nature of flow at these smaller stream sites.

A 10 sample minimum (20 for bacteria) is needed for assessment purposes, although fewer than 10 samples (4-9) can be used to identify nonsupport or concerns of use attainment parameters (TCEQ, 2012a). If fewer than 10 samples (4-9) were collected but values indicate compelling evidence of a potential water quality problem, a concern for near non-attainment but supporting the designated use was identified. Likewise, a concern for near non-attainment but supporting the designated use was identified if the number of exceedances from 10 or more samples were insufficient for designation of nonsupport but indicated evidence of a potential water quality problem. Near non-attainment was defined in the binomial tables developed by TCEQ (2012a). In general, assessment of no concern for criteria requires the fewest exceedances per sample size, concern for near non-attainment but supporting of criteria requires the second fewest, and nonsupport of criteria requires the highest number of exceedances. Assessments were not made if fewer than four samples were available.

Assessments of support and concern for individual values were made based on the binomial method for categorizing exceedances using tables and figures included in the *2012 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2012a). The binomial method takes into account sample size as well as the probability of making both Types I and II decision errors. Type I decision errors are inappropriate indications of concern or lack of full support when the water body is actually of no concern or fully supporting. Type II decision errors are inappropriate indications of no concern or full support when the water body actually has concerns or is not fully supporting. For conventional parameters and bacteria, the desired Type I error rate for identifying impairments and concerns is less than 20 percent and the desired Type II error rate is above 40 percent. The binomial tables developed in the TCEQ guidance indicate the number of exceedances needed for a given sample size to best meet these desired Type I and II error rates (TCEQ, 2012a). For constituents with screening levels but without numeric criteria (CHLA, NH_3-N, NO_2-N+NO_3-N, PO_4-P, and total-P), concerns were assessed using Figure B-4 in *2012 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2012a).

Because aquatic life uses differ some by segment (Table 2), DO criteria for these segments differ slightly (Table 9). Additionally, to protect fish spawning periods during that portion of the first half of the year when temperatures are 17.2 ^{o}C (63.0 ^{o}F) to 22.8 ^{o}C (73.0 ^{o}F) in classified water bodies, a springtime criteria for mean and absolute minimum DO are included as part of the TCEQ assessment (TCEQ, 2010) but are not evaluated in this report.

All DO and pH measurements used in this report represent instantaneous measurements taken during the daytime near the water surface. In reservoirs and slow, deep streams that are likely to stratify, measurements of DO and pH should be

made based on profile measurements within the mixed surface layer for assessment purposes (TCEQ, 2012a). Stream sites within the Bosque River watershed are generally shallow at baseflow and relatively fast moving when deeper, and, thus, not likely to stratify.

Even if waters do not stratify, a complete assessment for DO criteria requires intensive 24-hour measurements, which are not part of TIAER's routine monitoring program. Although support of the 24-hour DO criteria cannot be evaluated using instantaneous DO measurements, concerns can be identified by comparing individual observations to the 24-hour mean and minimum (TCEQ, 2012a).

Support of the pH and water temperature criteria was assessed by determining the number of individual readings that exceeded the criteria for a given sample size (TCEQ, 2012). Support of the absolute minimum DO criterion was assessed by comparing the number of exceedences of instantaneous DO data for a given sample size to binomial method-graphic tables developed by TCEQ (Figure B-1 in *2012 Guidance for Assessing and Reporting Surface Water Quality Data in Texas;* TCEQ, 2012a). Concerns with respect to DO were also assessed using instantaneous DO data compared to Figure B-2 in *2012 Guidance for Assessing and Reporting Surface Water Quality Data in Texas* (TCEQ, 2012a).

To assess whether a water body is fully supporting bacteria criteria for primary contact recreation, the geometric mean of samples is compared to the associated criterion (Table 9). If the geometric mean for *E. coli* indicates nonsupport, the water body is assessed as not supporting the use of primary contact recreation (TCEQ, 2012a). Support of bacteria criterion was assessed by comparing the seven-year geometric mean for *E. coli* to the long-term geometric average criterion.

Basic statistics (mean, median, standard deviation, minimum, maximum, and number of observations) for grab and storm event samples were also calculated to provide general information on the water quality at each site. Of note grab samples include routine grabs (biweekly or monthly) as well as any additional special project samples and are not necessarily representative of baseflow conditions. Storm samples are primarily flow-composited samples representing biased or elevated flows.

CHAPTER 5

Water Quality Assessment Results

Basic statistics for each site are presented in alphanumeric order in the appendices by category. The statistics include mean, median, standard deviation, minimum value, maximum value, number of values, and number of values measured below the reporting limit for all analytes at each sampling site. Because TDS was estimated from conductivity and not measured, it is excluded from the appendices. In addition, the long-term geometric average for *E. coli* is presented for sites on the North Bosque River and its major tributaries. Statistics for microwatershed sites are presented in Appendix B; for sites on major tributaries to the North Bosque River in Appendix C; and for North Bosque River sites in Appendix D.

Assessments compare TCEQ criteria and screening levels to values for both routine and storm samples collected at major tributary and mainstem sites. While TCEQ criteria and screening levels are established for comparison with routine sampling data, the comparison to storm samples is included because nonpoint source or storm driven runoff is considered a primary source of water quality impairment to the North Bosque River. An assessment of microwatershed sites was not included because these water bodies are highly intermittent. As a consequence, flow frequently exists only during and immediately following rainfall-runoff events. The appropriateness of applying TCEQ criteria and screening levels to these smaller microwatershed sites is questionable.

For assessments requiring the comparison of individual samples to criteria or screening levels, the number of samples analyzed and the percentage of those samples in exceedance of criteria or screening levels are shown. The binomial method for assessing support or concern, based on figures in *2012 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2012a), was used to determine the level of support or concern for constituents at each site.

Sites on Major Tributaries to the North Bosque River

Data from the four sites representing major tributaries to the North Bosque River were compared to criteria and screening levels to evaluate levels of support and concern with respect to designated uses (Table 11). Grab and storm data were compared for all four sites.

Table 11. Percent of North Bosque tributary samples exceeding criteria or screening levels for samples collected between July 1, 2007 and June 30, 2014. Shaded values indicate concern or lack of support of criteria based on the binomial method (TCEQ, 2012a).

Site	Sample Type[a]	DO < 3 or 2 mg/L[b]	DO Abs Min < 2 or 1.5 mg/L[c]	pH < 6.5 or > 9.0	Water Temp.> 32.8 ºC	CHLA > 14.1 µg/L	NO_2-N +NO_3-N > 1.95 mg/L	NH_3-N > 0.33 mg/L	PO_4-P > 0.37 mg/L	Total-P > 0.69 mg/L
GC100	R	0%	0%	0%	0%	17%	7%	2%	0%	0%
	n	60	60	60	60	60	60	60	60	60
	S						3%	9%	0%	17%
	n						79	79	78	79
NC060	R	1%	0%	0%	1%	2%	4%	0%	0%	2%
	n	125	125	125	125	124	124	124	125	125
	S						0%	0%	0%	3%
	n						114	114	113	113
NF050	R	0%	0%	0%	0%	77%	6%	9%	33%	21%
	n	33	33	33	33	13	33	33	33	33
	S						1%	9%	59%	54%
	n						144	144	144	144
SF085	R	0%	0%	0%	0%	42%	1%	3%	11%	3%
	n	71	71	71	71	34	71	71	71	71
	S						0%	6%	20%	22%
	n						193	193	193	193

a. R = routine grab sample, but may also include some special project samples; S = storm sample; n = number of samples.
b. The 24-hr DO mean criterion is 3 mg/L for sites GC100 and NC060 and 2 mg/L for sites NF050 and SF085.
c. The absolute minimum DO criterion is 2 mg/L for GC100 and NC060 and 1.5 mg/L for NF050 and SF085.

Different DO criteria were applied to the major tributary sites, based on the segment aquatic life use designation (TCEQ, 2010). Segments associated with GC100 and NC060 have a limited aquatic life use, while segments associated with NF050 and SF085 have a minimal aquatic life use. The 24-hour DO mean criterion is 3.0 mg/L for sites GC100 and NC060 and 2.0 mg/L for sites NF050 and SF085. The absolute minimum DO criterion is 2.0 mg/L for GC100 and NC060 and 1.5 mg/L for NF050 and SF085. A comparison of DO concentrations from individual grab samples to the 24-hr mean and minimum DO criteria indicated no concern for the aquatic life use for all four major tributary sites (Table 11).

No measurements of pH were outside the range of 6.5 to 9.0 standard units, and only one water temperature was greater than 32.8 ºC (Table 11). At NC060, a maximum water temperature of 33.1 ºC was measured in August 2010.

With regard to algal abundance, concerns for CHLA were indicated at sites NF050 and SF085. Concerns regarding excessive nutrients were also indicated at sites NF050 and SF085, although the nutrient or nutrients of concern varied by site. At site NF050, concerns were indicated for PO_4-P in both routine grab and storm samples and for total-P in storm samples. Site SF085 indicated concerns for PO_4-P and total-P only for storm samples.

To evaluate support of primary contact recreation, the geometric mean of *E. coli* was compared to the criterion of 126 colonies/100 mL (Table 12). For routine grab samples, support of primary contact recreation was indicated at sites GC100 and

NC060. At NF050 and SF085, the geometric-mean exceeded the criterion for routine grab samples indicating nonsupport of the primary contact recreation use.

Table 12. Geometric mean *E. coli* and mean SO_4, Cl, and TDS concentrations for routine grab samples at major tributary sites. Shaded values are above criteria.

Site	Geometric Mean *E. coli* (col/100 mL)	Number of Obs.	Mean SO_4 (mg/L)	Number of Obs.	Mean Cl (mg/L)	Number of Obs.	Mean TDS (mg/L)	Number of Obs.
Sites Associated with Segment 1226								
Criteria	126		100		100		500	
GC100	100	26	27	7	30	7	390	60
NC060	73	56	79	16	15	17	344	125
Sites Associated with Segment 1255								
Criteria	126		150		200		1000	
NF050	1200	33	Not applicable	No samples	Not applicable	No samples	696	33
SF085	320	69	Not applicable	No samples	Not applicable	No samples	460	71

Average TDS concentrations for these major tributary sites were below the associated segment criterion. Sites NF050 and SF085 are associated with Segment 1255, which has a TDS criterion of 1000 mg/L, while sites GC100 and NC060 are associated with Segment 1226, which has a TDS criterion of 500 mg/L. Mean SO_4 and Cl concentrations at sites GC100 and NC060 were also well below criteria concentrations for general use for Segment 1226 of 100 mg/L for chloride and sulfate. Concentrations of Cl and SO_4 were not evaluated at NF050 or SF085.

It should be noted that during the seven-year reporting period, water was flowing only 32 percent of the time at site NF050 and 33 percent of the time at site GC100 when routine biweekly monitoring was conducted, while flow was indicated over 65 percent of the time at SF085 and at NC060 (see Table A-3). The limited occurrence of flow at NF050 and GC100 indicates that these two sites are highly intermittent.

Sites on the North Bosque River

In the assessment summary for the mainstem of the North Bosque River, sites are presented in upstream to downstream order beginning with BO020, the most upstream site, and ending with BO095, the most downstream site (Table 13). Routine and storm samples were collected at all sites on the North Bosque River but BO083. Site BO083 was added to the North Bosque River monitoring program in November of 2002. Only routine grab samples were collected at site BO083.

The DO criteria vary along the North Bosque River based on changes in the aquatic life use. The 24-hour mean criterion is 4.0 mg/L for Segment 1255 (sites BO020 and BO040) for support of an intermediate aquatic life use and 5.0 mg/L for Segment 1226 (the remainder of the North Bosque River sites) for support of a high aquatic life use. The absolute minimum criterion is 3.0 mg/L for both segments.

Table 13. Percent of North Bosque River samples exceeding criteria or screening levels for samples collected between July 1, 2007 and June 30, 2014. Shaded values indicate concern or lack of support of criteria based on the binomial method (TCEQ, 2012a).

Site	Sample Type[a]	DO < 4 or 5 mg/L[b]	DO Abs Min < 3 mg/L	pH < 6.5 or > 9.0	Water Temp. > 32.8 ºC	CHLA > 14.1 µg/L	NO_2-N +NO_3-N > 1.95 mg/L	NH_3-N > 0.33 mg/L	PO_4-P > 0.37 mg/L	Total-P > 0.69 mg/L
BO020	R	30%	22%	0%	0%	50%	0%	4%	24%	8%
	N	107	107	107	107	107	106	106	107	105
	S						0%	7%	26%	27%
	N						203	203	208	203
BO040	R	5%	2%	0%	0%	32%	88%	11%	49%	23%
	N	182	182	182	182	179	180	180	178	180
	S						29%	11%	30%	26%
	N						195	194	194	194
BO070	R	2%	0%	0%	1%	31%	1%	1%	1%	1%
	N	165	165	165	165	165	164	164	165	163
	S						2%	4%	3%	17%
	N						221	221	220	221
BO083	R	0%	0%	0%	0%	40%	0%	0%	0%	0%
	N	135	135	135	135	135	134	134	135	135
BO090	R	0%	0%	0%	0%	32%	0%	0%	0%	0%
	N	178	178	178	178	177	177	177	178	179
	S						0%	0%	0%	5%
	N						197	197	195	197
BO095	R	1%	0%	0%	0%	20%	0%	0%	0%	1%
	N	179	179	179	179	178	178	178	178	180
	S						0%	0%	0%	6%
	n						194	194	192	192

a. R = routine grab sample, but may also include some special project samples; S = storm sample; n = number of samples.
b. The 24-hr DO mean criterion is 4 mg/L for sites BO020 and BO040 and 5 mg/L for sites BO070, BO083, BO090, and BO095.

All DO comparisons represent individual measurements taken in conjunction with grab samples compared to the 24-hr mean and absolute minimum criteria. Concern for the 24-hour DO mean criterion and nonsupport of the absolute minimum criterion was indicated at site BO020. The remaining five sites on the North Bosque River were fully supporting with respect to the minimum DO criterion and had no concerns associated with the 24-hour mean criteria.

Only one measurement of water temperature was greater than 32.8 ºC and all pH measurements were within the designated range of 6.5 to 9.0 standard units, indicating a preliminary assessment of full support for these general use criteria. The one water temperature greater than 32.8 ºC occurred at BO070 when a temperature of 33.4ºC was measured on July 23, 2013.

A concern regarding algal abundance was indicated for CHLA at sites BO020, BO040, BO070, BO083, and BO090, and concerns regarding excessive nutrients were indicated at sites BO020 and BO040. At BO020, routine grab samples indicated concerns for PO_4-P and storm samples indicated concern for PO_4-P and total-P. Routine and storm samples at BO040 indicated concern for NO_2-N+NO_3-N, PO_4-P and total-P. No concerns were indicated for excessive nutrients at sites BO070, BO083, BO090, and the most downstream site BO095.

Nonsupport for primary contact recreation was indicated at both sites BO020 and BO040 based on the long-term geometric mean of *E. coli* (Table 14).

Table 14. Geometric mean *E. coli* and mean SO_4, Cl, and TDS for routine grab samples at mainstem sites. Shaded values are above criteria.

Site or Segment	Geometric Mean *E. coli* (col./100mL)	Number of Obs.	Mean SO_4 (mg/L)	Number of Obs.	Mean Cl (mg/L)	Number of Obs.	Mean TDS (mg/L)	Number of Obs.
Segment 1255								
Criteria	126		150		200		1000	
BO020	240	45	50	14	55	14	437	106
BO040	180	82	68	25	137	25	663	182
Segment 1226								
Criteria	126		100		100		540	
BO070	88	74	32	22	57	22	407	165
BO083	26	58	41	19	36	19	331	135
BO090	36	80	26	22	25	22	304	178
BO095	61	81	31	24	22	24	306	179

The Cl and SO_4 criteria for Segment 1226 are both 100 mg/L. For Segment 1255, the Cl criterion is 200 mg/L and the SO_4 criterion is 150 mg/L. Both Cl and SO_4 indicated a preliminary assessment of full support for these general use criteria for all sites along the mainstem of the North Bosque River.

Mean conductivity for each site was multiplied by 0.65 to estimate TDS. Mean TDS concentrations were then compared to the appropriate criterion (540 mg/L for Segment 1226 and 1000 mg/L for Segment 1255) on a site-by-site basis to assess general use. All sites had mean TDS concentrations below the segment specific criterion for general use.

CHAPTER 6

Summary and Conclusions

This report presents a synthesis of water quality data for TIAER sites within the Bosque River watershed for July 1, 2007 through June 30, 2014. Most grab samples were collected on a routine biweekly schedule at stream sites, although in September 2008 a monthly schedule was implemented at microwatershed sites and major tributary sites NF050, and SF085 within the North Bosque River watershed. Most routine samples were analyzed for DO, pH, water temperature, CHLA, TSS, nutrients, and *E. coli*. Analyses of Cl and SO_4 were conducted only on a quarterly basis starting in late 2006 at selected sites. Direct measurement of TDS was not conducted, rather mean TDS values were calculated from the seven-year mean of conductivity multiplied by 0.65. At some sites, storm samples were collected for analysis of *E. coli*. Basic statistics for all sites monitored are presented separately for storm and routine grab data in Appendices B-D.

Based on TCEQ assessment methodology (TCEQ, 2012a), water quality data for river and major tributary stations within the Bosque River watershed were compared to state numeric criteria and screening levels. Numeric criteria are the part of the state water quality standards that protect designated uses, while numeric screening levels for nutrients and CHLA are used to identify areas of concern with regard to nutrient enrichment compared to other water bodies within the state. Levels of support and concern can be identified for parameters with numeric criteria; concerns can be identified for parameters with screening levels.

Assessments in most cases employed the binomial method for determining levels of support or concern (TCEQ, 2012a). The binomial method incorporates sample size and probability rates for making Type I and II decision errors in determining the number of exceedances that can occur before impairment or concern is indicated. Other constituents were assessed by comparing mean values for Cl, SO_4, and TDS or the geometric mean for *E. coli* directly to the assessment criterion.

Numeric criteria for DO, pH, water temperature, and *E. coli* were based on designated uses for Segment 1226, North Bosque River and Segment 1255, Upper North Bosque River (TCEQ, 2010). Screening levels used to evaluate CHLA and nutrients were from the *2012 Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ, 2012a). Numeric criteria for Cl, SO_4, and TDS used to evaluate general use were from Appendix A in the Texas Surface Water Quality Standards (TCEQ, 2010). Chloride and sulfate were measured only at selected sites associated with Segments 1226 and 1255.

Measurements for DO represented instantaneous measurements taken during daylight hours rather than summary data from intensive 24-hour evaluations. To

fully assess the DO criteria for aquatic life use, intensive 24-hour measurements are required, which are not part of TIAER's routine monitoring program.

A summary of the water quality findings for the six mainstem sites and four major tributaries evaluated for the North Bosque River follows:

- DO, pH, and water temperature supported designated uses throughout the North Bosque River watersheds, except at site BO020 (Table 15). Of the 10 sites evaluated, nonsupport of the minimum DO criterion and concern for the 24-hr mean DO criterion were indicated at site BO020. Full support for pH and temperature criteria were indicated at all 10 sites.
- For routine grab samples, four sites (BO020, BO040, NF050, and SF085) indicated nonsupport of the use of primary contact recreation with regard to *E. coli* concentrations based on the geometric mean compared to the criterion (Table 15). All stations indicating nonsupport of primary contact recreation were located in the upper portion of the North Bosque River watershed.
- Regarding general use criteria for Cl, SO_4, and TDS, a preliminary assessment of routine grab samples indicated full support at sites evaluated along Segments 1226 and 1255.

Table 15. Sampling sites indicating nonsupport or concern for numeric criteria for samples collected between July 1, 2007 and June 30, 2014.

Constituent	Site Type[a]	Site	Sample Type[b]	% Samples Exceeding Criterion	# Samples Evaluated	Geometric Mean *E. coli* (col./100 mL)[c]	Assessment
DO minimum	NBR	BO020	R	22%	107	Not applicable	Not supporting
DO mean	NBR	BO020	R	30%	107	Not applicable	Concern
E. coli	MT	NF050	R	Not applicable	33	1200	Not supporting
E. coli	MT	SF085	R	Not applicable	69	320	Not supporting
E. coli	NBR	BO020	R	Not applicable	45	240	Not supporting
E. coli	NBR	BO040	R	Not applicable	82	180	Not supporting

a. NBR = site on the North Bosque River and MT = site on major tributary to the North Bosque River.
b. R = routine grab samples and S = storm samples.
c. The long-term geometric mean criterion of 126 colonies/100 mL *E. coli* was exceeded.

- Concerns for CHLA occurred at 7 of the 10 sites evaluated indicating general use concerns with regard to excessive algae (Table 16).
- Of the 10 sites assessed, concerns regarding excessive nutrients were indicated in routine samples, storm samples, or both for 4 sites in the upper portion of the North Bosque watershed (Table 16).

Of note, criteria and screening levels were not intended to be strictly applied to storm or biased flow sampling, but rather routine, ambient sampling. Comparisons of storm data to criteria and screening levels are presented as a relative comparison to routine grab data.

Table 16. Sampling sites indicating concern for screening levels for samples collected between July 1, 2007 and June 30, 2014. Routine grab sample concerns are indicated by R, and storm sample concerns are indicated by S.

Site Type[a]	Site	CHLA	NO_2-N+ NO_3-N	NH_3-N	PO_4-P	Total-P
MT	NF050	R	—	—	R, S	S
MT	SF085	R	—	—	S	S
NBR	BO020	R	—	—	R, S	S
NBR	BO040	R	R,S	—	R, S	R, S
NBR	BO070	R	—	—	—	—
NBR	BO083	R	—	—	—	—
NBR	BO090	R	—	—	—	—

a. MT = site on major tributary to North Bosque River and NBR = North Bosque River site.

More detailed reports on trends in water quality within the Bosque River watershed are available from TIAER or may be accessed from TIAER's website at http://tiaer.tarleton.edu/.

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APPENDIX A

Grab Sampling History

These tables indicate the routine sampling history for each site and the presence or absence of flow during each biweekly or monthly sampling at stream sites. All samples were collected between July 1, 2007 and June 30, 2014. The last row of each table for stream sites presents the percentage of sampling events for which flow was present and grab samples were collected.

Table A-1. Biweekly grab sampling history at microwatershed sites.

Year	Month	Day	AL020	DB035	GB020	GC045	GM060	IC020	LD040	LG060	NF009	NF020	SP020
2007	Jul	2	X[a]	X	X	X	X	X	X	X	X	X	X
		17	X	X	D[b]	X	X	X	X	X	X	D	X
		30	X	D	D	X	X	X	X	X	X	D	X
	Aug	13	X	D	D	X	X	D	X	X	D	D	X
		27	X	D	D	X	X	D	X	X	D	D	X
	Sep	10	X	X	D	X	X	X	X	X	X	D	X
		24	X	D	D	X	X	D	X	X	X	D	X
	Oct.	8	X	D	D	X	X	D	D	X	D	D	X
		22	X	D	D	X	X	D	D	X	D	D	X
	Nov	5	X	D	D	X	D	D	D	X	D	D	X
		19	X	D	D	X	D	D	D	X	D	D	X
	Dec	3	X	D	D	X	X	D	D	X	X	D	X
		17	X	D	D	X	X	D	X	X	X	D	X
2008	Jan	2	X	D	D	X	X	D	X	X	X	D	X
		14	X	D	D	X	X	D	X	X	X	D	X
		28	X	D	D	X	X	D	X	X	X	D	X
	Feb	11	X	D	D	X	X	D	X	X	X	D	X
		25	X	D	D	X	X	D	X	X	X	D	X
	Mar	10	X	X	D	X	X	X	X	X	X	X	X
		24	X	X	D	X	X	X	X	X	X	X	X
	Apr	7	X	X	D	X	X	X	X	X	X	X	X
		21	X	D	D	X	X	X	X	X	X	D	X
	May	6	X	X	X	X	X	X	X	X	X	X	X
		19	X	D	D	X	D	X	X	X	X	X	X
	Jun	2	X	D	D	X	D	D	D	D	X	D	X
		17	D	D	D	X	D	D	D	D	D	D	D
		30	D	D	D	X	D	D	D	D	D	D	D
	Jul	14	D	D	D	D	D	D	D	D	D	D	D
		28	D	D	D	D	D	D	D	D	D	D	D
	Aug	11	D	D	D	D	D	D	D	D	D	D	D
		25-26	D[c]	D[c]	D[c]	D[c]	D[c]	D[c]	D[c]	D[c]	D[c]	D[c]	D[c]
	Sep	8	D	D	D	D	D	D	D	D	D	D	D
	Oct.	6-7	D	D	X	D	D	D	D	D	D	D	D
	Nov	3 or 17	D	D	D	D	D	D	D	D	X	D	D
	Dec	1	D	D	D	D	D	D	D	D	X	D	D
2009	Jan	5-6	D	D	D	D	D	D	D	D	X	D	D
	Feb	3	D	D	D	D	D	D	D	D	X	D	D
	Mar	2-3	D	D	D	D	D	D	D	D	X	D	D
	Apr	13-14	D	D	D	D	D	D	D	D	X	D	D
	May	12	D	D	D	D	D	D	D	D	X	D	D
	Jun	8-9	D	D	D	D	D	D	D	D	D	D	D
	Jul	6-7	D	D	D	D	D	D	D	D	D	D	D
	Aug	3-4	D	X	D	D	D	D	X	D	D	D	D
	Sep	1	D	D	D	D	D	D	D	D	D	D	D
	Oct.	12	X	X	D	D	D	X	X	D	D	X	D
	Nov	9-10	X	X	D	X	X	X	X	D	X	X	X
	Dec	7	X	X	D	X	X	X	X	X	X	D	X
2010	Jan	26	X	X	D	X	X	X	X	X	X	D	X
	Feb	10	X	X	D	X	X	X	X	X	X	X	X
	Mar	3	X	X	D	X	X	X	X	X	X	X	X

Year	Month	Day	AL020	DB035	GB020	GC045	GM060	IC020	LD040	LG060	NF009	NF020	SP020
	Apr	13	X	X	D	X	X	X	X	X	X	X	X
	May	10	X	D	D	X	X	X	X	X	X	D	X
	Jun	7	X	D	D	X	D	D	D	X	D	D	X
	Jul	6	D	D	D	X	D	D	D	D	D	D	D
	Aug	4	D	D	D	X	D	D	D	D	D	D	D
	Sep	31	D	D	D	D	D	D	D	D	D	D	D
	Oct	13	D	D	D	D	D	D	D	D	D	D	D
	Nov	9	D	D	D	D	D	D	D	D	D	D	D
	Dec	20	D	D	D	X	D	D	D	D	X	D	D
2011	Jan	18	D	X	D	X	D	D	D	D	X	D	D
	Feb	14	D	X	D	X	D	D	D	D	X	D	D
	Mar	15	D	D	D	X	D	D	D	D	X	D	D
	Apr	11	D	D	D	X	D	D	D	D	X	D	D
	May	9	D	D	D	D	D	D	D	D	X	D	D
	Jun	6	D	D	D	D	D	D	D	D	D	D	D
	Jul	5	D	D	D	D	D	D	D	D	D	D	D
	Aug	2	D	D	D	D	D	D	D	D	D	D	D
	Sep	27	D	D	D	D	D	D	D	D	D	D	D
	Oct	11	X	X	D	X	X	D	X	X	D	X	X
	Nov	22	X	D	D	X	X	D	D	X	D	D	X
	Dec	7	X	X	D	X	X	X	X	X	D	D	X
2012	Jan	4	D	D	D	X	X	D	D	X	D	D	X
	Feb	13-14	X	X	D	X	X	X	X	X	X	X	X
	Mar	8	X	X	D	X	X	X	X	X	X	X	X
	Apr	9	X	X	D	X	X	X	X	X	X	X	X
	May	10	X	D	D	X	X	D	X	X	X	D	X
	Jun	4	D	D	D	X	D	D	D	X	D	D	X
	Jul	3	D	D	D	X	D	D	D	X	D	D	D
	Aug	27	D	D	D	D	D	D	D	D	D	D	D
	Sep	24	D	D	D	D	D	D	D	D	D	D	D
	Oct	24	D	D	D	D	D	D	D	D	D	D	D
	Nov	19-21	D	D	D	D	D	D	D	D	D	D	D
	Dec	18	D	D	D	D	D	D	D	D	D	D	D
2013	Jan	23	D	D	D	X	D	X	D	D	D	D	D
	Feb	19	D	D	D	X	D	X	D	D	D	D	D
	Mar	25	D	D	D	X	D	X	D	D	D	D	D
	Apr	15	D	D	D	X	X	X	D	D	D	D	D
	May	13	D	D	D	D	D	D	D	D	D	D	D
	Jun	24-25	D	D	D	D	D	D	D	D	D	D	D
	Jul	31	D	D	D	D	D	D	D	D	D	D	D
	Aug	21	D	D	D	D	D	D	D	D	D	D	D
	Sep	25	D	D	D	D	D	D	D	D	D	D	D
	Oct	16	X	X	X	D	X	X	X	X	D	D	X
	Nov	18	D	D	D	D	D	D	D	D	D	D	D
	Dec	16-17	D	D	D	D	X	D	D	D	D	D	D
2014	Jan	30	D	D	D	X	X	D	D	X	D	D	X
	Feb	26	D	D	D	X	X	D	D	X	D	D	X
	Mar	26	D	D	D	X	D	D	D	X	D	D	D
	Apr	28	D	D	D	D	D	D	D	D	D	D	D
	May	28	D	X	D	X	X	X	X	X	X	D	X
	Jun	17-18	D	D	D	D	D	D	D	D	D	D	D

Year	Month	Day	AL020	DB035	GB020	GC045	GM060	IC020	LD040	LG060	NF009	NF020	SP020
Percentage of events at which flow was present[d]			42%	24%	4%	59%	42%	28%	36%	46%	44%	15%	46%

a. X indicates a grab sample was collected.
b. D indicates no flow (pooled) or dry conditions during which grab samples were not collected.
c. Biweekly sampling for this site was discontinued due to changing project requirements. Monthly grab sampling began September 2008.
d. The percentage is based the total number of visits to a site for the full seven-year period or 101 visits for these sites. The percentages are adjusted according to the number of times site was monitored.

Table A-2. Biweekly grab sampling history at major tributary sites along the North Bosque River.

Year	Month	Day	GC100	NC060	NF050	SF085
2007	Jul	2	X[a]	X	X	X
		16-17	X	X	X	X
		30	X	X	X	X
	Aug	13	X	X	D[b]	X
		27	X	X	D	X
	Sep	10-11	X	X	X	X
		24	X	X	D	X
	Oct.	8	X	X	D	X
		22-23	X	X	D	X
	Nov	5	X	X	D	X
		19	X	X	D	D
	Dec	3	X	X	D	X
		17	X	X	D	X
2008	Jan	2	X	X	D	X
		11-14	X	X	D	X
		28	X	X	D	X
	Feb	11	X	X	D	X
		25	X	X	D	X
	Mar	10-11	X	X	X	X
		24	X	X	X	X
	Apr	7-8	X	X	X	X
		21-22	X	X	X	X
	May	5	X	X	X	X
		19-20	X	X	X	X
	Jun	2-3	X	X	X	X
		17	D	X	D	X
		30	D		D	X
	Jul	1		X		
		14	D	X	D	D
		28	D	X	D	D
	Aug	11	D	D	D	D
		25-26	D	D	D	D
	Sep	8	D	D	D	D
		22	D	D		
	Oct.	6-7	D	X	D	X
		20	D	D		
	Nov	3	D	X	D	D
		17	D	D	X	X
	Dec	1	D	X	D	D
		15	D	X		
2009	Jan	5-6	D	X	D	X
		20	D	X		
	Feb	3	D	X	D	X
		17	D	X		
	Mar	2-3	D	X	D	X
		16	D	X		
		31	D	X		
	Apr	13-14	D	X	D	X
		27	D	X		
	May	12	D	X	D	X
		26	D	X		
	Jun	8-9	D	X	D	X
		23	D	X		
	Jul	6-7	D	X	D	D
		21	D	X		
	Aug	3-4	D	X	X	X
		17	D	D		
	Sep	1	D	D	D	D
		15-16	D	X		
		29	D	X		
	Oct	12-13	D	X	X	X
		27	X	X		
	Nov	10-11	X	X	X	X
		23	X	X		
	Dec	7-8	X	X	D	X
		21	X	X		
2010	Jan	5-6	X	X		

Year	Month	Day	GC100	NC060	NF050	SF085
		19	X	X		
		26			X	X
	Feb	2	X	X		
		10			X	X
		16	X	X		
	Mar	2-3	X	X	X	X
		15-16	X	X	D	D
		30	X	X		
	Apr	12-13	X	X	X	X
		27	X	X		
	May	10-11	X	X	X	X
		26	X	X		
	Jun	7-8	X	X	D	X
		23	X	X		
	Jul	6	D	D	D	X
		22	D	X		
	Aug	3-4	D	X	D	X
		17	D	X		
		31	D		D	
	Sep	1		X		X
		14	D	X		
		28	D	X		
	Oct	13	D	X	D	X
		27	D	X		
	Nov	9	D	X	D	X
		22	D	X		
	Dec	7	D	X		
		20	D	X	X	X
2011	Jan	4	D	X		
		18	D	X	X	X
		31	D	X		
	Feb	14-15	D	X	X	X
		28	D	X		
	Mar	14-15	D	X	X	X
		30	D	X		
	Apr	11-12	D	X	X	X
		26	D	X		
	May	9	D	X	D	X
		24	D	X		
	Jun	6-7	D	D	D	D
		20	D	D		
	Jul	5	D	D	D	D
		19	D	D		
	Aug	2	D	D	D	D
		15	D	D		
	Sep	1	D	D		
		12	D	D		
		26-27	D	D	D	D
	Oct	11-12	X	D	X	X
		24	D	D		
	Nov	7	D	D		
		21-22	D	D	D	D
	Dec	6-7	D	X	X	X
		19	D	D		
2012	Jan	3-4	D	D	D	D
		17	X	X		
		31	X	X		
	Feb	13, 16	X	X	X	X
		28	X	X		
	Mar	8-9	X	X	X	X
		26-27	X	X		
	Apr	9-10	X	X	X	X
		23	X	X		
	May	7-8, 10	X	X	X	X
		21	X	X		
	Jun	4-5	X	X	D	X
		19	X	X		
	Jul	2-3	X	D	D	D

Year	Month	Day	GC100	NC060	NF050	SF085
		16	D	D		
		31	D	D		
	Aug	14	D	D		
		27-29	D	D	D	D
	Sep	11	D	D		
		24-26	D	D	D	D
	Oct	10	D	D		
		24	D	D	D	D
	Nov	5	D	D		
		19	D	D	D	D
	Dec	3	D	D		
		17-18	D	D	D	D
2013	Jan	7	D	D		
		22-23	D	D	D	D
	Feb	5	D	D		
		18-19	D	D	D	X
	Mar	5	D	D		
		19&25	D	D	D	D
	Apr	2	X	D		
		15-16	X	D	D	X
		30	X	D		
	May	13-14	D	D	D	D
		29	D	D		
	Jun	11	D	D		
		24	D	D	D	D
	Jul	8	D	D		
		22	D	D		
		31			D	D
	Aug	5-6	D	D		
		19	D	D		
		22			D	D
	Sep	3	D	D		
		16	D	D	D	D
		25			D	D
	Oct	1	D	X		
		14, 16	D	D	X	X
		29	D	X		
	Nov	11	D	X		
		18			D	D
		25	D	X		
	Dec	11	D	X		
		16-18	D	X	D	D
2014	Jan	9	D	X		
		21	D	X		
		30			D	X
	Feb	3	D	X		
		18	D	X		
		26			D	X
	Mar	5	D	X		
		17	D	X		
		26			D	X
	Apr	1	D	X		
		15	D	X		
		28-29	D	X	D	X
	May	12	D	X		
		27-28	D	X	X	
	Jun	10	D	X		
		17			D	D
		24	D	X		
Percentage of events at which flow was present[c]			33%	69%	32%	67%

a. X indicates a grab sample was collected.

b. D indicates no flow (pooled) or dry conditions during which grab samples were not collected.

c. The percentage is based on total visits to a site during the full seven-year period (182 for GC100 and NC060 and 104 for NF050 and SF085). The percentages are adjusted according to the number of times a site was monitored.

Table A-3. Biweekly grab sampling at main stem sites along the North Bosque River.

Year	Month	Day	BO020	BO040	BO070	BO083	BO090	BO095
2007	Jul	2	X[z]	X	X	X	X	X
		16	X	X	X	X	X	X
		30	X	X	X	X	X	X
	Aug	13	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Sep	11	X	X	X	X	X	X
		24	X	X	X	X	X	X
	Oct.	8	X	X	X	X	X	X
		23	X	X	X	X	X	X
	Nov	5	X	X	X	X	X	X
		19	D[b]	X	X	X	X	X
	Dec	3	X	X	X	X	X	X
		17	X	X	X	X	X	X
2008	Jan	2	X	X	X	X	X	X
		14	X	X	X	X	X	X
		28	X	X	X	X	X	X
	Feb	11	X	X	X	X	X	X
		25	X	X	X	X	X	X
	Mar	11	X	X	X	X	X	X
		24	X	X	X	X	X	X
	Apr	8	X	X	X	X	X	X
		22	X	X	X	X	X	X
	May	5	X	X	X	X	X	X
		20	X	X	X	X	X	X
	Jun	2-3	X	X	X	X	X	X
		17	X	X	X	X	X	X
	Jul	1	D	X	X	X	X	X
		14	D	X	X	X	X	X
		28	D	X	X	D	X	X
	Aug	11	D	X	X	D	X	X
		25-26	D	X	X	D	X	X
	Sep	8	D	X	X	D	X	X
		22-26	D	X	X	D	X	X
	Oct.	7	X	X	X	X	X	X
		20	D	X	X	X	X	X
	Nov	3	D	X	X	D	X	X
		17	X	X	X	X	X	X
	Dec	1	D	X	X	D	X	X
		15	D	X	X	X	X	X
2009	Jan	5	D	X	X	X	X	X
		20	D	X	X	X	X	X
	Feb	3	D	X	X	X	X	X
		17	D	X	X	X	X	X
	Mar	2-3	D	X	X	X	X	X
		16	X	X	X	X	X	X
		31	X	X	X	X	X	X
	Apr	14	X	X	X	X	X	X
		27	X	X	X	X	X	X
	May	12	D	X	X	X	X	X
		26	X	X	X	X	X	X
	Jun	9	D	X	X	X	X	X
		23	D	X	X	D	X	X
	Jul	6-7	D	X	X	D	X	X
		21	D	X	D	D	X	X
	Aug	4	X	X	X	X	X	X
		17	D	X	D	D	X	X
	Sep	1	D	X	D	D	X	X
		15	X	X	X	X	X	X
		29	X	X	X	X	X	X
	Oct.	13	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Nov	10-11	X	X	X	X	X	X
		23	X	X	X	X	X	X
	Dec	8	X	X	X	X	X	X
		21	X	X	X	X	X	X
2010	Jan	5-6	X	X	X	X	X	X
		19	X	X	X	X	X	X

Year	Month	Day	BO020	BO040	BO070	BO083	BO090	BO095
	Feb	02	X	X	X	X	X	X
		16	X	X	X	X	X	X
	Mar	02	X	X	X	X	X	X
		15	X	X	X	X	X	X
		30	X	X	X	X	X	X
	Apr	12	X	X	X	X	X	X
		27	X	X	X	X	X	X
	May	11	X	X	X	X	X	X
		26	X	X	X	X	X	X
	Jun	8	X	X	X	X	X	X
		23	X	X	X	X	X	X
	Jul	7	X	X	X	X	X	X
		20	X	X	X	X	X	X
	Aug	3	X	X	X	X	X	X
		17	X	X	X	X	X	X
	Sep	1	D	X	X	X	X	X
		14	X	X	X	X	X	X
		28	X	X	X	X	X	X
	Oct	13	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Nov	9	X	X	X	X	X	X
		22	X	X	X	X	X	X
	Dec	7	X	X	X	X	X	X
		20	X	X	X	X	X	X
2011	Jan	4	X	X	X	X	X	X
		18	X	X	X	X	X	X
		31	X	X	X	X	X	X
	Feb	14	X	X	X	X	X	X
		28	X	X	X	X	X	X
	Mar	13-14	X	X	X	X	X	X
		30	X	X	X	X	X	X
	Apr	12	X	X	X	X	X	X
		26	X	X	X	X	X	X
	May	9	X	X	X	X	X	X
		24	X	X	X	X	X	X
	Jun	7	D	X	D	D	X	X
		20	D	X	D	D	X	X
	Jul	5	D	X	D	D	X	X
		19	D	X	D	D	X	X
	Aug	2-3	D	X	D	D	X	X
		15	X	X	X	D	X	X
	Sep	1	D	X	D	D	X	X
		12	D	X	D	D	X	X
		26	D	X	D	D	X	X
	Oct	12	X	X	X	X	X	X
		24	D	X	X	X	X	X
	Nov	7	D	X	X	D	X	X
		21	D	X	X	D	X	X
	Dec	6	X	X	X	X	X	X
		19	X	X	X	X	X	X
2012	Jan	3	X	X	X	X	X	X
		17	X	X	X	X	X	X
		31	X	X	X	X	X	X
	Feb	16	X	X	X	X	X	X
		28	X	X	X	X	X	X
	Mar	9	X	X	X	X	X	X
		27	X	X	X	X	X	X
	Apr	9-10	X	X	X	X	X	X
		23	X	X	X	X	X	X
	May	7-8	X	X	X	X	X	X
		21	X	X	X	X	X	X
	Jun	5	X	X	X	X	X	X
		19	D	X	X	X	X	X
	Jul	2-3	D	X	X	X	X	X
		16	D	X	X	X	X	X
		31	D	X	X	D	X	X
	Aug	14	D	X	X	D	X	X
		29	D	X	X	D	X	X

Year	Month	Day	BO020	BO040	BO070	BO083	BO090	BO095
	Sep	11	D	X	X	D	X	X
		26	D	X	X	D	X	X
	Oct	10	D	X	X	D	X	X
		24	D	X	X	D	X	X
	Nov	5	D	X	X	D	X	X
		19	D	X	X	D	X	X
	Dec	3	D	X	X	D	X	X
		17	D	X	X	D	X	X
2013	Jan	7	D	X	X	X	X	X
		22	D	X	X	X	X	X
	Feb	5	D	X	X	X	X	X
		18	D	X	X	X	X	X
	Mar	5	D	X	X	X	X	X
		19	D	X	X	X	X	X
	Apr	2	X	X	X	X	X	X
		16	X	X	X	X	X	X
		30	D	X	X	X	X	X
	May	14	X	X	X	X	X	X
		29	X	X	X	X	X	X
	Jun	11	D	X	X	D	X	X
		24	D	X	D	D	X	X
	Jul	8	D	X	D	D	D	X
		22	X	X	X	X	X	X
	Aug	5	D	X	D	D	X	X
		19	D	X	D	D	D	D
	Sep	3	D	X	D	D	D	D
		16	D	X	D	D	D	D
	Oct	1	D	X	X	D	X	X
		14	X	X	X	D	X	X
		29	D	X	X	X	X	X
	Nov	11	D	X	X	D	X	X
		25	X	X	X	D	X	X
	Dec	11	X	X	X	D	X	X
		18	X	X	X	X	X	X
2014	Jan	9	X	X	X	X	X	X
		21	D	X	X	X	X	X
	Feb	3	D	X	X	X	X	X
		18	D	X	X	X	X	X
	Mar	5	D	X	X	X	X	X
		17	D	X	X	X	X	X
	Apr	1	D	X	X	X	X	X
		15	X	X	X	X	X	X
		29	D	X	X	X	X	X
	May	12	D	X	X	O	X	X
		27	X	X	X	X	X	X
	Jun	10	X	X	X	X	X	X
		24	X	X	X	X	X	X
Percentage of events at which flow was present[c]			59%	100%	91%	75%	98%	98%

a. X indicates a grab sample was collected.

b. D indicates no flow or dry conditions during which grab samples were not collected.

c. The percentage is based on total number of biweekly visits (182) to each site over the full seven-year period. The percentages are adjusted according to the length of time the site was monitored.

APPENDIX B

Microwatershed Sites

This appendix covers basic statistics for routine grab samples and automatic storm event samples collected from microwatershed sites between July 1, 2007 and June 30, 2014. Grab samples represent routine biweekly sampling plus a few special project samples at some sites. Bacteria statistics are associated with the arithmetic mean only. Reporting limits (MDLs or AWRLs) are not established for field parameters DO, pH, conductivity, and water temperature. Therefore, the number of samples below the reporting limit for those parameters is NA (not applicable).

Table B-1. Preliminary water quality analysis for microwatershed site AL020.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
AL020	Grab	Conductivity (µS/cm)	1140	1070	572	131	2610	42	NA
AL020	Grab	DO (mg/L)	7.4	6.9	3.3	2.3	13.2	42	NA
AL020	Grab	*E. coli* (colonies/100 mL)	8200/300[a]	230	38000	3	240000	41	0
AL020	Grab	NH_3-N (mg/L)	0.127	0.050	0.288	0.010	1.75	42	23
AL020	Grab	NO_2-N+NO_3-N (mg/L)	0.620	0.046	1.032	0.020	4.88	42	21
AL020	Grab	pH (standard units)	8.0	7.9	0.3	7.6	8.9	42	NA
AL020	Grab	PO_4-P (mg/L)	0.202	0.121	0.223	0.003	0.816	42	1
AL020	Grab	TKN (mg/L)	1.12	0.87	1.08	0.10	4.55	42	8
AL020	Grab	Total-P (mg/L)	0.36	0.23	0.44	0.03	2.59	42	4
AL020	Grab	TSS (mg/L)	11	5	18	2	87	42	17
AL020	Grab	Water temp. (°C)	15.4	16.5	6.8	3.8	25.6	42	NA
AL020	Storm	NH_3-N (mg/L)	0.155	0.077	0.208	0.010	1.28	103	41
AL020	Storm	NO_2-N+NO_3-N (mg/L)	0.717	0.607	0.799	0.020	5.64	103	9
AL020	Storm	PO_4-P (mg/L)	0.353	0.367	0.205	0.003	0.917	103	4
AL020	Storm	TKN (mg/L)	1.98	1.78	1.25	0.10	7.31	103	5
AL020	Storm	Total-P (mg/L)	0.65	0.63	0.35	0.03	1.92	103	1
AL020	Storm	TSS (mg/L)	119	39	247	2	1810	103	2

a. Arithmetic mean/geometric mean.

Table B-2. Preliminary water quality analysis for microwatershed site DB035.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
DB035	Grab	Conductivity (µS/cm)	993	1010	642	231	2250	24	NA
DB035	Grab	DO (mg/L)	9.2	8.0	3.7	4.2	20.9	24	NA
DB035	Grab	*E. coli* (colonies/100 mL)	2200/420[a]	400	4400	2	15000	24	0
DB035	Grab	NH_3-N (mg/L)	0.113	0.050	0.177	0.010	0.733	24	18
DB035	Grab	NO_2-N+NO_3-N (mg/L)	1.36	0.848	1.55	0.020	5.67	24	4
DB035	Grab	pH (standard units)	7.9	7.9	0.2	7.7	8.8	24	NA
DB035	Grab	PO_4-P (mg/L)	0.413	0.400	0.246	0.008	0.910	24	0
DB035	Grab	TKN (mg/L)	1.57	1.46	0.77	0.53	3.40	24	0
DB035	Grab	Total-P (mg/L)	0.59	0.57	0.34	0.08	1.41	24	0
DB035	Grab	TSS (mg/L)	11	8	9	2	42	24	4
DB035	Grab	Water temp. (°C)	14.6	15.0	7.2	2.8	26.2	24	NA
DB035	Storm	NH_3-N (mg/L)	0.165	0.103	0.194	0.010	1.56	130	46
DB035	Storm	NO_2-N+NO_3-N (mg/L)	0.719	0.566	0.803	0.020	6.76	130	9
DB035	Storm	PO_4-P (mg/L)	0.583	0.524	0.259	0.003	1.39	128	1
DB035	Storm	TKN (mg/L)	2.00	1.86	0.95	0.10	6.06	130	2
DB035	Storm	Total-P (mg/L)	0.90	0.83	0.38	0.27	2.50	129	0
DB035	Storm	TSS (mg/L)	68	31	117	2	900	130	1

a. Arithmetic mean/geometric mean.

Table B-3. Preliminary water quality analysis for microwatershed site GB020.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
GB020	Grab	Conductivity (µS/cm)	777	368	939	190	2180	4	NA
GB020	Grab	DO (mg/L)	6.9	6.4	1.8	5.5	9.2	4	NA
GB020	Grab	*E. coli* (colonies/100 mL)	210000/160000[a]	170000	170000	61300	440000	4	0
GB020	Grab	NH_3-N (mg/L)	8.36	0.650	15.6	0.338	31.8	4	0
GB020	Grab	NO_2-N+NO_3-N (mg/L)	1.51	1.63	0.74	0.518	2.25	4	0
GB020	Grab	pH (standard units)	8.0	8.0	0.2	7.8	8.3	4	NA
GB020	Grab	PO_4-P (mg/L)	3.19	3.16	0.771	2.44	3.98	3	0
GB020	Grab	TKN (mg/L)	20.9	6.09	31.1	4.09	67.5	4	0
GB020	Grab	Total-P (mg/L)	8.14	4.52	7.80	3.72	19.8	4	0
GB020	Grab	TSS (mg/L)	273	221	267	23	628	4	0
GB020	Grab	Water temp. (°C)	18.3	18.4	3.9	13.5	23.1	4	NA
GB020	Storm	NH_3-N (mg/L)	1.32	0.424	3.87	0.050	31.0	73	4
GB020	Storm	NO_2-N+NO_3-N (mg/L)	2.00	2.06	1.21	0.074	5.83	73	0
GB020	Storm	PO_4-P (mg/L)	2.30	2.11	1.25	0.134	6.70	73	0
GB020	Storm	TKN (mg/L)	7.67	5.61	9.15	0.98	64.9	73	0
GB020	Storm	Total-P (mg/L)	3.76	3.30	2.57	0.40	20.8	73	0
GB020	Storm	TSS (mg/L)	642	210	1800	10	15100	73	0

a. Arithmetic mean/geometric mean.

Table B-4. Preliminary water quality analysis for microwatershed site GC045.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
GC045	Grab	Conductivity (µS/cm)	677	654	206	312	1440	60	NA
GC045	Grab	DO (mg/L)	8.1	8.1	2.5	2.0	12.4	60	NA
GC045	Grab	*E. coli* (colonies/100 mL)	410/88[a]	79	1200	1	7500	58	0
GC045	Grab	NH_3-N (mg/L)	0.044	0.050	0.029	0.010	0.185	60	54
GC045	Grab	NO_2-N+NO_3-N (mg/L)	1.28	0.036	2.45	0.020	10.6	60	30
GC045	Grab	pH (standard units)	7.8	7.8	0.2	7.1	8.2	60	NA
GC045	Grab	PO_4-P (mg/L)	0.042	0.010	0.081	0.003	0.436	60	13
GC045	Grab	TKN (mg/L)	0.48	0.30	0.47	0.10	2.05	60	18
GC045	Grab	Total-P (mg/L)	0.11	0.08	0.10	0.03	0.57	60	21
GC045	Grab	TSS (mg/L)	5	2	6	2	28	60	45
GC045	Grab	Water temp. (°C)	15.3	16.1	7.1	3.6	27.2	60	NA
GC045	Storm	NH_3-N (mg/L)	0.095	0.050	0.093	0.010	0.475	85	50
GC045	Storm	NO_2-N+NO_3-N (mg/L)	0.751	0.552	0.957	0.025	6.33	85	9
GC045	Storm	PO_4-P (mg/L)	0.182	0.156	0.124	0.003	0.632	85	1
GC045	Storm	TKN (mg/L)	1.66	1.50	1.21	0.10	9.08	85	2
GC045	Storm	Total-P (mg/L)	0.44	0.37	0.29	0.03	2.28	83	1
GC045	Storm	TSS (mg/L)	307	54	995	2	6400	85	1

a. Arithmetic mean/geometric mean.

Table B-5. Preliminary water quality analysis for microwatershed site GM060.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
GM060	Grab	Conductivity (µS/cm)	749	748	283	128	1410	42	NA
GM060	Grab	DO (mg/L)	9.8	9.9	1.9	6.4	13.1	42	NA
GM060	Grab	*E. coli* (colonies/100 mL)	1400/37[a]	21	6500	1	41000	41	1
GM060	Grab	NH_3-N (mg/L)	0.039	0.050	0.026	0.010	0.154	42	37
GM060	Grab	NO_2-N+NO_3-N (mg/L)	0.074	0.025	0.189	0.020	1.22	42	34
GM060	Grab	pH (standard units)	7.9	7.9	0.2	7.7	8.3	42	NA
GM060	Grab	PO_4-P (mg/L)	0.058	0.013	0.120	0.003	0.495	42	4
GM060	Grab	TKN (mg/L)	0.31	0.10	0.32	0.10	1.41	42	25
GM060	Grab	Total-P (mg/L)	0.12	0.07	0.14	0.03	0.61	42	13
GM060	Grab	TSS (mg/L)	8	2	13	2	81	42	22
GM060	Grab	Water temp. (°C)	15.8	15.2	8.0	3.9	32.5	42	NA
GM060	Storm	NH_3-N (mg/L)	0.058	0.050	0.059	0.010	0.546	87	62
GM060	Storm	NO_2-N+NO_3-N (mg/L)	0.299	0.228	0.271	0.020	1.26	87	11
GM060	Storm	PO_4-P (mg/L)	0.199	0.176	0.188	0.003	0.818	87	10
GM060	Storm	TKN (mg/L)	1.22	0.94	1.27	0.10	9.35	87	7
GM060	Storm	Total-P (mg/L)	0.38	0.31	0.30	0.03	1.63	87	6
GM060	Storm	TSS (mg/L)	263	37	1040	2	9080	87	8

a. Arithmetic mean/geometric mean.

Table B-6. Preliminary water quality analysis for microwatershed site IC020.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
IC020	Grab	Conductivity (µS/cm)	1080	1080	572	157	2710	28	NA
IC020	Grab	DO (mg/L)	11.6	11.0	3.3	5.8	19.0	28	NA
IC020	Grab	*E. coli* (colonies/100 mL)	1800/130[a]	92	5100	1	25000	28	0
IC020	Grab	NH_3-N (mg/L)	0.058	0.050	0.050	0.010	0.231	28	25
IC020	Grab	NO_2-N+NO_3-N (mg/L)	2.98	0.930	5.05	0.020	20.1	28	11
IC020	Grab	pH (standard units)	8.1	8.1	0.3	7.6	8.6	28	NA
IC020	Grab	PO_4-P (mg/L)	0.196	0.068	0.307	0.003	1.32	28	3
IC020	Grab	TKN (mg/L)	1.07	0.85	0.87	0.10	4.37	28	2
IC020	Grab	Total-P (mg/L)	0.32	0.17	0.40	0.03	1.71	28	4
IC020	Grab	TSS (mg/L)	8	2	12	2	56	28	15
IC020	Grab	Water temp. (°C)	16.8	17.2	7.8	4.0	29.5	28	NA
IC020	Storm	NH_3-N (mg/L)	0.156	0.050	0.371	0.040	3.06	74	40
IC020	Storm	NO_2-N+NO_3-N (mg/L)	1.35	1.07	1.33	0.025	6.58	74	2
IC020	Storm	PO_4-P (mg/L)	0.452	0.457	0.299	0.011	1.27	74	0
IC020	Storm	TKN (mg/L)	2.01	1.77	1.23	0.34	8.12	74	0
IC020	Storm	Total-P (mg/L)	0.72	0.68	0.43	0.15	2.34	74	0
IC020	Storm	TSS (mg/L)	116	47	141	2	732	74	1

a. Arithmetic mean/geometric mean.

Table B-7. Preliminary water quality analysis for microwatershed site LD040.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
LD040	Grab	Conductivity (µS/cm)	1210	1320	601	255	2390	36	NA
LD040	Grab	DO (mg/L)	8.8	8.0	3.8	1.3	16.6	36	NA
LD040	Grab	*E. coli* (colonies/100 mL)	15000/780[a]	390	39000	8	170000	35	0
LD040	Grab	NH_3-N (mg/L)	0.253	0.050	0.466	0.010	2.38	36	16
LD040	Grab	NO_2-N+NO_3-N (mg/L)	3.12	1.68	3.82	0.020	14.1	36	4
LD040	Grab	pH (standard units)	7.9	7.9	0.2	7.5	8.3	36	NA
LD040	Grab	PO_4-P (mg/L)	0.541	0.368	0.450	0.008	1.64	36	0
LD040	Grab	TKN (mg/L)	1.94	1.72	1.41	0.10	5.72	36	1
LD040	Grab	Total-P (mg/L)	0.81	0.46	0.69	0.03	2.66	36	1
LD040	Grab	TSS (mg/L)	32	9	48	2	202	36	10
LD040	Grab	Water temp. (°C)	15.3	16.3	7.1	3.5	26.8	36	NA
LD040	Storm	NH_3-N (mg/L)	0.644	0.248	1.18	0.026	7.91	77	14
LD040	Storm	NO_2-N+NO_3-N (mg/L)	2.33	1.71	3.12	0.250	25.1	77	0
LD040	Storm	PO_4-P (mg/L)	0.874	0.825	0.362	0.221	2.54	77	0
LD040	Storm	TKN (mg/L)	4.24	3.49	2.41	1.08	13.3	77	0
LD040	Storm	Total-P (mg/L)	1.49	1.37	0.57	0.44	3.36	77	0
LD040	Storm	TSS (mg/L)	226	130	260	10	1170	77	0

a. Arithmetic mean/geometric mean.

Table B-8. Preliminary water quality analysis for microwatershed site LG060.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
LG060	Grab	Conductivity (µS/cm)	660	645	208	176	1100	46	NA
LG060	Grab	DO (mg/L)	9.9	9.4	2.6	4.3	15.2	46	NA
LG060	Grab	*E. coli* (colonies/100 mL)	4300/190[a]	140	18000	1	110000	45	0
LG060	Grab	NH_3-N (mg/L)	0.059	0.050	0.097	0.010	0.651	46	37
LG060	Grab	NO_2-N+NO_3-N (mg/L)	0.384	0.073	0.668	0.020	2.51	46	21
LG060	Grab	pH (standard units)	8.0	8.0	0.2	7.8	8.4	46	NA
LG060	Grab	PO_4-P (mg/L)	0.052	0.013	0.101	0.003	0.508	46	11
LG060	Grab	TKN (mg/L)	0.71	0.55	0.74	0.10	3.94	46	12
LG060	Grab	Total-P (mg/L)	0.14	0.09	0.14	0.03	0.62	46	13
LG060	Grab	TSS (mg/L)	13	6	21	2	98	46	20
LG060	Grab	Water temp. (°C)	15.4	16.3	7.6	2.5	27.4	46	NA
LG060	Storm	NH_3-N (mg/L)	0.109	0.050	0.105	0.010	0.490	68	32
LG060	Storm	NO_2-N+NO_3-N (mg/L)	0.411	0.381	0.264	0.025	1.77	68	2
LG060	Storm	PO_4-P (mg/L)	0.135	0.121	0.093	0.003	0.384	67	2
LG060	Storm	TKN (mg/L)	1.73	1.63	0.81	0.10	3.85	68	2
LG060	Storm	Total-P (mg/L)	0.37	0.34	0.16	0.10	0.83	68	0
LG060	Storm	TSS (mg/L)	109	60	126	11	600	68	0

a. Arithmetic mean/geometric mean.

Table B-9. Preliminary water quality analysis for microwatershed site NF009.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
NF009	Grab	Conductivity (µS/cm)	1990	1980	857	218	3990	44	NA
NF009	Grab	DO (mg/L)	7.0	7.1	3.4	1.4	15.3	44	NA
NF009	Grab	*E. coli* (colonies/100 mL)	2600/640[a]	730	5600	6	31000	44	0
NF009	Grab	NH_3-N (mg/L)	0.061	0.050	0.055	0.010	0.272	44	31
NF009	Grab	NO_2-N+NO_3-N (mg/L)	0.279	0.025	0.680	0.020	3.07	44	30
NF009	Grab	pH (standard units)	7.9	7.8	0.2	7.4	8.3	44	NA
NF009	Grab	PO_4-P (mg/L)	0.171	0.093	0.172	0.003	0.666	44	1
NF009	Grab	TKN (mg/L)	0.91	0.81	0.59	0.10	2.18	44	6
NF009	Grab	Total-P (mg/L)	0.30	0.21	0.22	0.07	0.84	44	0
NF009	Grab	TSS (mg/L)	10	6	13	2	57	44	13
NF009	Grab	Water temp. (°C)	13.2	12.3	7.0	2.6	24.7	44	NA
NF009	Storm	NH_3-N (mg/L)	0.198	0.090	0.435	0.010	3.96	99	44
NF009	Storm	NO_2-N+NO_3-N (mg/L)	0.705	0.497	0.804	0.020	6.72	99	4
NF009	Storm	PO_4-P (mg/L)	0.385	0.362	0.205	0.083	1.24	99	0
NF009	Storm	TKN (mg/L)	2.55	2.16	1.88	0.60	13.7	99	0
NF009	Storm	Total-P (mg/L)	0.76	0.72	0.36	0.28	2.30	99	0
NF009	Storm	TSS (mg/L)	191	88	237	7	1360	99	0

a. Arithmetic mean/geometric mean.

Table B-10. Preliminary water quality analysis for microwatershed site NF020.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
NF020	Grab	Conductivity (µS/cm)	2520	2520	1640	260	4830	15	NA
NF020	Grab	DO (mg/L)	8.5	7.4	4.4	3.1	18.4	15	NA
NF020	Grab	*E. coli* (colonies/100 mL)	2300/550[a]	580	3900	23	12000	15	0
NF020	Grab	NH_3-N (mg/L)	0.511	0.117	1.234	0.050	4.92	15	5
NF020	Grab	NO_2-N+NO_3-N (mg/L)	2.00	0.658	2.58	0.025	7.63	15	1
NF020	Grab	pH (standard units)	8.0	8.0	0.2	7.7	8.5	15	NA
NF020	Grab	PO_4-P (mg/L)	0.632	0.583	0.506	0.016	2.01	15	0
NF020	Grab	TKN (mg/L)	3.38	2.58	3.44	1.48	15.5	15	0
NF020	Grab	Total-P (mg/L)	0.93	0.82	0.68	0.11	2.54	15	0
NF020	Grab	TSS (mg/L)	16	10	19	2	80	15	1
NF020	Grab	Water temp. (°C)	13.8	15.4	5.6	3.4	23.3	15	NA
NF020	Storm	NH_3-N (mg/L)	0.229	0.155	0.262	0.043	1.72	94	22
NF020	Storm	NO_2-N+NO_3-N (mg/L)	0.977	0.858	0.587	0.025	3.05	94	1
NF020	Storm	PO_4-P (mg/L)	0.751	0.703	0.328	0.090	2.09	94	0
NF020	Storm	TKN (mg/L)	3.16	2.72	1.88	1.41	15.5	94	0
NF020	Storm	Total-P (mg/L)	1.25	1.19	0.60	0.21	4.67	94	0
NF020	Storm	TSS (mg/L)	243	76	398	9	2960	94	0

a. Arithmetic mean/geometric mean.

Table B-11. Preliminary water quality analysis for microwatershed site SP020.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
SP020	Grab	Conductivity (µS/cm)	484	511	89	179	587	46	NA
SP020	Grab	DO (mg/L)	9.0	8.7	1.7	4.9	12.5	46	NA
SP020	Grab	*E. coli* (colonies/100 mL)	930/73[a]	62	3400	1	19000	44	0
SP020	Grab	NH_3-N (mg/L)	0.035	0.050	0.019	0.010	0.050	46	45
SP020	Grab	NO_2-N+NO_3-N (mg/L)	0.081	0.025	0.166	0.020	0.777	46	37
SP020	Grab	pH (standard units)	7.9	7.9	0.1	7.5	8.1	46	NA
SP020	Grab	PO_4-P (mg/L)	0.006	0.003	0.010	0.003	0.048	46	36
SP020	Grab	TKN (mg/L)	0.19	0.10	0.20	0.10	1.17	46	34
SP020	Grab	Total-P (mg/L)	0.07	0.07	0.04	0.03	0.21	46	18
SP020	Grab	TSS (mg/L)	10	2	31	2	206	46	36
SP020	Grab	Water temp. (°C)	16.7	17.6	6.6	4.8	26.2	46	NA
SP020	Storm	NH_3-N (mg/L)	0.042	0.050	0.022	0.010	0.133	69	60
SP020	Storm	NO_2-N+NO_3-N (mg/L)	0.166	0.089	0.200	0.020	0.979	69	29
SP020	Storm	PO_4-P (mg/L)	0.022	0.013	0.023	0.003	0.106	69	18
SP020	Storm	TKN (mg/L)	1.07	0.68	1.26	0.10	7.89	69	13
SP020	Storm	Total-P (mg/L)	0.20	0.14	0.24	0.03	1.52	69	9
SP020	Storm	TSS (mg/L)	239	43	506	2	3270	69	9

a. Arithmetic mean/geometric mean.

APPENDIX C

Sites on Major Tributaries to the North Bosque River

These tables list basic statistics and automatic storm event samples for sites on major tributaries to the North Bosque River. All samples were collected between July 1, 2007 and June 30, 2014. Grab samples represent routine biweekly sampling plus a few samples for special projects. The mean for bacteria provides both the arithmetic mean and the seven-year geometric mean. Reporting limits (MDLs or AWRLs) are not established for field parameters DO, pH, conductivity, and water temperature. Therefore, the number of samples below the reporting limit for those parameters is NA (not applicable).

Table C-1. Preliminary water quality analysis for major tributary site GC100.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
GC100	Grab	CHLA (µg/L)	9.6	5.6	11.5	1.5	70.4	60	24
GC100	Grab	Cl (mg/L)	30	37	18	3	50	7	0
GC100	Grab	Conductivity (µS/cm)	599	643	147	123	805	60	NA
GC100	Grab	DO (mg/L)	9.3	9.1	2.3	5.8	13.9	60	NA
GC100	Grab	*E. coli* (colonies/100 mL)	1600/100[a]	89	6000	4	31000	26	0
GC100	Grab	NH_3-N (mg/L)	0.039	0.030	0.063	0.010	0.436	60	50
GC100	Grab	NO_2-N+NO_3-N (mg/L)	0.601	0.070	0.932	0.020	4.70	60	30
GC100	Grab	pH (standard units)	8.0	8.0	0.2	7.8	8.7	60	NA
GC100	Grab	PO_4-P (mg/L)	0.046	0.007	0.083	0.003	0.357	60	22
GC100	Grab	SO_4 (mg/L)	27	36	16	4	43	7	0
GC100	Grab	TKN (mg/L)	0.62	0.47	0.66	0.10	3.37	60	21
GC100	Grab	Total-P (mg/L)	0.12	0.09	0.12	0.03	0.68	60	19
GC100	Grab	TSS (mg/L)	17	4	83	2	646	60	26
GC100	Grab	Water temp. (°C)	17.6	17.4	7.0	4.3	29.7	60	NA
GC100	Storm	NH_3-N (mg/L)	0.140	0.075	0.224	0.010	1.80	79	26
GC100	Storm	NO_2-N+NO_3-N (mg/L)	0.727	0.588	0.737	0.020	5.49	79	6
GC100	Storm	PO_4-P (mg/L)	0.119	0.116	0.087	0.003	0.325	78	3
GC100	Storm	TKN (mg/L)	2.16	1.44	2.38	0.10	13.3	79	3
GC100	Storm	Total-P (mg/L)	0.52	0.38	0.55	0.03	3.27	79	3
GC100	Storm	TSS (mg/L)	453	166	1050	2	8400	79	1

a. Arithmetic mean/geometric mean.

Table C-2. Preliminary water quality analysis for major tributary site NC060.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
NC060	Grab	CHLA (µg/L)	3.2	1.5	8.6	1.5	82.9	124	107
NC060	Grab	Cl (mg/L)	15	15	8	2	34	17	1
NC060	Grab	Conductivity (µS/cm)	529	520	108	184	840	125	NA
NC060	Grab	DO (mg/L)	9.9	9.7	2.1	2.8	15.1	125	NA
NC060	Grab	*E. coli* (colonies/100 mL)	470/73[a]	69	2700	1	20000	56	0
NC060	Grab	NH_3-N (mg/L)	0.030	0.030	0.016	0.010	0.157	124	114
NC060	Grab	NO_2-N+NO_3-N (mg/L)	0.513	0.413	0.498	0.025	3.36	124	7
NC060	Grab	pH (standard units)	8.0	8.1	0.2	7.4	8.3	125	NA
NC060	Grab	PO_4-P (mg/L)	0.004	0.003	0.004	0.003	0.032	125	107
NC060	Grab	SO_4 (mg/L)	79	69	50	28	206	16	0
NC060	Grab	TKN (mg/L)	0.33	0.10	0.56	0.10	4.91	125	65
NC060	Grab	Total-P (mg/L)	0.08	0.07	0.11	0.03	1.03	125	56
NC060	Grab	TSS (mg/L)	31	2	181	2	1500	126	102
NC060	Grab	Water temp. (°C)	18.1	18.4	7.6	3.0	33.1	125	NA
NC060	Storm	NH_3-N (mg/L)	0.031	0.030	0.015	0.010	0.123	114	92
NC060	Storm	NO_2-N+NO_3-N (mg/L)	0.341	0.310	0.209	0.025	1.23	114	2
NC060	Storm	PO_4-P (mg/L)	0.007	0.003	0.009	0.003	0.051	113	72
NC060	Storm	TKN (mg/L)	0.70	0.37	0.85	0.10	5.13	114	43
NC060	Storm	Total-P (mg/L)	0.18	0.13	0.18	0.03	0.94	113	24
NC060	Storm	TSS (mg/L)	219	31	407	2	2480	114	17

a. Arithmetic mean/geometric mean.

Table C-3. Preliminary water quality analysis for major tributary site NF050.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
NF050	Grab	CHLA (µg/L)	29.7	20.8	23.4	7.7	95.1	13	0
NF050	Grab	Conductivity (µS/cm)	1070	1070	789	177	3560	33	NA
NF050	Grab	DO (mg/L)	9.6	8.4	4.9	2.0	24.8	33	NA
NF050	Grab	*E. coli* (colonies/100 mL)	12000/1200[a]	1100	44000	20	240000	33	0
NF050	Grab	NH_3-N (mg/L)	0.101	0.050	0.118	0.010	0.513	33	22
NF050	Grab	NO_2-N+NO_3-N (mg/L)	0.645	0.342	0.850	0.025	4.09	33	5
NF050	Grab	pH (standard units)	8.1	8.1	0.3	7.6	8.9	33	NA
NF050	Grab	PO_4-P (mg/L)	0.334	0.249	0.279	0.014	1.20	33	0
NF050	Grab	TKN (mg/L)	1.78	1.63	0.88	0.48	4.75	33	0
NF050	Grab	Total-P (mg/L)	0.52	0.40	0.41	0.03	1.76	33	1
NF050	Grab	TSS (mg/L)	33	12	104	2	610	33	4
NF050	Grab	Water temp. (°C)	15.2	16.2	7.1	1.9	26.9	33	NA
NF050	Storm	NH_3-N (mg/L)	0.139	0.102	0.132	0.010	0.738	144	58
NF050	Storm	NO_2-N+NO_3-N (mg/L)	0.518	0.422	0.347	0.020	2.05	144	2
NF050	Storm	PO_4-P (mg/L)	0.429	0.411	0.181	0.071	1.08	144	0
NF050	Storm	TKN (mg/L)	2.38	2.10	1.34	0.66	8.61	144	0
NF050	Storm	Total-P (mg/L)	0.84	0.72	0.42	0.25	2.40	144	0
NF050	Storm	TSS (mg/L)	262	80	494	4	3140	144	0

a. Arithmetic mean/geometric mean.

Table C-4. Preliminary water quality analysis for major tributary site SF085.

Site	Type	Constituent	Mean	Median	Std Dev.	Min	Max	Number	Number Below Reporting Limit
SF085	Grab	CHLA (µg/L)	15.3	9.1	19.3	1.5	108	34	8
SF085	Grab	Conductivity (µS/cm)	708	707	339	152	1280	71	NA
SF085	Grab	DO (mg/L)	8.4	8.2	3.1	2.3	15.2	71	NA
SF085	Grab	*E. coli* (colonies/100 mL)	2600/320[a]	290	12000	1	98000	69	0
SF085	Grab	NH_3-N (mg/L)	0.063	0.050	0.081	0.010	0.554	71	55
SF085	Grab	NO_2-N+NO_3-N (mg/L)	0.414	0.377	0.405	0.020	2.36	71	16
SF085	Grab	pH (standard units)	8.1	8.1	0.2	7.5	8.6	71	NA
SF085	Grab	PO_4-P (mg/L)	0.171	0.144	0.146	0.003	0.671	71	1
SF085	Grab	TKN (mg/L)	0.83	0.65	0.62	0.10	3.50	71	5
SF085	Grab	Total-P (mg/L)	0.26	0.21	0.18	0.03	0.99	71	3
SF085	Grab	TSS (mg/L)	12	2	23	2	160	71	38
SF085	Grab	Water temp. (°C)	15.4	16.0	7.6	1.2	27.3	71	NA
SF085	Storm	NH_3-N (mg/L)	0.107	0.050	0.103	0.010	0.536	193	101
SF085	Storm	NO_2-N+NO_3-N (mg/L)	0.372	0.345	0.236	0.025	1.86	193	2
SF085	Storm	PO_4-P (mg/L)	0.275	0.272	0.109	0.049	0.595	193	0
SF085	Storm	TKN (mg/L)	1.61	1.43	1.15	0.10	10.9	193	4
SF085	Storm	Total-P (mg/L)	0.55	0.52	0.31	0.13	3.11	193	0
SF085	Storm	TSS (mg/L)	165	53	344	2	2730	193	2

a. Arithmetic mean/geometric mean.

APPENDIX D

North Bosque River Sites

These tables list basic statistics for routine grab samples and automatic storm event samples for sites on the North Bosque River collected between July 1, 2007 and June 30, 2014. Grab samples represent routine biweekly sampling plus some sampling for special projects. The mean for *E. coli* provides the arithmetic mean and the seven-year geometric mean. Reporting limits (MDLs or AWRLs) are not established for field parameters DO, pH, conductivity, and water temperature. Therefore, the number of samples below the reporting limit for those parameters is NA (not applicable).

Table D-1. Preliminary water quality analysis for North Bosque River site BO020.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
BO020	Grab	CHLA (µg/L)	20.8	13.2	26.3	1.5	141	107	16
BO020	Grab	Cl (mg/L)	55	36	54	4	160	14	0
BO020	Grab	Conductivity (µS/cm)	672	634	398	95	1500	106	NA
BO020	Grab	DO (mg/L)	6.5	6.0	3.8	0.5	17.5	107	NA
BO020	Grab	*E. coli* (colonies/100 mL)	7300/240[a]	170	27000	4	130000	45	0
BO020	Grab	NH_3-N (mg/L)	0.088	0.030	0.105	0.010	0.561	106	56
BO020	Grab	NO_2-N+NO_3-N (mg/L)	0.204	0.054	0.265	0.020	1.12	106	52
BO020	Grab	pH (standard units)	8.0	8.0	0.3	7.4	8.8	107	NA
BO020	Grab	PO_4-P (mg/L)	0.260	0.241	0.159	0.003	0.714	107	2
BO020	Grab	SO_4 (mg/L)	50	29	57	3	163	14	1
BO020	Grab	TKN (mg/L)	1.23	1.12	0.69	0.10	4.51	107	3
BO020	Grab	Total-P (mg/L)	0.40	0.39	0.22	0.08	1.11	105	0
BO020	Grab	TSS (mg/L)	23	9	66	2	592	107	13
BO020	Grab	Water temp. (°C)	16.5	16.8	7.0	4.4	27.9	107	NA
BO020	Storm	NH_3-N (mg/L)	0.121	0.075	0.122	0.010	0.691	201	58
BO020	Storm	NO_2-N+NO_3-N (mg/L)	0.327	0.317	0.198	0.020	1.10	203	11
BO020	Storm	PO_4-P (mg/L)	0.291	0.272	0.135	0.011	0.685	208	0
BO020	Storm	TKN (mg/L)	1.77	1.64	1.14	0.10	8.55	203	3
BO020	Storm	Total-P (mg/L)	0.58	0.53	0.29	0.03	2.17	203	1
BO020	Storm	TSS (mg/L)	165	48	331	4	2700	203	0

a. Arithmetic mean/geometric mean.

Table D-2. Preliminary water quality analysis for North Bosque River site BO040.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
BO040	Grab	CHLA (µg/L)	15.7	8.3	22.5	1.5	164	179	29
BO040	Grab	Cl (mg/L)	137	151	45	30	185	25	0
BO040	Grab	Conductivity (µS/cm)	1020	1140	266	239	1370	182	NA
BO040	Grab	DO (mg/L)	8.5	8.2	2.6	1.8	15.6	182	NA
BO040	Grab	*E. coli* (colonies/100 mL)	2300/180[a]	140	12000	7	98000	81	0
BO040	Grab	NH_3-N (mg/L)	0.159	0.102	0.315	0.010	3.90	180	40
BO040	Grab	NO_2-N+NO_3-N (mg/L)	5.01	5.50	2.12	0.345	9.19	180	0
BO040	Grab	pH (standard units)	8.0	8.0	0.2	7.3	8.9	182	NA
BO040	Grab	PO_4-P (mg/L)	0.438	0.362	0.319	0.036	1.75	178	0
BO040	Grab	SO_4 (mg/L)	68	64	26	21	119	25	0
BO040	Grab	TKN (mg/L)	1.07	0.92	0.82	0.10	8.75	181	10
BO040	Grab	Total-P (mg/L)	0.55	0.47	0.34	0.12	1.87	180	0
BO040	Grab	TSS (mg/L)	10	5	23	2	246	181	60
BO040	Grab	Water temp. (°C)	18.9	19.7	6.8	5.8	28.6	182	NA
BO040	Storm	NH_3-N (mg/L)	0.165	0.120	0.173	0.010	1.50	194	31
BO040	Storm	NO_2-N+NO_3-N (mg/L)	1.65	1.42	1.09	0.020	6.89	195	1
BO040	Storm	PO_4-P (mg/L)	0.306	0.286	0.169	0.008	1.81	195	0
BO040	Storm	TKN (mg/L)	1.96	1.67	1.60	0.10	18.1	194	2
BO040	Storm	Total-P (mg/L)	0.62	0.52	0.49	0.20	5.47	194	0
BO040	Storm	TSS (mg/L)	136	43	231	2	1190	195	1

a. Arithmetic mean/geometric mean.

Table D-3. Preliminary water quality analysis for North Bosque River site BO070.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
BO070	Grab	CHLA (µg/L)	14.3	8.4	19.4	1.5	175	165	36
BO070	Grab	Cl (mg/L)	57	54	31	5	118	22	0
BO070	Grab	Conductivity (µS/cm)	626	627	181	130	978	165	NA
BO070	Grab	DO (mg/L)	10.6	10.4	2.8	3.7	18.3	165	NA
BO070	Grab	*E. coli* (colonies/100 mL)	890/88[a]	60	3900	4	31000	74	0
BO070	Grab	NH_3-N (mg/L)	0.044	0.030	0.053	0.010	0.426	164	134
BO070	Grab	NO_2-N+NO_3-N (mg/L)	0.211	0.025	0.353	0.020	2.17	164	100
BO070	Grab	pH (standard units)	8.2	8.2	0.2	7.5	8.9	165	NA
BO070	Grab	PO_4-P (mg/L)	0.060	0.031	0.079	0.003	0.457	165	20
BO070	Grab	SO_4 (mg/L)	32	33	15	5	53	22	0
BO070	Grab	TKN (mg/L)	0.64	0.53	0.55	0.10	4.50	165	29
BO070	Grab	Total-P (mg/L)	0.15	0.11	0.16	0.03	1.45	163	24
BO070	Grab	TSS (mg/L)	19	5	112	2	1430	165	67
BO070	Grab	Water temp. (°C)	18.9	19.2	7.9	4.3	33.4	165	NA
BO070	Storm	NH_3-N (mg/L)	0.195	0.030	0.953	0.010	8.71	221	107
BO070	Storm	NO_2-N+NO_3-N (mg/L)	0.447	0.400	0.439	0.020	3.49	221	43
BO070	Storm	PO_4-P (mg/L)	0.152	0.122	0.168	0.003	2.13	220	1
BO070	Storm	TKN (mg/L)	1.94	1.17	3.90	0.10	36.9	221	16
BO070	Storm	Total-P (mg/L)	0.51	0.35	0.73	0.03	6.46	221	3
BO070	Storm	TSS (mg/L)	283	71	789	2	7560	221	4

a. Arithmetic mean/geometric mean.

Table D-4. Preliminary water quality analysis for North Bosque River site BO083.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
BO083	Grab	CHLA (µg/L)	18.6	11.5	34.6	1.5	376	135	15
BO083	Grab	Cl (mg/L)	36	33	18	6	71	19	0
BO083	Grab	Conductivity (µS/cm)	509	519	117	169	742	135	NA
BO083	Grab	DO (mg/L)	9.0	8.7	2.1	5.4	15.9	135	NA
BO083	Grab	*E. coli* (colonies/100 mL)	460/26[a]	22	2300	1	17000	58	1
BO083	Grab	NH_3-N (mg/L)	0.034	0.030	0.021	0.010	0.148	134	114
BO083	Grab	NO_2-N+NO_3-N (mg/L)	0.101	0.025	0.191	0.020	1.11	134	104
BO083	Grab	pH (standard units)	8.2	8.1	0.2	7.8	8.7	135	NA
BO083	Grab	PO_4-P (mg/L)	0.024	0.003	0.048	0.003	0.222	135	80
BO083	Grab	SO_4 (mg/L)	41	32	62	5	293	19	1
BO083	Grab	TKN (mg/L)	0.64	0.51	0.59	0.10	3.51	135	31
BO083	Grab	Total-P (mg/L)	0.11	0.09	0.08	0.03	0.45	135	26
BO083	Grab	TSS (mg/L)	16	11	18	2	146	135	14
BO083	Grab	Water temp. (°C)	18.7	19.0	7.6	4.9	31.9	135	NA

a. Arithmetic mean/geometric mean.

Table D-5. Preliminary water quality analysis for North Bosque River site BO090.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
BO090	Grab	CHLA (µg/L)	16.0	8.2	25.5	1.5	275	177	21
BO090	Grab	Cl (mg/L)	25	22	12	8	52	22	0
BO090	Grab	Conductivity (µS/cm)	468	478	87	213	641	178	NA
BO090	Grab	DO (mg/L)	9.5	9.1	2.0	5.8	15.4	178	NA
BO090	Grab	*E. coli* (colonies/100 mL)	610/36[a]	30	4300	1	39000	80	1
BO090	Grab	NH_3-N (mg/L)	0.036	0.030	0.023	0.010	0.168	177	145
BO090	Grab	NO_2-N+NO_3-N (mg/L)	0.310	0.215	0.287	0.025	1.64	177	28
BO090	Grab	pH (standard units)	8.0	8.0	0.3	7.3	8.7	178	NA
BO090	Grab	PO_4-P (mg/L)	0.012	0.003	0.029	0.003	0.182	178	131
BO090	Grab	SO_4 (mg/L)	26	27	7	12	44	22	0
BO090	Grab	TKN (mg/L)	0.53	0.41	0.40	0.10	1.84	179	48
BO090	Grab	Total-P (mg/L)	0.09	0.09	0.08	0.03	0.54	179	52
BO090	Grab	TSS (mg/L)	17	9	50	2	543	178	20
BO090	Grab	Water temp. (°C)	20.0	21.2	7.2	6.6	32.4	178	NA
BO090	Storm	NH_3-N (mg/L)	0.045	0.030	0.035	0.010	0.188	197	132
BO090	Storm	NO_2-N+NO_3-N (mg/L)	0.297	0.268	0.185	0.025	0.941	197	18
BO090	Storm	PO_4-P (mg/L)	0.047	0.023	0.056	0.003	0.319	195	55
BO090	Storm	TKN (mg/L)	0.98	0.74	0.95	0.10	5.95	197	25
BO090	Storm	Total-P (mg/L)	0.25	0.16	0.26	0.03	1.66	197	19
BO090	Storm	TSS (mg/L)	209	46	548	2	4390	197	3

a. Arithmetic mean/geometric mean.

Table D-6. Preliminary water quality analysis for North Bosque River site BO095.

Site	Type	Constituent	Mean	Median	Std Dev	Min	Max	Number	Number Below Reporting Limit
BO095	Grab	CHLA (µg/L)	10.3	5.4	13.5	1.5	87.0	178	48
BO095	Grab	Cl (mg/L)	22	22	8	6	43	24	0
BO095	Grab	Conductivity (µS/cm)	471	479	70	232	670	179	NA
BO095	Grab	DO (mg/L)	8.4	8.3	2.0	5.1	13.4	179	NA
BO095	Grab	*E. coli* (colonies/100 mL)	470/61[a]	46	2500	4	22000	81	0
BO095	Grab	NH_3-N (mg/L)	0.051	0.030	0.042	0.010	0.258	178	113
BO095	Grab	NO_2-N+NO_3-N (mg/L)	0.455	0.357	0.376	0.025	1.45	178	15
BO095	Grab	pH (standard units)	8.0	8.0	0.2	7.5	8.6	179	NA
BO095	Grab	PO_4-P (mg/L)	0.009	0.003	0.022	0.003	0.149	178	135
BO095	Grab	SO_4 (mg/L)	31	31	9	12	56	24	0
BO095	Grab	TKN (mg/L)	0.55	0.45	0.52	0.10	4.18	180	49
BO095	Grab	Total-P (mg/L)	0.09	0.08	0.10	0.03	1.00	180	57
BO095	Grab	TSS (mg/L)	26	9	119	2	1330	179	21
BO095	Grab	Water temp. (°C)	19.5	19.8	7.6	3.5	31.7	179	NA
BO095	Storm	NH_3-N (mg/L)	0.042	0.030	0.030	0.010	0.189	194	136
BO095	Storm	NO_2-N+NO_3-N (mg/L)	0.368	0.302	0.254	0.025	1.39	194	9
BO095	Storm	PO_4-P (mg/L)	0.037	0.015	0.044	0.003	0.188	192	59
BO095	Storm	TKN (mg/L)	1.12	0.81	1.00	0.10	5.74	193	20
BO095	Storm	Total-P (mg/L)	0.27	0.21	0.23	0.03	1.23	192	15
BO095	Storm	TSS (mg/L)	242	99	372	4	2250	193	0

a. Arithmetic mean/geometric mean.