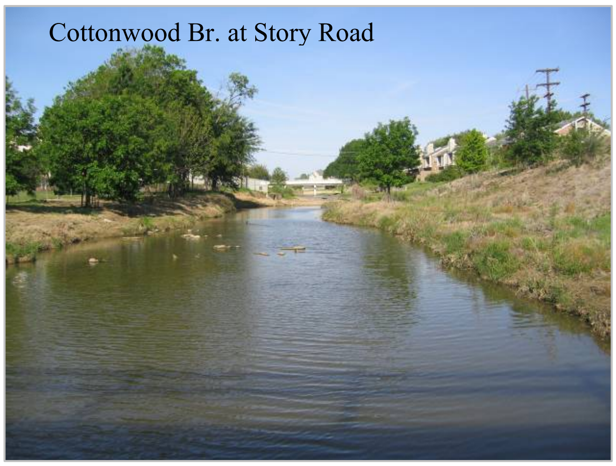
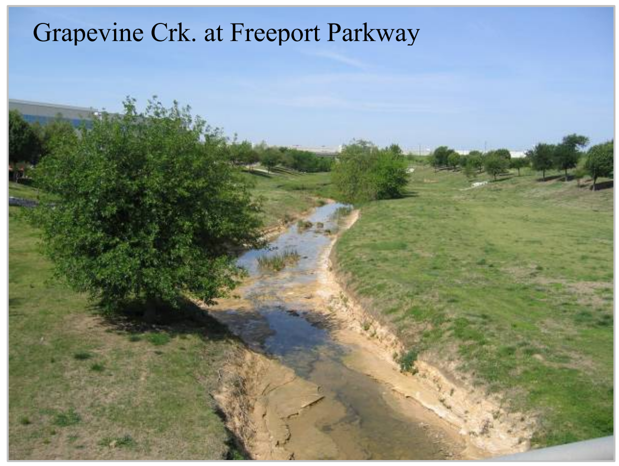
Technical Support Document for Bacteria TMDLs

Segment 0822A—Cottonwood Branch
&
Segment 0822B—Grapevine Creek





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TR0904

March 2010

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&
Segment 0822B—Grapevine Creek

Prepared for:

TMDL Program
Texas Commission on Environmental Quality
Austin, Texas

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LIST OF ABBREVIATIONS AND ACRONYMS

AU	Assessment Unit
AVMA	American Veterinary Medical Association
BMP	Best Management Practice
CFR	Code of Federal Regulations
CFS	Cubic Feet per Second
CMS	Cubic Meters per Second
CWA	Clean Water Act
DAR	Drainage Area Ratio
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
FDC	Flow Duration Curve
FG	Future Growth
GIS	Geographic Information System
ha	Hectare
I/I	Inflow and Infiltration
km	Kilometer
LA	Load Allocation
LDC	Load Duration Curve
mL	Milliliter
MGD	Million Gallons per Day
mm	Millimeter
MOS	Margin Of Safety
MPN	Most Probable Number
MS4	Municipal Separate Storm Sewer System
NCTCOG	North Central Texas Council of Governments
NDEP	Nevada Division of Environmental Protection
NEIWPCC	New England Interstate Water Pollution Control Commission
NPDES	National Pollutant Discharge Elimination System
NWS	National Weather Service
OSSF	Onsite Sewage Facility
SSO	Sanitary Sewer Overflow
SWMP	Stormwater Management Program
SWQMIS	Surface Water Quality Monitoring Information System
SWPPP	Storm Water Pollution Prevention Plan
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TIAER	Texas Institute for Applied Environmental Research
TRA	Trinity River Authority
TMDL	Total Maximum Daily Load
TPDES	Texas Pollutant Discharge Elimination System
TSSWCB	Texas State Soil and Water Conservation Board
TSWQS	Texas Surface Water Quality Standards
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WLA	Waste Load Allocation
WWTF	Wastewater Treatment Facility

SECTION 1

INTRODUCTION

1.1 Background and Water Quality Standards

Protection of our state's water resources is one of the most significant environmental challenges with which Texans currently contend. Texas' water resources are being depleted or impacted daily, through actions such as overuse, urban development, agricultural activities, and wetland degradation. Conservation and protection of our water resources will be one of the most important measures undertaken by local, state and federal agencies, as well as environmental groups, during the 21st century. As our state's population increases, so does the need for dependable and useable water resources. Large cities such as Houston, San Antonio, and the Dallas/Fort Worth metroplex will require the largest percentages of clean, dependable water. In 2000 the estimated population of the Texas Water Development Board's Region C, which includes the Dallas /Fort Worth metroplex, was 5.3 million. This represents almost 25 percent of the state's total population. Over 90 percent of that population is found within the Dallas/Fort Worth area, and 95 percent were estimated to live in the Trinity River basin. The region's population is expected to practically double by 2050, increasing the water supply requirements of the region, as well (TRA, 2003). This increasing need emphasizes that currently reliable water sources be protected and those that display negative impacts be restored and then maintained.

Water quality standards were developed to ensure that designated uses for water bodies are met (TCEQ, 2000). These standards include specific criteria set forth by the Texas Commission on Environmental Quality (TCEQ) in the Texas Surface Water Quality Standards (TSWQS) (Title 30 Texas Administrative Code (TAC) Chapter 307). Section 303(d) of the Clean Water Act (CWA) and the U.S. Environmental Protection Agency (USEPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) require that states perform total maximum daily loads (TMDLs) for water bodies not meeting water quality standards. TMDLs establish the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. TMDLs allow each state to implement water-quality based controls to reduce pollution from both point and nonpoint sources and to restore and maintain the quality of its water resources (USEPA, 1991).

Designated uses for water bodies in Texas include: aquatic life use, public water supply use, fish consumption use, oyster waters use, non-contact recreation use, and contact recreation use (TCEQ, 2008a). Contact recreation use is assigned to all water bodies in Texas, except in special situations (e.g., where ship or barge traffic makes contact recreation use unsafe, thus requiring the designation of *non-contact recreation use)* (TCEQ, 2008a).

Assessment of contact recreation use is based upon the concentration of *Escherichia coli (E. coli)* bacteria identified in a particular body of water. *E. coli*, a species of coliform bacteria, is often used as an indicator of the possible presence of fecal pathogens in water, because its concentration in water is relatively easy to measure and it is often the most abundant species of the fecal coliform bacteria (Talaro and Talaro, 1999). Applicable State of Texas water quality criteria for contact recreation use in freshwater state that the geometric mean concentration for *E.*

coli should not exceed 126 most probable number (MPN) per 100 mL, and the concentration in a single sample should not exceed 394 MPN/100 mL in greater than 25% of the individual samples. However, TCEQ recognizes that the chance of falsely classifying a station or assessment unit as impaired (Type I Error) under the single sample criterion is relatively high for the historically utilized method. TCEQ for the last several years has applied the binomial method in their water quality assessments in order to maintain a Type I error probability below 20% (TCEQ, 2008a).

New criteria have been proposed that divide contact recreation standards into primary contact recreation use, secondary contact recreation I, and secondary contact recreation II. The proposed criteria are as follows:

- Primary Contact: geometric mean criterion of 206 MPN/100 mL
- Secondary Contact I: geometric mean criterion of 630 MPN/100 mL
- Secondary Contact II: geometric mean criterion of 1030 MPN/100 mL

This report will address these criteria along with the existing contact recreation use criteria of 126 MPN/100 mL. The single sample criterion will not be addressed for purposes of pollutant load allocation in this report.

1.2 Report Purpose and Organization

TCEQ's most recent assessment of ambient bacteria data led to the conclusion that all or portions of Cottonwood Branch (Segment 0822A) and Grapevine Creek (Segment 0822B) do not support their contact recreation uses (TCEQ, 2008b). Subsequently, TCEQ contracted with the Texas Institute for Applied Environmental Research (TIAER) at Tarleton State University as the lead performing entity to: (1) acquire data and information necessary to support modeling and assessment activities, and (2) assist the TCEQ in preparing the information to develop TMDLs for the two creeks. The purpose of this report is to provide technical documentation and supporting information for developing the bacteria TMDLs for Segments 0822A and 0822B. This report contains:

- information on historical data,
- watershed properties and characteristics,
- summary of historical bacteria data that confirm the State of Texas Section 303(d) listings of impairment due to presence of indicator bacteria (*E. coli*),
- development of load duration curves, and
- application of the load duration curve approach for the pollutant load allocation process.

SECTION 2

HISTORICAL DATA REVIEW AND WATERSHED PROPERTIES

2.1 Definition of Study Area

Cottonwood Branch and Grapevine Creek are urban creeks located in the north central portion of the Dallas-Fort Worth metroplex (Figure 2-1). Grapevine Creek is the larger of the two creeks with a drainage area of 3,762 hectare (ha) or 9,295 acres, while Cottonwood Branch has a drainage area of 1,200 ha (2,964 acres). Both watersheds lie entirely within the wastewater and sewered collection system area of the Trinity River Authority (TRA) Central Regional Wastewater Treatment Facility (WWTF) as indicated by the cross hatched area on Figure 2-1.

Cottonwood Branch (Segment 0822A) is within the jurisdictional area of the City of Irving, Dallas County. The creek is defined in the 2008 TCEQ Water Quality Assessment (TCEQ 2008b) as starting at Valley View Lane, which is the frontage road for President George Bush Turnpike (TX 161), at the south end of Dallas-Fort Worth (DFW) International Airport and extends approximately 6 miles eastward to the confluence with Hackberry Creek (Figure 2-1).

Grapevine Creek (Segment 0822B) flows approximately 10 miles from its headwaters west of International Parkway on the north side of DFW Airport in Tarrant County, downstream to its confluence with the Elm Fork Trinity River (Segment 0822) west of President George Bush Turnpike (TX161; TCEQ, 2010). The Grapevine Creek drainage area lies within the jurisdictional areas of the City of Grapevine, City of Irving, City of Coppell and DFW International Airport. North Lake, a cooling reservoir for a power plant, has a storage capacity of approximately 2,100 hectare meters and drains via an unnamed tributary into Grapevine Creek approximately 300-m upstream of TCEQ station 20311 at MacArthur Blvd. (Figure 2-1). The North Lake reservoir and its drainage area are considered as a non-contributing or minimally contributing portion of the Grapevine Creek watershed from the perspective of both bacteria loading and streamflow. Because all reservoirs, in general, and North Lake, in particular, very effectively slow streamflow and greatly increase detention times, *E. coli* levels are invariably low in both the main body of the reservoir and in any releases. Also, power company staff report that North Lake rarely releases or spills into Grapevine Creek, with releases typically occurring a few years apart (personal communication, John Mummert, TCEQ, December 1, 2009). Consequentially, for the remainder of this report the Grapevine Creek watershed will be defined to exclude the drainage area of North Lake resulting in a remaining watershed area of 3,073 ha (7,594 acres).

Within the 303(d) lists for Segments 0822A and 0822B, in particular, and any segment, in general, attainment is reported by assessment unit (AU), which is the smallest geographic area used by TCEQ for assessment purposes. The most recent AU definitions are used in this report (see Figure 2-1 for AUs). Segment 0822A is divided into two AUs:

- AU 0822A_01 is the downstream portion of the creek, from the Elm Fork Trinity confluence upstream to 0.5 miles downstream of North Story Road.

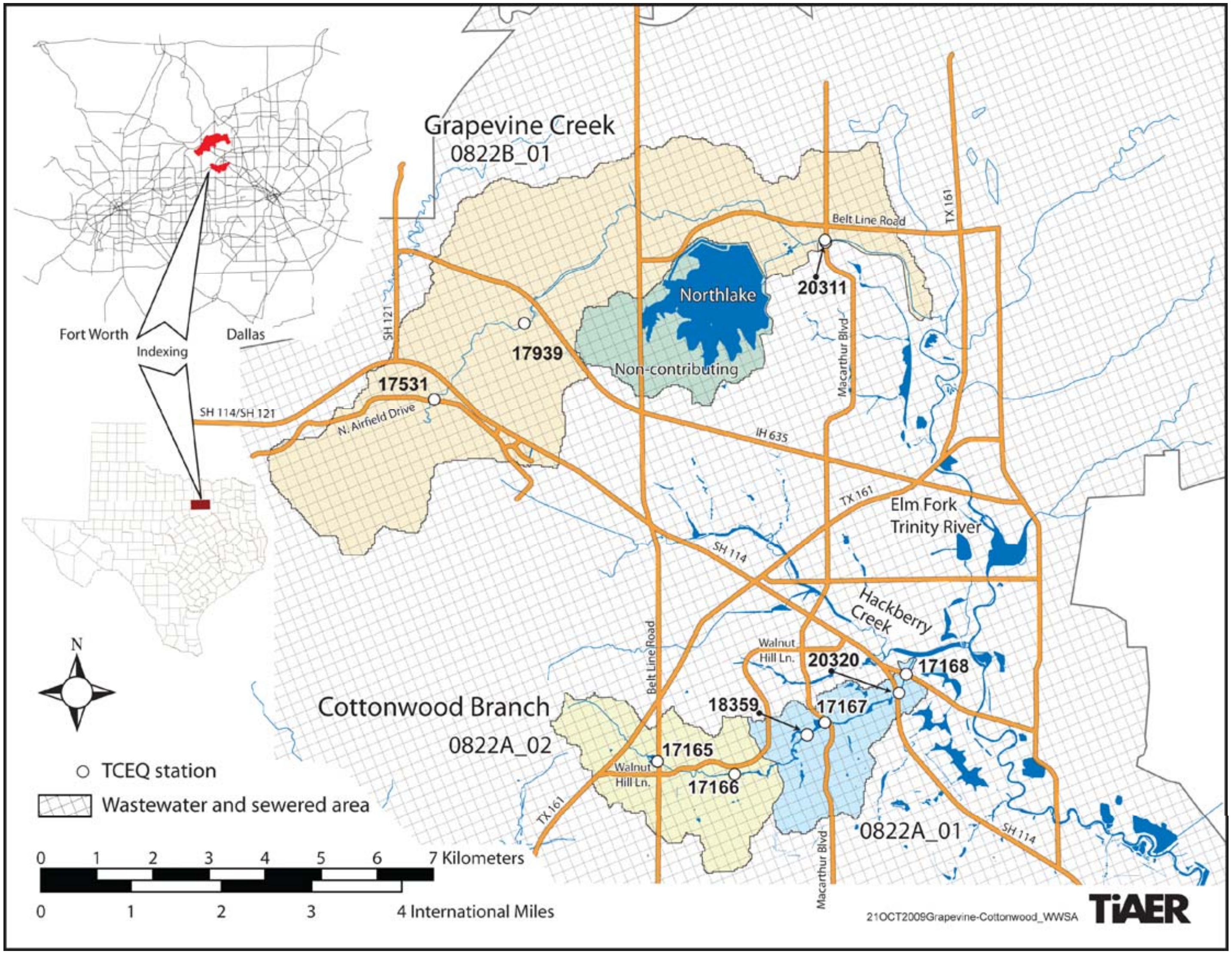

Figure 2-1 Cottonwood Branch and Grapevine Creek study area showing locations of assessment units and monitoring stations. Blue shaded area of the Grapevine Creek watershed is a non-contributing area of the watershed. Yellow and blue shaded areas of the Cottonwood Branch watershed denote the two assessment units (AUs).

• AU 0822A_02 is the upstream portion of the creek, from 0.5 miles downstream of North Story Road to the upstream end at Valley View Lane.

Segment 0822B consists of only one AU and will be referred to hereafter as 0822B_01 or Grapevine Creek.

2.2 Monitoring Station Descriptions

Five TCEQ monitoring stations have historically been sampled in Cottonwood Branch (17165, 17166, 17167, 17168 and 18359) with a fifth station added (20320) when station 17168 became influenced by backwater from a small dam on Hackberry Creek. Two stations have been historically monitored on Grapevine Creek (17531 and 17939), with a third station added more recently (20311). The *E. coli* data collected at the historical TCEQ stations in Cottonwood Branch and Grapevine Creek were used in the assessment process to determine whether or not these two creeks support their contract recreation use, and the two more recent stations were added to provide supplemental information to facilitate TMDL development. Brief descriptions of each station are provided below:

2.2.1 Monitoring Stations on Segment 0822A – Cottonwood Branch

Two stations are located in AU 0822A_02 (Figure 2-2):

Figure 2-2 Water quality monitoring stations located within AU 0822A_02

• Station 17165 is located on Cottonwood Branch at North Beltline Road in Irving in Dallas County and is the most upstream station on Segment 0822A. The streambed and both banks at this location are lined with concrete and the north bank is situated in close proximity to an apartment complex, while the south bank is bordered by a parking lot.

• Station 17166 is located at North Story Road in Irving. The stream bed consists mostly of cobble and mud and the stream banks are vegetated with mostly grasses. A small shopping center borders the north bank of this stream while the south bank is bordered by grass.

Four stations are located in AU 0822A_01 (Figure 2-3):

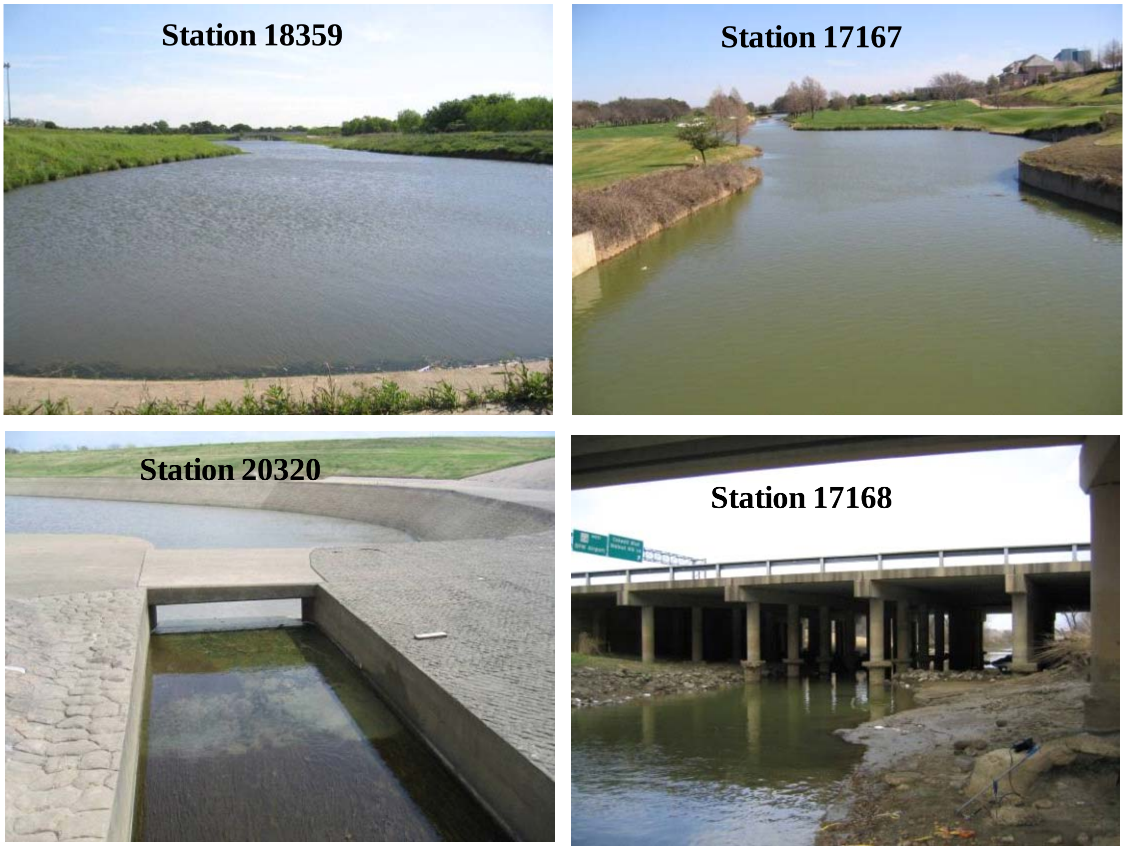

Figure 2-3 Water quality monitoring stations located within AU 0822A_01

• Station 18359 is located 433 m upstream of North MacArthur Boulevard in Irving at a concrete culvert. Cottonwood Branch at this location is pooled due to a small dam and is within the North Lake College campus.

• Station 17167 is located at North MacArthur Boulevard in Irving. This station is located on the golf course of the Cottonwood Valley Country Club. The previously described historical TCEQ station 18359 is located approximately 400 meters upstream of this station. The close proximity of these stations allowed for the data collected from both to be combined for this study and will hereafter be referred to as data from station 17167.

• Station 20320 is located at State Highway 114 in Irving and represents the most downstream station on AU 0822A_01 that can be sampled without experiencing backwater effects originating in Hackberry Creek. The creek at this location is essentially a narrow concrete lined channel.

• Station 17168 is located at State Highway Spur 348 (Northwest Highway) in Irving. Upstream of Spur 348 the channel is concrete line whereas downstream it more natural. Backwater effects are often experienced at this station location as a result of a dam constructed on Hackberry Creek. These backwater effects necessitated that sampling occur at the more upstream station 20320. Since stations 20320 and 17168 are in close proximity, for this study their data were combined and the stations referred to as station 20320.

2.2.2. Monitoring Stations on Segment 0822B – Grapevine Creek

Three stations are located in AU 0822B_01 (Figure 2-4):

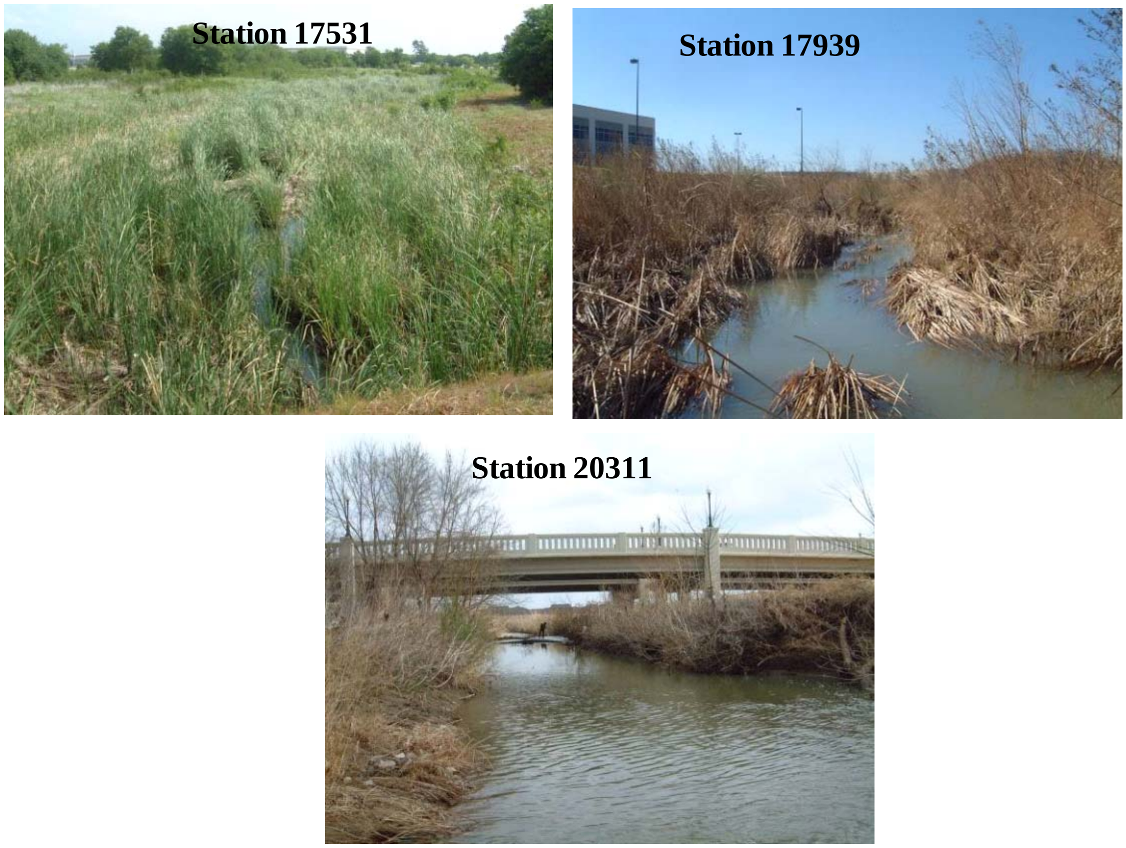

Figure 2-4 Water quality monitoring stations located within AU 0822B_01

- Station 17531 is located on Grapevine Creek at Airfield Drive North, at the edge of DFW Airport property in Grapevine in Tarrant County and represents the most upstream station in AU 0822B_01. Grapevine Creek at this station is characterized as having large amounts of emergent vegetation and has banks dominated by grasses.

- Station 17939 is located on Grapevine Creek at Regent Blvd. in Irving, 535 m upstream of IH-635 in Dallas County. Grapevine Creek at this station is characterized as having moderate amounts of emergent vegetation with banks dominated by maintained grasses.

- Station 20311 is located at North MacArthur Boulevard between Irving and Coppell in Dallas County and is the most downstream station on AU 0822B_01. Grapevine Creek at this location is characterized as having a gravel bottom with banks immediately bordered by trees and brush.

2.3 Cottonwood Branch and Grapevine Creek Historical Bacterial Data

2.3.1 Data Acquisition

Ambient *E. coli* data were obtained from the TCEQ Surface Water Quality Monitoring Information System (SWQMIS). The data represented the routine ambient *E. coli* and other water quality data collected in the project area under the TCEQ Surface Water Quality Monitoring Program by the TCEQ Field Operations Division and City of Irving as a Texas Clean Rivers Program partner. The water quality data included in SWQMIS are typically compared to water quality criteria to assess use attainment and were provided to TIAER for the specific purposes of this project. Routine ambient data from December 2001 through July 2004 were available for Segment 0822A and data from November 2001 through October 2004 were available for Segment 0822B at the time the data analysis in this report was performed. The other major source of ambient *E. coli* data was collected by TIAER at selected stream stations within Cottonwood Branch and Grapevine Creek to provide information to assist in TMDL development. TIAER's bacteria monitoring consisted of base-flow and wet-weather sampling for 12 events during the period January - August 2008. The timing of the TIAER data collection events were defined by objectives of capturing certain streamflow regimes (e.g., high and low flows) and therefore represent biased data collection not used for assessment purposes. Collectively the data obtained from both routine ambient and TMDL development bacteria monitoring provide a data set containing a substantial amount of *E. coli* data at several locations along Cottonwood Branch and Grapevine Creek and will be referred to herein as the "historical data set." The data set containing only routine ambient *E. coli* concentrations, with *E. coli* data collected under biased conditions removed, will be referred to as the "assessment data set."

2.3.2 Analysis of Bacteria Data

The assessment bacteria data set as obtained from the TCEQ SWQMIS spans a date range of November 2001 through October 2004. These routine monitoring data were used to assess the water quality according to TCEQ procedures (TCEQ 2008a). For Cottonwood Branch the assessment data set contained data for stations 17167, 17168, and 18359 in AU 0822A_01 and data for stations 17165 and 17166 in AU 0822A_02. Stations 17531 and 17939 within AU 0822B_01 had routine monitoring *E. coli* data for Grapevine Creek (Table 2-1).

Data obtained from stations 18359 and 17168 within AU 0822A_01 indicated that *E. coli* concentrations were below the geometric mean and single sample criteria while data from station 17167 exceeded both criteria. However, the combined dataset from the three stations within AU 0822A_01 indicated support of the contact recreation use for both criteria. Data obtained from stations 17165 and 17166 in AU 0822A_02 indicated that both stations failed to support the contact recreation use based on both the geometric mean and single sample criteria. Assessment of the data obtained from station 17531 within AU 0822B_01 indicated that *E. coli* concentrations were in support of the contact recreation use, while data from downstream station 17939 indicated non-support of the contact recreation use. Assessment of the combined dataset from these two stations indicated non-support of the contact recreation use based on both the geometric mean and single sample criteria. It should be noted that the geometric mean criterion will be the basis for pollutant load allocations and required percent reductions within the two study watersheds. The single sample criterion will not be used in the allocation process and reduction calculations.

Table 2-1 Summary of routine monitoring *E. coli* data for Cottonwood Branch (0822A_01 and 0822A_02) and Grapevine Creek (0822B_01) collected from November 2001 through October 2004. Bacteria concentrations given in most probable number per 100 mL aliquots (MPN/100 mL)

Assessment Unit	Station	No. of Samples	Min. Measured *E. coli* Conc.	Max. Measured *E. coli* Conc.	Single Sample Exceed-ances	Single Sample % Exceedance	Geometric Mean	Location
0822A_01	18359	16	2	2,600	1	6%	37	433 m upstream of N. MacArthur Blvd / Dallas Co.
0822A_01	17167	7	3	>2,400	4	57%	154	N. MacArthur Blvd / Dallas Co.
0822A_01	17168	31	<1	977	3	10%	41	Spur 348 (Northwest Hwy) / Dallas Co.
0822A_01 total	---	54	<1	2,600	8	15%	47	---
0822A_02	17165	32	19	>4,838	22	69	764	N. Beltline Rd. / Dallas Co.
0822A_02	17166	30	99	>4,840	23	77	811	N. Story Rd. / Dallas Co.
0822A_02 total	---	62	19	>4,840	45	73	786	---
0822B_01	17531	12	21	>2,419	3	25	121	Airfield North upstream of bridge / Tarrant Co.
0822B_01	17939	22	48	>4,838	18	82	799	Regent Blvd. 535 m upstream of I-635 / Dallas Co.
0822B_01 total	---	34	21	>4,838	21	62	411	---

2.4 Watershed Hydrology and Climate

North Central Texas, which contains the two creeks for this study, has a subtropical climate characterized by hot summers and mild winters, resulting in a wide annual temperature range (National Weather Service (NWS), 2009a). Fair skies generally accompany the highest temperatures of summer, which are often above 100° F; however, the low temperature rarely exceeds 80° F at night (NWS, 2009a). Winters are mild, but northern cold fronts occur about three times each month, and often are accompanied by sudden drops in temperature. Periods of extreme cold that occasionally occur are short lived, so that even in January mild weather occurs frequently (NWS, 2009a). The frost-free period generally lasts for about 249 days, with the last frost occurring in mid March and the first frost occurring in mid to late November (NWS, 2009a). Annual average precipitation is approximately 35.5 inches (902 mm) based on recorded measurements at DFW International Airport from 1994 through 2008 (NWS, 2009b).

Because of the absence of any streamflow gages on these two creeks, the hydrologic conditions (e.g., perennial, intermittent, ephemeral) of Cottonwood Branch and Grapevine Creek can not be absolutely determined, although limited information and data do provide valuable insights into this issue. Observational records from TCEQ sampling events for upstream sites in Cottonwood Branch indicate no flow on several occasions; however, at least very low flow was always present during monthly sampling events conducted by TIAER during January – August of 2008, including dry summer periods. In Grapevine Creek similar contradictions are present between TCEQ historical sampling data and more recent 2008 TIAER sampling data. Flow was always present during TIAER's sampling on Grapevine Creek although it was only a negligible trickle in the upstream sites during dry periods. The thick channel vegetation in Grapevine Creek at Airfield Drive (see Figure 2-4, station 17531) can make it difficult to discern whether or not flow is present, which may be a factor in the difference in observations. Mr. Tim Wentrcek, a representative of DFW Airport, attested that he had never seen the creek dry, although flow was extremely low during periods of low precipitation (personal communication, 2008). He attributed the perennial flow to a deeply cut channel, suspecting that seeps from the channel wall contributed at least some water to the creek. Mr. Wentrcek also observed groundwater infiltration into the DFW Airport stormwater conduits, buried 6-8 m below ground, which also contributes flow to Grapevine Creek. Though available information are not totally conclusive, perennial flows in Cottonwood Branch and Grapevine Creek can be largely inferred from anecdotal information and field observations in sampling records.

2.5 Land Use / Land Cover

The land use/land cover data for Cottonwood Branch and Grapevine Creek were obtained from the North Central Texas Council of Governments (NCTCOG) GIS Data Clearinghouse website (NCTCOG, 2009a) and represents land use/land cover estimates for 2005. The land use/ land cover is represented by the following categories and definitions:

- **Commercial/industrial** – Commercial/ industrial includes land occupied by commercial businesses, industrial complexes, government institutions, and/or transportation areas such as airports, airport runways, highways, and parking lots.

- **Residential** – Residential is property that contains single-family and multi-family housing units.

- **Undeveloped** – Undeveloped includes land that is either vacant or under construction and may include expanded parking areas.

- **Infrastructure** – Infrastructure includes roadways and utility structures.

- **Parks** – Parks includes open areas with maintained turf for the purpose of outdoor recreation such as traditional parks and golf courses.

- **Water** – Water includes all areas of open water.

The drainage area encompassing AU 0822A_02 of Cottonwood Branch is 723 ha (about 3 square miles). Dominant land uses in the AU 0822A_02 watershed include residential (31%), undeveloped (22%), commercial/industrial (22%); and infrastructure (19%) (Figure 2-5, Table 2-2). The remaining land use categories comprise 7% of the land cover. The watershed area encompassing Grapevine Creek is 3,073 ha (about 12 square miles). Dominant land uses in the AU 0822B-01 watershed include infrastructure (33%), undeveloped (26%), commercial/industrial (25%), and residential (14%). The remaining land use categories comprise 2% of the land cover (Figure 2-6; Table 2-3).

Table 2-2 Land use/cover summary for the Cottonwood Branch, impaired AU 0822A_02 watershed.

Description	Area (ha)	% of Total
Residential	224	31.01
Undeveloped	156	21.56
Commercial/Industrial	156	21.53
Infrastructure	138	19.12
Parks	45	6.17
Water	4	0.61
Totals	**723**	**100.00**

Table 2-3 Land use/cover summary for the Grapevine Creek (AU 0822B_01) watershed

Description	Area (ha)	% of Total
Infrastructure	1,027	33.43
Undeveloped	789	25.68
Commercial/Industrial	770	25.04
Residential	423	13.75
Parks	56	1.82
Water	8	0.28
Totals	**3,073**	**100.00**

2.6 Source Analysis

Potential sources of indicator bacteria pollution can be divided into two primary categories: *regulated* and *non-regulated*. Pollution sources that are regulated have permits under the Texas Pollutant Discharge Elimination System (TPDES) and the National Pollutant Discharge Elimination System (NPDES). Examples of regulated sources are wastewater treatment facility (WWTF) discharges and storm water discharges from industries, construction, and municipal separate storm sewer systems (MS4s) of cities. Non-regulated sources are typically nonpoint source in nature, meaning the pollution originates from multiple locations and is usually carried to surface waters by rainfall runoff, and the sources generally are not regulated by permit under the TPDES.

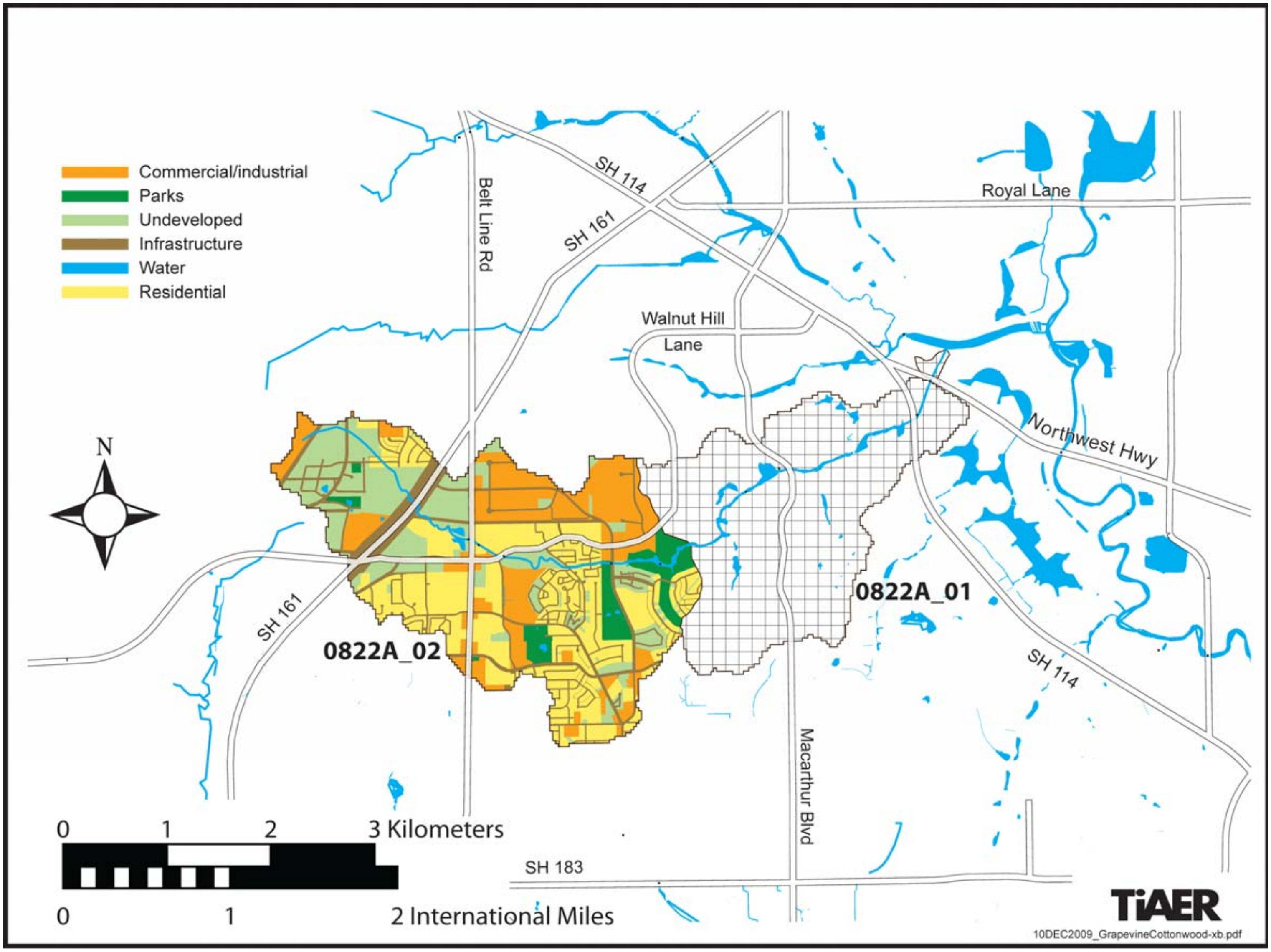

Figure 2-5 Land use/cover for the watershed of Cottonwood Branch impaired assessment unit (0822A_01)

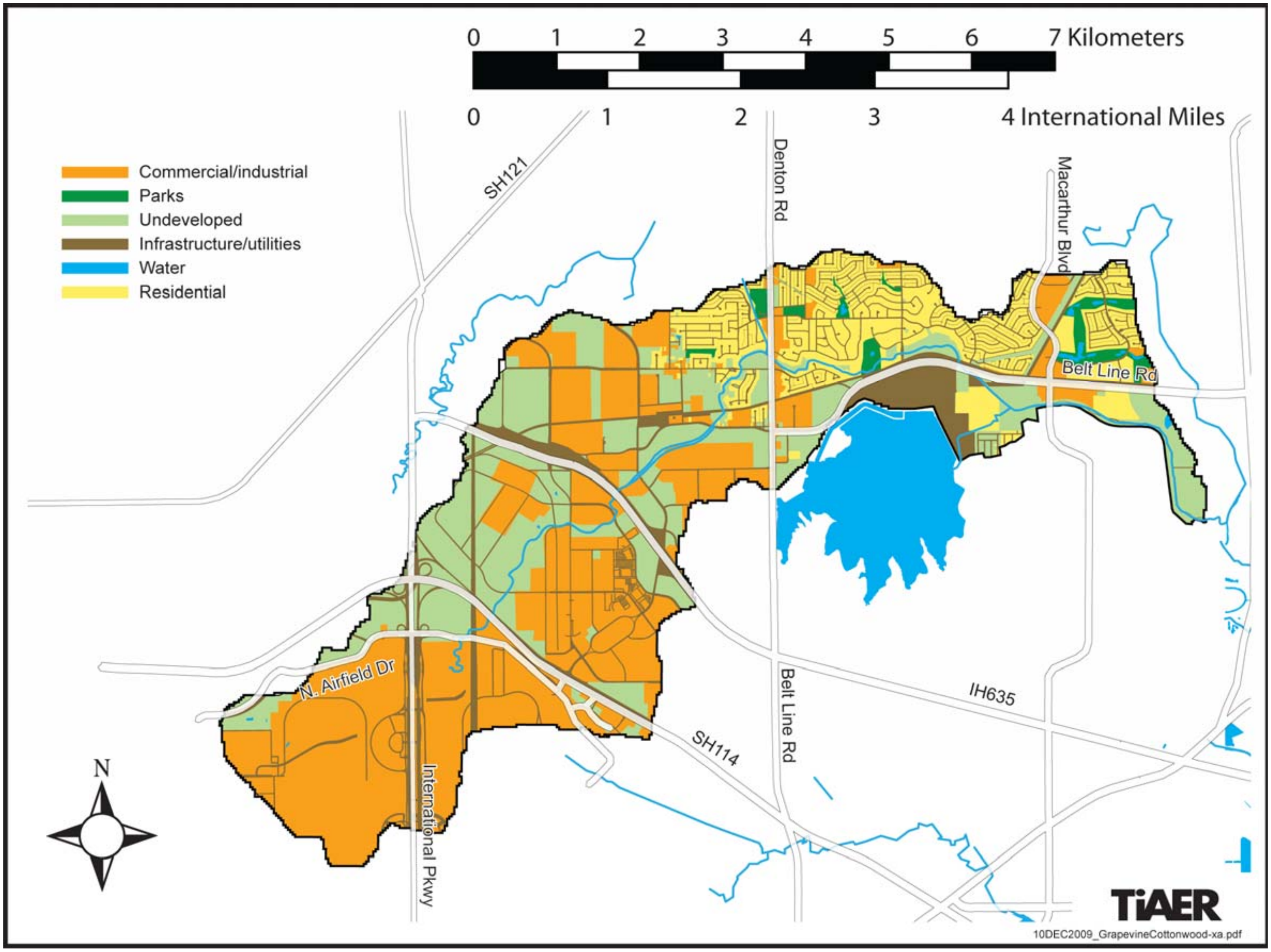

Figure 2-6 Land use/cover for the Grapevine Creek watershed

2.6.1 Permitted Sources

Permitted sources are regulated by permit under the TPDES and the NPDES. WWTF outfalls and storm water discharges from industries, construction, and municipal separate storm sewer systems or MS4s represent the potential permitted sources in the impaired assessment units of Cottonwood Branch and Grapevine Creek.

2.6.1.1 Wastewater Treatment Facility Discharges

Currently there are no authorized domestic or industrial WWTF dischargers located within the watershed of Cottonwood Branch. DFW Airport has an individual storm water permit (WQ0001441) that includes one outfall (059) that discharges to Grapevine Creek. The permit is targeted at the control of runoff following aircraft de-icing operations. The discharge is considered intermittent and variable (subject to precipitation and runoff), and no flow limit is specified in the permit. In addition, the Airport is also covered under the TPDES Phase II General Storm Water Permit. Given the circumstances of the permit, this outfall will be treated as part of the TPDES-permitted storm water discharge load (discussed below).

The entire watersheds of both impaired assessment units are located within the wastewater and sewered collection system area served by the Trinity River Authority (TRA) Central Regional WWTF (Figure 2-1).

2.6.1.2 Sanitary Sewer Overflows

Sanitary sewer overflows (SSO) are unauthorized discharges that must be addressed by the responsible party; either the TPDES/NPDES permittee or the owner of the collection system that is connected to a permitted system. SSOs in dry weather most often result from blockages in the sewer collection pipes caused by tree roots, grease and other debris. Inflow and infiltration (I/I) are typical causes of SSOs under conditions of high flow in the WWTF system. Blockages in the line may exacerbate the I/I problem. Other causes, such as a collapsed sewer line, may occur under any condition.

Determination of the importance of SSOs as a source of bacteria loadings is typically difficult to assess. A damaged sewer line in the vicinity of station 17166 in Cottonwood Branch (Figure 2-1), which has been repaired, is suspected of being a major source of high *E. coli* values determined for samples collected at this station in 2008 during TMDL bacteria data collection. Determination of the overall importance of SSOs as a source of bacteria loadings is typically difficult to assess. The TCEQ-maintained database of SSO data reported by responsible entities in the Dallas-Fort Worth Metroplex was reviewed for the period September 2003 – February 2009. The database contains entries that appear to be within the Cottonwood Branch and Grapevine Creek watershed, though most of these entries are the result of relatively minor line blockages. Based on available information it is concluded that SSOs are not a widespread source of bacteria to the two creeks; however, they may at times be a significant source in localized portions of either creek.

2.6.1.3 Regulated Storm Water

The NPDES/NPDES Municipal Separate Storm Sewer (MS4) Phase I and II rules require municipalities and certain other entities in urban areas to obtain permits for their stormwater systems. Both the Phase I and II permits include any conveyance, such as ditches, curbs, gutters, and storm sewers, that do not connect to a wastewater collection system or treatment facility. Phase I permits are individual permits for large and medium sized communities with populations exceeding 100,000, whereas Phase II permits are for smaller communities with populations less than 100,000 located within an urbanized area as defined by the 2000 Census. Phase II entities are regulated by a general permit. The purpose of a MS4 permit is to reduce discharges of pollutants in stormwater to the "maximum extent practicable" by developing and implementing a Stormwater Management Program (SWMP). The SWMPs require specification of best management practices (BMPs) for six minimum control measures:

- Public education and outreach;
- Public participation/involvement;
- Illicit discharge detection and elimination;
- Construction site runoff control;
- Post-construction runoff control; and
- Pollution prevention/good housekeeping

The geographic region of Cottonwood Branch and Grapevine Creek covered by Phase I and II MS4 permits is that portion of the study area within the jurisdictional boundaries of the regulated entity. For Phase I permits the jurisdictional area is defined by the city limits and for Phase II permits the jurisdictional area is defined as the intersection or overlapping areas of the city limits and the 2000 Census Urbanized Area. Of the MS4 permitted entities in either watershed, the City of Dallas, City of Irving and North Texas Tollway Authority have a Phase I permit (Table 2-4). The entire watershed of the impaired AU of Cottonwood Branch (0822A_02) is regulated under MS4 permits, and for Grapevine Creek (AU 0822B_01) 84.8% of its watershed is within the regulated area of MS4 permits (Figure 2-7). As noted previously, Outfall 059 in the individual storm water permit for DFW Airport will be treated as part of the MS4 loading for AU 0822B_01.

2.6.1.4 Dry Weather Discharges/Illicit Discharges

Bacteria loads from storm water can enter the streams from permitted outfalls and illicit discharges under both dry and wet weather conditions. The term "illicit discharge" is defined in TPDES General Permit No. TWR040000 for Phase II MS4s as "any discharge to a municipal separate storm sewer that is not composed entirely of storm water, except discharges pursuant to an NPDES permit and discharges resulting from fire-fighting activities" (NEIWPCC 2003). Illicit discharges can be categorized as either direct or indirect contributions. Examples of illicit discharges identified in the *Illicit Discharge Detection and Elimination Manual: A Handbook for Municipalities* (NEIWPCC 2003) include:

Table 2-4 Phase I and II MS4 permits associated with the TMDL area watersheds. (All Phase II entities are covered under TPDES General Permit No. TXR040000)

Impaired Assessment Unit	Regulated Entity Name	NPDES Permit Number	TPDES Permit Number
0822A_02	North Texas Tollway Authority	TXS000703	WQ0004400-000
0822A_02 and 0822B_01	City of Irving	TXS001301	WQ04691-000
0822B_01	City of Coppell	TXR040375	Phase II General Permit
0822B_01	City of Dallas	TXS000701	WQ0004396-000
0822B_01	DFW International Airport*	TXR040044	Phase II General Permit
0822B_01	City of Grapevine	TXR040114	Phase II General Permit

*For purposes of this TMDL, Outfall 059 on the DFW Airport individual storm water permit (WQ0001441) will be included as part of the MS4-permitted storm water coverage at the airport.

Direct illicit discharges:

- sanitary wastewater piping that is directly connected from a home to the storm sewer;
- materials (e.g., used motor oil) that have been dumped illegally into a storm drain catch basin;
- a shop floor drain that is connected to the storm sewer; and
- a cross-connection between the municipal sewer and storm sewer systems.

Indirect illicit discharges:

- an old and damaged sanitary sewer line that is leaking fluids into a cracked storm sewer line; and
- a failing septic system that is leaking into a cracked storm sewer line or causing surface discharge into the storm sewer.

2.6.2 Non-permitted Sources

Non-permitted source loadings enter the impaired segment through distributed, non-specific locations, and are not regulated. Non-permitted sources of indicator bacteria can emanate from wildlife, various agricultural activities, agricultural animals, land application fields, urban runoff not covered by a permit, failing onsite sewage facilities (OSSFs), and direct deposition from humans and animals.

The entire watersheds of Cottonwood Branch and Grapevine Creek are included in centralized wastewater collection and treatment systems of the Trinity River Authority Central Regional WWTF (Figure 2-1). Nevertheless, according to the North Central Council of Governments, who supplied this information, small portions of the areas included in the

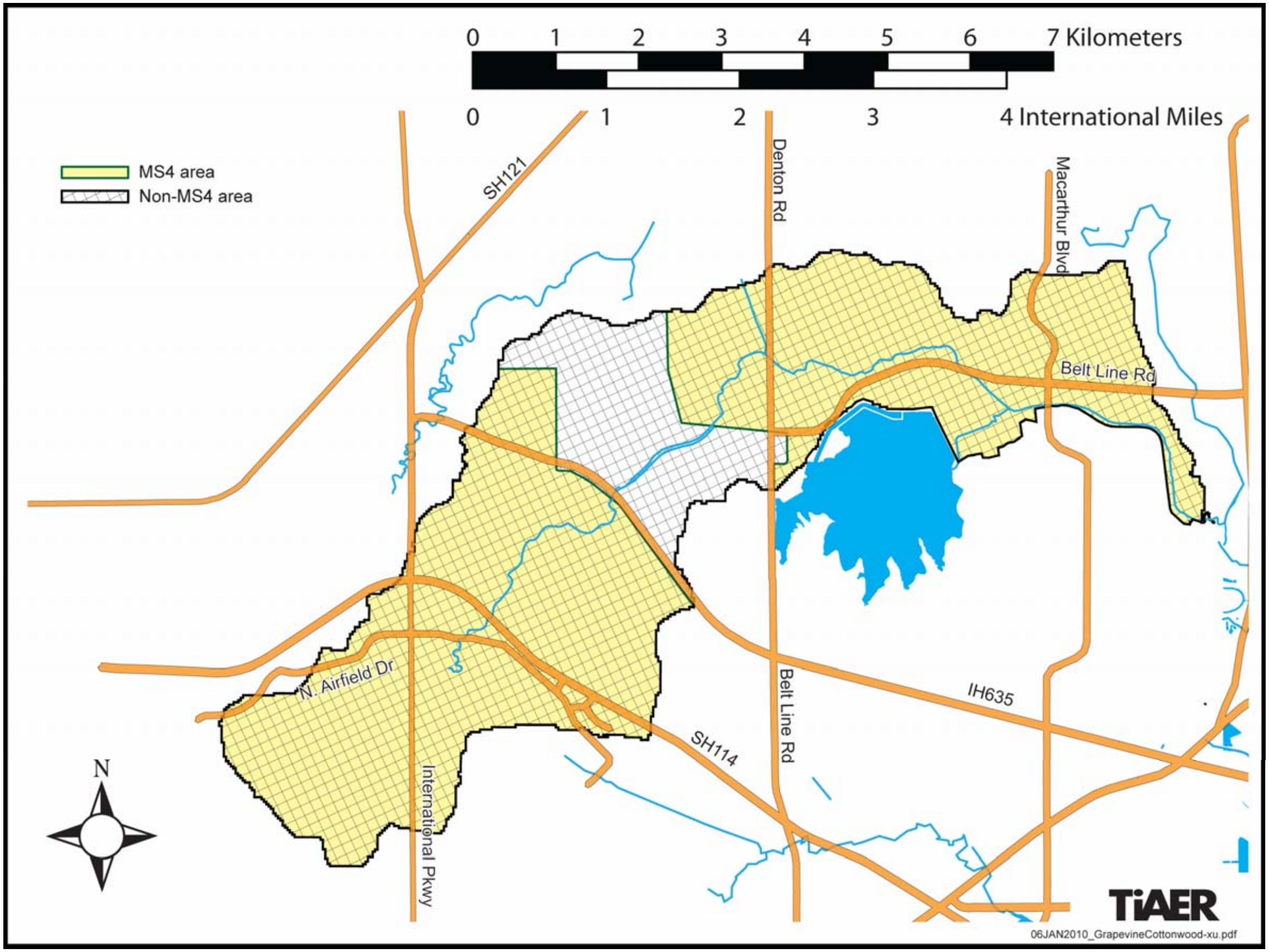

Figure 2-7 Grapevine Creek watershed with permitted and non-permitted storm water areas

centralized collection and treatment areas could still be serviced by on-site sewage facilities (OSSFs), though the likelihood of many OSSFs in these two watersheds is remote. Because OSSFs are either very small in number or entirely absent in these two watersheds due to the presence of centralized wastewater treatment and sewered collection areas, further consideration of OSSF as significant sources of bacteria is considered unnecessary.

2.6.2.1 Domestic Pets

The number of domestic pets in the watersheds of both creeks was estimated based on human population and number of households obtained from the NCTCOG Research and Information Services website (NCTCOG, 2009b). The information obtained from NCTCOG included population and households projections for population districts that encompassed the watersheds of AUs 0822A_02 and 0822B_01. The district level projections for the year 2005 of population and households were multiplied by the proportion of the district area within the watershed to generate an estimate of the watershed's population and number of households. This estimation assumes that the population/households are uniformly distributed within the area of each population district, which is the best estimate that can be made with the available data.

Based on the urban nature of this project and the availability of relevant data, dogs and cats are the only pets considered in calculating loads for domestic pets. Fecal matter from dogs and cats is transported to streams by runoff from urban and suburban areas and can be a potential source of bacteria loading. Table 2-5 summarizes the estimated number of dogs and cats for the assessment units of the TMDL area watershed.

Table 2-5 also provides an estimate of the fecal coliform loads from domestic dogs and cats. These estimates are based on estimated fecal coliform production rates of $5.4x10^8$ per day for cats and $3.3x10^9$ per day for dogs (Schueler, 2000). Pet population estimates were calculated as the estimated number of dogs (0.632) and cats (0.713) per household (AVMA, 2009). The actual contribution and significance of fecal coliform loads from pets reaching Cottonwood Branch and Grapevine Creek is unknown.

Table 2-5 Estimated households and pet populations within impaired assessment units (0822A_02 and 0822B_01)

Assessment Unit	Estimated Number of Households	Estimated Dog and Cat Population		Estimated Fecal Coliform Production (10^9 organisms)	
		Dogs	Cats	Dogs	Cats
0822A_02	5,602	3,540	3,994	11,683	2,157
0822B_01	11,673	7,377	8,323	24,344	4,494

2.6.2.2 Wildlife and Unmanaged Animal Contributions

E. coli bacteria are common inhabitants of the intestines of all warm blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify by watershed the potential for bacteria contributions from wildlife. Wildlife are naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a water body. Fecal bacteria from wildlife are also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. There are currently insufficient data available to estimate populations and spatial distribution of wildlife and avian species in the watershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

SECTION 3

BACTERIA TOOL DEVELOPMENT

This section provides the basis for the bacteria tool that will be used to assist in source identification and development of the TMDL. The discussion will begin with an explanation of the reasoning behind the selection of an empirical based approach, commonly referred to as the load duration curve (LDC) method. Next a description of the methodology is provided for developing load duration curves and associated flow exceedance curves. This section concludes with presentation of the flow exceedance and load duration curves developed for relevant monitoring stations in AUs 0822A_01, 0822A_02, and 0822B_01.

3.1 Tool Selection

The TMDL development process to address impairments to recreational uses involves assigning bacteria, i.e., *E. coli*, loads to their sources such that the total loads do not result in violations of pertinent numeric criteria protecting the contact recreation use. To accomplish this goal a tool must be applied to assist in determining differences between existing loadings and the criteria. The decision on the appropriate bacteria tool to apply was informed by the data requirements of each tool, the availability of watershed-specific data for AUs 0822A_02 and 0822B_01, and guidance in the Texas Bacteria Task Force Report (TWRI, 2007). In general, two basic tools are commonly used for bacteria TMDLs—mechanistic computer models and an empirical approach referred to as the load duration curve.

Mechanistic models, also referred to as process models, are based on theoretical principles that provide for representation of governing physical, chemical, and biological processes that determine the response of certain variables, such as streamflow and bacteria concentration. Under circumstances where the governing processes are acceptably quantifiable, the mechanistic model provides understanding of the important biological, chemical, and physical processes of the prototype system and reasonable predictive capabilities to evaluate alternative allocations of pollutant load sources.

The LDC method allows for estimation of existing and allowable loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, the load duration curve method allows for the determination of the hydrologic conditions under which impairments are typically occurring. This information can be used to identify broad categories of sources (point and nonpoint) that may be contributing to the impairment. The LDC method has found relatively broad acceptance among the regulatory community, primarily due to the simplicity of the approach and ease of application. The regulatory community recognizes the frequent information limitations with bacteria TMDLs that constrain use of the more powerful mechanistic models. Further, the Task Force on Bacterial TMDLs appointed by the TCEQ and the Texas State Soil and Water Conservation Board (TSSWCB) suggested application of the load duration curve method within their three-tiered approach to TMDL development (TWRI, 2007). In June 2007, the TCEQ and the TSSWCB adopted the principles and general process (three-tiered approach including LDCs) recommended by the Task Force. The LDC method does not have the predictive capabilities to evaluate alternative allocation approaches to reach TMDL goals, nor can it be used to quantify specific source contributions and instream fate and transport processes. The method does, however, provide a means to estimate the difference in bacteria loads and criteria, and can give indications of broad sources of the bacteria, i.e., point source and nonpoint source

Streamflow and *E. coli* data availability were used to assist in the bacteria tool selection process. Hydrologic data in the form of daily streamflow records were not available for Cottonwood Branch or Grapevine Creek; however, an extensive period of hydrologic data was available from a US Geological Survey (USGS) gage on nearby White Rock Creek (Table 3-1). Streamflow records can be derived for Cottonwood Branch and Grapevine Creek by utilizing streamflow records obtained from the White Rock Creek gage and applying a drainage area ratio to those records, which is a standard technique used to estimate streamflow for ungaged streams.

Table 3-1 USGS streamflow gage at White Rock Creek, Dallas County, Texas

Gage No.	Site Description	Drainage Area (ha)	Daily Streamflow Period of Record (date)
08057200	White Rock Creek, Dallas, TX	17,198	Oct. 1960 – Present

Collectively the data obtained from both routine ambient and TMDL development bacteria monitoring provide a data set containing a substantial amount of *E. coli* data at several locations in the watershed (Table 3-2; Figure 2-1).

Table 3-2 Summary of combined data set of TCEQ and TIAER Project Team *E. coli* concentrations

TCEQ Station ID	Segment & AU	Routine Ambient Data	TMDL Development Data	Total Number of Data Values
17167*	0822A_01	04Dec01 – 02Dec03	09Jan08 – 07Aug08	35
20320§	0822A_01	04Dec01 – 19Oct04	09Jan08 – 07Aug08	43
17165	0822A_02	04Dec01 – 19Oct04	09Jan08 – 07Aug08	44
17166	0822A_02	21Aug02 – 15Jun04	09Jan08 – 07Aug08	42
17531	0822B_01	05Nov01 – 23Jun04	09Jan08 – 07Aug08	24
17939	0822B_01	03Sep02 – 18Oct04	09Jan08 – 07Aug08	34
20311	0822B_01	No Historical Data	09Jan08 – 07Aug08	12

* The data for station 17167 also includes the *E. coli* data collected at station 18359

§ The data for station 20320 also includes the *E. coli* data collected at station 17168

3.1.1 Bacteria Tool Selection

Based on availability of an adequate amount of *E. coli* data for stations in Cottonwood Branch and Grapevine Creek, the nearby hydrologic record for White Rock Creek and the absence of detailed site-specific information on fate and transport of bacteria in Cottonwood

Branch and Grapevine Creek, the decision was made to use the LDC method as opposed to a mechanistic watershed loading and hydrologic/water quality model.

3.2 Methodology for Flow Duration & Load Duration Curve Development

To develop the LDCs, the previously discussed data resources were used in the following sequential steps.

Step 1: Determine the hydrologic period of record to be used in developing the flow duration curves (FDCs).

Step 2: Determine desired stream locations for which flow and load duration curves will be developed.

Step 3: Develop daily streamflow records at desired stream locations using historical daily streamflow records.

Step 4: Develop FDCs at desired stream locations.

Step 5: Develop the allowable bacteria LDCs at the same stream locations based on the relevant criterion and the data from the FDCs.

Step 6: Superimpose bacteria data, i.e., *E. coli* data from November 2001–August 2008, on the allowable bacteria LDCs.

Additional information explaining the load duration curve method may be found in Cleland (2003), NDEP (2003), and USEPA (2007).

Daily streamflow records form the basis for the bacteria LDCs, which are used to determine the differences between existing loads of bacteria and the geometric mean criteria. The following sections address the development of the LDCs.

3.3 Development of Load Duration Curves

3.3.1 Step 1: Determine Hydrologic Period

No daily streamflow records were available for Cottonwood Branch and Grapevine Creek, but daily hydrologic (streamflow) records from the past 48 years were available for the White Rock Creek USGS gage 08057200 in north Dallas (Table 3-1), a stream roughly 22 km (14 miles) to the east of Cottonwood Branch and Grapevine Creek. USGS gage 08057200 was chosen based on proximity and the similarity of land use to that of Cottonwood Branch and Grapevine Creek. Optimally, the period of record to develop flow duration curves should include as much data as possible in order to capture extremes of high and low streamflows and hydrologic variability from high to low precipitation years. The flow during the period of record selected should, however, also be representative of recent conditions experienced within the watershed including, but not limited to, the time period when the *E. coli* data were collected. Therefore, a 15-year record of daily streamflow from August 8, 1993 through August 7, 2008 was selected to develop the streamflow duration curves at each station, and this 15-year period includes the collection dates of all available *E. coli* data at the time this effort was undertaken. A 15-year period is of sufficient duration to contain a reasonable variation from dry months and years to wet months and years and at the same time is short enough in duration to contain a hydrology that is responding to recent and current conditions in the watershed.

3.3.2 Step 2: Determine Desired Stream Locations

The stations from which adequate *E. coli* data were available (Table 3-2) determined the stream locations for which flow and bacteria load duration curves would be developed. Stations 17165 and 17166 were located within the impaired portion of Cottonwood Branch (0822A_02) and stations 17531, 17939, and 20311 were located within the impaired portion of Grapevine Creek (0822B_01). Stations 17167 and 20320 were located in the non-impaired portion of Cottonwood Branch (0822A_01) and were included as additional information, though bacteria TMDL development is not required for this assessment unit.

3.3.3 Step 3: Develop Daily Streamflow Records

Once the hydrologic period of record and station locations were selected, the next step was to compile the 15-year daily streamflow record for each station. The method to develop the necessary streamflow record for each selected station involved a drainage-area ratio (DAR) approach. With this basic approach, each daily streamflow value at the nearest representative USGS gage is multiplied by a factor to estimate the flow at another station based upon the relative drainage area of each station. The factor is determined by calculating the ratio of the drainage area above the sampling station to the drainage area above USGS gage 08057200 on White Rock Creek. The drainage area for USGS gage station 08057200 and the sampling stations in 0822A_02, 0822A_01, and 0822B_01 are presented in Table 3-3. The drainage areas were developed using the Geographic Information System (GIS) interface called AVSWAT-X (Di Luzio et al., 2004).

Table 3-3 Drainage area ratios (DAR) for USGS 08057200 at White Rock Creek, Dallas, TX, and sampling stations from AUs 0822A_01, 0822A_02 and 0822B_01

Assessment Unit	Station	Station Drainage Area (km^2)	USGS 08057200 at White Rock Creek Drainage Area (km^2)	DAR
0822A_02	17165	2.40	172	0.014
0822A_02	17166	5.12	172	0.030
0822A_01	17167	9.67	172	0.056
0822A_01	20320	11.9	172	0.069
0822B_01	17531	6.09	172	0.035
0822B_01	17939	9.73	172	0.057
0822B_01	20311	34.9	172	0.203

The drainage area ratio (DAR) approach is intended to estimate streamflow records between creeks and rivers with similar watershed characteristics (e.g., land use) and in close proximity. Often the flow from point source discharges, if any are present, are simply subtracted from the streamflow record of the reference stream gage (i.e., White Rock Creek gage). The North Texas Municipal Waster District Floyd Branch Regional WWTP, with a maximum annual average permitted flow limit of 4.75 million gallons per day, discharges into Floyd Branch thence to Cottonwood Creek and then into White Rock Creek above the USGS gauge. However, when the discharge monitoring report (DMR) data for this WWTF were subtracted from the gaged record for White Rock Creek, negative flow values were created for approximately 3 percent of the period of record. Negative flow values are typically set to zero indicating absence of streamflow. While inaccuracies in both recorded Floyd Branch Regional WWTF discharges and White Rock Creek streamflow are undoubtedly part of the issue, it is also highly likely that during dry conditions the creek system experiences in-channel losses of unknown amounts dependent upon environmental conditions (e.g., air temperature, streamflow, shallow groundwater depth). Because it was concluded in Section 2.3, albeit based on limited data, that even the headwaters of Cottonwood Branch and Grapevine Creek experienced perennial flow, it was concluded that it was unacceptable to show the absence of streamflow in the White Rock Creek record that resulted from subtracting the WWTF discharge. Therefore, the White Rock Creek gaged streamflow record was used in the DAR approach without subtracting the Floyd Branch Regional WWTF DMR discharge data.

The final step in developing the streamflow dataset involved adding a small flow to each daily value that represents the future growth component within the pollutant load allocation computations. The methodology employed to develop this future growth component is discussed in greater detail in Section 4.9.1.

3.3.4 Step 4: Development of Flow Duration Curves (FDC)

The daily flow data in units of cubic meters per second (cms) were used to develop a FDC for each station. The flow duration curves were generated by

1) Ranking the daily flow data from highest to lowest
2) Calculating the percent of days each flow was exceeded by dividing each rank by the total number of data points plus 1 and then multiplying by 100.
3) Plotting each flow value (y-axis) against its exceedance value (x-axis).

Exceedance values along the x-axis represent the percent of days that flow was at or above the associated flow value on the y-axis. Exceedance values near 100% occur during low flow or drought conditions while values approaching 0% occur during periods of high flow or flood conditions.

FDCs were developed for stations within both assessment units on Cottonwood Branch (0822A_01 and 0822A_02, Figures 3-1 and 3-2), and for stations on Grapevine Creek (0822B_01, Figure 3-3). While AU 0822A_01 is not impaired, the purpose of constructing flow duration curves within this assessment unit was to provide information regarding the flow downstream of the impaired AU 0822A_02. Because each FDC is based on the same streamflow

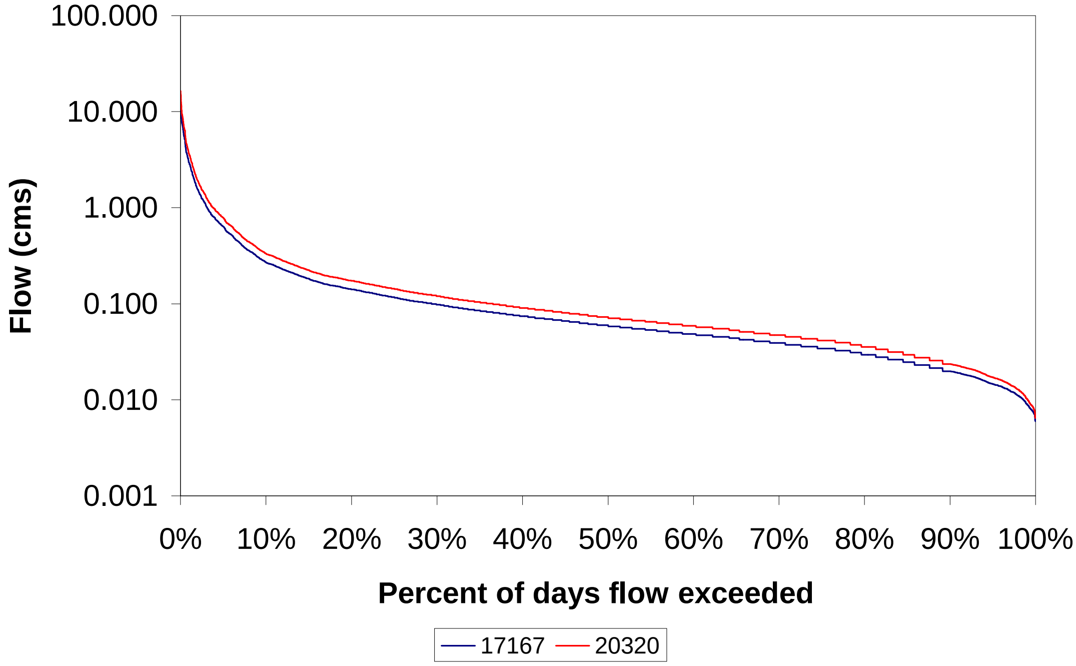

Figure 3-1 Flow duration curve for stations within Cottonwood Branch, AU 822A_01

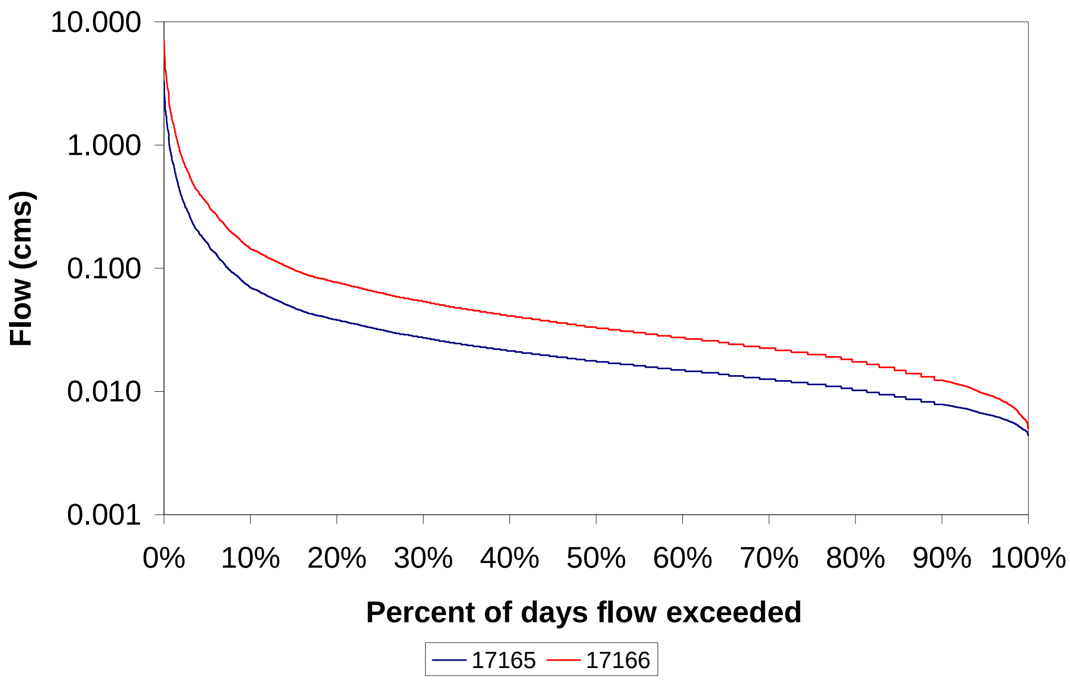

Figure 3-2 Flow duration curve for stations within Cottonwood Brach, AU 0822A_02

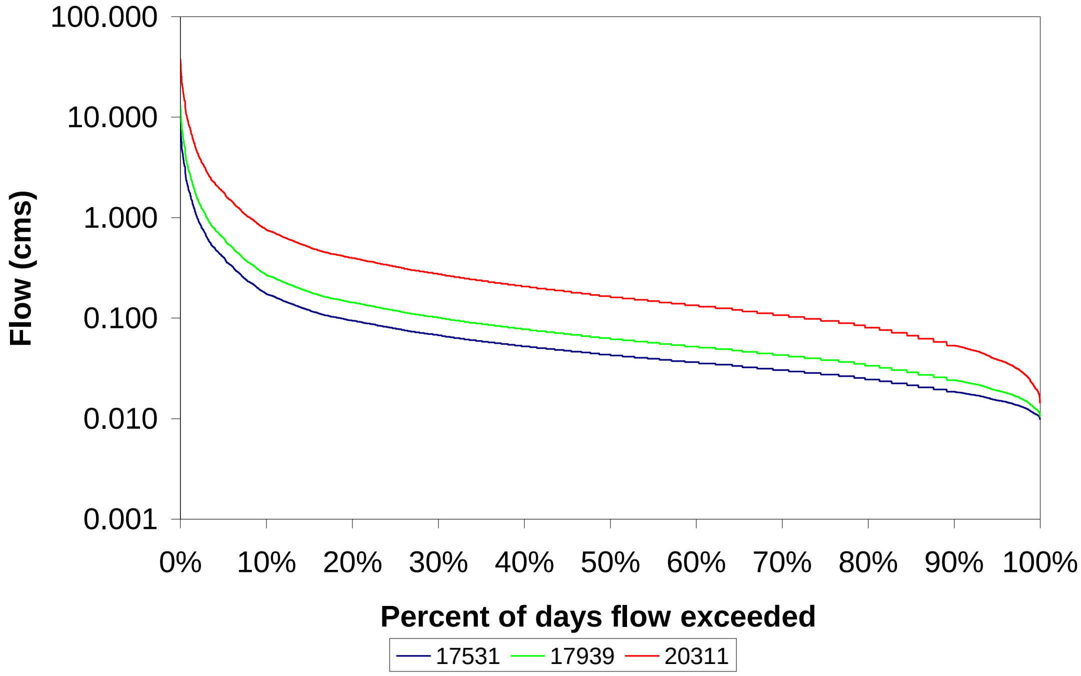

Figure 3-3 Flow duration curve for stations within Grapevine Creek, AU 0822B_01

record for White Rock Creek, the only difference between the FDCS is relative magnitude of daily flows based on the differences in DARs (Table 3-3).

3.3.5 Steps 5 and 6: Load Duration Curves and Bacteria Data

In Step 5, the flow duration curve is combined with the pertinent numeric water quality criterion established to protect the contact recreation use. The pertinent criterion is the geometric mean concentration of *E. coli* not to exceed 126 MPN per 100 mL. A LDC was developed by multiplying each streamflow value (cms) from Step 4 by the *E. coli* criterion (126 MPN/100 mL) and by the appropriate conversion factor (8.64×10^8 100 mL/m^3 * seconds/day) to express the loadings as MPN per day. The bacteria load duration curves for stations within AUs 0822A_01, 0822A_02, and 0822B_01 are presented in Figures 3-4 – 3-10 in a downstream to upstream direction for Cottonwood Branch and then Grapevine Creek.

In Step 6, for every station, each historical *E. coli* measurement was associated with the streamflow on the day of measurement. The historical *E. coli* measurements were combined with the corresponding daily average streamflow to give a loading as performed for the criterion in Step Five. The associated streamflow for each bacteria loading was compared to the flow duration curve data to determine its value for “percent days flow exceeded,” which becomes the “percent of days load exceeded” value on the load duration curve (LDC) for purposes of plotting the *E. coli* loading. Each load was then plotted on the load duration curve at its percent exceedance. This process was repeated for each *E. coli* measurement at each station (see Figures 3-4 – 3-10). Points above the curve developed in Step 5 represent exceedances of the bacteria criterion and associated allowable loadings. The streamflows and associated *E. coli* concentrations at each of the stations are provided in Appendix A.

Based on antecedent rainfall, each measurement was considered as being collected under dry or wet weather conditions. *E. coli* data from sampling events that occurred within 24 hours following a rainfall event was designated as a wet weather sampling event. Data obtained from wet weather sampling occurred during all flow regimes and often exceeded the geometric mean criterion. Data points indicated as wet weather that occurred under lower flow conditions (right side of Figures 3-4 – 3-10) typically represent *E. coli* data collected after a small rainfall runoff event when conditions up to the event were very dry. *E. coli* data plotted as occurring under high flow and not indicated to be collected under wet weather conditions are potentially an artifact of using the White Rock Creek streamflow data to create the FDCs and LDCs.

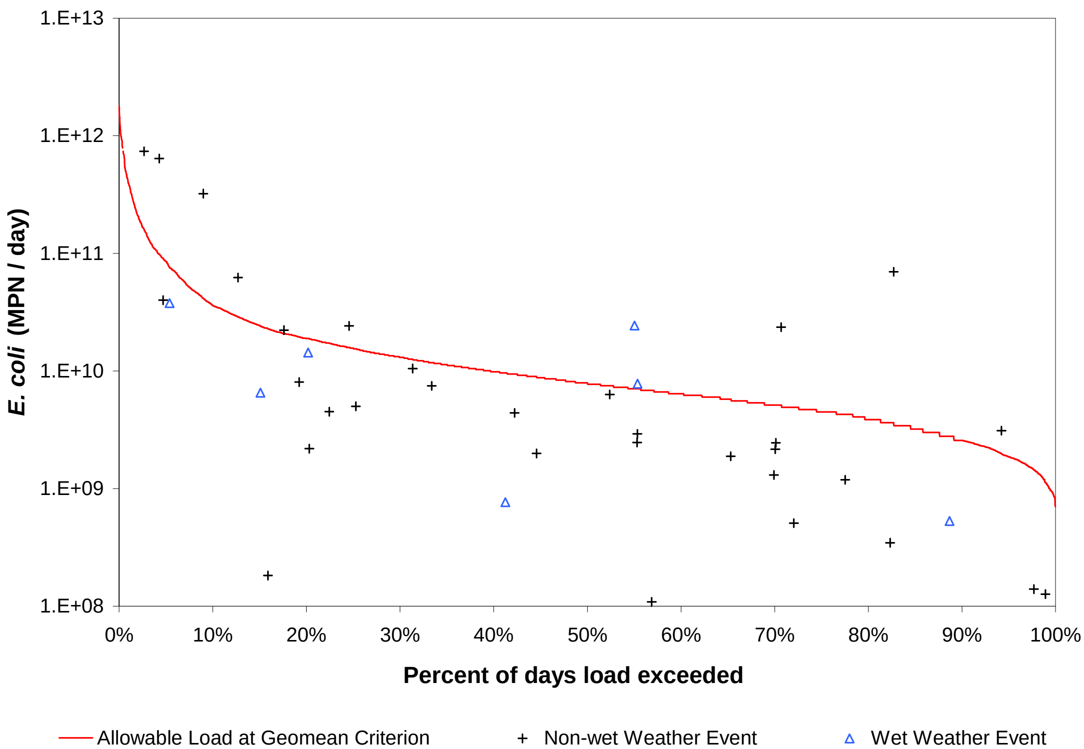

Figure 3-4 Load duration curve for station 20320, Cottonwood Branch, AU 0822A_01

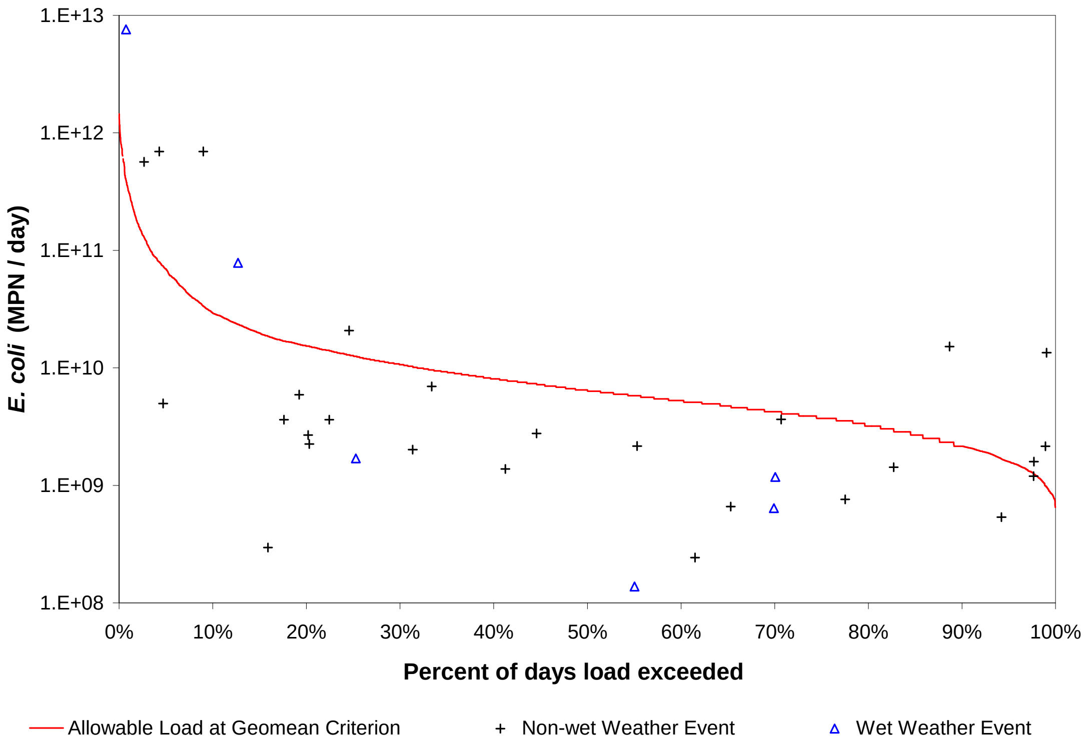

Figure 3-5 Load duration curve for station 17167, Cottonwood Branch, AU 0822A_01

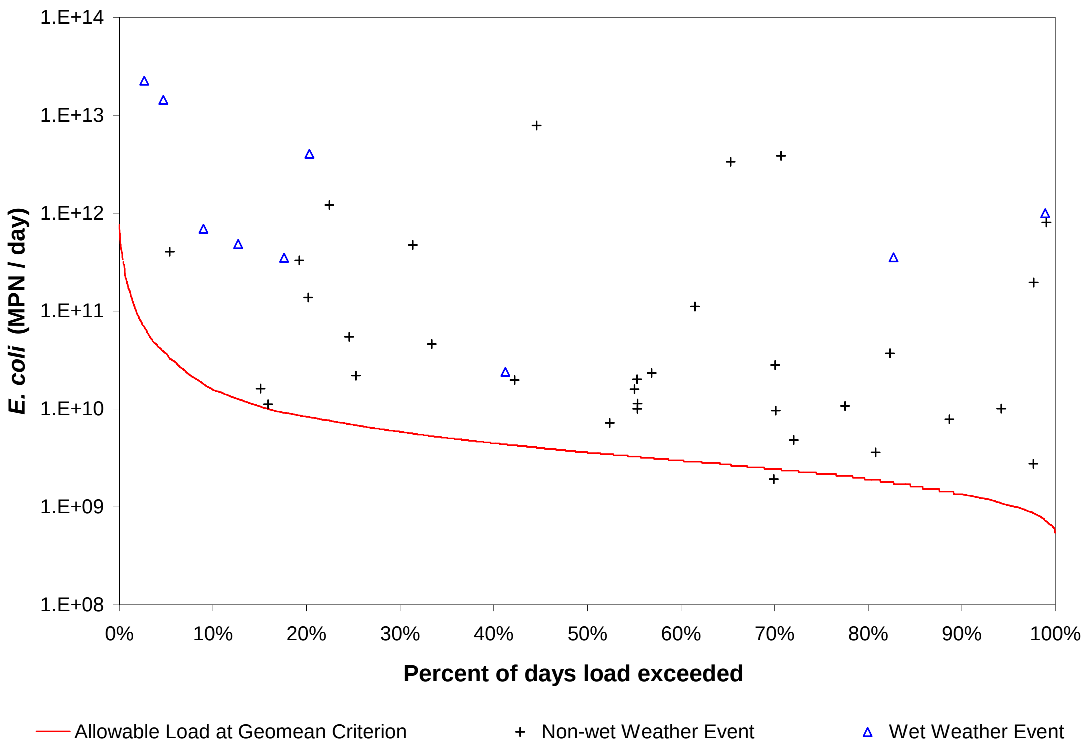

Figure 3-6 Load duration curve for station 17166, Cottonwood Branch, AU 0822A_02

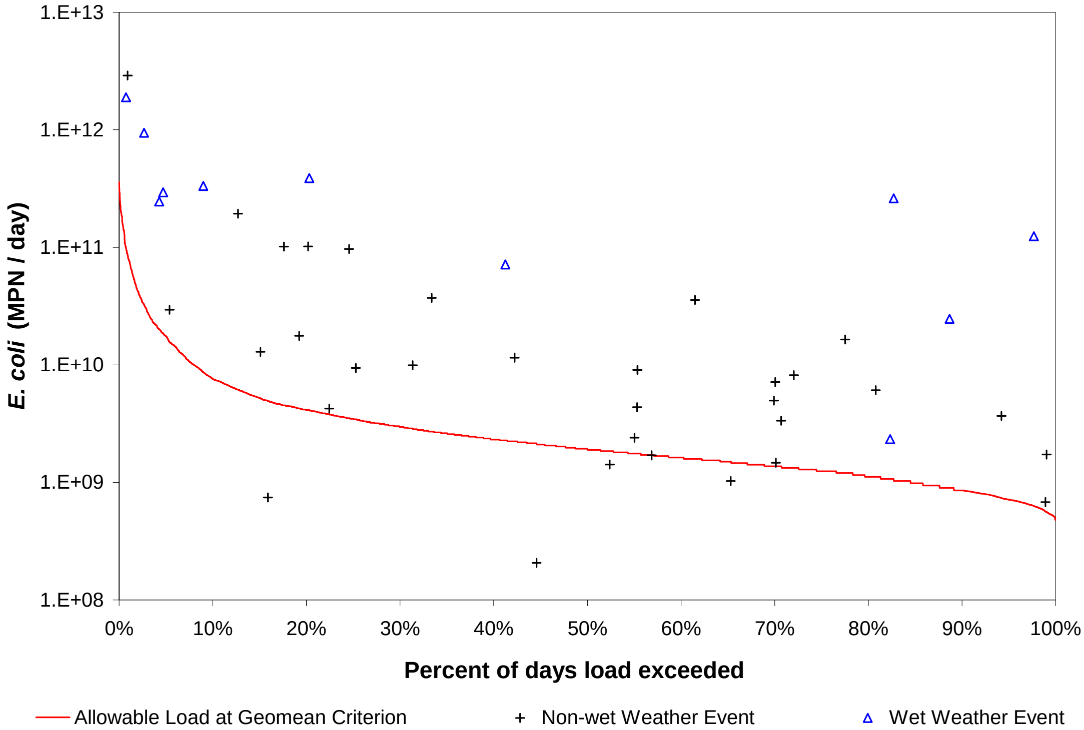

Figure 3-7 Load duration curve for station 17165, Cottonwood Branch, AU 0822A_02

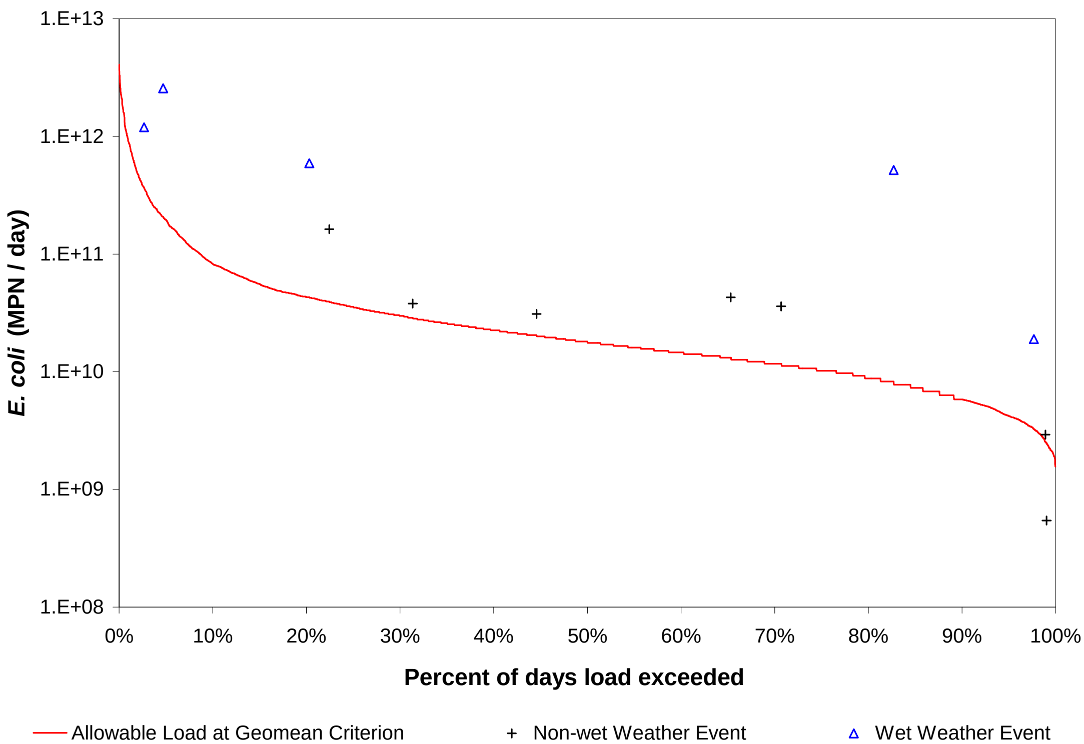

Figure 3-8 Load duration curve for station 20311, Grapevine Creek, AU 0822B_01

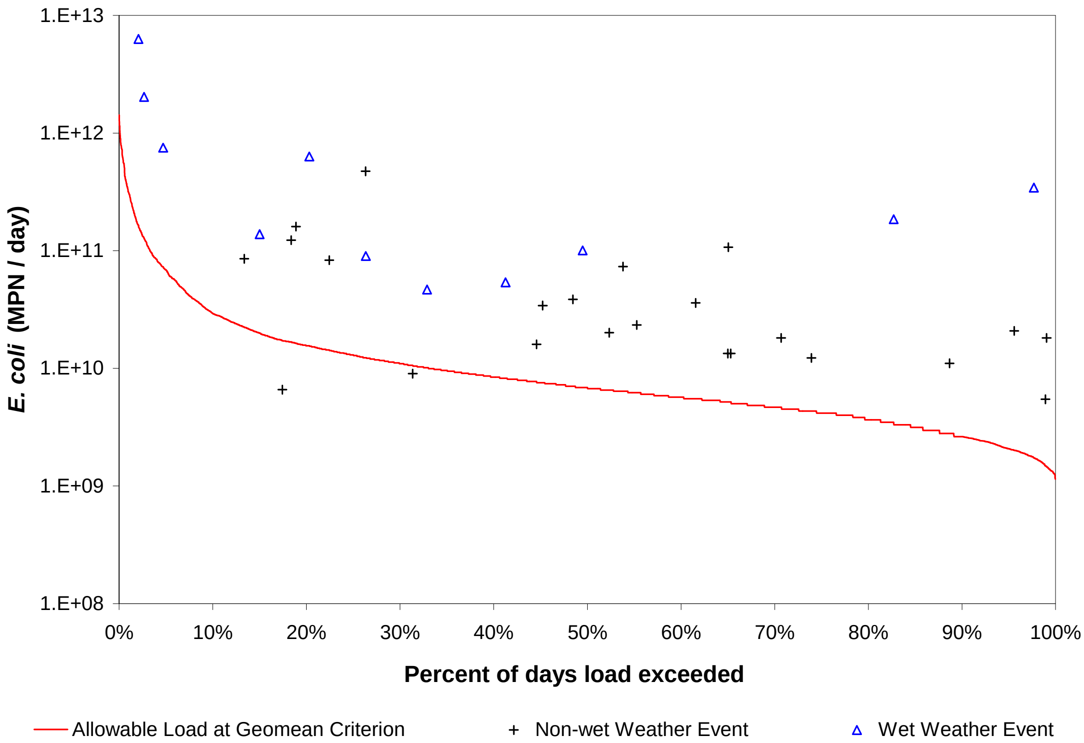

Figure 3-9 Load duration curve for station 17939, Grapevine Creek, AU 0822B_01

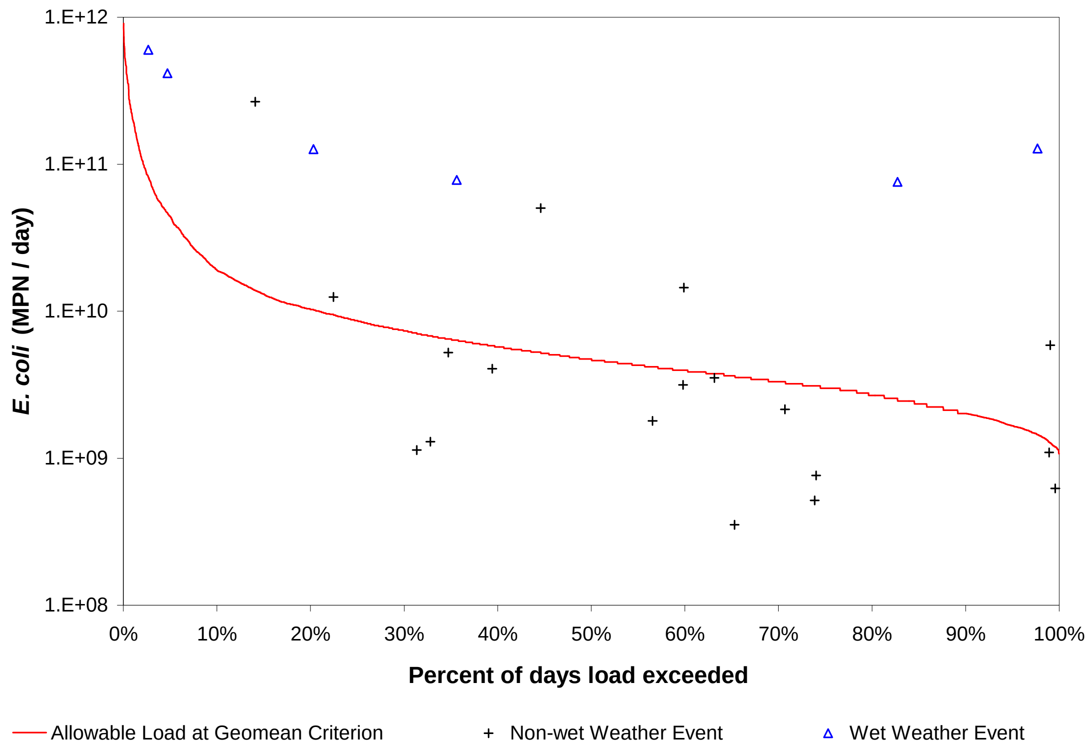

Figure 3-10 Load duration curve for station 17531, Grapevine Creek, AU 0822B_01

Load duration curves developed for stations within the impaired AU of Cottonwood Branch (0822A_02; Figures 3-6 and 3-7) indicate *E. coli* loadings often exceeded allowable loadings under all flow conditions. *E. coli* loading exceedances were also not restricted to wet-weather events but occurred during conditions not influenced by rainfall runoff as well. Sampling stations 17167 and 20320 within the non-impaired AU 0822A_01 (Figures 3-4 and 3-5) indicated fewer exceedances in bacteria loadings than at the impaired AU (0822A_02). When exceedances in bacteria loadings did occur in the non-impaired assessment unit these incidents typically occurred more frequently during high and low flow conditions than during mid-range flows. Actual interpretation of these curves in the context of the TMDL allocation process is reserved for the next report section. Similar patterns found for stations within the impaired assessment unit of Cottonwood Branch were also found for stations on Grapevine Creek where exceedances often occurred under all flow conditions and were recorded during both dry- and wet-weather conditions (Figures 3-8 – 3-10).

It should be noted that flow duration curves and load duration curves were developed for all stations for which adequate historical *E. coli* data existed in order to present as complete a representation of conditions in each segment as possible. Since stations 17167 and 20320 were located in non-impaired Segment 0822A_01, data from these stations were not used in the TMDL allocation analysis (Section 4).

SECTION 4

TMDL ALLOCATION ANALYSIS

Within this report section is presented the development of the bacteria TMDL allocation. The allocation tool used for the Cottonwood Branch (AU 0822A_02) and Grapevine Creek (AU 0822B_01) bacteria TMDLs was the load duration curve method previously described in Section 3 — Bacteria Tool Development. Endpoint identification, margin of safety, load reduction analysis, TMDL allocations, and other TMDL components are described herein.

The load duration curve method provided a flow-based approach to determine necessary reductions in bacteria loadings within impaired AUs 0822A_02 and 0822B_01. As developed previously in this report, the duration curve method uses frequency distributions to assess a bacteria criterion over the historical range of flows, providing a means to determine maximum allowable loadings and the load reduction necessary to achieve support of the contact recreation use.

A drainage area ratio approach has been used to estimate flows in the TMDL development for each segment's assessment unit not supporting its contact recreation use. Within the subsequent Implementation Plan, an adaptive approach will be used to bring the necessary spatial focus to improving water quality and restoring the contact recreation use.

4.1 Endpoint Identification

Cottonwood Branch and Grapevine Creek have a designated use for contact recreation, which is protected by numeric criteria for the indicator bacteria of *E. coli*. Indicator bacteria are not generally pathogenic and are indicative of potential viral, bacterial, and protozoan contamination originating from the feces of warm-blooded animals. *E. coli* criteria to protect freshwater contact recreation consist of geometric mean concentrations not to be exceeded of 126 MPN/100 mL and a single sample concentration not to be exceeded of 394 MPD/100 mL (TCEQ, 2000). All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

The endpoint for the TMDLs in this report is to maintain concentrations of *E. coli* below the geometric mean criterion of 126 MPN/100 mL. This endpoint applies to impaired AU 0822A_02 of Cottonwood Branch and AU 0822B_01 of Grapevine Creek.

4.2 Assessment Results from Historical Monitoring *E. coli* Data

As previously presented in this report (Table 2-1), historical indicator *E. coli* data indicate that AU 0822A_02 of Cottonwood Branch and AU 0822B_01 of Grapevine Creek do not support the contact recreation use whereas the data for AU 0822A_01 of Cottonwood Branch indicate support of that use. As anticipated because of use of the common data source in SWQMIS, these results corroborate the TCEQ 2008 assessment findings (TCEQ, 2008b).

4.3 Seasonality

Seasonal variations or seasonality occur when there is a cyclic pattern in streamflow and, more importantly, in water quality constituents, which for this study was *E. coli.* Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonal variation was accounted for in these TMDLs by using more than three years of water quality data and by using a 15-year period of USGS flow records when developing flow exceedance percentiles.

Seasonal differences in indicator bacteria concentrations were assessed by comparing *E. coli* concentrations obtained from routine monitoring collected in the warmer months (May – September) against those collected during the cooler months (October – April). Data obtained from stations 17165 and 17166 were combined into a single dataset for Cottonwood Branch impaired AU 0822A_02, while data obtained from stations 17531 and 17939 was combined to represent the dataset used for Grapevine Creek. Flow and *E. coli* data were transformed using the natural log and then adjusted for flow using locally weighted scatterplot smoothing (LOWESS) (Helsel and Hirsch, 1992). Differences in E. coli concentrations obtained in warmer versus cooler months were then evaluated by performing a t-test on the adjusted dataset. There was no significant difference (α=0.05) in indicator bacteria between cool and warm weather seasons for Cottonwood Branch Segment 0822A_02 (ρ=0.15) or Grapevine Creek Segment 0822B_01 (ρ=0.12).

4.4 Linkage Analysis

Establishing the relationship between instream water quality and the source of loadings is an important component in developing a TMDL. It allows for the evaluation of management options that will achieve the desired endpoint. The relationship may be established through a variety of techniques.

Generally, if high bacteria concentrations are measured in a water body at low to median flow in the absence of runoff events, the main contributing sources are likely to be point sources. During ambient flows, these constant inputs to the system will increase pollutant concentrations depending on the magnitude and concentration of the sources. As flows increase in magnitude, the impact of point sources is typically diluted, and would therefore be a smaller part of the overall concentrations.

Bacteria load contributions from permitted and non-permitted storm water sources are greatest during runoff events. Rainfall runoff, depending upon the severity of the storm, has the capacity to carry indicator bacteria from the land surface into the receiving stream. Generally, this loading follows a pattern of low concentration in the water body just before the rain event, followed by a rapid increase in bacteria concentrations in the water body as the first flush of storm runoff enters the receiving stream. Over time, the concentrations reduce because the sources of indicator bacteria are attenuated as runoff washes them from the land surface and the volume of runoff decreases following the rain event.

Load duration curve analysis (LDC) analyses were used to examine the relationship between instream water quality and the broad sources of indicator bacteria loads, and LDCs are the basis of the TMDL allocations. The strength of this TMDL is the use of the LDC method to determine the TMDL allocations. LDCs are a simple statistical method that provides a basic description of the water quality problem. This tool is easily developed and explained to stakeholders, and uses available water quality and flow data. The LDC method does not require any assumptions regarding loading rates, stream hydrology, land use conditions, and other conditions in the watershed. The U.S. EPA supports the use of this approach to characterize pollutant sources, and the Texas Bacterial Task Force identified this method as a tool for TMDL development. In addition many other states are using this method to develop TMDLs.

The weaknesses of this method include the limited information it provides regarding the magnitude or specific origin of the various sources. Only limited information is gathered regarding point and nonpoint sources in the watershed. The general difficulty in analyzing and characterizing *E. coli* in the environment is also a weakness of this method.

The LDC method allows for estimation of existing and TMDL loads by utilizing the cumulative frequency distribution of streamflow and measured pollutant concentration data (Cleland, 2003). In addition to estimating stream loads, this method allows for the determination of the hydrologic conditions under which impairments are typically occurring, can give indications of the broad origins of the bacteria (*i.e*., point source and storm water) and provides a means to allocate allowable loadings.

4.5 Margin of Safety

The margin of safety (MOS) is used to account for uncertainty in the analysis performed to develop the TMDL and thus provides a higher level of assurance that the goal of the TMDL will be met. According to EPA guidance (EPA 1991), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The margin of safety is designed to account for any uncertainty that may arise in specifying water quality control strategies for the complex environmental processes that affect water quality. Quantification of this uncertainty, to the extent possible, is the basis for assigning a margin of safety.

The TMDLs covered by this report incorporate an explicit MOS by setting a target for indicator bacteria loads that is 5 percent lower than the single sample criterion. The explicit margin of safety was used because of the limited amount of data for some of the sampling locations. For contact recreation, this equates to a geometric mean target for *E. coli* of 120 MPN/100 mL. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each water body is slightly reduced. The TMDLs covered by this report incorporate an explicit MOS in each LDC by using 95 percent of the geometric mean criterion.

4.6 Flow Regimes for Load Duration Curves and Pollutant Load Computations

A useful refinement of the LDC approach is to divide the curve into flow-regime regions to analyze exceedance patterns in smaller portions of the duration curves (various flow ranges). This approach assists in developing solutions specific to actions that occur during specific conditions that coincide with observed exceedances. A commonly used set of regimes that is provided in Cleland (2003) is based on the following five intervals along the x-axis of the FDCs and LDCs: (1) 0 – 10% (high flows); (2) 10 – 40% (moist conditions); (3) 40 – 60% (mid-range flows); (4) 60 – 90% (dry conditions); and (5) 90 – 100% (low flows). For sampling stations in the Cottonwood Branch and Grapevine Creek watersheds a three-interval system was selected: (1) 0 – 10% (high flows); (2) 10 – 50% (mid-range flows); (3) 50 – 100% (low flows). The high flows regime typically represents periods in which flows are dominated by runoff from medium and large sized rainfall events. The mid-range flows regime typically represents periods in which flows are dominated by runoff from smaller storm events and high base flow during cooler and wetter periods of the year. The low flow regime typically represents periods that are dominated by conditions ranging from small runoff events to dry conditions in which flow is dominated by natural base flow. The load duration curves with flow regimes are provided for all stations in AUs 0822A_02 and 0822B_01 in Figures 4-1 through 4-5. Existing bacteria geometric mean loadings by flow regime have also been distinguished on each figure to aid interpretation. For purposes of the pollutant load computations presented later in this section, the hydrologic records for the FDCs and subsequently allowable loads from the LDCs are adjusted to reflect future capacity estimates that account for the probability that additional flows from WWTF discharges may occur as a result of future population increases in the two watersheds. Calculation of the future capacity estimates are discussed later in this report.

For the assessment unit level TMDL calculations, the maximum allowable loading was determined at the median flow of the high (0 – 10%) flow regime or 5% exceedance value for the most downstream station in each impaired assessment unit. For 0822A_02 the most downstream station is 17166 (FDC on Figure 3-2; LDC on Figure 4-2), and for 0822B_01 the most downstream station is 20311 (FDC on Figure 3-3; LDC on Figure 4-5). The maximum allowable loading is expressed in the following formula, which is the loading value at the 5% exceedance point on the appropriate LDC.

TMDL (MPN/day) = criterion * flow * conversion factor (Eq. 1)

Where:

criterion = 126 MPN/100 mL (*E. coli*)
flow = 5% exceedance flow in cubic meter per second (cms)
conversion factor = 8.64×10^8 100 mL/m^3 * seconds/day

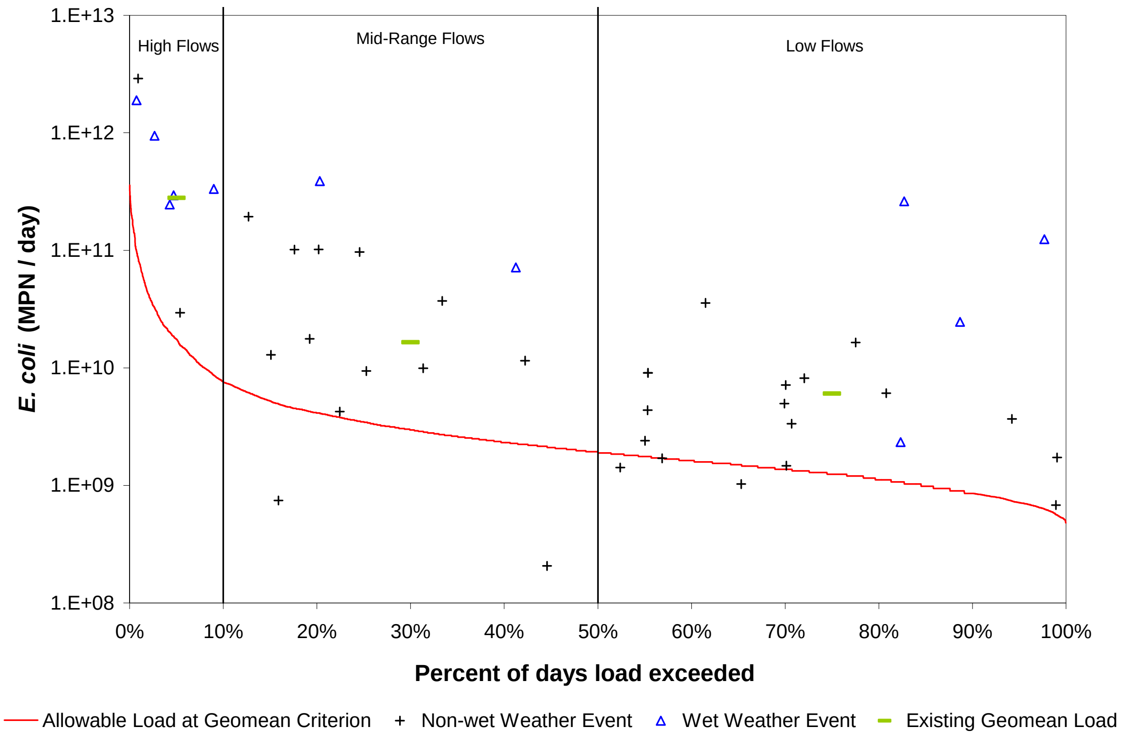

Figure 4-1 Load duration curve for station 17165, Cottonwood Branch, AU 0822A_02

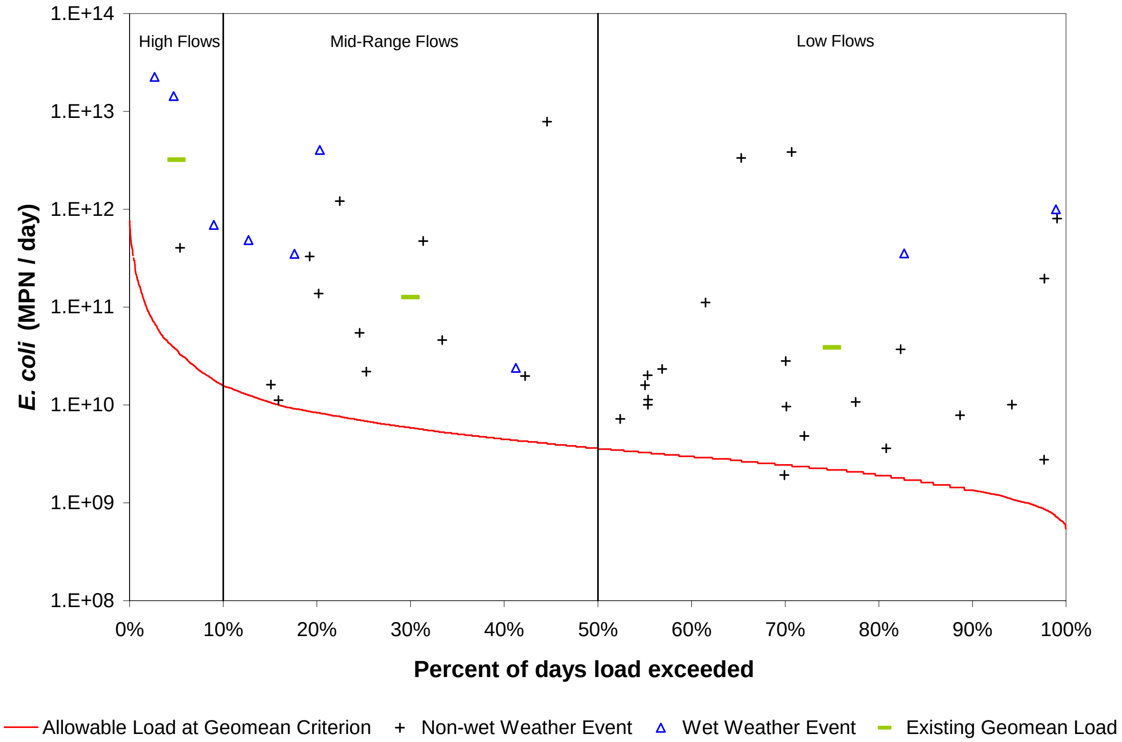

Figure 4-2 Load duration curve for station 17166, Cottonwood Branch, AU 0822A_02

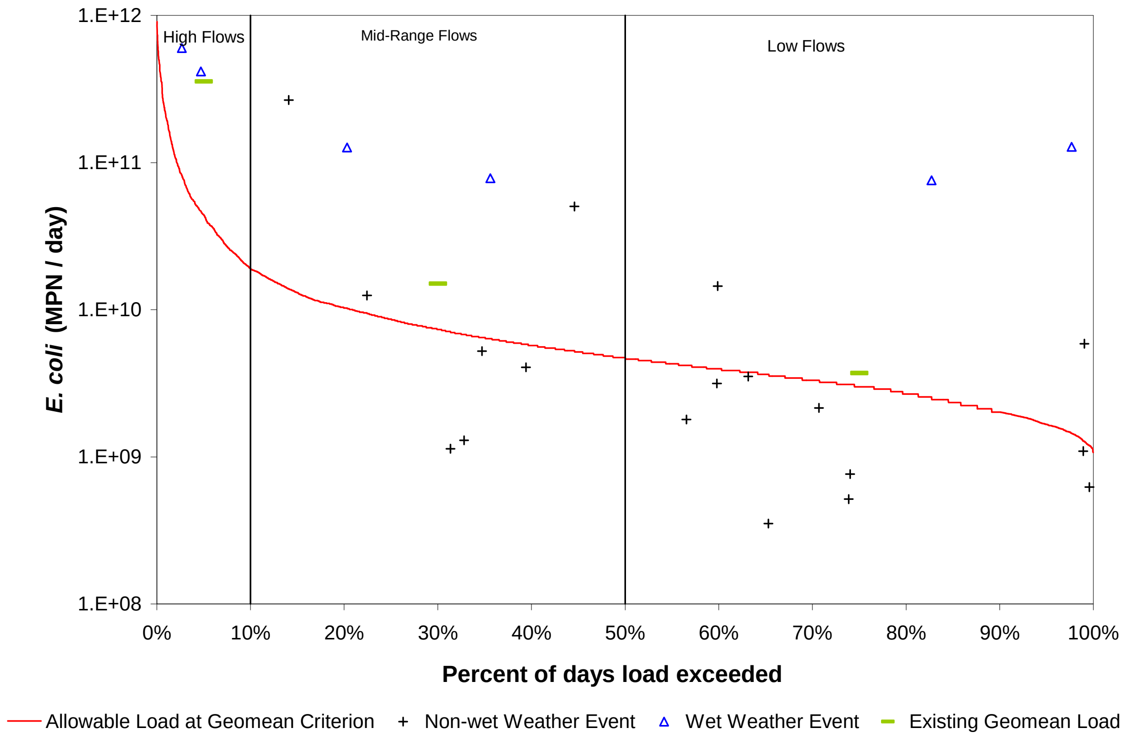

Figure 4-3 Load duration curve for station 17531, Grapevine Creek, AU 0822B_01

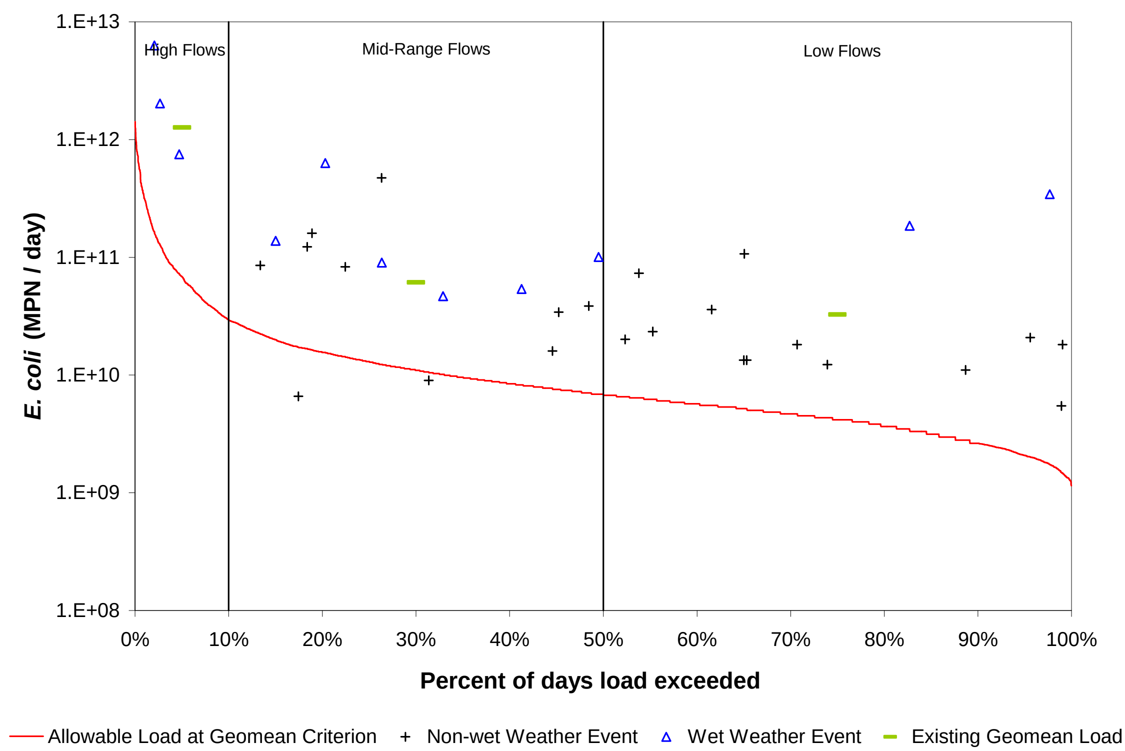

Figure 4-4 Load duration curve for station 17939, Grapevine Creek, AU 0822B_01

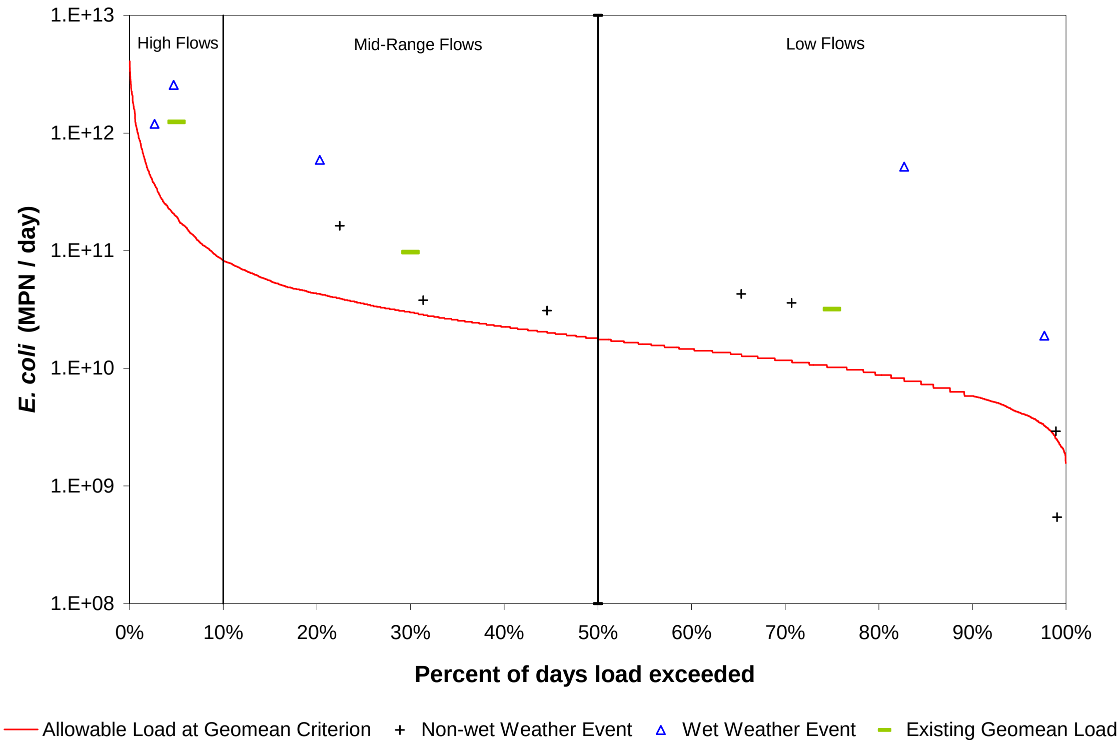

Figure 4-5 Load duration curve for station 20311, Grapevine Creek, AU 0822B_01

4.7 Load Reduction Analysis

A single percent load reduction required to meet the allowable loading for each of the three flow regimes was determined using the historical *E. coli* data obtained from stations within the impaired reaches. It should be noted that even though reductions for all three flow regimes have been computed and presented in this report, for purposes of TMDL allocations only the high flow regime will be considered. For simplicity of computation and presentation, the load reduction calculations were based on concentrations rather than loadings (concentration multiplied by flow), since the flow would be identical in both the existing and allowable loadings computations and, thus, the flow would effectively cancel out of the calculations. The following steps were used to determine the required percent load reduction for each station and each flow regime:

1. Develop load duration curves for all sampling stations within each segment's impaired AU. Stations 17165 and 17166 were used in AU 0822A_02 (Figures 4-1 & 4-2) and Station 17531, 17939, and 20311 were used in AU 0822B_01 (Figures 4-3 — 4-5).
2. For each station and flow regime, determine the geometric mean concentrations of the historical data within each of the three flow regimes, which represent the appropriate concentrations for comparison to the geometric mean criterion (126 MPN/100 mL) (Table 4-1). For each station the geometric mean concentration for each flow regime is plotted at the median value within that flow regime (Figures 4-1 — 4-5).

3. For each station and flow regime, determine the percent reduction required to achieve the geometric mean criterion by calculating the difference in the existing (or measured) geometric mean concentration and the 126 MPN/100 mL criterion and dividing that difference by the existing geometric mean concentration (Table 4-1).

Table 4-1 Existing geometric mean concentrations and percent reductions required to meet the geometric mean contact recreation criterion of 126 MPN/100 mL for stations within impaired AUs 0822A_02 and 0822B_01

Station	Segment / Assessment Unit	High Flows (0-10%)		Mid-Range Flows (10-50%)		Low Flows (50-100%)	
		Geometric Mean (MPN/100 mL)	Required Percent Reduction	Geometric Mean (MPN/100 mL)	Required Percent Reduction	Geometric Mean (MPN/100 mL)	Required Percent Reduction
17165	0822A_02	1,999	94%	703	83%	612	81%
17166	0822A_02	10,898	99%	2,728	96%	2,247	95%
17531	0822B_01	1,015	88%	258	54%	156	23%
17939	0822B_01	2,320	95%	704	83%	986	88%
20311	0822B_01	799	85%	410	71%	392	70%

4.8 Pollutant Load Allocations

4.8.1 TMDL Definition

The TMDL represents the maximum amount of a pollutant that the stream can receive in a single day without exceeding water quality standards. The pollutant load allocations for AU 0822A_02 of Cottonwood Branch and AU 0822B_01 of Grapevine Creek were calculated using the following equation:

$$TMDL = \Sigma WLA + \Sigma LA + \Sigma FG + MOS \qquad \text{(Eq. 2)}$$

Where:

WLA = waste load allocation, the amount of pollutant allowed by existing regulated or permitted dischargers
LA = load allocation, the amount of pollutant allowed by non-regulated or non-permitted sources
FG = loadings associated with future growth from potential permitted facilities
MOS = margin of safety

As stated in 40 CFR, §130.2(1), TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For *E. coli*, TMDLs are expressed as MPN/day, and represent the maximum one-day load the stream can assimilate while still attaining the standards for surface water quality.

The bacteria TMDLs for the 303(d)-listed AUs 0822A_02 and 0822B_01 as covered in this report were derived using the median flow within the high flow regime of the LDC developed for the most downstream station within each assessment unit.

4.8.1.1 Waste Load Allocation

The WLA is the waste load allocation for TPDES/NPDES-regulated sources. As previously discussed in this report there are currently no permitted wastewater treatment facilities within AUs 0822A_02 and 0822B_01, which would have otherwise been designated by the term WLA_{WWTF}. DFW Airport is the only facility with an individual permit; however, that permit authorizes the discharge of only storm water during periods of deicing activity and will be treated as part of the waste load allocation for TPDES-permitted storm water discharges (see below). The Airport is also covered under the TPDES Phase II General Permit. No individual WLA_{WWTF} was calculated for this permit.

Storm water discharges from MS4, industrial, and construction areas are considered regulated sources and are designated by the term WLA_{SW}. For both impaired AUs the WLA component of the TMDL are assigned solely to storm water permitted areas (see Section 2.6.1.3 Regulated Storm Water). The WLA_{SW} load is assigned based on the portion of any given watershed that has been defined as within the jurisdiction of an entity required to comply with MS4 permit regulations (FDA_{SWP}). Thus, WLA_{SW} is the sum of loads from regulated (or permitted) stormwater sources and is calculated as:

$$\Sigma WLA_{SW} = (TMDL - \Sigma WLA_{WWTF} - \Sigma FG - MOS) * FDA_{SWP} \qquad \text{(Eq. 3)}$$

Where:

ΣWLA_{SW} = sum of all permitted storm water loads
TMDL = total maximum allowable load calculated from Equation 1
ΣWLA_{WWTF} = sum of all WWTF loads = 0
ΣFG = sum of future growth loads from potential permitted facilities (see Section 4.8.1.3)
MOS = margin of safety load = 0.05 * TMDL
FDA_{SWP} = fractional proportion of drainage area under jurisdiction of storm water permits

4.8.1.2 Load Allocation

The LA includes the load allocation assigned to nonpoint sources that are not under TPDES/NPDES regulation and is the sum of loads from all non-permitted sources. Nonpoint sources include non-regulated stormwater runoff and direct deposition from warm-blooded animals. The LA term is calculated as:

$$LA = TMDL - \Sigma WLA_{WWTF} - \Sigma WLA_{SW} - \Sigma FG - MOS \qquad \text{(E.q. 4)}$$

Where:

LA = allowable load from non-permitted sources entering the assessment unit
TMDL = total maximum allowable load; calculated from Equation 1
ΣWLA_{WWTF} = sum of all WWTF loads = 0
ΣWLA_{SW} = sum of all permitted storm water loads; calculated from Equation 3
ΣFG = sum of future growth loads from potential permitted facilities (see Section 4.8.1.3)
MOS = margin of safety load = 0.05 * TMDL

4.8.1.3 Future Growth

The Future Growth component of the TMDL equation addresses the requirement of TMDLs to account for future loadings that may occur as a result of population growth, changes in community infrastructure, and development. Currently there are no permitted wastewater treatment facilities that discharge into AUs 0822A and 0822B. Wastewater generated within Cottonwood Branch and Grapevine Creek is transported out of both watersheds to the TRA Central Regional WWTF located on the Lower West Fork Trinity River (Segment 0841). To account for the probability that new flows from WWTF discharges may occur in both assessment units, a provision for future growth was included in the TMDL calculations based on an estimate of the amount of wastewater generated per person per day or gallons per capita per day (gpcd) and the population increase from year 2005 estimates to year 2030 projections.

Since both impaired watersheds lie within the much larger wastewater collection service area for the TRA Central Regional WWTF (partial service area shown on Figure 2-1), it is infeasible to readily determine average wastewater generation per person for each watershed. The approach taken was to determine the year 2005 average daily discharge for the TRA Central Regional WWTF based on its discharge monitoring reports (DMRs) obtained from the USEPA permit compliance system website (USEPA, 2009) for that year. Next the service population of the TRA WWTF for the year 2005 was determined using available GIS layers of the WWTF service area and NCTCOG population districts, and NCTCOG population estimates by population district available (NCTCOG, 2009a&b). The population within the TRA Central Regional WWTF service area was estimated based on the 2005 NCTCOG population district estimates and the percentage of each district in the service area, further assuming even population distribution within each district. The wastewater flow per capita was then determined by dividing the TRA Central Regional WWTF 2005 annual daily discharge by its service population giving a wastewater flow in gallons per capita per day (gpcd).

Next the population of the entire watersheds of Cottonwood Branch and Grapevine Creek were estimated using the GIS shape files of each watershed and the NCTCOG population districts and the NCTCOG population data for 2005 and 2030. Assuming even population distribution in each district, the population of each watershed was then determined based on percentage of each population district in each watershed, the 2005 and 2030 population estimates for each district, and summing the computed populations by watershed. With this information the future growth (FG) of each watershed is calculated as follows:

$$FG = \text{criterion} * Flow_{2005} * (Pop_{30} - Pop_{05}) * \text{conversion factor} * (1 - F_{MOS}) \quad \text{(Eq. 5)}$$

Where:

Criterion = 126 MPN/100 mL

$Flow_{2005}$ = gallons per capita per day (gpcd) based on the average daily discharge of TRA WWTF from year 2005 DMR data divided by the year 2005 TRA WWTF wastewater collection area population estimate

Pop_{30} = estimated watershed population for year 2030

Pop_{05} = estimated watershed population for year 2005

Conversion factor = 10^{-6} MGD/gpcd * 37,854,000 100 mL / MGD = 37.854 100 mL/gpcd

F_{MOS} = fraction of loading assigned to margin of safety (5% or 0.05)

4.9 Assessment Unit TMDL Calculations

As described in Section 4.6 and Equation 1, the allowable loading of *E. coli* that AUs 0822A_02 and 0822B_01 can receive on a daily basis was determined based on the median flow within the high flow regime of the LDC for the most downstream station in each impaired assessment unit, which is station 17166 for AU 0822A_02 and station 20311 for AU 0822B_01 (Table 4-2).

Table 4-2 Summary of TMDL calculation for Cottonwood Branch (Segment 0822A) and Grapevine Creek (Segment 0822B)

Segment	Station	Median Value of High Flow Regime (cms)	TMDL (MPN/day)
0822A_02	17166	0.3401	3.70E+10
0822B_01	20311	1.802	1.96E+11

4.9.1 Future Growth Computations

The following computations were performed to account for the possibility of future WWTF discharges within each watershed in response to population growth and associated wastewater production. First the average daily discharge from the TRA Central Regional WWTF was estimated to be approximately 134 million gallons per day (MGD) based on DMR records for the year 2005. Second, the year 2005 population of the service area of the TRA WWTF was estimated to be 1,247,173 based on NCTCOG GIS layers of the service area and population districts (NCTCOG, 2009 a&b). The wastewater generated per capita was computed by dividing 134 MGD by the service population giving a value of 107 gpcd. Next using Equation 5 the amount of wastewater produced per capita per day was multiplied by the estimated population increase from year 2005 to year 2030 within the entire watersheds of Segment 0822A (AU 01and AU 02) and Segment 0822B (AU 01) to obtain an estimate of the total amount of wastewater produced within each segment and that amount was converted into a load (Table 4-3).

Table 4-3 Future Growth computations for Cottonwood Branch (Segment 0822A) and Grapevine Creek (Segment 0822B)

Segment	2005 Population	2030 Population	Population Increase 2005 to 2030	Additional Wastewater Production (MGD)	Future Growth *(MPN/day)
0822A	19,499	20,328	829	0.089	4.03E+08
0822B	20,807	22,622	1,815	0.195	8.82E+08

* Future growth includes a reduction for MOS of 5%

4.9.2 Regulated Storm Water Computation

The entire drainage area of AU 0822A_02 is located within jurisdictional areas regulated by storm water permits whereas 84.8% of the drainage area of AU 0822B_01 is located within the jurisdictional areas regulated by storm water permits (entire drainage area of 3,073 ha of which 2,605 ha are under storm water permit regulation). Table 4-4 summarizes the computation of term WLA_{SW} as calculated using Equation 3.

Table 4-4 Regulated storm water computation for Cottonwood Branch (AU 0822A_02) and Grapevine Creek (AU 0822B_01)

AU	TMDL (MPN/day)	WLA_{WWTF} (MPN/day)	Future Growth (MPN/day)	MOS (MPN/day)	FDA_{SWP}	WLA_{SW} (MPN/day)
0822A_02	3.70E+10	0.00	4.03E+08	1.85E+09	1.000	3.48E+10
0822B_01	1.96E+11	0.00	8.82E+08	9.81E+09	0.848	1.57E+11

4.9.3 Non-Regulated Storm Water Computation

Since the entire drainage of AU 0822A_02 is within the jurisdictional areas regulated by storm water permits, the LA associated with this assessment unit is zero. For AU 0822B_01, 468 ha or 15.2% of its drainage area is not regulated by storm water permits, and LA was computed using Equation 4 from the value of terms in Table 4-4 (see Table 4-5).

Table 4-5 Non-regulated storm water computation for Cottonwood Branch (AU 0822A_02) and Grapevine Creek (AU 0822B_01)

AU	LA (MPN/day)
0822A_02	0
0822B_01	2.83E+10

4.9.4 Summary of TMDL Calculations

Table 4-6 summarizes the TMDL calculations for AUs 0822A_02 and 0822B_01. The TMDL was calculated based on the median flow in the 0-10 percentile range (high flow) for flow exceedance from the LDC developed for the most downstream station within each assessment unit. Allocations are based on the current geometric mean criterion for *E. coli* in freshwater of 126 counts/100 mL for each component of the TMDL.

Table 4-6 TMDL allocation summary for Cottonwood Branch (AU 0822A_02) and Grapevine Creek (AU 0822B_01)

Assessment Unit	Stream Name	TMDL	WLA_{WWTF}	WLA_{SW}	LA	MOS	Future Growth
(all units in billion MPN per day)							
0822A_02	Cottonwood Branch	37.04	0.00	34.78	0	1.85	0.40
0822B_01	Grapevine Creek	196.22	0.00	157.25	28.28	9.81	0.88

The final TMDL allocations needed to comply with the requirements of 40 CFR 130.7 includes the future growth component designated as WLA_{WWTF} while allocations to permitted MS4 entities are designated as WLA_{sw} (Table 4-7). In the event that the criteria change due to future revisions in the state's surface water quality standards, Appendix B provides guidance for recalculating the allocations in Table 4-7. Figures B-1 and B-2 of Appendix B were developed to demonstrate how assimilative capacity, TMDL calculations, and pollutant load allocations change in relation to a number of proposed water quality criteria for *E. coli*. The equations provided, along with Figures B-1 and B-2, allow calculation of new TMDLs and pollutant load allocations based on any potential new water quality criterion for *E. coli*.

Table 4-7 Final TMDL allocations for Cottonwood Branch (AU 0822A_02) and Grapevine Creek (AU 0822_01)

Assessment Unit	TMDL	WLA_{WWTF}*	WLA_{SW}	LA	MOS
(all units in billion MPN per day)					
0822A_02	37.04	0.40	34.78	0	1.85
0822B_01	196.22	0.88	157.25	28.28	9.81

*WLA_{wwtf} represents the future potential allocation to wastewater treatment facilities

SECTION 5

REFERENCES

AVMA (American Veterinary Medical Association). 2009. U.S. Pet Ownership-2007. <www.avma.org/reference/marketstats/ownership.asp>. Accessed 28 October 2009.

Cleland, B. 2003. TMDL Development From The "Bottom Up" –Part III: Duration Curves and Wet Weather Assessments. America's Clean Water Foundation, Washington, D.C.

Di Luzio, M., R. Srinivasan, J. Arnold. 2004. A GIS-coupled Hydrological Model System for the Watershed Assessment of Agricultural Nonpoint and Point Source of Pollution.Transactions in GIS 8(1):113-136.

Helsel, D.R. and R.M. Hirsch, 1992. Statistical methods in water resources. Elsevier Science B.V., Amsterdam, The Netherlands.

NCTCOG (North Central Texas Council of Governments) 2009a. GIS Data Clearinghouse < http://www.dfwmaps.com/clearinghouse/metadata.asp>. Accessed November 5, 2009

NCTCOG (North Central Texas Council of Governments) 2009b. North Central Texas Demographic Forecast 2030 <www.nctcog.org/ris/demographics/forecast.asp>. Accessed October 16, 2009

NDEP (Nevada Division of Environmental Protection). 2003. Load Duration Curve for Assessment and TMDL Development. <ndep.nv.gov/bwqp/loadcurv.pdf>. Accessed November 6, 2009.

NWS (National Weather Service). 2009. <www.srh.noaa.gov/fwd/?n=dnarrative>. Accessed November 5, 2009.

NWS (National Weather Service). 2009. <http://lwf.ncdc.noaa.gov/oa/climate/stationlocator.html>. Accessed November 17, 2009.

NEIWPCC (New England Interstate Water Pollution Control Commission). 2003. Illicit Discharge Detection and Elimination Manual. January 2003.

Schueler, T.R. 2000. Microbes and Urban Watersheds: Concentrations, Sources, and Pathways. *In* The Practice of Watershed Protection, T.R. Schueler and H.K. Holland, eds. Center for Watershed Protection, Ellicott City, MD.

Talaro and Talaro. 1999. Foundations in Microbiology, Third Edition. McGraw-Hill, New York, New York. 873 pp.

TWRI. 2007. Bacteria Total Maximum Daily Load Task Force Report, Fourth Draft, June 4, 2007. Prepared for Texas Commission on Environmental Quality and Texas State Soil and Water Conservation Board.

TCEQ 2000. Texas Surface Water Quality Standards, 2000 update, 30 TAC 307. <www.tceq.state.tx.us/permitting/water_quality/wq_assessment/standards/ WQ_standards_2000.html>.

TCEQ. 2008a. Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data, 2008. <http://www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_guidance.pdf>. Accessed December 7, 2009.

TCEQ. 2008b. 2008 Water Quality Inventory and 303(d) List. <www.tceq.state.tx.us/assets/public/compliance/monops/water/08twqi/2008_303d.pdf>

TCEQ. 2010. Draft 2010 Texas 303(d) List (February 5, 2010). <http://www.tceq.state.tx.us/assets/public/compliance/monops/water/10twqi/2010_303d.pdf>. Accessed February 16, 2010.

TRA (Trinity River Authority). 2003. Trinity River Basin Master Plan. Trinity River Authority of Texas, Arlington, Texas.

USEPA. 1991. Guidance for Water Quality-based Decisions: The TMDL Process. Office of Water, USEPA 440/4-91-001.

USEPA. 2007. An approach to using load duration curves in the development of TMDLs. EPA 841-B-07-006. Office of Wetlands, Oceans and Watersheds, U.S. Environmental Protection Agency, Washington, D.C.

USEPA 2009. (United States Environmental Protection Agency). 2009. <http://www.epa.gov/enviro/html/pcs/adhoc.html>. Accessed December 8, 2009.

APPENDIX A

BACTERIA DATA USED IN DEVELOPING LOAD DURATION CURVES

Table A-1 Measured *E. coli* concentration and estimated streamflow at station 17167, Cottonwood Branch, AU 0822A_01

Sample Date	*E. coli* (MPN/100 mL)	Estimated Daily Average Flow (cms)	Estimated Daily Average Flow Including Allowance for Future Discharges (cms)*
04-Dec-01	3	0.0493	0.0533
09-Jan-02	19	0.0351	0.0389
06-Feb-02	1100	0.7280	0.7319
18-Mar-02	2400	3.6636	3.6676
02-Jul-02	420	0.2118	0.2158
19-Aug-02	40	0.0116	0.0155
03-Sep-02	821	0.0176	0.0214
10/1/2002	4	0.0238	0.0278
11/4/2002	27	0.1512	0.1552
12/4/2002	2600	0.3058	0.3097
1/14/2003	17	0.1116	0.1154
2/5/2003	2	0.1674	0.1712
3/4/2003	47	0.1419	0.1457
4/2/2003	6	0.0430	0.0469
5/8/2003	22	0.1371	0.1409
6/4/2003	27	0.0286	0.0326
7/8/2003	35	0.0351	0.0389
8/6/2003	120	0.0076	0.0115
9/4/2003	91	0.0844	0.0883
10/7/2003	22	0.0685	0.0724
11/11/2003	203	0.1147	0.1186
12/2/2003	47	0.0493	0.0533
09-Jan-08	17.5	0.0399	0.0437
2/5/2008	18.5	0.1371	0.1409
2/12/2008	8.5	0.6739	0.6777
3/3/2008	547.5	1.1930	1.1970
3/26/2008	24.6	0.0909	0.0947
4/23/2008	32.3	0.1257	0.1297
22-May-08	108.1	0.0351	0.0389
11-Jun-08	47.3	0.0637	0.0676
26-Jun-08	59.4	0.0238	0.0278
7/7/2008	272.3	0.0054	0.0092
7/30/2008	159.7	0.0076	0.0115
8/7/2008	1732.9	0.0051	0.0090

* A constant future growth discharge of 0.089 MGD (0.004 cms) was added to estimated daily streamflow values for load duration curve development.

Table A-2 Measured *E. coli* concentration and estimated streamflow at station 20320, Cottonwood Branch, AU 0822A_01

Sample Date	*E. coli* (MPN/100 mL)	Estimated Daily Average Flow (cms)	Estimated Daily Average Flow Including Allowance for Future Discharges (cms)*
04-Dec-01	435	0.061	0.065
09-Jan-02	32	0.043	0.047
06-Feb-02	821	0.898	0.902
02-Jul-02	271	0.261	0.265
19-Aug-02	197	0.014	0.018
03-Sep-02	24	0.022	0.026
01-Oct-02	12	0.029	0.033
04-Nov-02	135	0.187	0.191
04-Dec-02	977	0.377	0.381
14-Jan-03	41	0.138	0.142
05-Feb-03	1	0.206	0.210
04-Mar-03	52	0.175	0.179
02-Apr-03	2	0.053	0.057
08-May-03	96	0.169	0.173
04-Jun-03	35	0.035	0.039
08-Jul-03	53	0.043	0.047
06-Aug-03	4	0.009	0.013
04-Sep-03	80	0.104	0.108
07-Oct-03	10	0.085	0.088
11-Nov-03	192	0.142	0.145
02-Dec-03	44	0.061	0.065
07-Jan-04	2	0.059	0.063
04-Feb-04	62	0.700	0.704
03-Mar-04	34	0.218	0.222
19-Apr-04	2	0.031	0.035
04-May-04	52	0.061	0.065
15-Jun-04	139	0.061	0.065
13-Jul-04	13	0.041	0.045
10-Aug-04	60	0.043	0.047
08-Sep-04	59	0.083	0.086
19-Oct-04	106	0.065	0.069
1/9/2008	41.1	0.049	0.053
2/5/2008	14.6	0.169	0.173
2/12/2008	55.4	0.832	0.836
3/3/2008	579.4	1.473	1.476
3/26/2008	104.6	0.112	0.116
4/23/2008	32.7	0.155	0.159
5/22/2008	579.4	0.043	0.047
6/11/2008	27.9	0.079	0.083
6/26/2008	2419.6	0.029	0.033
7/7/2008	14.1	0.006	0.010
7/30/2008	12.1	0.009	0.013
8/7/2008	9.7	0.006	0.010

* A constant future growth discharge of 0.089 MGD (0.004 cms) was added to estimated daily streamflow values for load duration curve development.

Table A-3 Measured *E. coli* concentration and estimated streamflow at station 17165, Cottonwood Branch, AU 0822A_02

Sample Date	*E. coli* (MPN/100 mL)	Estimated Daily Average Flow (cms)	Estimated Daily Average Flow Including Allowance for Future Discharges (cms)*
4-Dec-01	172	0.012	0.016
9-Jan-02	456	0.009	0.013
6-Feb-02	1540	0.181	0.185
18-Mar-02	2400	0.910	0.914
20-Mar-02	4180	0.799	0.803
2-Jul-02	3970	0.053	0.056
19-Aug-02	626	0.003	0.007
3-Sep-02	3460	0.004	0.008
1-Oct-02	275	0.006	0.010
4-Nov-02	2830	0.038	0.041
4-Dec-02	4838	0.076	0.080
14-Jan-03	345	0.028	0.032
5-Feb-03	19	0.042	0.045
4-Mar-03	523	0.035	0.039
2-Apr-03	2830	0.011	0.015
8-May-03	3110	0.034	0.038
4-Jun-03	1730	0.007	0.011
8-Jul-03	656	0.009	0.013
4-Sep-03	1730	0.021	0.025
7-Oct-03	3970	0.017	0.021
11-Nov-03	3460	0.028	0.032
2-Dec-03	313	0.012	0.016
7-Jan-04	125	0.012	0.016
4-Feb-04	236	0.141	0.145
3-Mar-04	313	0.044	0.048
19-Apr-04	690	0.006	0.010
4-May-04	651	0.012	0.016
15-Jun-04	651	0.012	0.016
13-Jul-04	775	0.008	0.012
10-Aug-04	135	0.009	0.013
8-Sep-04	651	0.017	0.021
19-Oct-04	97	0.013	0.017
9-Jan-08	86.2	0.010	0.014
5-Feb-08	11874	0.034	0.038
12-Feb-08	1986.3	0.167	0.171
3-Mar-08	3641	0.296	0.300
26-Mar-08	435.2	0.023	0.026
23-Apr-08	140.1	0.031	0.035
22-May-08	307.6	0.009	0.013
11-Jun-08	12.1	0.016	0.020
26-Jun-08	30759	0.006	0.010
7-Jul-08	151.5	0.001	0.005
30-Jul-08	24809	0.002	0.006
7-Aug-08	387.3	0.001	0.005

* A constant future growth discharge of 0.089 MGD (0.004 cms) was added to estimated daily streamflow values for load duration curve development.

Table A-4 Measured *E. coli* concentration and estimated streamflow at station 17166, Cottonwood Branch, AU 0822A_02

Sample Date	*E. coli* (MPN/100 mL)	Estimated Daily Average (cms)	Estimated Daily Average Flow Including Allowance for Future Discharges (cms)*
4-Dec-01	613	0.026	0.030
9-Jan-02	99	0.019	0.022
2-Jul-02	4840	0.112	0.116
19-Aug-02	1160	0.006	0.010
3-Sep-02	690	0.009	0.013
1-Oct-02	2600	0.013	0.017
4-Nov-02	4838	0.080	0.084
4-Dec-02	4838	0.162	0.166
14-Jan-03	403	0.059	0.063
5-Feb-03	140	0.089	0.092
4-Mar-03	4838	0.075	0.079
2-Apr-03	4840	0.023	0.027
8-May-03	2090	0.072	0.076
4-Jun-03	651	0.015	0.019
8-Jul-03	1450	0.019	0.022
6-Aug-03	403	0.004	0.008
4-Sep-03	1100	0.045	0.049
7-Oct-03	690	0.036	0.040
11-Nov-03	977	0.061	0.065
2-Dec-03	775	0.026	0.030
7-Jan-04	922	0.025	0.029
4-Feb-04	1540	0.300	0.304
3-Mar-04	192	0.094	0.097
19-Apr-04	240	0.013	0.017
4-May-04	387	0.026	0.030
15-Jun-04	437	0.026	0.030
13-Jul-04	259	0.018	0.022
10-Aug-04	496	0.019	0.022
8-Sep-04	582	0.035	0.039
19-Oct-04	263	0.028	0.032
9-Jan-08	155312	0.021	0.025
5-Feb-08	61314	0.072	0.076
12-Feb-08	46111	0.357	0.360
3-Mar-08	41058	0.631	0.635
26-Mar-08	10537	0.048	0.052
23-Apr-08	19890	0.067	0.070
22-May-08	198629	0.019	0.022
11-Jun-08	241960	0.034	0.038
26-Jun-08	24809	0.013	0.017
7-Jul-08	173289	0.003	0.007
30-Jul-08	28510	0.004	0.008
7-Aug-08	141361	0.003	0.007

* A constant future growth discharge of 0.089 MGD (0.004 cms) was added to estimated daily streamflow values for load duration curve development.

Table A-5 Measured *E. coli* concentration and estimated streamflow at station 17531, Grapevine Creek, AU 0822B_01

Sample Date	*E. coli* (MPN/100 mL)	Flow on Sample Date (cms)	Estimated Daily Average Flow Including Allowance for Future Discharges (cms)*
5-Nov-01	118	0.029	0.034
20-Feb-02	102	0.054	0.059
1-May-02	21	0.023	0.028
6-Aug-02	66	0.005	0.011
12-Sep-02	54	0.033	0.038
5-Dec-02	1553	0.053	0.058
11-Mar-03	24	0.057	0.062
11-Jun-03	2419	0.122	0.127
30-Sep-03	31	0.023	0.028
4-Dec-03	100	0.031	0.036
18-Mar-04	88	0.048	0.053
23-Jun-04	460	0.031	0.036
9-Jan-08	12.2	0.028	0.033
5-Feb-08	1553.1	0.089	0.094
12-Feb-08	1119.9	0.425	0.430
3-Mar-08	920.8	0.750	0.755
26-Mar-08	20.1	0.060	0.065
23-Apr-08	165.8	0.082	0.087
22-May-08	81.6	0.025	0.030
11-Jun-08	1203.3	0.043	0.048
26-Jun-08	3734	0.018	0.023
7-Jul-08	107.1	0.006	0.012
30-Jul-08	11123	0.008	0.013
7-Aug-08	579.4	0.006	0.012

* A constant future growth discharge of 0.195 MGD (0.006 cms) was added to estimated daily streamflow values for load duration curve development.

Table A-6 Measured *E. coli* concentration and estimated streamflow at station 17939, Grapevine Creek, AU 0822B_01

Sample Date	*E. coli* (MPN/100 mL)	Flow on Sample Date (cms)	Estimated Daily Average Flow Including Allowance for Future Discharges (cms)*
3-Sep-02	496	0.020	0.026
9-Oct-02	4838	1.500	1.505
3-Mar-03	48	0.153	0.159
3-Apr-03	476	0.051	0.057
6-May-03	922	0.148	0.154
3-Jun-03	357	0.034	0.040
7-Jul-03	1840	0.058	0.063
4-Aug-03	1300	0.013	0.019
3-Sep-03	4838	0.108	0.113
1-Oct-03	821	0.045	0.051
10-Nov-03	1230	0.145	0.151
1-Dec-03	1450	0.053	0.059
5-Jan-04	387	0.055	0.060
2-Feb-04	870	0.178	0.184
2-Mar-04	480	0.200	0.206
12-Apr-04	582	0.087	0.093
3-May-04	570	0.064	0.070
14-Jun-04	821	0.070	0.076
12-Jul-04	325	0.042	0.048
9-Aug-04	2600	0.042	0.048
7-Sep-04	922	0.108	0.113
18-Oct-04	690	0.059	0.065
9-Jan-08	325.5	0.042	0.048
5-Feb-08	5122	0.138	0.143
12-Feb-08	1299.7	0.665	0.670
3-Mar-08	1986.3	1.174	1.180
26-Mar-08	106.7	0.092	0.098
23-Apr-08	727	0.127	0.132
22-May-08	488.4	0.037	0.043
11-Jun-08	260.3	0.066	0.071
26-Jun-08	6695	0.026	0.032
7-Jul-08	461.1	0.008	0.014
30-Jul-08	24809	0.011	0.016
7-Aug-08	1553.1	0.008	0.014

* A constant future growth discharge of 0.195 MGD (0.006 cms) was added to estimated daily streamflow values for load duration curve development.

Table A-7 Measured *E. coli* concentration and estimated streamflow at station 20311, Grapevine Creek, AU 0822B_01

Sample Date	*E. coli* (MPN/100 mL)	Flow on Sample Date (cms)	Estimated Daily Average Flow Including Allowance for Future Discharges (cms)*
9-Jan-08	410	3.371	3.376
5-Feb-08	1700	1.905	1.910
12-Feb-08	1600	0.390	0.395
3-Mar-08	410	0.358	0.364
26-Mar-08	170	0.259	0.265
23-Apr-08	520	0.183	0.188
22-May-08	390	0.115	0.121
11-Jun-08	190	0.102	0.107
26-Jun-08	7900	0.070	0.076
7-Jul-08	150	0.025	0.030
30-Jul-08	730	0.018	0.023
7-Aug-08	28	0.017	0.023

* A constant future growth discharge of 0.195 MGD (0.006 cms) was added to estimated daily streamflow values for load duration curve development.

APPENDIX B

EQUATIONS FOR CALCULATING TMDL ALLOCATIONS FOR CHANGED CONTACT RECREATION STANDARD

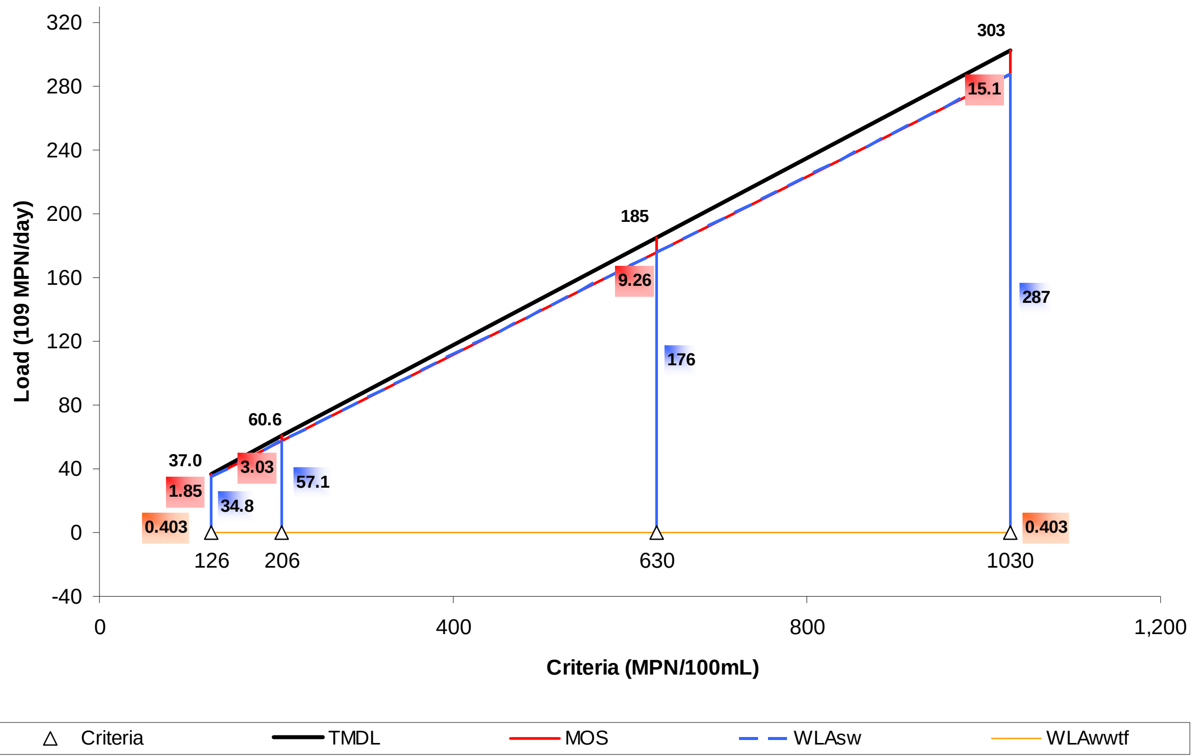

Figure B-1 Allocation Loads for Cottonwood Branch, AU 0822A_02, as a function of Water Quality Criteria

Equations for Calculating New TMDL and Allocations

$TMDL = WLA_{WWTF} + WLA_{SW} + LA + MOS$

> $TMDL = 0.2939 * Std$
> WLA_{WWTF} = Future Growth * Conversion Factor * 126 * (1 – 0.05) = 0.4031
> $WLA_{SW} = 0.2792 * Std – 0.4031$
> $LA = 0$
> $MOS = 0.05 * TMDL$

Where:

> WLA_{SW} = Waste load allocation (permitted storm water)
> WLA_{WWTF} = Potential future permitted WWTF discharge load allocation
> LA = Load allocation (non-permitted storm water)
> Future Growth = Potential future permitted WWTF discharge (MGD)
> Std = Revised Contact Recreation Standard
> MOS = Margin of Safety

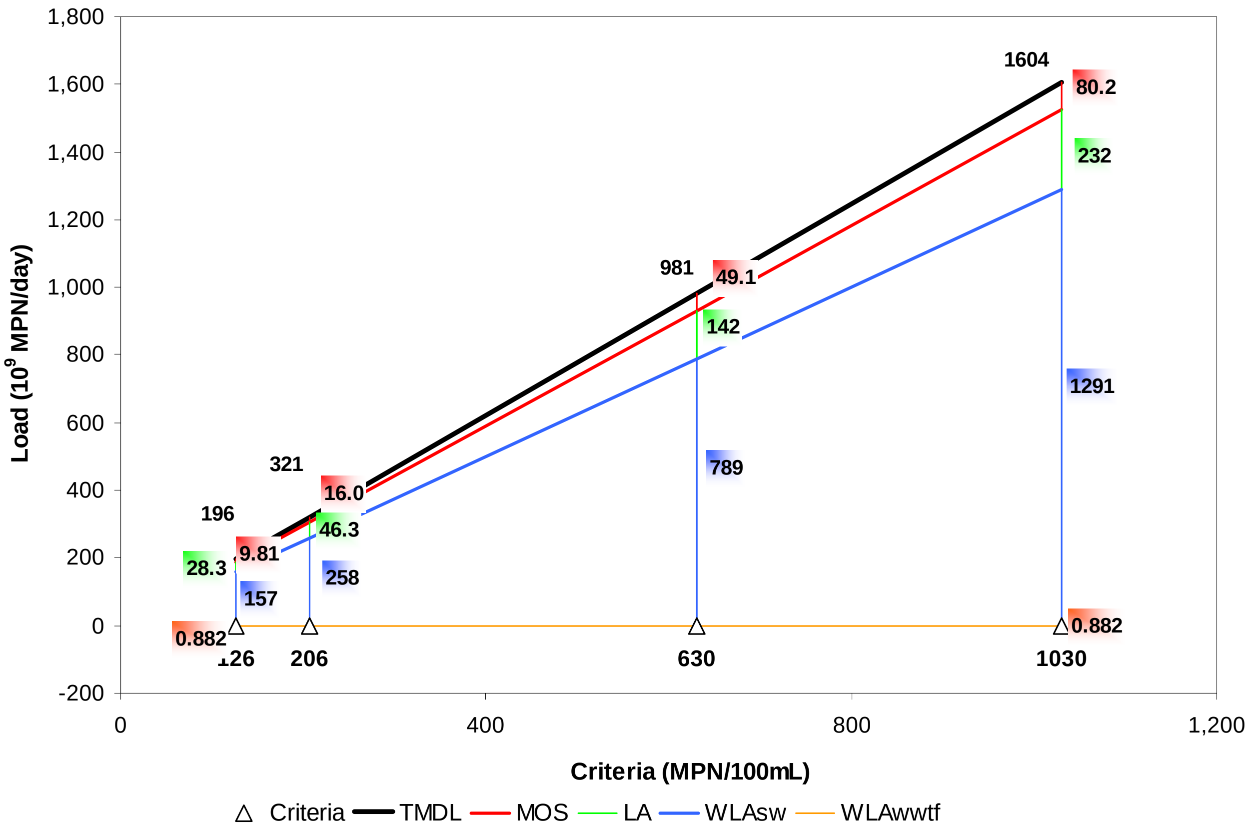

Figure B–2 Allocation Loads for Grapevine Creek, AU 0822B_01, as a function of Water Quality Criteria

Equations for Calculating New TMDL Allocations

$TMDL = WLA_{WWTF} + WLA_{SW} + LA + MOS$

$TMDL = 1.5573 * Std$
$WLA_{WWTF} = \text{Future Growth} * \text{Conversion Factor} * 126 * (1 – 0.05) = 0.8822$
$WLA_{sw} = 1.2540 * Std – 0.7477$
$LA = 0.2255 * Std – 0.1345$
$MOS = 0.05 * TMDL$

Where:

WLA_{WWTF} = Potential future permitted WWTF discharge load allocation
WLA_{sw} = Waste load allocation (permitted storm water)
LA = Load allocation (non-permitted storm water)
Future Growth = Potential future permitted WWTF discharge (MGD)
Std = Revised Contact Recreation Standard
MOS = Margin of Safety