Regional Wet Weather

Characterization Program

of North Central Texas

Final Summary Monitoring Report
(2006-2010)

Prepared by the
North Central Texas Council of Governments
February 2011

CONTENTS

TABLES

FIGURES

APPENDICES

ATTACHMENTS

ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of Variance
ASCE	American Society of Civil Engineers
BMP	Best Management Practices
BOD	biochemical oxygen demand
COD	chemical oxygen demand
CRP	Clean Rivers Program
DMR	Discharge Monitoring Report
EPA	U.S. Environmental Protection Agency
FSO	field sampling organization
LN	natural logarithm
MS4	municipal separate storm sewer system
NCTCOG	North Central Texas Council of Governments
NELAC	National Environmental Laboratory Accreditation Conference
NPDES	National Pollutant Discharge Elimination System
NRC	National Research Council
NSQD	National Stormwater Quality Database
NTTA	North Texas Tollway Authority
PGBT	President George Bush Turnpike
RWWCP	Regional Wet Weather Characterization Program
su	standard units
TX-IBI	Texas Index of Biotic Integrity
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TMDL	total maximum daily load
TNTC	too numerous to count
TPDES	Texas Pollutant Discharge Elimination System
TxDOT	Texas Department of Transportation
TSS	total suspended solids
USGS	U.S. Geological Survey
WLA	waste load allocation

1.0 INTRODUCTION

1.1 OVERVIEW

In 1996, a regional wet weather monitoring program for North Central Texas was approved by the U.S. Environmental Protection Agency (EPA) Region 6 for the five-year National Pollutant Discharge Elimination System (NPDES) municipal storm water permit term. Seven municipalities (Dallas, Fort Worth, Arlington, Irving, Garland, Plano and Mesquite) and two local districts of the Texas Department of Transportation (TxDOT) participated in the program, which utilized the assistance of a regional consultant team and the U.S. Geological Survey (USGS) to sample and analyze outfalls from small watersheds of a predominantly single land use type.

From 1997 to 2001 over 330 samples were collected from 22 sites and analyzed for 33 constituents. While the samples served to characterize typical runoff from these specific land use areas, they did little to characterize urban runoff in general and much less to evaluate impacts on receiving streams. As the participants looked toward permit renewal, they proposed to move away from strict fixed station automated sampling as conducted previously and switch to wet-weather impacted in-stream monitoring in order to better assess this impact.

The proposal (Appendix A) for this new regional effort was submitted to the Texas Commission on Environmental Quality (TCEQ) and approved on April 15, 2003 (Appendix B). The Regional Wet Weather Characterization Program (RWWCP) was then added as an option in Part IV.A.3 of the Texas Pollutant Discharge Elimination System (TPDES) Phase I Municipal Separate Storm Sewer System (MS4) permits issued to the North Central Texas governmental entities.

In 2006, the North Central Texas Council of Governments (NCTCOG) retained the consulting firm, PBS&J under a Contract for Consulting Services to develop a comprehensive monitoring plan for the RWWCP and perform long-term systematic storm water quality monitoring at 19 in-stream stations across the Dallas-Fort Worth Metroplex area. The goal was to collect and analyze quarterly storm water samples to help with determining long-term trends and potentially assessing impacts of storm water on receiving streams.

Annual regional monitoring reports were prepared annually by the NCTCOG on behalf of the regional participants and submitted, either directly or by reference, along with each participant's annual report of their local storm water management programs. This final regional monitoring report summarizes activities and reports of the second permit term (2006 to 2010). The following topics are discussed: permit requirements, monitoring sites and activities, data analysis and results and recommendations for future monitoring. This monitoring report was adapted from the Final Comprehensive Summary Report (PBS&J, 2010), which was submitted to the NCTCOG in March 2010 by PBS&J as a contractual deliverable after sampling concluded. Most of the information presented in Chapters 6, 7 and 8 summarizes the key results presented in PBS&J's report. For a more in-depth look at these results, see the PBS&J report (Included as Attachment A in the digital version of this document only).

1.2 RWWCP AND TPDES PERMITS

The RWWCP began its five-year implementation plan for all participants with the issuance of the first Phase I permit renewal in the region, the City of Garland's TPDES MS4 permit, on December 22, 2005. As documented in the approval letter dated February 10, 2006 from the TCEQ (Appendix B), all participants in the RWWCP received credit for sampling based on this start date regardless of their own permit issuance date.

Although the parameters to be tested as well as the number of samples collected were not specified in the permit language, they were listed in the approved RWWCP. Furthermore, the permit requirements found in Parts IV.A.4 and IV.A.5 for collecting storm event data, seasonal loadings and event mean concentrations did not apply to the RWWCP. Participants in the program were not required to submit separate Discharge Monitoring Reports (DMRs) as approved by the TCEQ on February 13, 2008 (Appendix B). Nevertheless, the RWWCP protocol did include collection and reporting of storm event data. Lastly, each program participant was required by permit language to coordinate with all other program participants on any proposed amendments to the RWWCP. Any such modifications were submitted in writing to TCEQ's Storm Water and Pretreatment Team for consideration at any time during the permit term. These amendments did not trigger formal permit modification procedures since the RWWCP existed outside of each permit, thus allowing greater flexibility in this unique program.

In spite of these notable differences in the RWWCP participants' permits, the information collected under the approved regional program had to meet or exceed the goals of the Representative Storm Event Monitoring (Part IV.A.1). The approved program also allowed participants to operate independently in sample collection and analysis as long as they generally followed the regional protocol. As described in a later section, the Cities of Fort Worth and Dallas both decided to take this option.

2.0 REGIONAL WET WEATHER CHARACTERIZATION PROGRAM

This section discusses the permit requirements and participants in the RWWCP as well as the associated sampling schedule, requirements and parameters to be sampled.

2.1 PARTICIPANTS AND PERMIT REQUIREMENTS

The NCTCOG provided coordination support services for the implementation of the RWWCP to execute in-stream storm water monitoring services for compliance with the TCEQ storm water monitoring discharge permits. The entities that participated in this program were the Cities of Arlington, Dallas, Fort Worth, Garland, Irving, Mesquite and Plano, and the roadway authorities NTTA and TxDOT-Dallas District. Table 2-1 lists each permittee's TPDES permit number and permit issue date.

Table 2-1: List of Permittees

Permittee	TPDES Permit Number	Date Issued	Expiration Date
City of Arlington	WQ0004635000	5/26/2006	5/26/2011
City of Dallas	WQ0004396000	7/27/2007	2/22/2011
City of Fort Worth	WQ0004350000	2/22/2006	2/22/2011
City of Garland	WQ0004682000	12/22/2005	12/22/2010
City of Irving	WQ0004691000	5/26/2006	5/26/2011
City of Mesquite	WQ0004641000	5/26/2006	5/26/2011
City of Plano	WQ0004775000	7/20/2007	7/20/2012
North Texas Tollway Authority (NTTA)	WQ0004400000	2/22/2006	2/22/2011
Texas Department of Transportation (TxDOT)-Dallas District	WQ0004521000	6/30/2006	6/30/2011

2.2 SAMPLING SCHEDULE AND REQUIREMENTS

In the initial RWWCP proposal submittal, the nine participating entities pre-selected the watersheds in their respective jurisdictions to sample during the permit term. The actual sampling sites for the first year and for each subsequent year were selected by the end of each calendar year and were detailed in the following year's annual report. As stated in the RWWCP, participants collected samples from one of their selected watersheds during each of Years 2, 3 and 4. Figure 2-1 shows a map of the watersheds sampled during each of the three sampling years.

Municipal participants collected data from three sampling sites in the watershed (typically upstream, midstream and downstream stations); whereas the transportation agencies collected data from two sites (upstream and downstream stations only). Samples were collected quarterly from each site during a qualifying rain event (unless otherwise specified in the participant's permit; see the Modification to the Regional Protocol section). A qualifying rain event is an event that has at least 0.1 inches of measurable rain and has had a preceding antecedent dry period of at least 72 hours.

The monitoring periods corresponded to calendar year quarters (January 1-March 31; April 1-June 30; July 1-September 30; October 1-December 31). Because the summer quarter (July-September) is often very dry, with very few storm events available for sampling, a sample collected during ambient conditions during any quarter could be substituted for the summer quarter sample, if needed. This ambient sample should be collected under normal flow conditions with at least 72 hours of dry weather preceding the collection. Also, if a valid event did not occur during a quarter, an attempt was made to collect the sample in the following quarter. If the sample still could not be collected, it was waived.

Samples collected were analyzed for 18 parameters that are listed in Table 2-2 along with their respective collection methods (i.e. grab or composite). A first-flush grab sample was collected followed by a composite sample consisting of five aliquots taken every 30 minutes for a period of no more than two hours, regardless of storm duration. Sampling was initiated after the site received a sufficient rise in water level, which could vary between watersheds depending on such factors as watershed size and the amount of impervious area.

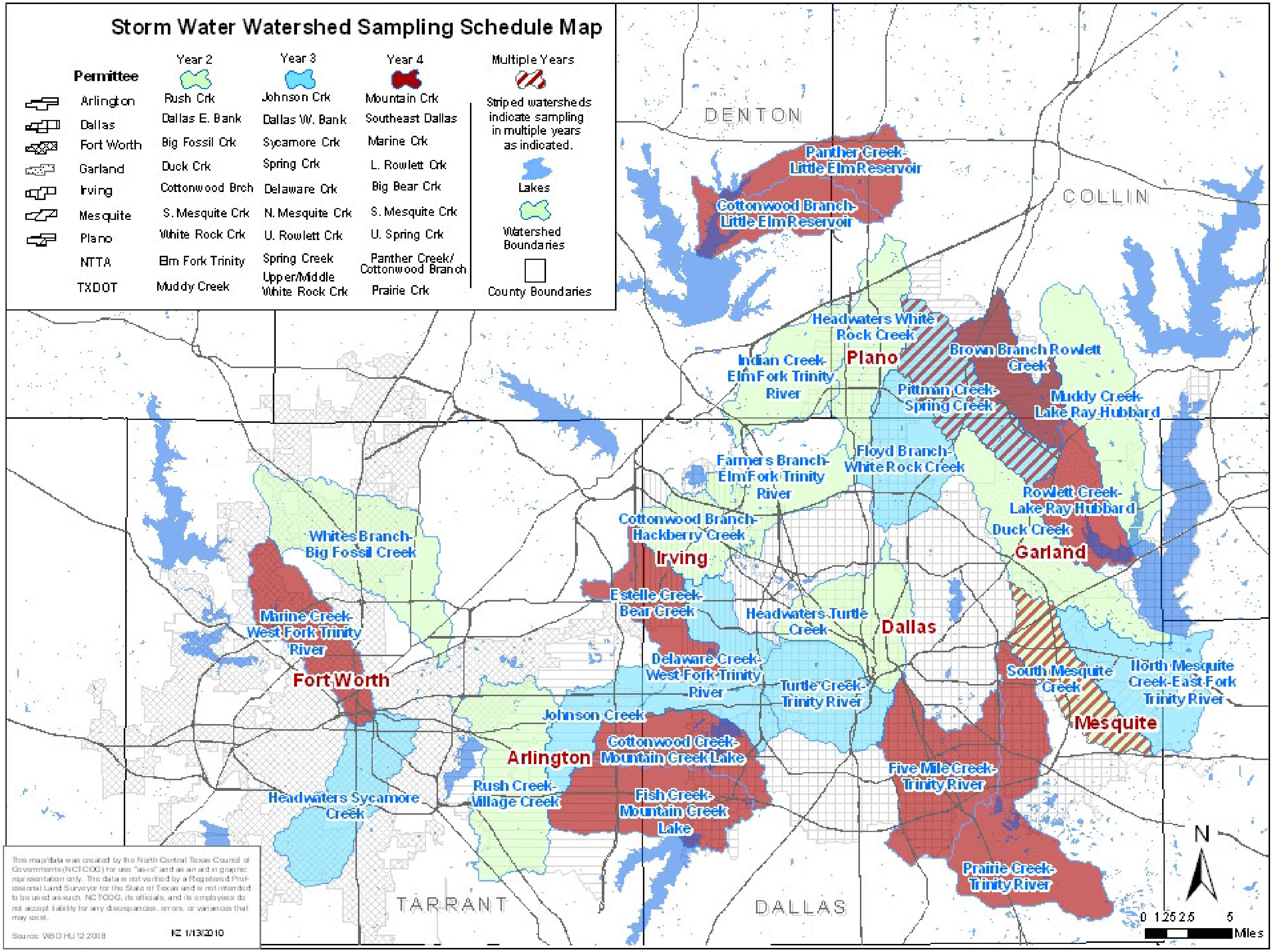

Figure 2-1: Storm Water Watershed Sampling Schedule

Table 2-2: List of Parameters Analyzed

Parameter	Method of Collection
Oil/Grease	Grab
pH	Grab
E.coli	Grab
Total Coliforms	Grab
Total Dissolved Solids (TDS)	Composite
Total Suspended Solids (TSS)	Composite
Biochemical Oxygen Demand (BOD)	Composite
Chemical Oxygen Demand (COD)	Composite
Total Nitrogen	Composite
Dissolved Phosphorus	Composite
Total Phosphorus	Composite
Diazinon	Composite
Total Arsenic	Composite
Total Copper	Composite
Total Cadmium	Composite
Total Lead	Composite
Total Zinc	Composite
Total Chromium	Composite

3.0 MODIFICATIONS TO THE REGIONAL PROTOCOL

3.1 REGIONAL PROTOCOL

In the first year, the five smaller cities (Arlington, Garland, Irving, Mesquite and Plano) and the two transportation agencies (TxDOT and NTTA) contracted with the consulting firm PBS&J (in association with Freese and Nichols, Inc. and TTI Environmental Laboratories) to assist with the field collection and analysis of their storm water samples. See Appendix C for TTI Environmental Laboratories' qualifications. This consultant team or Field Sampling Organization (FSO) prepared the Monitoring Program and Quality Assurance Project Plan for Wet Weather Equipment Deployment and Sampling Protocol for FY2006-FY2010 (PBS&J, 2007), as the primary protocol, based on the components of the approved RWWCP. This protocol was included as Appendix B in the Year 1 (January-December 2006) Annual Monitoring Report (NCTCOG, 2007).

All sampling sites were equipped with automatic samplers (ISCO 6712, ISCO 730 Bubbler Module) that contained four 1-gallon glass sample containers. Following an initial 1-gallon aliquot in the first sample container for the first-flush "grab" sample, the sampler collected 0.5-gallon aliquots every 30 minutes for 120 minutes. As a result, sample containers two and three received two 0.5-gallon aliquots and sample container four received one 0.5-gallon aliquot. Most of the upstream sampling sites included a tipping bucket rain gauge (ISCO 674) to verify rainfall amounts and antecedent dry periods. Graduated cylinder rain gauges were used at all other sites. In the event that the on-site rain gauge information was not applicable (e.g. malfunction or qualifying storm is only at the midstream or downstream stations), an online rain gauge was used to verify the rainfall amount and antecedent dry period.

The Cities of Dallas and Fort Worth utilized their own staff to collect and analyze samples and developed modified protocols to address the minor variances in their programs. The sections below describe in more detail how their monitoring programs differed from the rest of the participating entities.

3.2 CITY OF DALLAS PROTOCOL

The City of Dallas staff generally followed the primary protocol in regards to sample collection and methods of analysis. However, Dallas' protocol had some differences in that they used a different program script due to the use of different equipment models (ISCO 750 Bubbler Module). The sampling equipment was programmed to activate at a 1-inch level rise within a 1-hour period. At activation, the sampler collected two 1-gallon (first-flush) aliquots. Then after 15 minutes, the sampler filled the remaining two 1-gallon jars (composite) over an hour period in five equal aliquots. During the permit term, the City of Dallas also operated their own equipment and used a different laboratory (Xenco) to carry out the analysis of samples collected. See Appendix C for the certifications held by Xenco Laboratories. Other minor technical variations are detailed in the Dallas protocol document which was submitted as Appendix C in the Year 1 (January-December 2006) Annual Monitoring Report (NCTCOG, 2007).

3.3 CITY OF FORT WORTH PROTOCOL

The City of Fort Worth selected the Representative Rapid Bioassessment Monitoring Option (Part IV.2). With this option, Fort Worth's permit (Part IV.A.2(b)) allowed the chemical sampling frequency to be reduced from four times per year per site to once per year per site. Samples were collected using ISCO 3700 automatic samplers initiated by liquid level actuators. The actuators were set to start sampling when there was a 1-inch rise in flow. Samplers were equipped with four 1-gallon glass sampling containers. The first container was set to contain the initial grab sample. Every 30 minutes after the initial grab was collected, an additional 0.5-gallon aliquot was placed in the second, third and fourth container. Two bioassessments were conducted each year at a minimum of nine sites. Additionally, Fort Worth elected to sample for all five years of the permit term instead of three. This generated at least 18 bioassessment samples per year for a minimum of 90 samples for the permit term. Combining the biological and chemical samples produced a total program effort of at least 108 samples compared to 36 which resulted from chemical sampling alone.

The City of Fort Worth contracted with Accutest Laboratories to conduct analysis of the storm water samples. See Appendix C for more information regarding certifications held by Accutest Laboratories. The City of Fort Worth changed the watershed they selected for Year 4 chemical sampling from Mary's Creek to Marine Creek. Documentation of the formal request to modify the RWWCP as well as the official approval of the revision can be found in Appendix B. Details of Fort Worth's protocol were submitted as Appendix D in the Year 1 (January-December 2006) Annual Monitoring Report (NCTCOG, 2007).

3.4 BIOASSESSMENTS CONDUCTED BY THE CITY OF FORT WORTH

The City of Fort Worth conducted bioassessments in its representative monitoring program based on protocols developed by the EPA. The City of Fort Worth's program included an assessment of benthic macroinvertebrates, habitat and water quality. Macroinvertebrates were collected from riffle areas by disturbing an approximately 0.09-square meter area contained by a Surber stream bottom sampler. A multimetric index was used to compare macroinvertebrate community data from test sites to a reference site to determine the impairment status (non-impaired or slight, moderate or severe impairment). Habitat quality was assessed by scoring 10 factors on a scale from 0 (poor) to 20 (optimal). Other physico-chemical data collected included length, width, depth and velocity measurements; water temperature, pH, turbidity, dissolved oxygen and specific conductance measurements; and analysis for ammonia, nitrate and phosphate concentrations.

During spring and fall 2010, rapid bioassessments were conducted at 12 sites along four Trinity River tributaries in Fort Worth. Habitat assessment scores were rated in the sub-optimal and marginal categories during both seasons. Macroinvertebrate scores using EPA protocol metrics indicate macroinvertebrate communities at all sites rated non-impaired during spring sampling (Barbour et al, 1999). Texas Index of Biotic Integrity (TX-IBI) metrics produced ratings at all but one site (upper reach on Sycamore Creek) with high aquatic life use during spring sampling (TCEQ, 2007). See Appendix D for the City of Fort Worth's 2010 Bioassessment Report.

4.0 MONITORING SITES

This section describes the various watersheds monitored during the three years (2007, 2008 and 2009), including land use composition estimates (Tables 4-1, 4-3 and 4-5) and site locations (Figures 4-1, 4-2 and 4-3 and Tables 4-2, 4-4 and 4-6). More detailed narrative descriptions of the sampling site subwatersheds can be found in each year's annual monitoring report (NCTCOG 2008, 2009 and 2010).

4.1 YEAR 2 MONITORING SITES

The following summarizes the Year 2 (2007) watershed site locations, as derived from the Year 2 (January-December 2007) Annual Monitoring Report (NCTCOG, 2008).

Arlington: Rush Creek Watershed is located in southeast Tarrant County entirely within the City of Arlington. The watershed is approximately 22,322 acres and is predominantly residential (46 percent) with open space (22 percent), highway (19 percent) and commercial (11 percent).

Dallas: Dallas East Bank Watershed is located within the Dallas city limits in central Dallas County and is approximately 17,029 acres. The watershed land use is predominantly highway (31 percent) with some commercial (19 percent), industrial (19 percent) and residential (16 percent).

Fort Worth: Big Fossil Creek Watershed is located in northwest Tarrant County and drains southeast through north Fort Worth between Haslet and Saginaw. The watershed is approximately 36,941 acres and the land use is made up of open space (48 percent), residential (27 percent), highway (14 percent), commercial (7 percent) and industrial (3 percent).

Garland: Upper Duck Creek Watershed is located in southeast Dallas County, with a portion in Richardson, west Garland, and down through Sunnyvale and Mesquite. The watershed is approximately 20,357 acres. The watershed land use is composed of residential (37 percent), commercial (16 percent), highway (approximately 21 percent) and industrial (13 percent).

Irving: Cottonwood Branch Watershed is located in northeast Dallas County, which includes the northern half of Irving's city limits. The watershed is 14,494 acres and the land use is predominately highway (38 percent), where DFW International Airport resides in the western side of the watershed. Also in the watershed are segments of open space (29 percent), commercial (17 percent) and industrial (4 percent).

Mesquite: Upper South Mesquite Creek Watershed is located in eastern Dallas County and flows through the northern portion of Mesquite, Balch Springs and Dallas. The watershed is 14,416 acres and the land use is predominantly residential (34 percent), highway (22 percent) and commercial (16 percent), and a small portion of industrial (5 percent).

Plano: Upper White Rock Creek Watershed is located in southwest Collin County, which includes portions of Plano (east of the Dallas North Tollway), Frisco (north of SH 121), and Dallas (south of President George Bush Turnpike). The watershed is 18,750 acres and the land use is predominantly residential (36 percent), followed by open space (27 percent), highway (21 percent), commercial (15 percent) and industrial (less than 1 percent).

NTTA: Elm Fork above Denton Creek Watershed is located in the southeastern portion of Denton County, with portions in Dallas and Collin Counties. The watershed is 51,979 acres composed of portions of several cities: Plano, The Colony, Hebron, Carrollton, Lewisville, Double Oak and Flower Mound. The watershed land use is predominantly open space (41 percent), followed by residential (28 percent), highway (16 percent), commercial (10 percent) and industrial (3 percent).

NTTA: Elm Fork above Cottonwood Branch Watershed is located in northwestern Dallas County with portions stretching into the northeastern corner of Tarrant County. The watershed includes portions of Grapevine, Coppell, Carrollton and small portions of Farmers Branch and Dallas. The watershed is 14,942 acres and the land use is predominantly open space (37 percent), highway (24 percent), residential (13 percent) and a small portion of industrial (9 percent) and commercial (9 percent).

TxDOT: Muddy Creek Watershed is located in Collin County and part of northeastern Dallas County. The watershed is 25,273 acres and includes portions of several cities: Allen, Garland, Parker, Murphy, Sachse, Rowlett, Wylie, Lucas and St. Paul. The land use is predominately open space (59 percent), followed by residential (26 percent), commercial (3 percent) and industrial (1 percent)

Table 4-1: Year 2 Watershed Land Use Composition Estimates

WATERSHED	SITE ID	LOCATION	ACREAGE	MONITORING LAND USE CATEGORIES (%)					
				COM	HWY	IND	OPEN	RES	WATER
Rush Creek	AR0701	Rush Creek at Sublett Road	5,942	5.2	13.0	3.5	41.1	36.8	0.4
	AR0702	Kee Branch at Pleasant Ridge Road	4,180	10.2	23.4	0.3	16.9	49.0	0.1
	AR0703	Rush Creek at Woodland Park Boulevard	8,165	13.1	19.4	1.2	14.8	51.1	0.3
			22,322	**10.5**	**18.5**	**2.5**	**22.4**	**45.7**	**0.4**
Dallas East Bank	DL0701a	Old River Channel at Regal Row	36	37.0	21.7	3.5	29.7	0.0	8.1
	DL0701b	Cedar Branch at Cedar Springs Road	816	7.0	27.3	0.0	2.7	63.1	0.0
	DL0701c	Turtle Creek at Cedar Springs Road and Gillespie Avenue	3,362	10.5	23.8	0.1	9.0	56.2	0.5
	DL0703a	Elm Fork Creek at Irving Boulevard	1,943	25.8	31.0	10.1	7.9	25.0	0.0
	DL0703b	Old River Channel at Conveyor Lane	7,660	19.1	32.2	23.0	6.9	18.5	0.3
			17,029	**19.2**	**30.8**	**18.5**	**14.9**	**15.9**	**0.7**
Big Fossil Creek	BFC1	Big Fossil Creek at Blue Mound Road	4,049	1.7	9.4	1.8	64.1	22.3	0.7
	BFC2	Big Fossil Creek at IH-35W	9,608	4.0	9.6	3.6	64.0	18.0	0.7
	BFC3	Big Fossil Creek at Beach Street	6,292	4.5	14.9	2.0	54.1	23.5	1.0
			36,941	**6.5**	**14.2**	**3.3**	**48.0**	**27.3**	**0.8**
Upper Duck Creek	GA0701	Duck Creek at Shiloh Bridge	5,039	21.7	21.9	8.4	9.7	38.0	0.2
	GA0702	Forest North and Forest South	2,434	16.6	21.1	9.9	6.4	46.0	0.0
	GA0703	Duck Creek Under La Prada Bridge	7,112	11.9	19.7	22.1	8.3	37.8	0.1
			20,357	**15.6**	**21.0**	**13.0**	**13.1**	**37.1**	**0.2**
Cottonwood Branch	IR0701	Cottonwood Branch at Beltline Road	630	7.5	27.5	1.1	44.3	19.0	0.5
	IR0702	Cottonwood Branch at Story Road	643	21.8	15.7	12.6	12.2	37.5	0.3
	IR0703	Cottonwood Branch at SH114	1,595	20.6	12.6	6.4	35.4	22.5	2.5
			14,494	**16.7**	**37.8**	**3.8**	**28.8**	**11.3**	**1.6**
South Mesquite Creek	MS0701	S. Mesquite Creek at N Mesquite Drive	2,206	20.3	27.3	0.3	6.1	45.9	0.0
	MS0702	North of New Market Road	7,759	19.0	23.0	8.9	19.8	29.2	0.2
	MS0703	North of Pioneer, behind house on west side of Creek	2,595	11.3	19.0	2.3	27.1	39.6	0.7
			14,416	**16.1**	**22.1**	**5.3**	**21.9**	**34.3**	**0.3**
Upper White Rock Creek	PL0702	Hill from parking lot of Preston Hedgcoxe Plaza	5,198	15.4	20.2	0.2	34.2	29.5	0.5
	PL0703	South of Parker Road	5,884	16.9	19.6	29.8	33.1	0.5	0.0
	PL0704	North of Plano Parkway	2,944	13.6	21.3	18.6	44.9	1.6	0.0
			18,750	**15.2**	**21.3**	**0.1**	**26.8**	**35.8**	**0.8**
Elm Fork above Denton Creek	NTTA0701	Furneaux Creek at Broadway Street	6,568	11.7	24.8	4.2	15.7	43.0	0.5
			51,979	**10.2**	**16.4**	**2.8**	**40.8**	**27.9**	**1.9**
Elm Fork above Cottonwood Branch	NTTA0702	Elm Fork at PBGT	12,951	9.5	25.3	10.2	31.6	15.3	8.0
			14,942	**8.8**	**23.7**	**9.2**	**36.5**	**13.3**	**8.6**
Muddy Creek	TX0701	Muddy Creek at Kirby Street	8,892	1.8	7.3	0.5	65.0	24.3	1.0
	TX0702	Muddy Creek at SH-78	549	2.5	19.0	1.9	32.6	43.8	0.1
			25,273	**3.4**	**8.7**	**1.4**	**59.4**	**26.0**	**1.1**

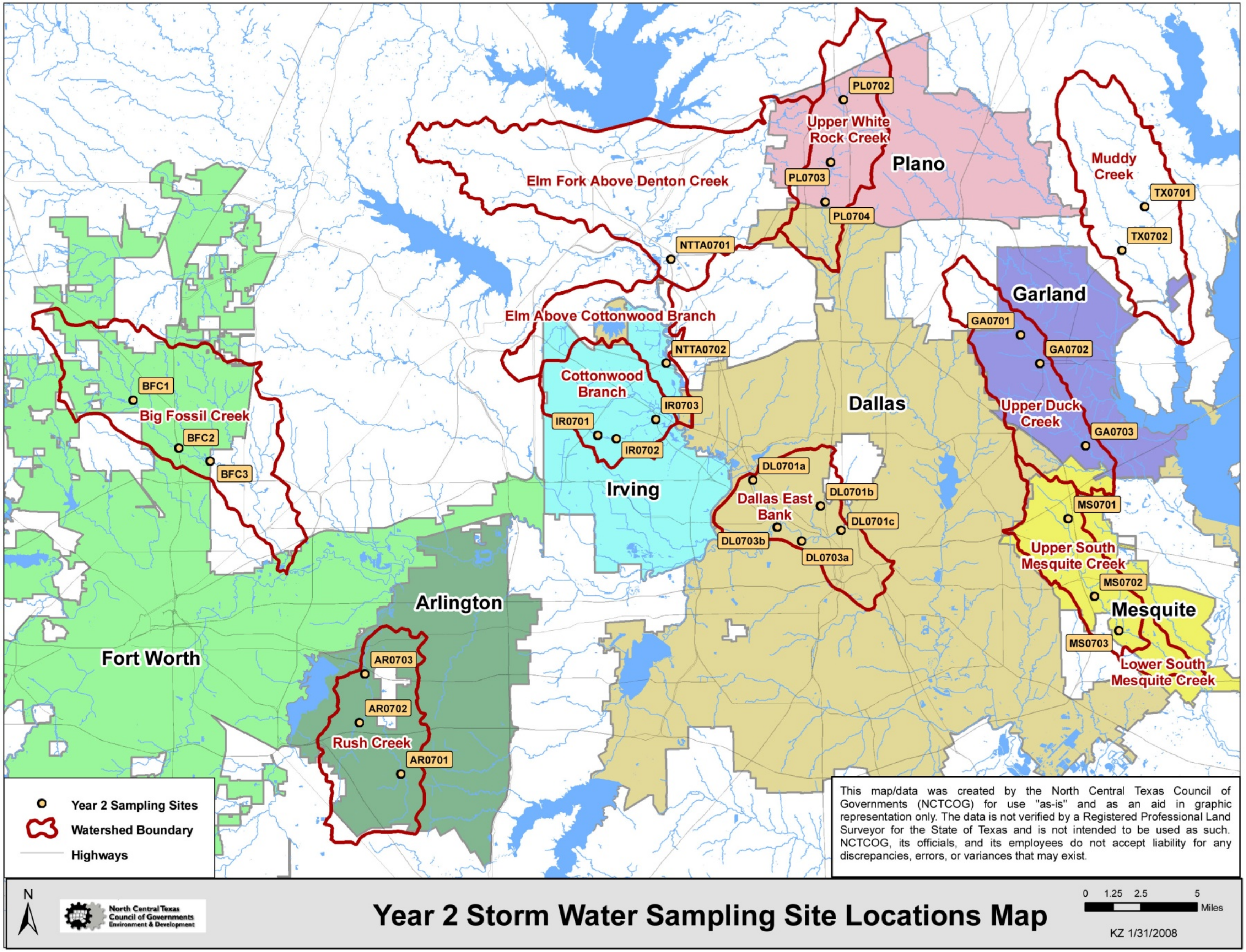

Figure 4-1: Year 2 Storm Water Sampling Site Locations Map

Table 4-2: Year 2 Storm Water Sampling Site Locations

JURISDICTION / WATERSHED	STATION ID	LOCATION	LATITUDE	LONGITUDE	# OF SAMPLES
ARLINGTON					
Rush Creek	AR0701	Rush Creek at Sublett Rd.	N 32° 38' 55. 86"	W 97° 8' 47. 22"	4
	AR0702	Kee Branch at Pleasant Ridge	N 32° 40' 57.42"	W 97° 10' 39.36"	4
	AR0703	Rush Creek at Woodland Park	N 32° 42' 50.58"	W 97° 10' 22.14"	4
DALLAS					
Dallas East Bank	DL0701a	Old River Channel south of Regal Row on west bank	N 32° 50' 11.52"	W 96° 52' 22.05"	4
	DL0701b	Cedar Branch south of Cedar Springs Rd on east bank	N 32° 49' 8.60"	W 96° 49' 16.24"	4
	DL0701c	Turtle Creek west of Cedar Springs Rd. on south bank	N 32° 48' 11.03"	W 96° 48' 20.98"	4
	DL0703a	Elm Fork Creek south of Irving Blvd. on east bank	N 32° 47' 46.80"	W 96° 50' 10.02"	4
	DL0703b	Old River Channel north of Conveyor Ln. on south bank	N 32° 48' 20.67"	W 96° 51' 17.34"	4
FORT WORTH					
Big Fossil Creek	BFC1	Big Fossil Creek at Blue Mound	N 32° 52' 47.48"	W 97° 20' 33.50"	1 (2)
	BFC2	Big Fossil Creek at IH-35W	N 32° 51' 44.59"	W 97° 18' 49.89"	1 (2)
	BFC3	Big Fossil Creek at Beach St.	N 32° 51' 12.62"	W 97° 17' 23.18"	1 (2)
Mary's Creek	MRY1	Mary's Creek at F.M. 2871	N 32° 42' 47.63"	W 97° 29' 49.31"	(2)
	MRY2	Mary's Creek at West Loop 820	N 32° 42' 41.79"	W 97° 28' 38.67"	(2)
	MRY3	Mary's Creek at Winscott Rd.	N 32° 41' 43.00"	W 97° 26' 49.65"	(2)
Sycamore Creek	SCY1	Sycamore Creek at IH-20 & IH-35W	N 32° 39' 53.58"	W 97° 19' 16.06"	(2)
	SCY2	Sycamore Creek at Redbud Trail	N 32° 42' 47.52"	W 97° 17' 51.65"	(2)
	SCY3	Sycamore Creek at Scott Ave.	N 32° 44' 51.30"	W 97° 17' 41.47"	(2)
Big Fossil Creek	BFC1	Big Fossil Creek at Blue Mound	N 32° 52' 47.48"	W 97° 20' 33.50"	1 (2)
	BFC2	Big Fossil Creek at IH-35W	N 32° 51' 44.59"	W 97° 18' 49.89"	1 (2)
	BFC3	Big Fossil Creek at Beach St.	N 32° 51' 12.62"	W 97° 17' 23.18"	1 (2)
GARLAND					
Upper Duck Creek	GA0701	Duck Creek at Shiloh Bridge	N 32° 55' 41.1"	W 96° 39' 54.2"	4
	GA0702	Forest North and Forest South	N 32° 54' 33.8"	W 96° 39' 02.0"	4
	GA0703	Duck Creek Under La Prada Bridge	N 32° 51' 19.2"	W 96° 37' 0.42"	4
IRVING					
Cottonwood Branch	IR0701	Cottonwood Branch at Beltline Rd.	N 32° 52' 1.56"	W 96° 59' 29.52"	4
	IR0702	Cottonwood Branch at Story Rd.	N 32° 51' 19.2"	W 96° 59' 29.52"	4
	IR0703	Cottonwood Branch at SH114	N 32° 52' 37.02"	W 96° 56' 48.78"	4
MESQUITE					
Upper South Mesquite Creek	MS0701	S. Mesquite Creek at N Mesquite Dr.	N 32° 48' 28.9"	W 96° 37' 51.5"	4
	MS0702	North of New Market Rd.	N 32° 45' 26.1"	W 96° 36' 43.0"	4
	MS0703	North of Pioneer, behind house on west side of Creek	N 32° 44' 05.2"	W 96° 35' 37.2"	4
PLANO					
Upper White Rock Creek	PL0702	Hill from parking lot of Preston Hedgcoxe Plaza	N 33° 4' 57.9"	W 96° 47' 54.2"	4
	PL0703	South of Parker Rd.	N 33° 2' 32.4"	W 96° 48' 33.2"	4
	PL0704	North of Plano Parkway	N 33° 0' 59.3"	W 96° 48' 49.3"	4
N. TX. TOLLWAY AUTHORITY					
Elm Fork above Denton Creek	NTTA0701	Furneaux Creek at Broadway	N 32° 58' 51.08"	W 96° 56' 0. 41"	4
Elm Fork above Cottonwood Branch	NTTA0702	Elm Fork at President George Bush Turnpike	N 32° 54' 48.06"	W 96° 56' 17.68"	4
TXDOT-DALLAS					
Muddy Creek	TX0701	Muddy Creek at Kirby St.	N 33° 0' 35.69"	W 96° 34' 3.71"	4
	TX0702	Muddy Creek at SH78	N 32° 58' 55.09"	W 96° 35' 9.88"	4

Note: Numbers in parentheses reflect biomonitoring samples.

4.2 YEAR 3 MONITORING SITES

The following summarizes the Year 3 (2008) watershed site locations, as derived from the Year 2 (January-December 2008) Annual Monitoring Report (NCTCOG, 2009).

Arlington: Johnson Creek Watershed is located mainly in Tarrant County, with a small portion in Dallas County. The watershed is 13,589 acres and the land use is predominantly residential (29 percent) and includes portions of highway (22 percent), commercial (21 percent), open space (16 percent) and industrial (12 percent).

Dallas: Dallas West Bank Trinity River Watershed is located in west Dallas County. The watershed is 22,453 acres and the land use is predominantly composed of residential (32 percent) and open space (26 percent).

Fort Worth: Sycamore Creek Watershed is located in southern Tarrant County and flows northeastward through Fort Worth and into the West Fork Trinity River. The watershed is composed of 23,650 acres and the land use is predominantly residential (35 percent) and open space (27 percent). The watershed also includes an estimated 10 percent of commercial land use and 5 percent industrial.

Garland: Spring Creek Watershed is located in southeastern Collin County and north-central Dallas County. The watershed is 23,412 acres and the land use is predominantly residential (41 percent) and highway (23 percent). The watershed also includes open space (19 percent), commercial (15 percent) and industrial (2 percent).

Irving: Delaware Creek Watershed is located in western Dallas County and includes the city boundaries of Dallas, Grand Prairie and Irving. The watershed is 21,586 acres and the land use is predominantly open space (32 percent) and residential (27 percent). The watershed also includes highway (17 percent), commercial (18 percent) and industrial (4 percent).

Mesquite: North Mesquite Creek Watershed is located in eastern Dallas County and partially within the Dallas city limits. The watershed is 23,939 acres and the land use is mostly open space (64 percent) and residential (17 percent). The watershed also includes highway (10 percent), commercial (5 percent) and industrial (2 percent) areas.

Plano: Brown Branch-Rowlett Creek Watershed is located in southwestern Collin County and a small portion in northern Dallas County. The watershed is 16,243 acres and the land use is predominantly open space (38 percent) and residential (27 percent). The remainder of the watershed is highway (18 percent), commercial (10 percent) and industrial (7 percent).

NTTA: Spring Creek Watershed is located in southeastern Collin County and north-central Dallas County. The watershed is 23,412 acres and the land use is predominantly residential (41 percent) and highway (23 percent). The other portions of the watershed include open space (19 percent), commercial (15 percent) and industrial (2 percent).

TxDOT: Floyd Branch-White Rock Creek Watershed is located in north-central Dallas County with portions in the Dallas city limits. The watershed is 21,090 acres and the land use is predominantly residential (44 percent) and highway (22 percent). The watershed has portions of commercial (20 percent), open space (12 percent) and industrial (3 percent).

Table 4-3: Year 3 Watershed Land Use Composition Estimates

WATERSHED	SITE ID	LOCATION	ACREAGE	MONITORING LAND USE CATEGORIES (%)					
				COM	HWY	IND	OPEN	RES	WATER
Johnson Creek	AR0801	Johnson Creek at Matlock Road	647	30.7	22.4	1.8	15.4	29.7	0.0
	AR0802	Johnson Creek at Meadowbrook Park	4,838	22.2	20.9	2.5	10.7	43.7	0.0
	AR0803	Johnson Creek at E. Copeland Road	3,539	28.1	22.3	8.8	18.2	21.8	0.7
			13,589	**20.9**	**21.8**	**12.4**	**15.7**	**28.7**	**0.3**
Dallas West Bank	DL0801	East of Bastille Rd. at La Reunion Parkway	896	6.3	15.3	21.6	51.5	5.0	0.3
	DL0802	North of Bickers Street between Hollystone & Rupert	220	13.2	17.5	21.0	27.2	19.7	1.3
	DL0803	Front (south) of Delta pump station, west of N. Hampton Road	5,287	6.4	19.9	20.9	32.2	19.4	1.4
			22,453	**8.4**	**23**	**9.1**	**26.1**	**32.1**	**1.5**
Sycamore Creek	SCY1	Sycamore Creek at I-20 & I-35W	11,289	8.3	19.4	4.4	29.1	38.6	0.2
	SCY2	Sycamore Creek near Redbud Trail	6,904	10.8	23.1	7.9	27.4	30.4	0.3
	SCY3	Sycamore Creek at Scott Avenue	5,510	12.4	27.3	4.4	22.8	32.9	0.2
			23,650	**10**	**22.3**	**5.4**	**27.1**	**34.9**	**0.2**
Spring Creek	GA0801	Spring Creek at N. Shiloh Road	18,458	15.6	23.4	1.6	16.2	43	0.2
	GA0802	Spring Creek at N. Garland Avenue	1,761	9.5	18.7	1.0	39.4	30.9	0.6
	GA0803	Spring Creek at President George Bush Turnpike	2,289	15.3	22.2	0.0	23.7	38.7	0.1
			23,412	**14.7**	**23**	**1.5**	**19.3**	**41.3**	**0.2**
Delaware Creek	IR0801	Delaware Creek at Pilgrim Drive	794	19.1	23	0.7	1.4	55.6	0.1
	IR0802	Delaware Creek at Sowers Road	2,332	21.9	20	0.7	1.7	55.7	0.0
	IR0803	Delaware Creek at Oakdale Road	1,496	19.0	22.8	1.7	11.1	45.5	0.0
			21,586	**17.6**	**16.8**	**3.8**	**32**	**27.3**	**2.5**
North Mesquite Creek	MS0801	N. Mesquite Creek at Town East	697	19.8	23.7	0.0	4.9	51.7	0.0
	MS0802	N. Mesquite Creek at 352 and Kearney	3,366	14.5	16.5	2.0	36.6	29.9	0.5
	MS0803	N. Mesquite Creek at Edward's Church Road	2,192	6.5	19.3	6.6	31.2	36.2	0.2
			23,939	**5**	**10.4**	**1.9**	**64.2**	**16.7**	**1.7**
Upper Rowlett Creek	PL0801	Rowlett Creek at Oak Point Park	27,094	5.1	13.0	1.0	61.6	18.9	0.4
	PL0802	Rowlett Creek at Park Boulevard in Bob Woodruff Park (South)	3,845	19.2	20.3	1.0	30.0	29.1	0.4
	PL0803	Rowlett Creek at Los Rios Boulevard	2,140	13.8	27	1.6	12.9	44.7	0
			16,243	**10.2**	**17.9**	**6.7**	**37.8**	**26.8**	**0.6**
Spring Creek	NTTA0801	Pittman Creek at PGBT and Alma	3,242	14.9	23.2	1.0	10.3	50.7	0.0
	NTTA0802	Spring Creek Trib. at PGBT and W. Campbell Road	61	0.0	23.8	0.0	74.9	1.3	0.0
			23,412	**14.7**	**23**	**1.5**	**19.3**	**41.3**	**0.2**
Upper/Middle White Rock	TX0801	Middle White Rock Creek at 635 S and Park Central Drive	30,398	15.9	21.6	0.4	22.5	39	0.6
	TX0802	Middle White Rock Creek between Forest & Royal east of US-75	2,246	18.0	20.2	0.0	8.8	52.2	0.7
			21,090	**19.8**	**22.3**	**2.8**	**11.3**	**43.7**	**0.2**

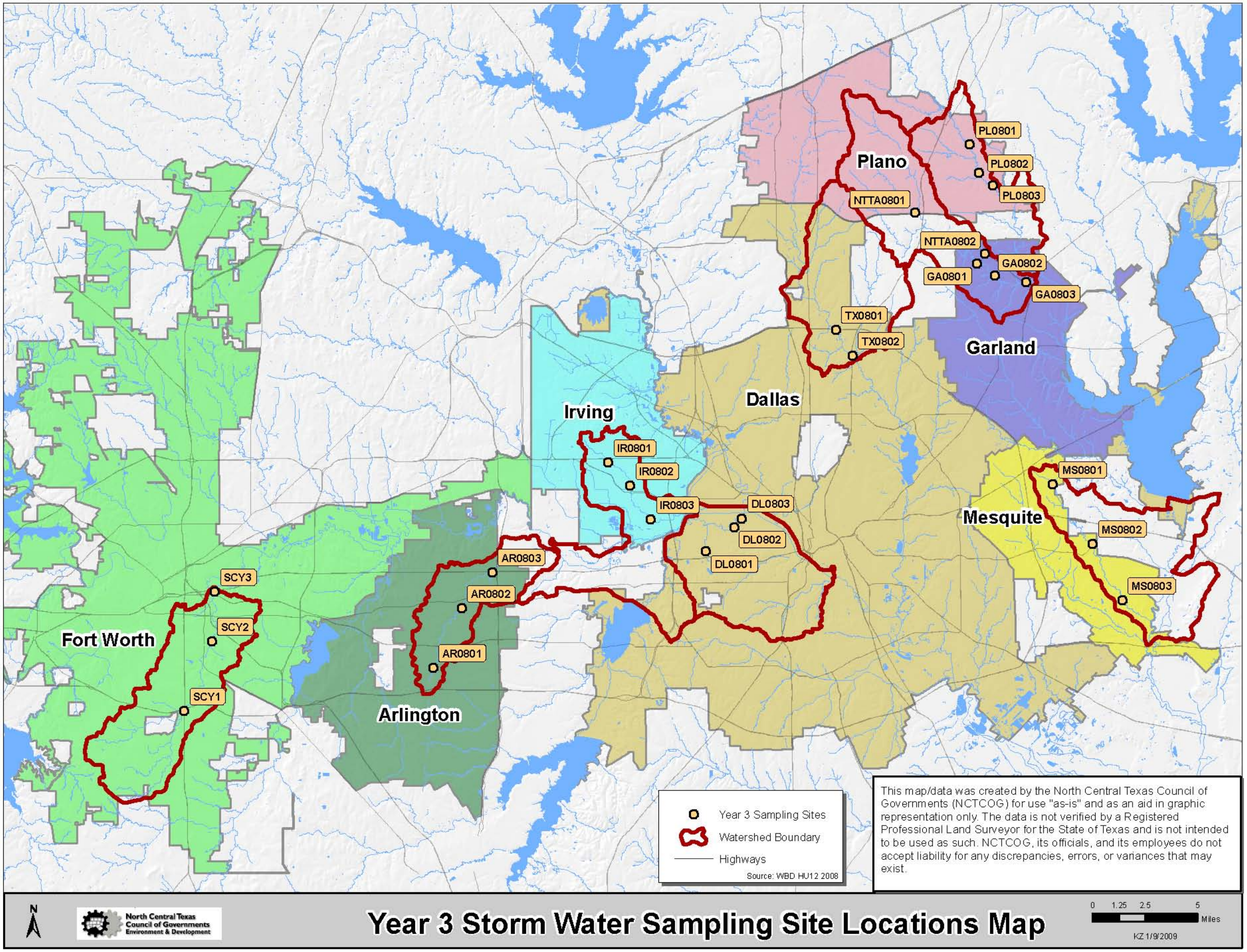

Figure 4-2: Year 3 Storm Water Sampling Site Locations

Table 4-4: Year 3 Storm Water Sampling Site Locations

JURISDICTION / WATERSHED	STATION ID	LOCATION	LATITUDE	LONGITUDE	# OF SAMPLES
ARLINGTON					
Johnson Creek	AR0801	Johnson Creek at Matlock Road	32° 41' 34.5" N	97° 06' 59.6" W	4
	AR0802	Johnson Creek at Meadowbrook Park	32° 44' 01.8" N	97° 05' 32.78" W	4
	AR0803	Johnson Creek at E. Copeland Road	32° 45' 31.7" N	97° 04' 01.3" W	4
DALLAS					
Dallas West Bank	DL0801	East of Bastille Rd. at La Reunion Parkway	32° 46' 16.24" N	96° 53' 28.78" W	4
	DL0802	North of Bickers Street between Hollystone & Rupert	32° 47' 14.74" N	96° 52' 3.53" W	4
	DL0803	Front (south) of Delta pump station, west of N. Hampton Road	32° 47' 37.17" N	96° 51' 40.86" W	4
FORT WORTH					
Big Fossil Creek	BFC1	Big Fossil Creek at Pepperidge Lane	32 53' 07.79" N	97 20' 33.30" W	(2)
	BFC2	Big Fossil Creek at IH-35W	32° 51' 44.59" N	97° 18' 49.89" W	(2)
	BFC3	Big Fossil Creek at Beach Street	32° 51' 12.62" N	97° 17' 23.18" W	(2)
Marine Creek	MAR1	Marine Creek at Angle Ave & Long Ave	32° 48' 19.65" N	97° 21' 51.89" W	(1)
	MAR2	Lincoln Park, north of NW 28th Street	32° 47' 43.27" N	97° 21' 25.31" W	(1)
	MAR3	Saunders Park and north of NE 23rd	32° 47' 10.20" N	97° 20' 45.59" W	(1)
Mary's Creek	MRY1	Mary's Creek at F.M. 2871	32° 42' 47.63" N	97° 29' 49.31" W	(2)
	MRY2	Mary's Creek at West Loop 820	32° 42' 41.79" N	97° 28' 38.67" W	(2)
	MRY3	Mary's Creek at Winscott Road	32° 41' 43.00" N	97° 26' 49.65" W	(2)
Sycamore Creek	SCY1	Sycamore Creek at I-20 & I-35W	32° 39' 53.58" N	97° 19' 16.06" W	1(2)
	SCY2	Sycamore Creek near Redbud Trail	32 43' 18.37" N	97 17' 36.72" W	1(2)
	SCY3	Sycamore Creek at Scott Avenue	32° 44' 51.30" N	97° 17' 41.47" W	1(2)
GARLAND					
Spring Creek	GA0801	Spring Creek at N. Shiloh Road	32° 58' 06.1" N	96° 39' 52.4" W	4
	GA0802	Spring Creek at N. Garland Avenue	32° 57' 35.2" N	96° 39' 00.2" W	4
	GA0803	Spring Creek at President George Bush Turnpike	32° 57' 17.0" N	96° 37' 28.4" W	4
IRVING					
Delaware Creek	IR0801	Delaware Creek at Pilgrim Drive	32° 50' 02.1" N	96° 58' 14.2" W	4
	IR0802	Delaware Creek at Sowers Road	32° 49' 03" N	96° 57' 10.1" W	4
	IR0803	Delaware Creek at Oakdale Road	32° 47' 37.6" N	96° 56' 10.9" W	4
MESQUITE					
North Mesquite Creek	MS0801	N. Mesquite Creek at Town East	32° 48' 49.6" N	96° 36' 19.9" W	4
	MS0802	N. Mesquite Creek at 352 and Kearney	32° 46' 19.0" N	96° 34' 25.4" W	4
	MS0803	N. Mesquite Creek at Edward's Church Road	32° 43' 55.6" N	96° 33' 01.8" W	4
PLANO					
Upper Rowlett Creek	PL0801	Rowlett Creek at Oak Point Park	33° 03' 03.7" N	96° 40' 08.2" W	4
	PL0802	Rowlett Creek at Park Boulevard in Bob Woodruff Park (South)	33° 01' 53.3" N	96° 39' 42.6" W	4
	PL0803	Rowlett Creek at Los Rios Boulevard	33° 01' 20.7" N	96° 39' 02.8" W	4
N. TX TOLLWAY AUTHORITY					
Spring Creek	NTTA0801	Pittman Creek at PGBT and Alma	33° 00' 16.0" N	96° 42' 52.3" W	4
	NTTA0802	Spring Creek Trib. at PGBT and W. Campbell Road	32° 58' 29.4" N	96° 39' 28.3" W	4
TXDOT-DALLAS					
Upper/Middle White Rock Creek	TX0801	Middle White Rock Creek at 635 S and Park Central Drive	32° 55' 26.1" N	96° 46' 54.1" W	4
	TX0802	Middle White Rock Creek between Forest and Royal east of US-75	32° 54' 20.7" N	96° 46' 06.5" W	4

Note: Numbers in parentheses reflect biomonitoring samples.

4.3 YEAR 4 MONITORING SITES

The following summarizes the Year 4 (2009) watershed site locations, as derived from the Year 2 (January-December 2009) Annual Monitoring Report (NCTCOG, 2010).

Arlington: Fish Creek-Mountain Creek Lake Watershed is located within parts of Tarrant and Dallas County and is north of Joe Pool Lake. The watershed is 27,532 acres and the land use is predominantly composed of open space (42 percent) and residential (26 percent). The City of Arlington sampled in two watersheds for the 2009 monitoring year. Fish Creek-Mountain Creek Lake was the watershed that included monitoring of the upstream monitoring location.

Arlington: Cottonwood Creek-Mountain Creek Lake Watershed is located south of IH 30 and lies partially in Tarrant County and Dallas County. The watershed is 18,853 acres and the land use is predominantly open space (28 percent) and residential (22 percent). The watershed also has highway (15 percent), commercial (14 percent) and industrial (8 percent). Cottonwood Creek-Mountain Creek Lake was also monitored in 2009 in Arlington and is the watershed that contained the midstream and downstream monitoring locations.

Dallas: Five Mile Creek-Trinity River Watershed is located in southeast Dallas County. The watershed is 30,304 acres and the land use is predominantly open space (48 percent) and residential (20 percent). The watershed is also made up of highway (14 percent), commercial (10 percent) and industrial (5 percent).

Fort Worth: Marine Creek-West Fork Trinity River Watershed is located in Tarrant County on the west side of the Fort Worth city limits. The watershed is 20,017 acres and the land use is composed of open space (39 percent), highway (24 percent), residential (19 percent), commercial (8 percent) and industrial (8 percent).

Garland: Brown Branch-Rowlett Creek Watershed is located in southwestern Collin County and extends into northern Dallas County. The watershed contained the upstream monitoring site and is made up of 16,253 acres. The land use is predominantly open space (38 percent) and residential (27 percent). Other portions of the watershed include highway (18 percent), commercial (10 percent) and industrial (7 percent).

Garland: Pittman Creek-Spring Creek Watershed is located in southeastern Collin County and north-central Dallas County. The watershed contained the midstream monitoring site and is approximately 23,412 acres. The land is predominantly residential (41 percent) and highway (23 percent). Other portions of the watershed include open space (19 percent), commercial (15 percent) and industrial (1 percent).

Garland: Rowlett Creek-Lake Ray Hubbard Watershed is located near Lake Ray Hubbard in northeast Dallas County. The watershed contained the downstream monitoring site and is 17,257 acres. The land use is predominantly residential (32 percent) and open space (31 percent). Other portions of the watershed include highway (16 percent), commercial (8 percent) and industrial (3 percent).

Irving: Estelle Creek-Bear Creek Watershed is located within Dallas County and northeastern Tarrant County. The watershed is 16,950 acres and the land use is predominantly open space (38 percent) and highway (26 percent). Other portions of the watershed include residential (16 percent), commercial (10 percent) and industrial (6 percent).

Mesquite: Upper South Mesquite Creek Watershed is located in eastern Dallas County where it flows through the northern portion of Mesquite, Balch Springs and Dallas. The watershed is 14,416 acres and the land use is predominantly residential (34 percent), highway (22 percent) and commercial (16 percent), and a small portion of industrial (5 percent).

Plano: Pittman Creek-Spring Creek Watershed is located in southeastern Collin County and north-central Dallas County. The watershed is 23,412 acres and the land use is predominantly residential (41.3 percent) and highway (23 percent). The watershed also contains open space (19 percent), commercial (15 percent) and industrial (1 percent).

NTTA: Panther Creek-Little Elm Reservoir Watershed is located northeast of Lewisville Lake with portions in Denton County and Collin County. This watershed contained the upstream monitoring site and is 15,929 acres and the land use is predominantly open space (86 percent). The remainder of the watershed contained highway (5 percent) and residential (2 percent).

NTTA: Cottonwood Branch-Little Elm Reservoir Watershed is located in Denton County and Collin County and includes a portion of Lewisville Lake. This watershed contained the downstream monitoring site and is 19,210 acres. The land use is predominantly open space (54 percent) followed by highway (10 percent), residential (16 percent) and commercial (3 percent).

TxDOT: Prairie Creek-Trinity River Watershed is located in southeast Dallas County. The watershed is 37,087 acres and the land use is predominantly open space (61 percent).

Table 4-5: Year 4 Watershed Land Use Composition Estimates

WATERSHED	SITE ID	LOCATION	ACREAGE	MONITORING LAND USE CATEGORIES (%)					
				COM	HWY	IND	OPEN	RES	WATER
Fish Creek-Mountain Creek Lake	AR0901	North Fish Creek at SH-360	2,033	13	21.4	2.9	10.4	52.1	0.0
			27,532	**8.9**	**18.9**	**1.6**	**41.8**	**26.1**	**2.7**
Cottonwood Creek-Mountain Creek Lake	AR0902	South Cottonwood Creek at Forum Road	860	28.6	30.1	0.3	14.1	36.8	0.0
	AR0903	North Cottonwood Creek at Timberlake Drive	1,742	11.7	23.7	6.7	11.2	46.7	0.0
			18,853	**14.4**	**14.9**	**7.9**	**27.5**	**22.4**	**12.8**
Five Mile Creek-Trinity River	DL0901	Honey Springs Branch Creek at Easter Avenue and E. Kiest Boulevard	93	7.4	22.4	0.0	0.3	69.8	0.0
	DL0902	Honey Springs Branch Creek at Bonnie View Road	543	11.7	19.6	0.2	10.1	58.5	0.0
	DL0903	Honey Springs Branch Creek at Carbondale Street	936	9.0	25.7	5.4	15.3	44.4	0.0
			30,304	**9.6**	**14.1**	**4.8**	**47.8**	**20.3**	**3.4**
Marine Creek-West Fork Trinity River	MAR1	Marine Creek at Angle Avenue and Long Avenue	10,882	5.1	16.4	3.0	54.3	18.5	2.6
	MAR2	Marine Creek at Lincoln Park	752	6.4	36.6	0.5	20.6	35.7	0.2
	MAR3	Marine Creek at Saunders Park	1,523	12.6	39.4	16.4	15.4	16.2	0.0
			20,017	**8.3**	**24.3**	**8.1**	**38.7**	**18.9**	**1.8**
Brown Branch-Rowlett Creek	GA0901	Rowlett Creek at Brand Road	52,887	6.9	15.1	2.4	51.1	24.1	0.4
			16,253	**10.2**	**17.9**	**6.7**	**37.8**	**26.8**	**0.6**
Pittman Creek-Spring Creek	GA0902	Rowlett Creek at SH-78	23,901	14.4	22.7	1.3	20.1	41.3	0.3
			23,412	**14.7**	**23**	**1.4**	**19.4**	**41.3**	**0.2**
Rowlett Creek-Lake Ray Hubbard	GA0903	Rowlett Creek at Centerville Road/Castle Drive	5,047	5.7	15.1	0.6	46.7	31.5	0.4
			17,257	8.1	16.4	2.9	31.3	32.4	8.9
Estelle Creek-Bear Creek	IR0901	Bear Creek Tributary at Shady Grove Road	199	8.0	16.6	1.9	4.8	68.7	0.0
	IR0902	Bear Creek at Hunter Ferrell Road	58,739	7.6	20.7	3.5	31.3	35.6	1.3
	IR0903	Bear Creek at MacArthur Boulevard	840	17.5	5.3	3.3	58.8	9.4	5.8
			16,950	9.8	25.5	6	38	16.2	4.5
South Mesquite Creek	MS0901	South Mesquite Creek at Mesquite Drive	2,168	20.9	27.3	0.3	6.2	45.3	0.0
	MS0902	South Mesquite Creek at New Market Road	7,698	18.9	23.0	9.0	19.8	29.3	0.2
	MS0903	South Mesquite Creek at Pioneer Road	2,707	11.0	19.0	2.3	27.7	39.3	0.7
			17,840	14.6	18.9	5.4	30.1	30.4	0.6
Pittman Creek-Spring Creek	PL0901	Spring Creek at Legacy Drive	461	4.1	28.7	0.0	4.0	63.2	0.0
	PL0902	Spring Creek at 16th Street	5,129	13.4	24.4	0.2	10.1	51.8	0.0
	PL0903	Spring Creek at Central Expressway (US-75)	537	54.5	24.2	0.0	7.9	13.4	0.0
			23,412	14.7	23	1.4	19.4	41.3	0.2
Panther Creek-Little Elm Reservoir	NTTA0901	Panther Creek Tributary at Dallas North Tollway	648	19.9	3.7	0	75.5	0	0
			15,929	2.5	5.3	0.1	86.3	2.3	3.5
Cottonwood Branch-Little Elm Reservoir	NTTA0902	Cottonwood Branch Tributary at Dallas North Tollway	48	0.0	9.3	22.5	68.0	0.0	0.2
			19,210	3.2	10.1	0.6	54.4	15.9	15.7
Prairie Creek-Trinity River	TX0901	Prairie Creek at US-175	6,004	13.4	17.4	6.6	20.7	41.7	0.3
	TX0902	Prairie Creek at IH-20	4,559	7.0	16.7	3.3	27.7	45.1	0.3
			37,087	4.6	8.1	3.6	60.6	18	5.1

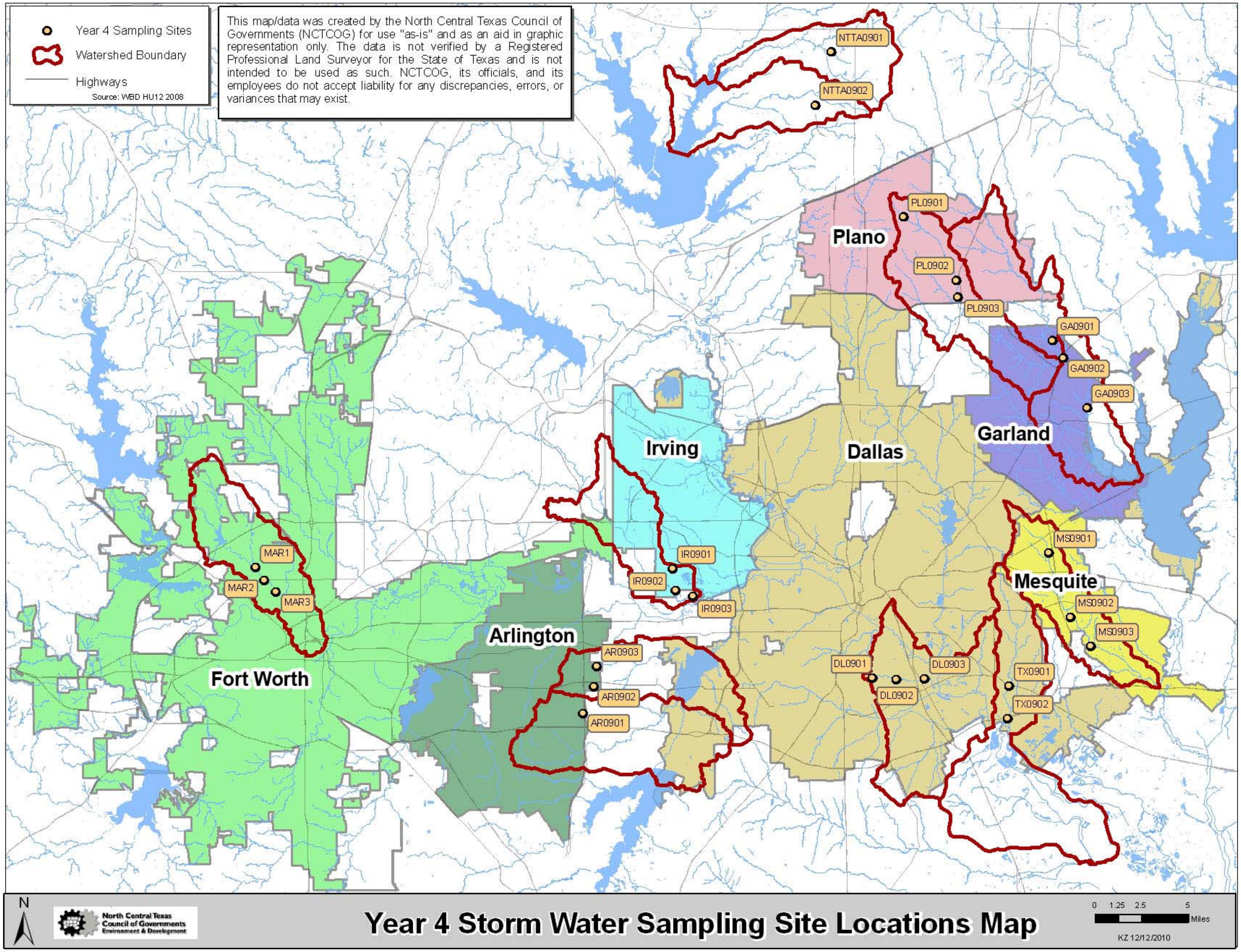

Figure 4-3: Year 4 Storm Water Sampling Site Locations Map

Table 4-6: Year 4 Storm Water Sampling Site Locations

JURISDICTION / WATERSHED	STATION ID	LOCATION	LATITUDE	LONGITUDE	# OF SAMPLES
ARLINGTON					
Mountain Creek	AR0901	North Fish Creek at SH-360	32°41' 19.0" N	97°03' 48.6" W	4
	AR0902	South Cottonwood Creek at Forum Road	32°42' 33.8" N	97°03' 13.0" W	4
	AR0903	North Cottonwood Creek at Timberlake Drive	32°43' 29.6" N	97°03' 01.8" W	4
DALLAS					
Southeast Dallas	DL0901	Honey Springs Branch Creek at Easter Avenue and E. Kiest Boulevard	32° 42' 46.24" N	96° 47' 46.13" W	4
	DL0902	Honey Springs Branch Creek at Bonnie View Road	32° 42' 40.06" N	96° 46' 26.94" W	4
	DL0903	Honey Springs Branch Creek at Carbondale Street	32° 42' 41.18" N	96° 44' 52.69" W	4
FORT WORTH					
Big Fossil Creek	BFC1	Big Fossil Creek at Pepperidge Lane	32 53' 07.79" N	97 20' 33.30" W	(2)
	BFC2	Big Fossil Creek at IH-35W	32° 51' 44.59" N	97° 18' 49.89" W	(2)
	BFC3	Big Fossil Creek at Beach Street	32° 51' 12.62" N	97° 17' 23.18" W	(2)
Marine Creek	MAR1	Marine Creek at Angle Avenue and West Long Avenue	32° 48' 19.65" N	97° 21' 51.89" W	1(2)
	MAR2	Marine Creek at Lincoln Park	32° 47' 43.27" N	97° 21' 25.31" W	1(2)
	MAR3	Marine Creek at Saunders Park	32° 47' 10.20" N	97° 20' 45.59" W	1(2)
Mary's Creek	MRY1	Mary's Creek at F.M. 2871	32° 42' 47.63" N	97° 29' 49.31" W	(2)
	MRY2	Mary's Creek at West Loop 820	32° 42' 41.79" N	97° 28' 38.67" W	(2)
	MRY3	Mary's Creek at Winscott Road	32° 41' 43.00" N	97° 26' 49.65" W	(2)
Sycamore Creek	SCY1	Sycamore Creek at IH-20 and IH-35W	32° 39' 53.58" N	97° 19' 16.06" W	(2)
	SCY2	Sycamore Creek near Redbud Trail	32 43' 18.37" N	97 17' 36.72" W	(2)
	SCY3	Sycamore Creek at Scott Avenue	32° 44' 51.30" N	97° 17' 41.47" W	(2)
GARLAND					
Rowlett Creek	GA0901	Rowlett Creek at Brand Road	32°58' 25.3" N	96°37' 26.5" W	4
	GA0902	Rowlett Creek at SH-78	32°57' 34.3" N	96°36' 53.2" W	4
	GA0903	Rowlett Creek at Centerville Road/Castle Drive	32°55' 14.4" N	96°35' 35.2" W	4
IRVING					
Bear Creek	IR0901	Bear Creek Tributary at Shady Grove Road	32°48' 01.4" N	96°58' 43.3" W	4
	IR0902	Bear Creek at Hunter Ferrell Road	32°47' 00.2" N	96°58' 35.0" W	4
	IR0903	Bear Creek at MacArthur Boulevard	32°46' 42.6" N	96°57' 37.8" W	4
MESQUITE					
South Mesquite Creek	MS0901	South Mesquite Creek at Mesquite Drive	32°48' 28.9" N	96°37' 51.5" W	4
	MS0902	South Mesquite Creek at New Market Road	32°45' 23.1" N	96°36' 43.0" W	4
	MS0903	South Mesquite Creek at Pioneer Road	32°44' 05.2" N	96°35' 37.2" W	4
PLANO					
Spring Creek	PL0901	Spring Creek at Legacy Drive	33°0' 31.7" N	96°42' 40.5" W	4
	PL0902	Spring Creek at 16th Street	33°1' 16.9" N	96°42' 44.6" W	4
	PL0903	Spring Creek at Central Expressway	33°4' 19.9" N	96°45' 37.5" W	4
N.TX TOLLWAY AUTHORITY					
Panther Creek/Cottonwood Branch	NTTA0901	Panther Creek Tributary at Dallas North Tollway	33°12' 06.8" N	96°49' 30.2" W	4
	NTTA0902	Cottonwood Branch Tributary at Dallas North Tollway	33°9' 37.1" N	96°50' 25.9" W	4
TXDOT-DALLAS					
Prairie Creek	TX0901	Prairie Creek and US-175	32°42' 17.5" N	96°40' 11.2" W	4
	TX0902	Prairie Creek and IH-20	32°40' 46.1" N	96°40' 18.5" W	4

Note: Numbers in parentheses reflect biomonitoring samples.

5.0 MONITORING ACTIVITIES

This section summarizes the monitoring activities for each year. Details of the individual monitoring results (e.g., laboratory data and field summaries) can be found in the annual reports for each respective year (NCTCOG, 2008, 2009 and 2010).

5.1 YEAR 2 MONITORING ACTIVITIES

In Year 2 (January 1 through December 31, 2007), all sites received qualifying rain events and were successfully monitored and analyzed. With the exception of additional maintenance due to flooding and vandalism, there were no issues encountered.

5.2 YEAR 3 MONITORING ACTIVITIES

In Year 3 (January 1 through December 31, 2008), all sites received qualifying rain events and were successfully monitored and analyzed. The following were exceptions to the year's monitoring:

- In 2008, the TCEQ announced that after July 1, 2008, the agency would only accept data from laboratories with National Environmental Laboratory Accreditation Conference (NELAC) certification. The FSO's laboratory, TTI Laboratories in Arlington, Texas, promptly submitted their application. Due to a backlog of applicants with the TCEQ, they were unable to receive certification by July 1, 2008. Samples collected from July 1 through October 15 (the date TTI received certification) were sent to NELAC-certified labs, including A&B Labs, LCRA Environmental Laboratory, Envirodyne, Oxidor and Talem, Inc. Certain samples for *E. coli* and total coliforms were sent to the NELAC-certified labs and did not make the Quality Assurance Project Plan 8-hour holding time; however, they were within the TCEQ's 24-hour holding time limit.

- The October 6, 2008, IR0803 sample was analyzed and had an immeasurable amount of bacteria (*E. coli*). Since no numeric value was assigned, the FSO collected an additional grab sample on November 11, 2008, at this location. The other grab and composite samples were collected successfully during the October 6, 2008 event, so no other parameters were collected.

- On March 3, 2008, the DL0802 sample collected was unable to be analyzed for *E. coli* and total coliforms due to a laboratory accident. Both were resampled on April 18, 2008. The total coliforms results for the sample collected on April 18, 2008 were originally reported as TNTC (too numerous to count), but the City of Dallas later confirmed that the result was greater than 20,000 cfu.

5.3 YEAR 4 MONITORING ACTIVITIES

In Year 4 (January 1 through December 31, 2009), all sites received qualifying rain events and were successfully monitored and analyzed. The following are issues and resolutions to specific events:

- The GA0902 site experienced severe vandalism during 2009. Garland and the FSO considered moving the site to a different location; however, a suitable alternative could not be located. Local law enforcement increased their presence at this area and equipment was promptly removed from the site after the quarterly sampling was complete. Samples were successfully collected from the site for all four quarters.

- During the first quarter of Year 4, the MS0901 site received a qualifying event. The FSO recorded a field pH level of 10.3 standard units (su) at this site. The FSO notified the City of Mesquite, who immediately began their investigation upstream of the 0901 site. The high pH was tracked to a commercial center parking lot where they found concrete road base materials scattered across the ground. Further investigation revealed that pools of water in the parking lot contained pH levels of 10.1. This evidence suggested that the concrete road base materials and the parking lot were the source of the high pH. The responsible party was instructed by the City of Mesquite to begin mitigation procedures at once.

6.0 STATISTICAL ANALYSIS

Statistical analysis of the results, including summary statistics, box-whisker plots and grouped statistical comparisons, are presented in this section. SYSTAT, Version 12 (Systat Software, Inc., San Jose, California, Copyright 2007) was used by PBS&J to perform the statistical analysis.

Diazinon and total cadmium were not included in the analyses because the parameters were not detected in 75 percent or greater of samples. For all other parameters, results reported from the lab as Undetected were included in the analyses using half of the lower detection limit. Bacteria sample results reported greater than (>) the upper detection limit were also included in the analyses as equal to the upper detection limit.

6.1 SUMMARY STATISTICS

Summary statistics are presented in Table 1 of Appendix E and are organized by sampling entity and watershed and include the number of samples, minimum value, maximum value, median, arithmetic mean, geometric mean, standard deviation and coefficient of variation for each parameter. See the annual monitoring reports for summary statistics by sampling station (NCTCOG, 2008, 2009 and 2010).

6.2 OUTLIER ANALYSIS

Outliers were identified as points that are more than three times the 75th percentile or less than three times the 25th percentile in accordance with Tukey, 1977.

Two outlier analyses were conducted. The first outlier analysis was conducted on all pooled data to identify suspected erroneous values that should be removed from the statistical analysis. This first outlier analysis revealed the outliers shown in Table 6-1, which were subsequently not included in the analyses presented in Sections 6.3 through 6.9. A field pH value was identified as an outlier through the method described above, but was not removed from the analysis because it was verified in the field by a second instrument. The second outlier analysis was conducted through box-whisker plotting, described in Section 6.3. These plots identify additional outliers among the smaller groupings of data for visual purposes only. These plotted outliers were included in subsequent statistical analyses.

Table 6-1: Outliers Removed from Statistical Analyses

Parameter	Date of Collection	Location	Value
TDS	8/17/07	South Mesquite Creek	20,300 mg/L
Oil and Grease	2/5/08	Upper Rowlett Creek	623 mg/L
Oil and Grease	1/25/08	Spring Creek	516 mg/L
Oil and Grease	2/5/08	Spring Creek	316 mg/L
Oil and Grease	2/5/08	Middle White Rock Creek	266 mg/L
Oil and Grease	4/4/08	Johnson Creek	263 mg/L

6.3 BOX-WHISKER PLOTS

Box-whisker plots were created by sorting the data by parameter, watershed and entity in order to summarize the median, upper and lower quartiles and the minimum and maximum data values. Figure 6-1 demonstrates the statistics shown by the box-whisker plot. The boxes represent the middle 50 percent of the data drawn between the lower and upper quartiles. The center of the notch within each box represents the median value. The notches represent the upper and lower 95 percent confidence interval. The whiskers are vertical lines drawn from the top and bottom of the boxes to the nearest data point that is less than 1.5 times from the 25th and 75th percentiles. These data points are represented by horizontal dashes (┴ or ┬) at the top or bottom of the line.

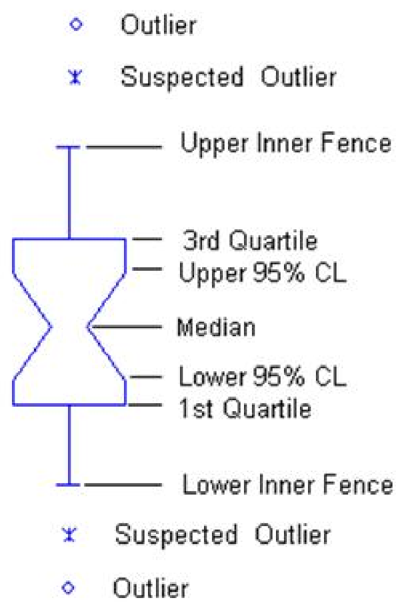

Figure 6-1: Box-Whisker Plot Legend

6.4 DATA TRANSFORMATION

Prior to the statistical analyses presented in Sections 6.5 through 6.9, the data were natural logarithm (LN) transformed based upon the observation of storm water quality parameters to follow a log-normal distribution as evidenced by the Results of the Nationwide Urban Runoff Program Final Report (EPA, 1983), analyses of the National Stormwater Quality Database (Maestre, et al, 2005), analyses of the International Stormwater Best Management Practice (BMP) Database (ASCE and EPA, 2000) and by the Final Summary Report Storm Water Discharge Characterization FY92 and FY93 (CDM, 1994).

6.5 STATISTICAL COMPARISONS

The data were grouped into various subgroups in order to conduct the statistical analyses discussed in Sections 6.6 through 6.9. When comparing two subgroups, the Student's t-Test of statistical significance was used to compare means of equal variances (statistically determined through two sample variance tests). When comparing more than two subgroups, the analysis of variance (ANOVA) test of statistical significance was used to compare the means of equal variance (statistically determined through the Levene's test). When the equal variance assumptions were not met, the medians from each station were compared using the non-parametric Kruskal-Wallis test for two or more subgroups.

The statistical significance tests identified differences among the subgroup means or medians at a confidence level of 95 percent. The probability or P values are reported in Sections 6.6 through 6.9. If the P value was less than 0.05, then there was a statistically-significant difference between the groups. Additional Tukey's and Bonferroni post-hoc tests were conducted to verify the significantly different stations within each watershed in cases with ANOVA P values less than 0.05.

The raw data, including laboratory results, storm data and sample collection date, are available for the Cities of Arlington, Dallas, Fort Worth, Garland, Irving, Mesquite and Plano, and for NTTA and TxDOT in the annual monitoring reports (NCTCOG, 2008, 2009 and 2010).

6.6 COMPARISON OF NCTCOG WATERSHED STATIONS

Stations were statistically compared to each other within each watershed to determine if there was a statistically-significant difference among the upstream, midstream and downstream stations. The stations with statistically significant P values ($p<0.05$) are presented in Table 6-2 and are discussed further in Section 7.0.

Table 6-2: Statistically-Significant Differences among Stations

Watershed	Parameter	Test	P Value
Dallas East Bank	BOD, 5-day	ANOVA/Student’s t-Test	0.014
Southeast Dallas	Total Chromium	ANOVA/Student’s t-Test	0.007
Dallas West Bank	Total Lead	Kruskal-Wallis	0.036
Cottonwood Branch (Irving)	TSS	ANOVA/Student’s t-Test	0.001
Delaware Creek (Irving)	Total Zinc	ANOVA/Student’s t-Test	0.030
Big Bear Creek (Irving)	Laboratory pH	ANOVA/Student’s t-Test	0.001
	Total Phosphorus	ANOVA/Student’s t-Test	0.030

6.7 SEASONAL VARIABILITY ANALYSIS

The seasonal variability of data collected for each entity and for all entities grouped together was statistically compared by grouping the data by monitoring quarter and determining if there was a statistically-significant difference between the quarters. Monitoring quarters consisted of January through March, April through June, July through September and October through December. One sample was collected at each station during each quarter. The locations (by entity) with statistically-significant P values ($p<0.05$) among seasons are presented in Table 6-3 and are discussed further in Section 7.0.

6.8 ANTECEDENT DRY PERIOD ANALYSIS

The variability due to the length of the antecedent dry period was statistically compared by grouping the data into short (>72 hours and <168 hours) and long (>168 hours) antecedent dry periods to determine if there was a statistically-significant difference among the means of these groups for each entity and for all entities grouped together. The 72 hour timeframe was selected as the lowest antecedent dry period because samples were not allowed to be collected from shorter antecedent dry periods under the permit requirements. The 168 hour timeframe was selected as the cutoff for the long antecedent dry period group because at 168 hours, a pollutant build-up time of one week has occurred. The locations (by entity) with statistically-significant P values ($p<0.05$) among antecedent dry periods are presented in Table 6-4 and are discussed further in Section 7.0.

Table 6-3: Statistically-Significant Differences among Seasons

Entity	Parameter	Test	P Value
Arlington	Total Arsenic	ANOVA	0.010
	E. coli	ANOVA	0.003
	Laboratory pH	ANOVA	0.000
	Total coliforms	ANOVA	0.002
	Total Zinz	Kruskal-Wallis	0.031
Dallas	Field pH	ANOVA	0.034
Fort Worth	Total Arsenic	Kruskal-Wallis	0.018
	COD	ANOVA	0.041
	Total Chromium	Kruskal-Wallis	0.015
	Total Lead	Kruskal-Wallis	0.015
	Oil and Grease	ANOVA	0.020
	Total Phosphorus	Kruskal-Wallis	0.030
Garland	Total Arsenic	ANOVA	0.014
	E. coli	Kruskal-Wallis	0.002
	Laboratory pH	ANOVA	0.031
	Total Coliforms	ANOVA	0.000
	TSS	ANOVA	0.004
Irving	Dissolved Phosphorus	Kruskal-Wallis	0.039
	Total Coliforms	ANOVA	0.041
	TDS	Kruskal-Wallis	0.049
Mesquite	COD	Kruskal-Wallis	0.015
	Laboratory pH	ANOVA	0.001
NTTA	Total Arsenic	ANOVA	0.040
	Total Coliforms	ANOVA	0.008
Plano	*E. coli*	Kruskal-Wallis	0.000
	Total Nitrogen	Kruskal-Wallis	0.005
	Dissolved Phosphorus	Kruskal-Wallis	0.042
	Total Phosphorus	ANOVA	0.023
	Total Coliforms	ANOVA	0.000
	TSS	ANOVA	0.019
TxDOT	Laboratory pH	ANOVA	0.006
	Total Coliforms	ANOVA	0.033
	TSS	ANOVA	0.026
All	Total Arsenic	ANOVA	0.000
	COD	Kruskal-Wallis	0.001
	E. coli	Kruskal-Wallis	0.000
	Laboratory pH	Kruskal-Wallis	0.000
	Total Lead	ANOVA	0.043
	Total Nitrogen	Kruskal-Wallis	0.003
	Dissolved Phosphorus	ANOVA	0.002
	Total Coliforms	ANOVA	0.000

Table 6-4: Statistically-Significant Differences among Antecedent Dry Periods

Entity	Parameter	Test	P Value
Arlington	Total Chromium	Student's t-Test	0.003
	Field pH	Student's t-Test	0.034
	Oil and Grease	Student's t-Test	0.043
	TDS	Student's t-Test	0.044
Dallas	Total Arsenic	Student's t-Test	0.032
	E. coli	Student's t-Test	0.005
	Field pH	Student's t-Test	0.002
	Total Phosphorus	Student's t-Test	0.043
	Total Coliforms	Student's t-Test	0.002
Garland	Total Chromium	Student's t-Test	0.006
	Dissolved Phosphorus	Kruskal-Wallis	0.007
Irving	Total Chromium	Student's t-Test	0.041
	Total Copper	Kruskal-Wallis	0.023
	Total Nitrogen	Kruskal-Wallis	0.028
Mesquite	Total Zinc	Kruskal-Wallis	0.009
Plano	TDS	Student's t-Test	0.019
TxDOT	Total Arsenic	Student's t-Test	0.018
	Total Phosphorus	Student's t-Test	0.006
All	COD	Kruskal-Wallis	0.014
	Total Chromium	Student's t-Test	0.001
	Total Nitrogen	Student's t-Test	0.003
	Dissolved Phosphorus	Student's t-Test	0.019

Fort Worth: No variation for the parameters between antecedent dry period groups

7.0 DISCUSSION OF RESULTS

This section presents the results of the statistical analyses described in Section 6.0. Natural variations in storm water quality at each sampling location require large numbers of samples in order to confidently identify statistically-significant results and to provide the adequate power for the statistical tests. Although a large number of data were available overall, the data were divided into various subcategories for the analyses, resulting in fewer observations than desired. The primary goal of the analyses was to identify important factors determining in-stream storm water quality in the Dallas-Fort Worth Metroplex. The factors that were focused on were in-stream processes (sampling station), season, antecedent dry period and storm size.

An assumption was made that the statistically-significant differences identified in Tables 6-2, 6-3 and 6-4 by monitoring entity follow the same general trends as those discussed below for the regional dataset as they are subsets of the dataset. In some cases, statistical differences were detected for one or more entities for various parameters but were not detected at the regional scale. These are likely the result of the smaller datasets associated with each entity and the number of comparisons conducted.

7.1 BOX-WHISKER PLOTS

The box-whisker plots displayed the observed concentrations for each parameter by sampling station, watershed and entity, and are presented in Appendices F and G in PBS&J's report (2010) and are not repeated here. The box-whisker plots allowed visual inspection for differences between the groupings and provided guidance for the statistical analyses described below. The box-whisker plots of the data grouped by watershed show that all watersheds sampled have relatively consistent concentrations when compared to each other. The trends between sampling stations can also be observed in the box-whisker plots for the respective parameter, entity and watershed. The box-whisker plots of the data grouped by sampling station display a general tendency of decreasing concentrations from upstream to downstream sites. This was expected due to the dilution of the concentrations as the volume of runoff increased from upstream to downstream.

7.2 COMPARISON OF NCTCOG WATERSHED STATIONS

Due to the number of statistical comparisons required between stations for each watershed and the small amount of samples collected per station (generally four), the sample size was insufficient to draw firm conclusions regarding the differences in mean concentrations among sampling stations.

Table 7-1 identifies the detected differences between stations and whether the mean concentration increased or decreased between the stations listed. The "X" in the table indicates that there was a statistically-significant difference found between the items noted in the corresponding column. There were six instances of increasing concentration from an upstream position to a downstream position and eight instances of decreasing concentration from an upstream position to a downstream position. This finding indicates that, as stated above, a firm conclusion regarding the effect that in-stream processes have on concentrations cannot be made with the current dataset. The detailed statistical tests and results are presented in Appendix L in PBS&J's report (2010).

Table 7-1: Statistically-Significant Differences between Stations by Watershed and Parameter

Parameter	Watershed	Stations (Upstream to Downstream)	Upstream/ Midstream	Upstream/ Downstream	Midstream/ Downstream	Change Between Stations
BOD	Dallas East Bank	DL 0701a DL 0701b DL 0701c				*
	South Mesquite Creek	MS 0701 MS 0901 MS 0702 MS 0902 MS 0703 MS 0903		X	X	Decrease
Total Chromium	Southeast Dallas	DL 0901 DL 0902 DL 0903	X	X		Increase
Laboratory pH	Big Bear Creek	IR 0901 IR 0902 IR 0903	X	X		Increase
Total Lead	Dallas West Bank	DL 0801 DL 0802 DL 0803	X	X		Decrease
	Prairie Creek	TX 0901 TX 0902		X		Increase
Total Phosphorus	Big Bear Creek	IR 0901 IR 0902 IR 0903	X			Decrease
TSS	Cottonwood Branch	IR 0701 IR 0702 IR 0703		X	X	Decrease
Total Zinc	Delaware Creek	IR 0801 IR 0802 IR 0803			X	Decrease
	Upper Rowlett Creek	PL 0801 PL 0802 PL 0803	X			Increase

*The sampling sites were located on independent tributaries and could not be classified into upstream, midstream and downstream stations. There was a statistically-significant decrease between DL 0701b and both DL 0701a and DL 0703c.

7.3 SEASONAL VARIABILITY ANALYSIS

The data were evaluated by monitoring entity and also combined into a regional dataset to identify statistically-significant differences between quarters (Table 6-3). Table 7-2 identifies the statistically-significant differences between quarters for the combined analysis (regional results) and whether the mean concentration increased or decreased between the quarters listed. The detailed summary statistics and statistical tests and results are presented in Appendices I and M in PBS&J's report (2010).

Table 7-2: Statistically-Significant Differences between Quarters by Constituent

Parameter	Quarter 1/ Quarter 2	Quarter 1/ Quarter 3	Quarter 1/ Quarter 4	Quarter 2/ Quarter 3	Quarter 2/ Quarter 4	Quarter 3/ Quarter 4
Total Arsenic		Increase		Increase		Decrease
COD		Increase	Increase			
E. coli	Increase	Increase	Increase	Increase		Decrease
Laboratory pH	Decrease	Decrease	Decrease	Increase	Increase	
Total Lead					Decrease	
Total Nitrogen	Decrease	Decrease	Decrease			
Dissolved Phosphorus	Increase	Increase				
Total Coliforms	Increase	Increase	Increase			Increase

Generally, the parameters exhibited an increasing trend from the first quarter to the third quarter, except for laboratory pH and total nitrogen, which exhibited a decreasing trend. The most statistically-significant differences occurred between the first and third quarters, the coldest months and the warmest months, respectively. These results suggest that water quality may be adversely impacted during the warm months as expected. The decrease in in-stream total nitrogen concentration from the cold months to the warm months potentially could be associated with the decreased rainfall observed during the monitoring period, which may have affected nitrogen application to yards and open spaces. The decrease in laboratory pH may be an indication of seasonal changes; however, since a similar trend was not detected in field pH, a firm conclusion cannot be made regarding this parameter.

7.4 ANTECEDENT DRY PERIOD ANALYSIS

The data were evaluated by monitoring entity and also combined into a regional dataset to identify statistically-significant differences between antecedent dry periods (Table 6-4). Table 7-3 identifies the statistically-significant differences between antecedent dry period groups for the combined analysis (regional results) and whether the mean concentration increased or decreased between the groups. There were nearly two times more storm events that occurred with a long antecedent dry period than with a short antecedent dry period. The detailed summary statistics and statistical tests and results are presented in Appendices J and N in PBS&J's report (2010).

Table 7-3: Statistically-Significant Differences in Antecedent Dry Period Groups by Parameter

Parameter	Change between Short and Long Antecedent Dry Period Groups
COD	Increase
Total Chromium	Decrease
Total Nitrogen	Decrease
Dissolved Phosphorus	Increase

Contrary to expected findings, the results indicated that for the majority of entities and parameters, antecedent dry period had little influence on the in-stream water quality, and that for total chromium and total nitrogen there was a decrease in the in-stream concentration for long antecedent dry periods as compared to short antecedent dry periods. Typical storm water quality theory suggests that long antecedent dry periods allow more pollutants to build up in the watershed and contributes to higher pollutant loadings during the following storm event. However, rainfall patterns during the sampling periods were uncharacteristic of normal years. According to the National Weather Service, the Dallas/Fort Worth mean annual precipitation is 33 inches. During the 2007, 2008 and 2009 monitoring periods, the area received 50, 27 and 41 inches of rainfall, respectively.

Due to the unbalanced sample size of the antecedent dry-period groups, the uncharacteristic rainfall patterns during the sample period, and the relatively small time span and sample size, a definite conclusion could not be made regarding the effect that antecedent dry period had on in-stream pollutant concentrations.

7.5 STORM SIZE ANALYSIS

The data were evaluated by monitoring entity and also combined into a regional dataset to identify statistically-significant differences between storm sizes (Table 6-5). Table 7-4 identifies the statistically-significant differences between mean concentrations associated with storm sizes for the combined analysis (regional results) and whether the mean concentration increased or decreased between the groups. The detailed summary statistics and statistical tests and results are presented in Appendices K and O in PBS&J's report (2010).

As expected, larger storms generally contributed to higher in-stream concentrations, except for field pH, total nitrogen and total dissolved solids, which exhibited a decrease from small to large storms. The decrease in total dissolved solids is expected as this indicates that there is a limited supply of dissolved solids in the watershed and that during larger storms the supply is exhausted and diluted. The decrease in field pH could be a result of slightly acidic soil addition to the stream or from a decreased pH of the rain water itself. The range of storms sampled was not large enough to make firm conclusions regarding the relationship between storm size and in-stream pollutant levels.

Table 7-4: Statistically-Significant Differences in Storm Size Group by Parameter

Parameter	Change between Small and Large Storm Size Groups
COD	Increase
Field pH	Decrease
Total Lead	Increase
Total Nitrogen	Decrease
Dissolved Phosphorus	Increase
Total Phosphorus	Increase
TDS	Decrease
TSS	Increase

7.6 COMPARISON TO OTHER DATA SOURCES

As of this writing, the EPA and the State of Texas have not yet promulgated wet-weather in-stream water quality standards that would be appropriate to use as benchmarks or comparison values for the results of this study. At this time, because no such benchmarks or comparison values exist, the monitoring in this study did not reveal any pollutants of significant concern. Because of the lack of wet-weather benchmarks or comparison values, the NCTCOG in-stream monitoring data were statistically compared to the National Stormwater Quality Database (NSQD), NCTCOG outfall monitoring data and Clean Rivers Program (CRP) data.

The NSQD is a collection of NPDES storm water outfall data assembled from permit holders by the University of Alabama and the Center for Watershed Protection. The NSQD data represents a 10-year monitoring period from more than 200 municipalities across the country (Maestre and Pitt, 2005). The NSQD data were collected from storm water discharge points by regulated large and medium MS4s during wet weather conditions.

The NCTCOG outfall monitoring data were collected by the USGS from 26 storm water outfalls sampled over seven storm events. It is independent of the NCTCOG in-stream data discussed in the previous sections. The NCTCOG outfall monitoring data were a subset of the NSQD data and were thus removed from that dataset.

Lastly, the CRP data were assembled by the Trinity River Authority and the TCEQ through state funds for in-stream water quality monitoring, evaluation and decision-making. The CRP data represent ambient, in-stream concentrations during mostly dry conditions.

For the comparisons discussed below, outliers as defined in Section 6.2 were removed from all datasets. Outliers identified through the outlier analyses are presented in Appendix P of PBS&J's report (2010). In addition, all zero values were removed from the dataset.

Box-whisker plots for each parameter and dataset are presented in Appendix Q of PBS&J's report (2010). Field pH and laboratory pH were combined into a single group for the NCTCOG in-stream and CRP datasets.

Each dataset was statistically compared to the NCTCOG in-stream data to determine if there were statistically-significant differences. The data were compared using the non-parametric Kruskal-Wallis test (comparison of medians) and were compared both including undetected lab results (at half of the lower detection limit) and excluding undetected results. The test identified statistically-significant differences at a confidence level of 95 percent. Basic summary statistics for the datasets both including undetected lab results and excluding undetected results are provided in Table 7-5. The detailed summary statistics and statistical tests and results are presented in Appendices R and S in PBS&J's report (2010).

Table 7-6 identifies the statistically-significant differences between NCTCOG in-stream data (NCTCOG 2) and CRP, NCTCOG outfall data (NCTCOG 1) and NSQD data for each parameter. The table identifies whether the median of the listed dataset was statistically higher or lower than the NCTCOG in-stream data.

The first column of the table compares the NCTCOG in-stream data to the CRP data, which represents data collected in-stream during dry weather. Compared to the CRP data, total arsenic, BOD (5-day), COD, total copper, *E. coli*, total nitrogen, dissolved phosphorus, total phosphorus, total coliforms, TDS, TSS and total zinc were found to be at slightly elevated concentrations within the NCTCOG in-stream dataset. Total chromium, total lead, oil and grease and pH exhibited the opposite with values lower than the in-stream data. The results show that the in-stream concentration of most pollutants is generally higher than samples collected in-stream during dry weather. Also, dry weather samples are typically collected from the surface, while the storm water in-stream samples were collected from the lower water column.

The second and third columns of Table 7-6 compare the NCTCOG in-stream data to the NCTCOG NSQD outfall data, which represent data collected during wet weather from storm water outfalls. Total arsenic, total copper, *E. coli*, total nitrogen, pH, total coliforms, TDS and TSS were found to be at slightly elevated concentrations within the NCTCOG in-stream dataset. BOD (5-day), COD, total chromium, total lead, oil and grease, dissolved phosphorus, total phosphorus and total zinc were found to be generally at concentrations lower than the comparison outfall datasets (NSQD and NCTCOG outfall data). The results indicate that for some parameters the in-stream concentration of pollutants may be higher than for samples collected from storm water outfalls but that for other parameters the in-stream concentration may be lower.

As mentioned above, the EPA and the State of Texas have not yet promulgated wet-weather in-stream water quality standards that would be appropriate to use as benchmarks or comparison values for the results of this study. If such standards did exist, exceedences observed in this monitoring effort might require those pollutants to be considered pollutants of concern. At this time, because no such benchmarks or comparison values exist, the monitoring in this study did not reveal any pollutants of significant concern.

In addition to the comparative approach used to determine pollutants of concern discussed above, MS4 managers are expected to consider impairment pollutants (those pollutants contributing to a 303(d) listing) as pollutants of concern in the implementation of their storm water management program.

Table 7-5: Summary Statistics for All Datasets Compared

Parameter	Total Arsenic (mg/L)				BOD 5-Day (mg/L)				COD (mg/L)			
Dataset	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD
No. of Samples	903	156	285	1384	5004	172	285	4384	1416	180	285	4662
Median with Undetects	0.002	0.002	0.003	0.002	2.00	7.20	6.49	8.60	24.00	64.00	32.10	53.00
No. of Samples	628	156	137	487	3581	172	243	4125	1336	177	264	4624
Median without Undetects	0.002	0.002	0.005	0.003	2.90	7.20	8.03	9.00	25.00	64.00	37.05	53.35
Parameter	**Total Chromium (mg/L)**				**Total Copper (mg/L)**				***E. coli* (colonies/100 mL)**			
Dataset	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD
No. of Samples	1507	161	285	1289	1668	169	285	4756	6482	--	281	160
Median with Undetects	0.005	0.006	0.004	0.005	0.005	0.009	0.023	0.012	80	--	1370	1000
No. of Samples	791	161	149	810	1163	168	224	4157	6185	--	248	149
Median without Undetects	0.008	0.006	0.006	0.007	0.007	0.009	0.027	0.016	88	--	1850	1200
Parameter	**pH (su)**				**Total Lead (mg/L)**				**Total Nitrogen (mg/L)**			
Dataset	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD
No. of Samples	54195	351	499	1957	1712	178	285	4194	262	182	282	681
Median with Undetects	8.00	7.60	7.70	7.36	0.010	0.021	0.006	0.010	1.90	1.46	2.01	1.61
No. of Samples	54195	351	499	1957	938	176	161	3328	259	182	246	643
Median without Undetects	8.00	7.60	7.70	7.36	0.019	0.021	0.012	0.013	1.90	1.46	2.39	1.70
Parameter	**Oil and Grease (mg/L)**				**Dissolved Phosphorus (mg/L)**				**Total Phosphorus (mg/L)**			
Dataset	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD
No. of Samples	--	98	281	1845	2390	182	284	2587	12870	182	284	7004
Median with Undetects	--	2.00	1.27	3.00	0.020	0.145	0.050	0.103	0.090	0.250	0.150	0.240
No. of Samples	--	98	85	1206	1709	181	147	2147	12052	182	211	6835
Median without Undetects	--	2.00	3.77	4.89	0.031	0.150	0.110	0.130	0.098	0.250	0.220	0.240
Parameter	**Total Coliforms (colonies/100 mL)**				**TDS (mg/L)**				**TSS (mg/L)**			
Dataset	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD	CRP	NCTCOG 1	NCTCOG 2	NSQD
No. of Samples	--	--	281	174	311	168	284	3146	11413	166	285	6354
Median with Undetects	--	--	75000	6350	220.0	60.0	290.0	82.0	14.2	79.0	78.0	60.0
No. of Samples	--	--	266	161	311	168	284	3131	10828	166	274	6309
Median without Undetects	--	--	89550	9000	220.0	60.0	290.0	82.0	15.5	79.0	83.6	60.0
Parameter	**Total Zinc (mg/L)**											
Dataset	CRP	NCTCOG 1	NCTCOG 2	NSQD								
No. of Samples	1642	178	285	4692								
Median with Undetects	0.021	0.090	0.043	0.080								
No. of Samples	1425	178	263	4557								
Median without Undetects	0.024	0.090	0.047	0.083								

Table 7-6: Statistically-Significant Differences of Medians between NCTCOG In-Stream Data and Other Datasets

Parameter	CRP		NCTCOG Outfall Data		NSQD	
	With Non-Detects	Without Non-Detects	With Non-Detects	Without Non-Detects	With Non-Detects	Without Non-Detects
Total Arsenic	Lower	Lower	Same	Lower	Lower	Lower
BOD (5-Day)	Lower	Lower	Same	Lower	Higher	Higher
COD	Lower	Lower	Higher	Higher	Higher	Higher
Total Chromium	Higher	Higher	Higher	Same	Higher	Same
Copper, Total	Lower	Lower	Lower	Lower	Lower	Lower
E. coli	Lower	Lower	N/A	N/A	Same	Lower
pH	Higher	Higher	Same	Same	Lower	Lower
Total Lead	Same	Higher	Higher	Higher	Higher	Same
Total Nitrogen	Same	Lower	Lower	Lower	Lower	Lower
Oil and Grease	N/A	N/A	Higher	Lower	Higher	Same
Dissolved Phosphorus	Lower	Lower	Higher	Same	Higher	Same
Total Phosphorus	Same	Lower	Higher	Higher	Higher	Higher
Total Coliforms	N/A	N/A	N/A	N/A	Lower	Lower
TDS	Same	Same	Lower	Lower	Lower	Lower
TSS	Lower	Lower	Same	Same	Lower	Lower
Total Zinc	Lower	Lower	Higher	Higher	Higher	Higher

Note: "Higher" or "Lower" indicate statistically significant higher or lower median concentrations than the NCTCOG in-stream levels. Half of the detection limit was used for the analyses conducted using non-detected results. "Same" indicates median concentrations in which there was no statistically significant difference detected. "N/A" indicates parameters that were not collected within the dataset listed.

8.0 CONCLUSIONS

8.1 SUMMARY OF DATA

Monitoring activities were conducted during Years 2 through 4 in various receiving streams in the North Central Texas region during wet weather conditions. The monitoring activities resulted in the collection of samples from 285 storm events (total), which were subsequently analyzed for total arsenic, BOD (5-day), COD, total copper, *E. coli*, field pH, laboratory pH, total lead, total nitrogen, oil and grease, dissolved phosphorus, total phosphorus, total coliforms, TDS, TSS and total zinc.

8.1.1 Baseline Data

The NCTCOG in-stream wet weather data is unique in that it is not of the traditional outfall monitoring for storm water permitting compliance. Since this is the first of its kind in the North Central Texas area, the data will serve as a baseline for future wet weather in-stream monitoring activities in the region.

8.1.2 Summary of Statistics

Summary statistics were computed for the data and an analysis was conducted to determine outlier values for each parameter, which were subsequently removed from the dataset. Box-whisker plots were created to graphically depict the data and aid in the interpretation of the results. Generated box-whisker plots depict outliers and suspected outliers calculated from the remaining dataset. The data were log-transformed and statistical tests were used to assess the impact of sampling location, season, antecedent dry period and storm size on pollutant concentrations. The statistical tests comparing results from different seasons, antecedent dry periods and storm sizes were conducted on monitoring data grouped by permittee and on all monitoring data grouped together by entity in a regional dataset.

The results of the statistical analyses examining variability of water column concentrations along each sampled stream reach and between watersheds showed that all watersheds sampled have relatively consistent pollutant concentrations when compared to each other and that water column concentrations generally decrease when moving from upstream sampling sites to downstream sampling sites.

The results of the statistical analyses examining concentration differences among seasons showed that water quality was generally worse during the warm months. This was expected since during higher temperatures bacteria are found at higher concentrations and quiescent settling occurs at a slower rate.

While traditional storm water quality science suggests that longer antecedent dry periods allow for more pollutant build-up to occur and tends to lead to higher pollutant concentrations during runoff events, results from this monitoring did not show any statistically-significant difference between long and short antecedent dry periods. Due to the large difference between the number of samples within the short antecedent dry period group and the long antecedent dry period group, the uncharacteristic rainfall patterns during the sample period, the relatively small time span of the monitoring period and the small number of sampling results, it was harder to detect a difference between concentrations obtained from storms with long or short antecedent dry periods.

Lastly, when examining storm size, larger storms generally produced higher in-stream concentrations for most parameters. The number and range of storm sizes sampled was small; therefore, more data are needed to positively identify statistical differences between larger and smaller storms.

8.1.3 Summary of Datum Comparisons

NCTCOG in-stream monitoring data were statistically compared to NSQD data (Maestre and Pitt, 2005), NCTCOG outfall monitoring data and the CRP data. The NSQD and NCTCOG data represent wet weather storm water outfall data, and the CRP data represents ambient, in-stream data collected during dry weather conditions.

The results of the comparison of NCTCOG in-stream data show that the in-stream concentration of most pollutants is generally higher than samples collected in-stream during dry weather. The results of the comparison of NCTCOG in-stream data with the NSQD and NCTCOG outfall data indicate that for some parameters, the in-stream concentration of pollutants may be higher than for samples collected from storm water outfalls; however, for other parameters the in-stream concentration may be lower.

8.2 ASSESSING BMP EFFECTIVENESS USING MONITORING RESULTS

Regional monitoring results obtained during the first permit term, coupled with narrative and descriptive information regarding the extent and type of storm water quality BMPs will serve as a baseline that can be used to evaluate the effectiveness of regional BMP implementation on in-stream water quality and health in the future.

For example, public educational efforts may be having a positive impact on turf grass management that may be seen in declining nutrient levels over time, as compared to baseline results. Bacteria levels may show declines in future years as a result of pet waste management efforts.

Going forward, it is recommended that BMP implementation efforts be documented during future monitoring periods. To reasonably assess the impact of BMP implementation on stream quality during wet weather, significant information on BMP implementation within monitored watersheds will need to be obtained and recorded. Information should include: the geographic scope of BMP implementation, the types of BMPs used, the number of BMPs implemented, the pollutants targeted for removal by deployed BMPs and the level of maintenance BMPs receive. This information should be obtained as frequently as warranted as storm water quality management programs may be altered to address total maximum daily load (TMDL) implementation and to implement changes to MS4 permits. At a minimum, BMP implementation efforts should be documented on a five-year cycle.

While monitoring of inflows and outflows at a particular structural BMP can help determine the technological capabilities of a particular structural approach, regional in-stream monitoring can help evaluate the effect of both non-structural and structural BMPs implemented across a watershed. Regional in-stream monitoring can help assess the benefits of illicit discharge detection and elimination programs, educational programs, street sweeping programs, construction site runoff control programs and similar efforts.

8.3 FUTURE MONITORING RECOMMENDATIONS

PBS&J recommends that NCTCOG continue the regional wet-weather in-stream water quality monitoring approach. The approach provides many benefits and allows MS4 operators to assess wet weather water quality in a holistic manner. The current approach leverages MS4 operator resources, coordinates monitoring efforts and builds on the baseline data obtained during the first cycle of regional monitoring. In continuing the regional watershed approach, the participants should consider the program recommendations discussed below.

8.3.1 Increase Number of Samples per Site

Currently, the entities are selecting up to three watersheds where monitoring occurs quarterly for one year. The sites are then rotated to a new watershed after every calendar year over a three-year monitoring period. This approach yielded four results per site during this five-year permit cycle. Four results per site limits the strength of statistical analyses and comparisons. In order to develop a more robust dataset to perform stronger statistical analyses, the entities will need to have more data. PBS&J recommends increasing the frequency of monitoring during each year or limiting the number of watersheds monitored during the permit term. If the entities limited the number of watersheds during the permit term, they may consider monitoring the same watershed for at least two years before moving to a new watershed. Monitoring the same watershed over more years in a permit term will provide a higher number of results more quickly than continuing to rotate through multiple watersheds over several permit terms.

8.3.2 Refine Sampling Site Selection Process

Sampling site selection process should be refined to address concerns expressed by the EPA and the TCEQ. These concerns stem from the need to restore impaired waters and to achieve the goals of the Clean Water Act. Sampling sites should also be selected to foster longer-term monitoring to allow for a larger number of samples to be obtained at each site. Site selection criteria that should be considered include the following:

- Locate sampling sites within impaired watersheds. This will help with assessing TMDL implementation and restoration efforts.

- Focus on measuring concentrations of pollutants causing watershed impairments. This will help with assessing TMDL implementation and restoration efforts. Coupled with flow measurements, it will help to assess achievement of waste load allocations (WLA).

- Locate sampling sites in locations that foster long-term deployment and that will minimize chances of vandalism. This will assist in deploying equipment for longer periods of time to allow collection of a higher number of samples at each site. During this monitoring term, there were several instances of vandalism and flooding of the equipment. These events lead to multiple equipment deployments and redeployments, repeated sampling efforts, increased maintenance costs and at times, the replacement of equipment. Vandalism and flooding events increase the cost of regional monitoring.

- Select sites that will allow for long-term flow monitoring or those that already have flow measurement gauge stations nearby. Flow data collected during the in-stream monitoring event are required to calculate pollutant loads, which is critical to assessing conformance with TMDL provisions and WLAs. Stream flow monitoring equipment might differ from those used in outfall monitoring and what was currently used in this program. Consideration and planning for developing flow monitoring sites will be necessary, but will allow for pollutant loads to be developed. In addition, consideration should be given to selecting sites near existing USGS gauging stations.

8.3.3 Conduct Rapid Bioassessments to augment Water Chemistry Monitoring

Although Dallas and Fort Worth are already performing rapid bioassessments, other entities may consider performing bioassessments in their respective watersheds as well. Rapid bioassessments are usually conducted in dry weather conditions and evaluate additional parameters (e.g., water chemistry, benthic and nekton populations, in-stream habitat, etc.) that the wet weather in-stream monitoring does not. The recent National Research Council (NRC) report Urban Stormwater Management in the United States (NRC, 2008) includes discussion of this concept and recommends the use of biological end points for storm water management programs and biological monitoring for assessing program progress. Chapter 3 of the NRC report provides a summary of biological responses to chemical, hydrologic, physical, biological and energy-related stressors arising from urbanization, along with a discussion of how biological monitoring can play a role in watershed management. The end of Chapter 3 recommends that storm water management approaches should include all stressors in an integrated manner, which can be accomplished through monitoring using Rapid Bioassessment Protocols.

8.3.4 Revise Monitored Pollutants

Diazinon was not detected in the first round of monitoring, suggesting that it could be omitted from future rounds. This is appropriate because diazinon has been banned and is no longer in use as a pesticide in the studied watersheds. Carbaryl could be added to replace diazinon as a pesticide surrogate. Carbaryl is a commonly-used pesticide in Texas (Merchant, 2007). Since diazinon and other pesticides are being phased out, the EPA believes that the use of carbaryl may increase. Carbaryl has been found in both agricultural and urban watersheds (EPA, 2007).

Cadmium was detected at very low levels and in less than 25 percent of the samples collected. PBS&J recommends dropping cadmium from the list of monitoring parameters.

9.0 PROPOSAL FOR THIRD PERMIT TERM

The proposal for a revised Regional Wet Weather Characterization Program to implement in the upcoming third permit term was submitted to the TCEQ in December 2010. This plan incorporated the majority of the consultant recommendations outlined in the prior section. A copy of the revised RWWCP proposal can be found in Appendix F of this report. The following is a synopsis of that plan.

The Regional Storm Water Monitoring Partners of North Central Texas (i.e. the Cities of Arlington, Dallas, Fort Worth, Garland, Irving, Mesquite and Plano, together with the North Texas Tollway Authority and TxDOT-Dallas District in cooperation with the North Central Texas Council of Governments) have agreed to continue their partnership and implement the revised RWWCP. The RWWCP partnership has allowed for: 1) more coordinated and comprehensive water quality sampling; 2) more sound and reliable data collection; 3) greater cost effectiveness; and 4) a truer assessment of regional impact on stream water quality.

The revised RWWCP resumes the in-stream watershed monitoring approach of the last permit term but will effectively sample the storm water quality from at least 50 percent of each jurisdictional area of the participating entities by the end of this next permit term. This extent of jurisdictional coverage will allow a reasonable assessment of jurisdictional watersheds while striving to achieve a balance among the various goals of obtaining valid scientific information, meeting permit compliance and addressing what is practicable for each entity. The plan seeks to obtain greater statistical robustness of the data by increasing the sampling period at each location to a minimum of two years. The primary goal of the RWWCP during this permit term will be to continue the assessment of urban impact on receiving stream water quality and to document any improvement presumably resulting from local BMP implementation. The data collected during this permit term will build upon the set of regional data needed from each site for meaningful trend analysis.

Other innovations to this revised plan include a more comprehensive biomonitoring component. Since assessing the impact of urban runoff on receiving stream quality is a primary focus of this program, assessing the biological integrity of the streams is fundamental. With this proposed plan, 24 watersheds will be chemically monitored and 12 watersheds will be bioassessed across the region, with substantial overlap of watersheds between the two sampling approaches.

Although most entities are chemically sampling one watershed in their jurisdiction for two consecutive years and then moving to a second watershed for another two years, there are a few exceptions to this standard pattern which can be found in the full proposal in Appendix F.

In summary:

- Each participant has selected watersheds to achieve greater than 50 percent coverage of their jurisdictional area.
- A total of 24 watersheds across the region will be chemically monitored while 12 watersheds will be bioassessed.
- To increase statistical robustness, most watersheds will be sampled for a minimum of two years.
- Most watersheds will be sampled quarterly; Fort Worth is putting a greater effort into the bioassessment sampling instead.
- The number of sites per watershed varies per entity based on local conditions.
- Arlington, Dallas, Garland, Irving, Mesquite, Plano, NTTA and TxDOT-Dallas will collect samples for the first four years of the five-year permit term.
- Fort Worth has elected to perform chemical monitoring for the entire five-year permit term.
- 17 chemical parameters will be analyzed in each storm event sample, including a new parameter, Carbaryl.
- Dallas, Fort Worth, Garland and Plano will also do biological assessments.

10.0 REFERENCES

ASCE and EPA. 2000. *Determining Urban Stormwater Best Management Practice (BMP) Removal Efficiencies. Task 3.4 – Final Data Exploration and Evaluation Report.* Urban Water Resources Research Council of American Society of Civil Engineers and Water Planning Division of U.S. Environmental Protection Agency, Washington, D.C. June 2000.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition*. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

CDM. 1994. *Final Summary Report Storm Water Discharge Characterization FY92 and FY 93*. Camp Dresser & McKee, Inc., Alan Plummer and Associates, Inc., and North Central Texas Council of Governments, March 1994.

EPA. 2007. *Reregistration Eligibility Decision (RED) for Carbaryl. Case No. 0080*. Environmental Protection Agency, Special Review and Reregistration Division, Washington, D.C. 2007.

EPA. 1983. *Results of the Nationwide Urban Runoff Program, Volume I Final Report.* U.S. Environmental Protection Agency, Water Planning Division, Washington, D.C. 1983.

Maestre, A., and R. Pitt. 2005. *The National Stormwater Quality Database, Version 1.1: A Compilation and Analysis of NPDES Stormwater Monitoring Information*. Center for Watershed Protection, Ellicott City, MA, September 2005.

Maestre, A., R. Pitt, S. R. Durrans, and S. Chakraborti. 2005. "Stormwater quality descriptions using the three parameter lognormal distribution." *Effective Modeling of Urban Water Systems*, Monograph 13 (edited by W. James, K. N. Irvine, E. A. McBean, and R. E. Pitt). CHI. Guelph, Ontario, pp. 247–274. 2005.

Merchant, 2007. *Quick Insecticide Reference Guide for Common Insect Pests of Lawns and Landscapes*. Michael Merchant, Ph.D. Texas AgriLIFE Extension, Texas A&M System. http://citybugs.tamu.edu/FastSheets/Ent-103O.html. September 2007.

NCTCOG. 2003. *Summary of the Dallas-Fort Worth Regional Monitoring Program. Letter to the Texas Commission on Environmental Quality dated January 30, 2003*. North Central Texas Council of Governments, 2003.

NCTCOG, 2007. *Regional Wet Weather Characterization Program of North Central Texas, Annual Monitoring Report – Year 1 – (January–December 2006)*. North Central Texas Council of Governments, February 2007.

NCTCOG. 2008. *Regional Wet Weather Characterization Program of North Central Texas, Annual Monitoring Report – Year 2 – (January–December 2007)*. North Central Texas Council of Governments, February 2008.

NCTCOG. 2009. *Regional Wet Weather Characterization Program of North Central Texas, Annual Monitoring Report – Year 3 – (January–December 2008)*. North Central Texas Council of Governments, February 2009.

NCTCOG. 2010. *Regional Wet Weather Characterization Program of North Central Texas Annual Monitoring Report Year 4 – (January through December 2009)*. North Central Texas Council of Governments, February 2010.

NRC, 2008. *Urban Stormwater Management in the United States*. National Research Council, October 2008.

PBS&J. 2007. *Regional Stormwater Monitoring Program: Monitoring Program and Quality Assurance Project Plan for Wet Weather Equipment Deployment and Sampling Program*. PBS&J. February 2007.

PBS&J. 2010. *Regional Storm Water Monitoring Program 2006-2010: Final Comprehensive Summary Report*. PBS&J. March 2010.

TCEQ, 2007. *Surface Water Quality Monitoring Procedures, Volume 2: Methods for Collecting and Analyzing Biological Assemblage and Habitat Data*. Texas Commission on Environmental Quality Surface Water Quality Monitoring Program. TCEQ RG-416. June 2007.

Tukey, J. W. 1977. *Exploratory Data Analysis*. Addison-Wesley Publishing Company, Reading, MA. 1977.