TOTAL MAXIMUM DAILY LOADS FOR PCBS IN SEGMENTS 0805, 0806, 0829, AND 0841 OF THE TRINITY RIVER

FINAL TECHNICAL REPORT

Prepared by:

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PREPARED IN COOPERATION WITH THE
Texas Commission on Environmental Quality AND
U.S. ENVIRONMENTAL PROTECTION AGENCY

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TCEQ

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ACRONYMS AND ABBREVIATIONS

°F	Degrees Fahrenheit
°C	Degrees Celsius
AU	Assessment Unit
BAF	Bioaccumulation Factor
BSAF	Biota-Sediment Accumulation Factor
CFR	Code Of Federal Regulations
CFS	Cubic Feet Per Second
CM	Centimeter
CMS	Cubic Meters Per Second
CN	Curve Number
DDE	4,4-Dichlorodiphenyldichloroethylene
FM	Farm To Market Road
G	Gram
GFF	Glass Fiber Filter
GIS	Geographic Information System
GUI	Graphical User Interface
GWLF	Generalized Watershed Loading Function
IH	Interstate Highway
KG	Kilogram
L	Liter
LA	Load Allocation
M^3	Cubic Meter
MG	Milligram
MGD	Million Gallons Per Day
MOS	Margin Of Safety
MS4	Municipal Separate Storm Sewer System
ng	Nanogram
NOAA	National Oceanic And Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NRCS	National Resources Conservation Service
PCB	Polychlorinated Biphenyl
PMF	Positive Matrix Factorization
SH	State Highway
STATSGO	State Soil Geographic Database
SWQS	Surface Water Quality Standards
TAC	Texas Administrative Code
TCEQ	Texas Commission On Environmental Quality
TMDL	Total Maximum Daily Load
TPDES	Texas Pollution Discharge Elimination System
TSS	Total Suspended Solids
µG	Microgram

USACE	U.S. Army Corps Of Engineers
USDA	U.S. Department Of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation
WLA	Wasteload Allocation
WQM	Water Quality Monitoring
WWTF	Wastewater Treatment Facility

SECTION 1
INTRODUCTION AND PROBLEM IDENTIFICATION

Section 303(d) of the federal Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. States must develop a total maximum daily load (TMDL) for each pollutant that contributes to the impairment of a listed water body. The Texas Commission on Environmental Quality (TCEQ) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is a budget—it determines the amount of a particular pollutant that a water body can receive and still meet its applicable water quality standards. TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load with units of mass per period of time, but may be expressed in other ways. TMDLs must also estimate how much the pollutant load must be reduced from current levels in order to achieve water quality standards.

The TMDL program is a major component of Texas' overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in, or bordering on, the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses—such as drinking water supply, recreation, support of aquatic life, or fishing—of impaired or threatened water bodies. This TMDL addresses impairments to the fish consumption use due to high levels of polychlorinated biphenyls (PCBs) in portions of the Trinity River system in north central Texas. The ultimate goal of these TMDLs is to reduce PCB levels in the Trinity River so that the fish consumption use is protected and the existing consumption advisory for the area can be lifted.

Enumeration and counting of TMDLs for tracking and reporting purposes considers each combination of one water body and one pollutant as one TMDL. This document discusses TMDL allocations for a set of 209 PCB congeners expressed as a single total PCB concentration. The TMDL allocations are developed for nine different assessment units (AU) of the Trinity River system. An assessment unit is the smallest geographic area of use support reported in a surface water quality assessment. Combining multiple TMDLs into single projects allows a more holistic and integrated assessment of pollutant effects and necessary management measures. Singular tense references to "the TMDL" are used within this document for the sake of clear communication regarding this singular project. However, for purpose of satisfying Clean Water Act requirements, this single project and document constitutes nine individual TMDLs and will be counted that way for reporting purposes.

Section 303(d) of the Clean Water Act and the implementing regulations of the U.S. Environmental Protection Agency (USEPA) in Title 40 of the Code of Federal Regulations, Part 130 (40 CFR 130) describe the statutory and regulatory requirements for acceptable TMDLs. The USEPA provides further direction in its *Guidance for Water Quality-Based Decisions: The TMDL Process* (USEPA 1991). This TMDL document has been prepared in accordance with those regulations and guidelines.

The TCEQ must consider certain elements in developing a TMDL; they are described in the following sections:

- Problem Definition
- Endpoint Identification
- Source Analysis
- Linkage Analysis
- Seasonal Variation
- Margin of Safety
- Pollutant Load Allocation
- Public Participation
- Implementation and Reasonable Assurance

1.1 Problem Definition

As a result of PCBs found in fish tissue, the Texas Department of State Health Services (TDSHS) issued an Aquatic Life Order and a Fish Consumption Advisory to limit human exposure to contaminated fish from the Trinity River. Aquatic Life Order AL-2 was issued in January 1990, banning fish possession due to high chlordane concentrations. AL-2 applied to the Trinity River from the Seventh Street bridge on the Clear Fork in downtown Fort Worth to Interstate Highway (IH) 20 in Dallas. Aquatic Life Order AL-14, issued in September 2002, extended the existing fish possession ban downstream to State Highway (SH) 34 near Rosser, in Kaufman County, Texas. AL-14 applied to all fish species because of PCB and 4,4’-dichlorodiphenyldichloroethylene (DDE) contamination, in addition to chlordane. Fish Consumption Advisory ADV-25 was issued in September 2002 for all gar species from SH 34 to the Cedar Creek reservoir discharge canal due to elevated levels of chlordane, DDE, and PCBs. Only PCBs are addressed in this Total Maximum Daily Load (TMDL) project. Chlordane in fish tissue was addressed in two previous legacy pollutant TMDL documents and Implementation Plans covering the Fort Worth and Dallas area. TMDLs were not required for DDE because it did not contribute significantly to the risk for which the consumption advisory was issued.

The Texas Commission on Environmental Quality (TCEQ) placed four segments of the Trinity River on the 2002 Clean Water Act §303(d) List of impaired water bodies due to “PCBs in fish tissue” as a result of the TDSHS closures and advisory. The term “TMDL Study Area” is used throughout this report and refers to impaired portions of the Trinity River system identified in AL-14 and ADV-25. Nine TMDL impaired assessment units comprise the impaired portions of the four segments (Table 1-1), which span approximately 150 river miles in Tarrant, Dallas, Kaufman, Ellis, Henderson, and Navarro Counties. The segments and assessment units included in this TMDL Study are listed below and shown in Figure 1.1.

Clear Fork Trinity River Below Lake Benbrook (0829). Segment 0829 is a 14 mile freshwater stream extending from immediately downstream of the Benbrook Dam to the confluence with Upper West Fork Trinity River (Segment 0806) in Fort Worth. Only the lower one mile of this segment, assessment unit 0829_01, is on the §303(d) List for PCBs and is addressed by these TMDLs.

Upper West Fork Trinity River below Lake Worth (Segment 0806). Segment 0806 is a 33 mile freshwater stream that begins immediately below the Lake Worth dam in Tarrant County and extends to a point immediately upstream of the confluence of Village Creek in Tarrant County. The lower 22 miles of the segment, below the confluence with the Clear Fork, comprises assessment unit 0806_01 and are addressed by these TMDLs.

Lower West Fork Trinity River (Segment 0841). Segment 0841 is a 27 mile freshwater stream that extends from immediately upstream of the confluence of Village Creek in Tarrant County to immediately upstream of the confluence of the Elm Fork Trinity River in Dallas County. Segment 0841 is divided into two assessment units: 0841_02 upstream of the Tarrant/Dallas county line, and 0841_01 downstream of that point. Both assessment units are on the §303(d) List for PCBs and are addressed by these TMDLs.

Upper Trinity River (Segment 0805). Segment 0805 is a 100 mile freshwater stream that extends from immediately upstream of the confluence of the Elm Fork Trinity River in Dallas County to a point immediately upstream of the confluence of the Cedar Creek Reservoir discharge canal in Henderson/Navarro Counties. All five assessment units of the 100 mile segment are included in the §303(d) list for PCBs.

The contributing watersheds to the impaired assessment units were delineated based on digital elevation models from the National Elevation Dataset (http://ned.usgs.gov), and extend to the boundary of the nearest upstream segment that is not considered impaired due to PCBs. For segments 0806 and 0829, in which only the downstream reaches were considered impaired, the watershed of the whole segment is considered to be the contributing watershed to the impaired assessment units and is included in the TMDL Study Area. Also, while Mountain Creek Lake is not a separate classified segment but an unclassified tributary to Segment 0841, it was not included in the TMDL Study Area for this project because it has been addressed by the TCEQ in an approved TMDL and implementation plan for PCBs. The contributing watersheds cover approximately 1,600 square miles, including most of the densely populated Dallas/Fort Worth metropolitan area.

In order to develop TMDLs, it was necessary to estimate the flow, sediment, and PCB loads from upstream segments. Flow measurements were commonly available at dams and at USGS stream gage locations. Because of the location of dams and flow gages, in some cases it was necessary to extend the watershed modeling area beyond the TMDL Study Area. The TMDL Modeled Domain included portions of the watersheds of the Elm Fork Trinity River upstream to Lake Lewisville Lake and Grapevine Lake, and the East Fork Trinity River upstream to Lake Ray Hubbard, in addition to the TMDL Study Area. This addition Modeled Domain is illustrated in Figure 1.1.

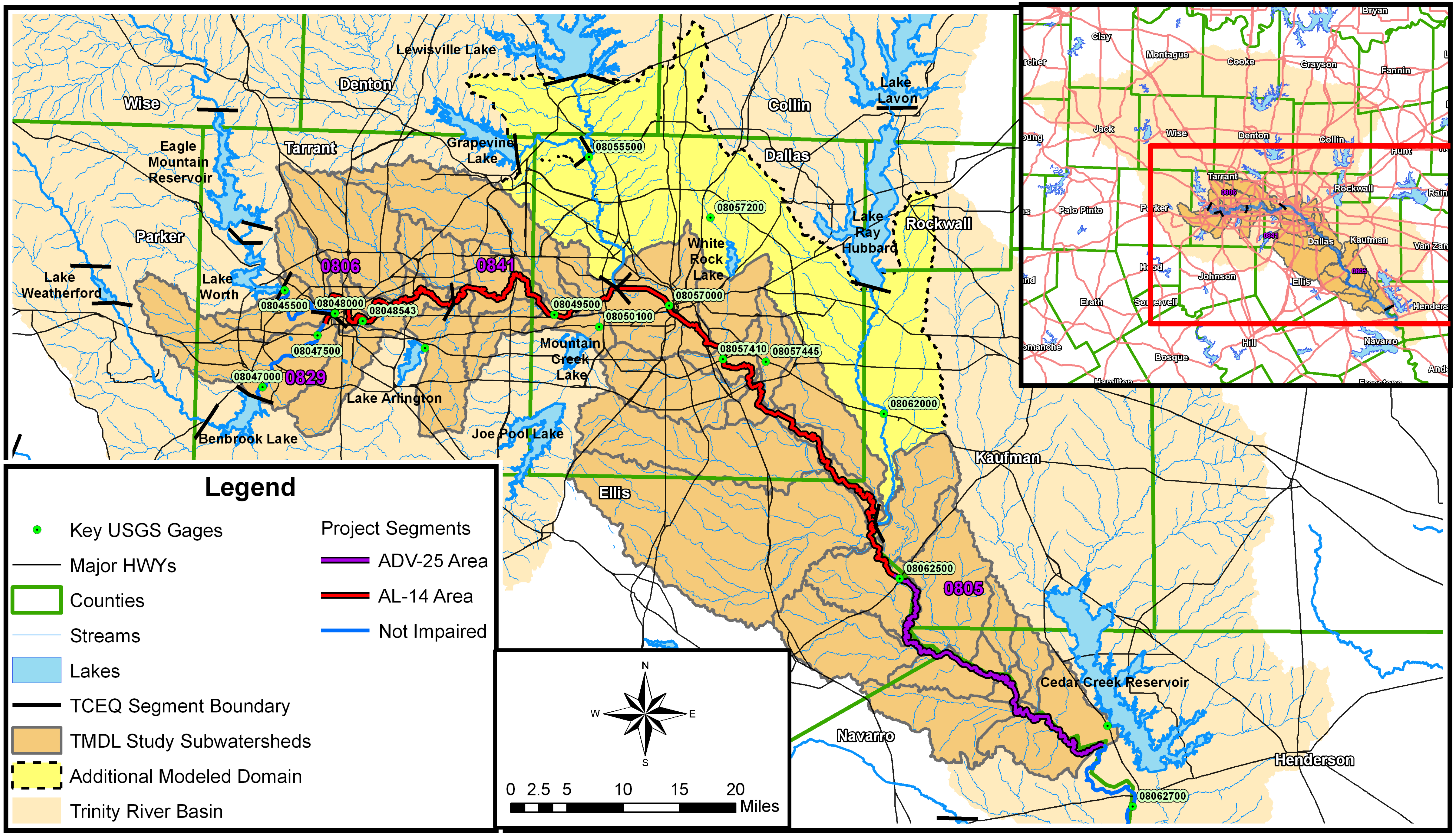

Figure 1.1 **Locations of Water Quality Impaired Segments and Their Watersheds**

Polychlorinated biphenyls (PCBs) are widespread and persistent synthetic organic contaminants that can affect human health at low concentrations. PCBs are comprised of 209 individual chemical compounds known as congeners. PCBs are composed of two connected phenyl rings with from one to ten chlorine atoms attached at 10 possible positions (2,3,4,5,6,2’,3’,4’,5’,6’) on the carbon atoms comprising the rings (Figure 1.2). Although the physical properties of PCBs vary a great deal among the 209 congeners, all PCBs are poorly soluble in water, and most PCBs in aquatic systems will be associated with sediment. PCBs are highly resistant to degradation, and their residence times in the aquatic environment are typically calculated to be on the order of decades. PCBs also tend to preferentially accumulate in the fatty portions of fishes and other organisms, where they can reach concentrations several orders of magnitude higher than the concentrations in water.

PCBs were first produced on an industrial scale in 1929 by the Swan Chemical Company. This company was later purchased by Monsanto Industrial Chemicals and became the main U.S. producer of PCBs for nearly its entire domestic production life (De Voogt and Brinkman 1989). In the early years of PCB production, their main use was as a dielectric fluid in transformers. Like many industrial products, the post-WWII era significantly diversified the application of these chemicals and increased their levels of production. The main applications were dielectric fluids, heat transfer fluids in heat exchangers, and as heat-resistant hydraulic fluids. Many other smaller miscellaneous applications for PCBs were also developed, including plasticizers, carbonless copy paper, lubricants, inks, laminating agents, impregnating agents, paints, adhesives, waxes, additives in cements and plasters, casting agents, de-dusting agents, sealing liquids, fire retardants, immersion oils, and pesticides (De Voogt and Brinkman 1989).

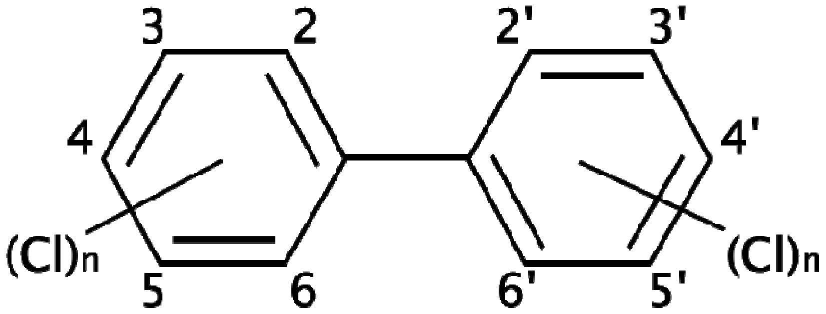

Figure 1.2 Schematic Diagram of a PCB

In 1971, Monsanto voluntarily limited its production of PCBs because of the growing public and scientific concerns of their effects (De Voogt and Brinkman 1989), and in 1976 the Toxic Substances Control Act (TSCA) was passed, calling for a ban on all production, distribution, and new use of PCBs (USEPA 2003a). Monsanto’s compliance with the TSCA resulted in a complete cessation of PCB production in mid-1977; PCBs have not been produced in the United States since that time (De Voogt and Brinkman 1989). Long-life PCB applications such as transformers were still allowed under strict regulations for operations and disposal, but those uses will eventually be phased out as the old technologies are replaced.

PCBs were produced and sold not as individual congeners, but as mixtures of congeners. They were sold in the U.S. primarily under the trade name Aroclor. Various Aroclor mixtures, varying in the amount of chlorine, were manufactured (*e.g.*, Aroclor 1232, 1242, 1248, 1254, 1260). The last two numbers of each Aroclor mixture indicate the approximate percentage of chlorine by mass in the product. An Aroclor 1260 would have a greater proportion of heavier congeners such as the hexa- to deca-chlorobiphenyls than would an Aroclor 1232. The various commercial Aroclor mixtures were tailored for different applications. For example, a heavier Aroclor mixture was preferred for high temperature applications.

1.1.1 Hydrology

The Trinity River Basin lies primarily in the eastern half of Texas and has an overall length of 360 miles. It is located generally along a northwest-southeast axis from Archer County, south of Wichita Falls and northwest of Fort Worth, to Chambers County, at Trinity Bay, east of Houston. The total area drained by the Trinity River and its tributaries is approximately 17,965 square miles (TRA 2007).

Generally, stream flows in the Trinity River Basin follow the rainfall pattern of the area. In the north-central portion of Texas where the Trinity River arises, the annual average rainfall ranges from 27 inches in the west to about 33 inches in the east.

Table 1.1 Trinity River Water Quality Segments and Assessment Units Addressed by this Report

Segment Name	Segment ID	Assessment Unit	Segment Description
Clear Fork Trinity River below Lake Benbrook	0829	0829_01	lower 1 mile of Segment
West Fork Trinity River below Lake Worth	0806	0806_01	from the confluence of Village Creek upstream to the confluence of the Clear Fork Trinity River
Lower West Fork Trinity River	0841	0841_02	from the Tarrant/Dallas county line upstream to the confluence of Village Creek
		0841_01	from the confluence of the Elm Fork Trinity River upstream to the Tarrant/Dallas county line
Upper Trinity River	805	0805_04	from the confluence of Cedar Creek upstream to the confluence of the Elm Fork Trinity River
		0805_03	from the confluence of Fivemile Creek upstream to the confluence of Cedar Creek
		0805_06	from the confluence of Tenmile Creek upstream to the confluence of Fivemile Creek
		0805_02	from the confluence of Smith Creek upstream to the confluence of Tenmile Creek
		0805_01	from the confluence of the Cedar Creek Reservoir discharge channel upstream to the confluence of Smith Creek

Flow summaries were compiled using data from the United States Geological Survey (USGS) gages obtained from http://waterdata.usgs.gov/tx/nwis/. The seven long-term USGS gage stations in the TMDL Study Area (Figure 1.1) have daily flow records for the most recent 25 year period (October 1983-September 2008). Data collected after September 2008 were not used in the analysis as they are provisional and subject to revision. An inventory of existing data for key USGS gages is presented in Table 1.2. Reported releases from selected reservoirs are summarized in Table 1.3.

Table 1.2 Daily Flow Data† at Key USGS Gages in the Model Domain (flows in cfs)

USGS Gage	Daily Observations	Minimum	Maximum	Average
08047000 – Clear Fork Trinity River near Benbrook	9,049	0	6,320	130
08047500 – Clear Fork Trinity River near IH 30 in Fort Worth	9,132	0	11,000	180
08048000 – West Fork Trinity River at Nutt Dam in Fort Worth	9,132	0.31	31,900	485
08048543 – West Fork Trinity River at Beach Street	9,132	0	35,200	548
08049500 – Lower West Fork Trinity River at Belt Line Road in Grand Prairie	9,132	23	48,900	948
08050100 – Mountain Creek at Grand Prairie	9,132	0	11,000	164
08055500 – Elm Fork Trinity River near Carrollton	9,075	0	25,300	971
08057000 – Upper Trinity River at Dallas (Commerce St.)	9,132	215	72,100	2,388
08057200 – White Rock Creek at Greenville Avenue	8,949	1.3	10,300	117
08057410 – Upper Trinity River at South Loop 12 below Dallas	8,036	297	79,200	2,879
08057445 – Prairie Creek at US Highway 175	8,949	0	1,500	10.8
08062000 – East Fork Trinity River near Crandall	8,772	32	48,800	854
08062500 – Upper Trinity River at SH 34 near Rosser, TX	9,132	418	107,000	4,116
08062700 – Upper Trinity River at SH 31 near Navidad, TX	9,132	555	94,100	4,993

† October 1, 1983 – September 30, 2008

Table 1.3 Daily Water Releases† from Selected Reservoirs (in cfs)

Reservoir	Daily Observations	Minimum	Maximum	Average
Lake Benbrook	7,668	0	6,290	115
Lake Worth	7,671	0	24,700	265
Lake Arlington	7,671	0	15,860	42

† January 1, 1988 – December 31, 2008

Major tributaries not included in the TMDL Study Area include the Elm and East Forks of the Trinity River.

The trends in precipitation and vegetation, taken in conjunction with land slopes and other factors, cause runoff in the upper basin to be rapid, but low in total volume. Runoff becomes progressively slower (in terms of time from rainfall to stream), but higher in total volume as one proceeds downstream (TRA 2007). As a result, stream flows in the upper portion of the TMDL Study Area are more erratic and quite often zero, as indicated by the minimum values in Table 1.2. Most of the smaller streams in the basin cease to flow within a few days or weeks without rain, depending on the season and drainage area.

Several of the Trinity River's tributaries, and the river itself below Dallas, have a base or dry weather flow of effluent discharged from wastewater treatment plants. A limited number of smaller streams have a consistent base flow maintained by springs.

Although the Trinity River Basin has moderate rainfall and runoff on average, it is notoriously erratic with floods at times and drought at other times. Even a normal year has much of the rain and streamflow in the late spring, followed by very hot dry weather from mid-June through August (Ulery, *et. al.* 1993). This trend is apparent in the monthly average flows presented in Figure 1.3. Monthly average flows ranged between 30 and 7,150 cfs, and, in general, increased from upstream to downstream.

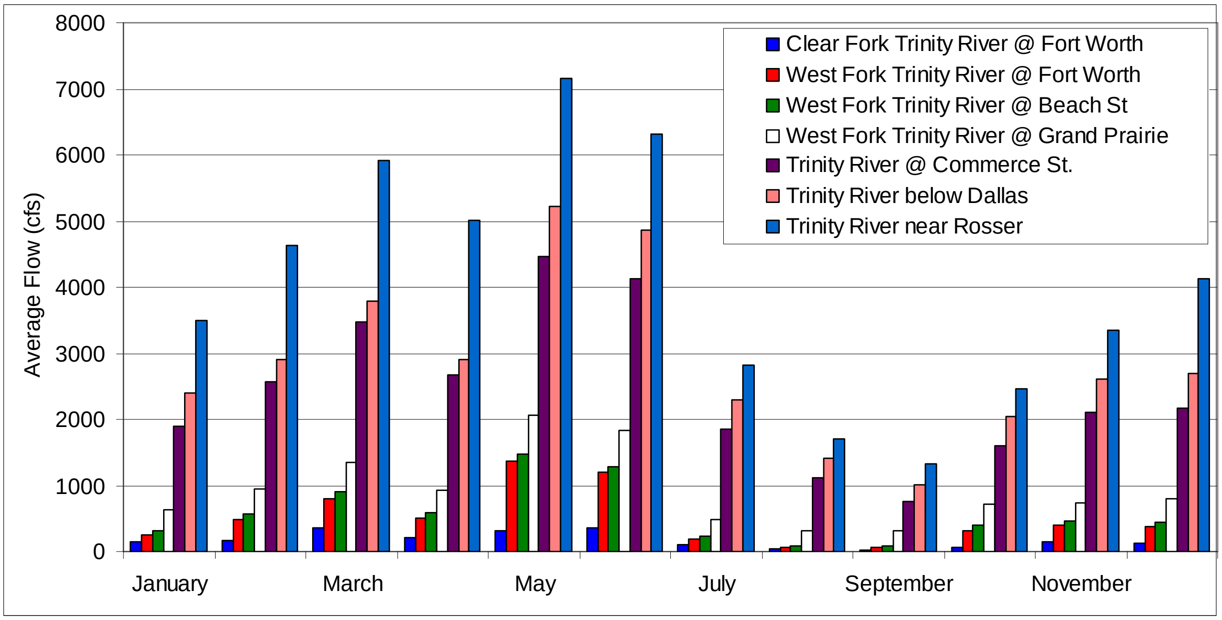

Figure 1.3 Twenty-Five Year Monthly Average Flows

1.1.2 Climate

The TMDL Study Area has a subtropical sub-humid climate characterized by hot summers and dry winters (TRA 2007). Typical conditions are represented by those of the Dallas/Forth Worth International Airport (DFW Airport) which gets about 33 inches of rain per year, much of which is delivered in the spring and autumn (Table 1.4). DFW Airport has an average daily minimum temperature of 54.6 degrees Fahrenheit (°F) and an average daily maximum temperature of 76.3 ºF. The average number of days with a minimum temperature of 32 ºF or less is 39 days a year. Snowfall in the Dallas area averages 2.7 inches per year. Winds average 12.7 miles per hour, primarily from the south/southeast.

1.1.3 Land Use

The land use in the TMDL Study Area is illustrated, on a percent basis, in Figure 1.4. Figure 1.5 depicts the land use/land cover distribution in the TMDL Study Area. Both figures are derived from the 1992 National Land Cover Dataset of the U.S. Geological Survey (USGS 1999b). Overall, pasture/hay was the most common land use (36% of the area), but 28 percent of the watershed was developed land (residential commercial, utility, and transportation), and 13 percent of the TMDL Study Area was forest. However, these land use assignments are based on satellite imagery from the late 1980s to early 1990s, and it is expected the developed land has expanded since that time. A more recent (2005) land use summary is provided for individual subwatersheds in the watershed modeling section of this report.

Table 1.4 Summary of Climate Data for the Dallas/Fort Worth Area

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average High Temperature (ºF)	54.1	58.9	67.8	76.3	82.9	91.9	96.5	96.2	87.8	78.5	66.8	57.5	76.3
Average Low Temperature (ºF)	32.7	36.9	45.6	54.7	62.6	70	74.1	73.6	66.9	55.8	45.4	36.3	54.6
Average Rain (inches)	1.83	2.18	2.77	3.5	4.88	2.98	2.31	2.21	3.39	3.52	2.29	1.84	33.7
Average Wind (mi/hr)	12.7	12.7	16.1	15	13.8	12.7	10.4	10.4	11.5	11.5	12.7	12.7	12.7
Thunderstorm Days	1	2	4	6	8	6	5	5	4	3	2	1	46
Highest Temperature (ºF)	93	96	100	100	107	113	110	112	111	106	89	90	113
Lowest Temperature (ºF)	-2	-8	10	29	34	48	56	55	40	24	19	-1	-8
Average Days above 90 ºF	-	-	-	1	5	21	28	27	15	3	-	-	100
Average Days below 32 ºF	14	8	3	-	-	-	-	-	-	-	3	10	39
Average Snowfall (inches)	1.2	1	0.2	-	-	-	-	-	-	-	0.1	0.2	2.7

Source: http://web2.airmail.net/danb1/climate.htm. Data obtained from the National Weather Service, DFW Airport Station.

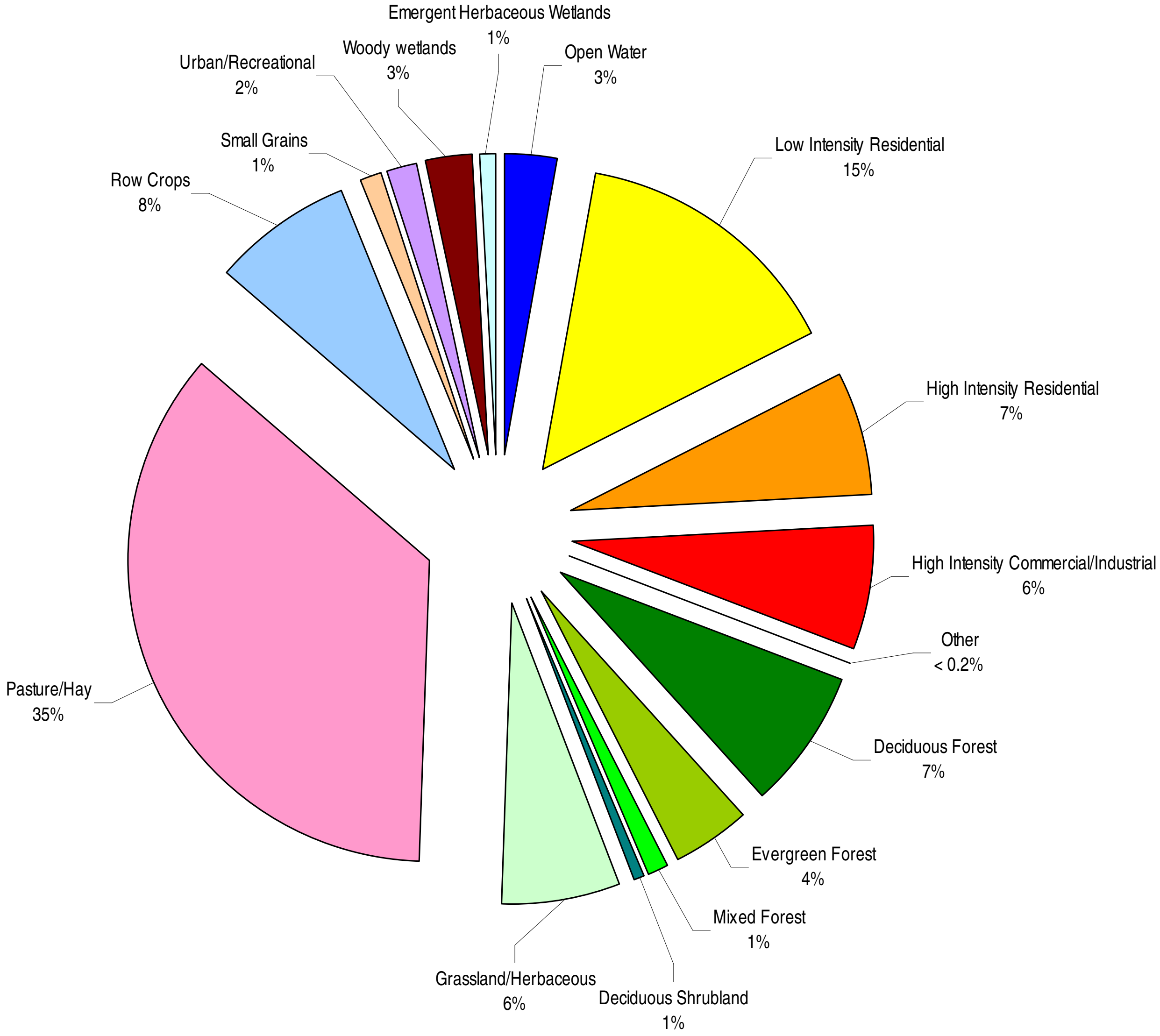

Figure 1.4 Land Use Distribution in the TMDL Study Area

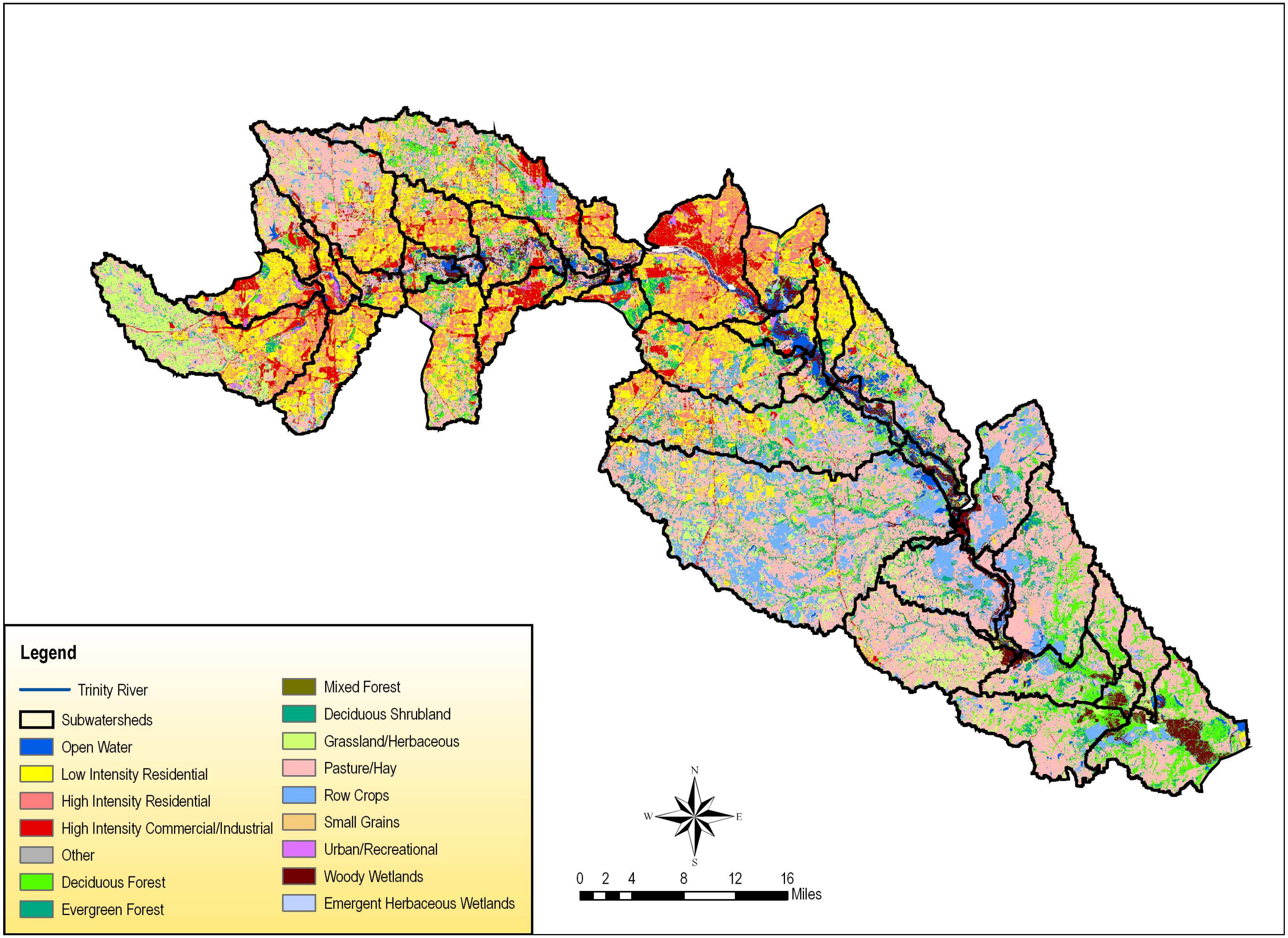

Figure 1.5 Land Use in Project Subwatersheds

1.2 Endpoint Identification

All TMDLs must identify a quantifiable water quality target that indicates the desired water quality condition and provides a measurable goal for the TMDL. The TMDL endpoint also serves to focus the technical work to be accomplished and as a criterion against which to evaluate future conditions.

Texas Surface Water Quality Standards (Title 30 Texas Administrative Code Chapter 307) state that "Water in the state shall be maintained to preclude adverse toxic effects on human health resulting from contact recreation, consumption of aquatic organisms, consumption of drinking water or any combination of the three." Numerical criteria are established for specific toxic substances in Section 307.6 of the Texas Surface Water Quality Standards (TSWQS). The water quality criterion of 1.3 ng/L for PCBs in fresh waters is intended to protect human health from consumption of contaminated fish and other aquatic organisms. This criterion is applied as a long-term average concentration designed to protect populations from exposure over a lifetime. The criterion applies to the sum of concentrations of individual PCB congeners, homolog[1] groups, or Aroclors. The criterion also applies to the total recoverable concentration in water, or the sum of dissolved and suspended fractions.

The water bodies addressed by this project were not identified as not meeting water quality standards due to exceedance of this criterion, but because high levels of PCBs were found in fish tissue by the Texas Department of State Health Services (TDSHS). Subsequent measurements have confirmed that PCB levels in water often exceed the 1.3 ng/L criterion.

The ultimate endpoint of the TMDL is the reduction of PCB concentrations in fish tissue to levels that constitute an acceptable risk to consumers of fish from the Trinity River, thereby allowing the TDSHS to remove the fish consumption advisories and aquatic life orders. The TDSHS based its health assessment of total PCBs on a screening level of 47 ng PCB per gram of fish tissue[2]. This screening value was derived from a USEPA chronic oral reference dose for Aroclor 1254 of 0.00002 milligrams per kilograms per day (mg/kg/day). Thus, the primary endpoint target of these TMDLs is a concentration lower than 47 ng/g (.047 mg/kg) of total PCB in fish tissue (Table 1.5).

Based on the primary endpoint of 47 ng/g total PCB in fish tissue, and a site-specific measured bioaccumulation factor of 8.3×10^4 L/kg (see section 2.5.3), a water quality target of 0.57 ng/L total PCB in whole water samples can be calculated. This target is less than half of the water quality criterion listed in current Texas SWQS.

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[1] A "homolog" group refers to all PCBs with the same number of chlorines (e.g., tri-chlorobiphenyls)

[2] This is the lower of the carcinogen and non-carcinogen comparison values. The comparison value using the USEPA slope factor of 2 $(mg/kg/day)^{-1}$ to account for the carcinogenic effects of PCBs was 271.

Table 1.5 TMDL Water Quality Endpoints for Total PCBs†

Phase	Water Quality Endpoint
Fish Tissue (primary endpoint)	< 47 ng/g
Water (total)	< 0.57 ng/L

† sum of congeners, Aroclors, or homolog groups

1.3 PCB Conceptual Model and TMDL Approach

It is expected that much of the PCBs present in the Trinity River causing elevated levels in fish originated from historical legacy sources, and that these legacy PCB levels will slowly decline. However, continuing sources to the Trinity River may also be significant in causing elevated PCB levels in water or sustaining elevated PCB levels in sediments. Potential continuing sources of PCBs to the Trinity River include point source effluents, storm water runoff, atmospheric deposition, and resuspension of buried sediments. Flows in Trinity River Segments 0841 and 0805 are effluent-dominated, with four major domestic wastewater treatment facilities (Fort Worth Village Creek, Trinity River Authority Central, Dallas Central, and Dallas Southside) each discharging approximately 100 million gallons per day (MGD), on average. Storm water runoff may also contribute significant PCB loads. While PCBs have not been produced in the U.S. since 1977, they may continue to be deposited to land surfaces by atmospheric deposition, old and leaking electrical transformers, land application of sewage sludge, and improper waste disposal practices. These new sources, as well as soil eroded from historically contaminated sites, may contribute PCB loading via storm water to the Trinity River and its tributaries. Contaminated sediments can also act as a continuing source of PCBs to the water column. While a river is not inherently a long-term depositional environment, and PCBs will ultimately be trapped in sediments of downstream reservoirs and bays, a number of low-head dams along the Trinity River in Fort Worth and Dallas provide low-velocity pools that serve as temporary depositional areas for suspended sediments. The primary natural mechanisms for PCB removal from the Trinity River include volatilization to the atmosphere, decay, burial in deep sediments, and flushing downstream. Flushing downstream is considered likely to be the major removal mechanism. Decay rates for most PCBs are very slow, as are sediment burial rates in the river. Some of the deposited sediments are likely flushed downstream with each high-flow event, and dissolved PCBs in the water column are slowly but continuously flushed downstream.

The TMDL development approach relies on a multiple-box, mass balance analytical model. The system is divided into multiple boxes, with different boxes for water and sediment for each reach of the river. The major PCB sources and removal mechanisms are treated as first-order processes. Chapter 4 presents a detailed description of the model developed for this project.

To implement the model, quantification must be made of the existing levels of PCBs in each segment or reach, the rate of PCB exchange between each reach (which is primarily proportional to flows), and the external loading of PCBs to each reach. The multiple removal mechanisms, most of which are difficult to measure, can then by estimated by difference. Internal loading from the sediments to the water column is also difficult to measure, and is pooled with settling (removal from the water column to the sediments), volatilization, and degradation as a net internal removal/loading rate. Based on this, it is possible to predict the reduction in PCB concentrations to be expected from a reduction in external loading from one or more sources, or from removal of contaminated sediment "hot spots."

SECTION 2
DATA COLLECTION AND ANALYSIS

2.1 Objectives

The main goals of the sampling activities were to quantify levels of PCBs in the impaired segments and to estimate pollutant loadings from major sources. The monitoring program included four major components: in-stream water, bed sediments, wastewater discharges, and storm water. The collected data were used to set-up and calibrate a box-model to simulate the transport and fate of PCBs in the Trinity River.

2.2 Methods

PCBs may be quantified as individual congeners, as Aroclor equivalents, or as homolog groups (i.e., mono-chlorobiphenyls, di-chlorobiphenyls, etc.). Historically, the most commonly used method has been Aroclor analysis (USEPA Method 8082). However, this procedure may yield significant error in determining both total PCB and their total toxicity, because it assumes that the distribution of PCB congeners in environmental samples and parent Aroclor compounds is similar (USEPA 2000). In this project all samples were analyzed for the full set of 209 congeners by high-resolution gas chromatography/high resolution mass spectrometry (HRGC/HRMS) using EPA Method 1668A (USEPA 1999).

2.3 Data Quality and Completeness

The Quality Assurance Project Plan (QAPP) for this TMDL, included in Appendix A, outlines the sampling and analytical methods to be used and sets data quality objectives to ensure that all data collected under this project is scientifically sound and defensible.

All data collected under this project were checked for accuracy, precision, and representativeness to verify that the data quality objectives set forth in the approved QAPP were met. Data that did not meet the requirements were flagged accordingly and not used for TMDL development. Overall a 99% completeness was achieved for the sampling activities compared to the minimum acceptance limit of 90%. Data verification summary reports are included in Appendix B.

2.4 Results Including Spatial Patterns

The monitoring included collection of sixteen high-volume water samples to quantify current PCB levels in each impaired assessment unit. Sediment samples were collected at 74 sites. In addition, two independent high-volume samples of wastewater effluent were collected on separate dates from each of the four largest wastewater treatment facilities (WWTFs), for eight total wastewater samples. Eight storm water runoff samples were collected at five locations to estimate pollutant loads in storm water.

2.4.1 Water

A total of sixteen high-volume water samples were collected from thirteen locations to quantify the existing in-stream concentrations of PCBs in each assessment unit. This count excludes duplicate samples collected for quality control purposes. In some assessment units, samples were collected from more than one location. A first round of sampling for the thirteen selected locations was conducted in March and May of 2008 with most of the samples collected under moderate flow conditions that included releases from reservoirs and flow from most tributaries. In an effort to improve sampling representativeness, a second round of high-volume water samples were collected in August 2008 from three of the same sites where PCB concentrations were measured in the spring. Flows in August were very low, and dominated by WWTF effluents.

Because PCB concentrations in water, storm water, and wastewaters are usually too low to quantify reliably using typical sampling methods, water sampling was conducted using a high-volume technique with a commercially available high-volume sampling system (Infiltrex 300, Axys Environmental Systems, Sydney, BC). Using this technique allows concentrating PCBs from large volumes of water to obtain measurable quantities. The high-volume system uses a four-inch diameter glass fiber filter (GFF) cartridge with a 1 µm nominal pore size to collect PCBs on suspended particulate matter. Dissolved PCBs that pass through the GFF cartridge are then trapped on hydrophobic polymeric resin beads (Amberlite XAD-2 resin) in a stainless steel column. The PCBs were then recovered from the GFF and XAD-2 resin in a laboratory by extraction with a nonpolar organic solvent using EPA Method 1668A. Water was pumped at a rate of approximately 1 liter per minute, and the volume of water processed varied between 120 and 280 liters. Along with PCB measurements in water, total suspended solids (TSS) concentrations were measured from grab samples.

A summary of results from this sampling component are included in Table 2.1. It is noted that Maxxam Analytical reported dissolved (XAD-resin) and suspended (filter) levels on a mass basis (in nanograms); thus, dissolved and suspended concentrations were calculated by dividing those results by the sampled volume and by then adding them up to obtain the total concentration in water presented in Table 2.1. Overall, total PCB concentrations in water varied between 0.67 and 3.42 ng/L. Total PCB levels in water exceeded the water quality standard for freshwater (1.3 ng/L) in 72% of the samples (13 out of 18). All of the samples exceeded the proposed water quality target of 0.66 ng/L. The highest total PCB concentration was measured at station 11087 (West Fork Trinity River at FM 157) in Segment 0841. A map illustrating average PCB concentrations in water is shown in Figure 2.1. A longitudinal profile, included in Figure 2.2, shows a complex profile of in-stream PCB levels. PCB levels rise downstream of downtown Fort Worth. Inflows from the Elm Fork Trinity River, Trinity River Authority Central WWTF, Bear Creek, Mountain Creek, and Delaware Creek appear to reduce in-stream PCB levels just upstream of downtown Dallas. PCB levels then increase downstream of downtown Dallas. The anomalous high PCB concentration measured at FM 157 was likely due to elevated suspended solids concentrations.

Total PCB levels were below the water quality criterion in all three samples collected during August, largely due to very low concentrations of PCBs associated with suspended sediments. Figure 2.3 shows that under high flow conditions, a larger fraction of the total PCB load is associated with suspended particles, whereas at lower flow rates most of the PCBs are dissolved in water.

A database of individual congener concentrations is provided in Appendix C.

2.4.2 Sediment

While in-stream PCB measurements in water represent only a snapshot of a particular time, and water concentrations of PCBs can be quite dynamic, sediments serve as long-term reservoirs of PCBs in streams and PCB levels in sediments are considered much less dynamic than those in water. By deriving a sediment-water PCB distribution coefficient from the paired sediment-water PCB measurements, sediment PCB levels may better predict long-term in-stream loads than the PCB measurements in water. A total of 82 bed sediment samples were collected from 74 locations, 31 from the impaired AUs and 43 in tributaries to these AUs. All sediment samples were analyzed for PCB congeners by USEPA Method 1668A. Sediment organic carbon content was also measured, as this has been found to strongly influence the PCB capacity of the sediment. In order to better understand the sediment depositional environment of the river, grain size analysis was performed on all main stem Trinity River sediment samples from segments 0829, 0806, 0841, and 0805. However, grain size was not analyzed on some smaller tributaries, as it is assumed they are not depositional environments.

Table 2.2 summarizes the results of the sediment samples and Figure 2.4 shows the distribution of total PCBs in sediments along the study area. Measured total PCB concentrations in bed sediments varied from 0.1 to 265.6 ng/g. Figure 2.5 shows a longitudinal profile of total PCB concentrations in Trinity River sediments with distance from the confluence of the West and Clear Forks near downtown Fort Worth. Significant spatial variability in sediment concentrations was noted, with peak concentrations downstream of downtown Dallas and Fort Worth. A third peak in PCB concentrations was noted near Greenbelt Road in Arlington. Normalizing the sediment PCB concentrations by the sediment's organic carbon content (Figure 2.6) removed some of the variability in sediment concentrations. PCBs preferentially partition into organic matter relative to mineral phases in sediment. Grain size may also explain some of the variability in PCB concentrations in sediments. A low-head dam on the West Fork downstream of Beach Street creates a low energy environment above the dam where fine-grained sediments are deposited (sediments are 90% silt and clay) and PCB concentrations are relatively high. Below the dam at East 1st Street, sediments are primarily composed of sand, which has a relatively low capacity to hold PCBs, and PCB concentrations are drastically lower than above the dam. Grain size may also explain the large gradient in PCB concentrations between Greenbelt Road and SH 360 in segment 0841.

Figures 2.7 to 2.9 compare PCB levels measured in tributaries, all on the same scale. The segment average PCB concentration in sediment is also illustrated for reference. PCB concentrations in several tributaries and storm water outfalls, particularly those draining the older urban centers, were higher than those in the impaired segments. This implies the presence of continuing sources of PCBs to the Trinity River.

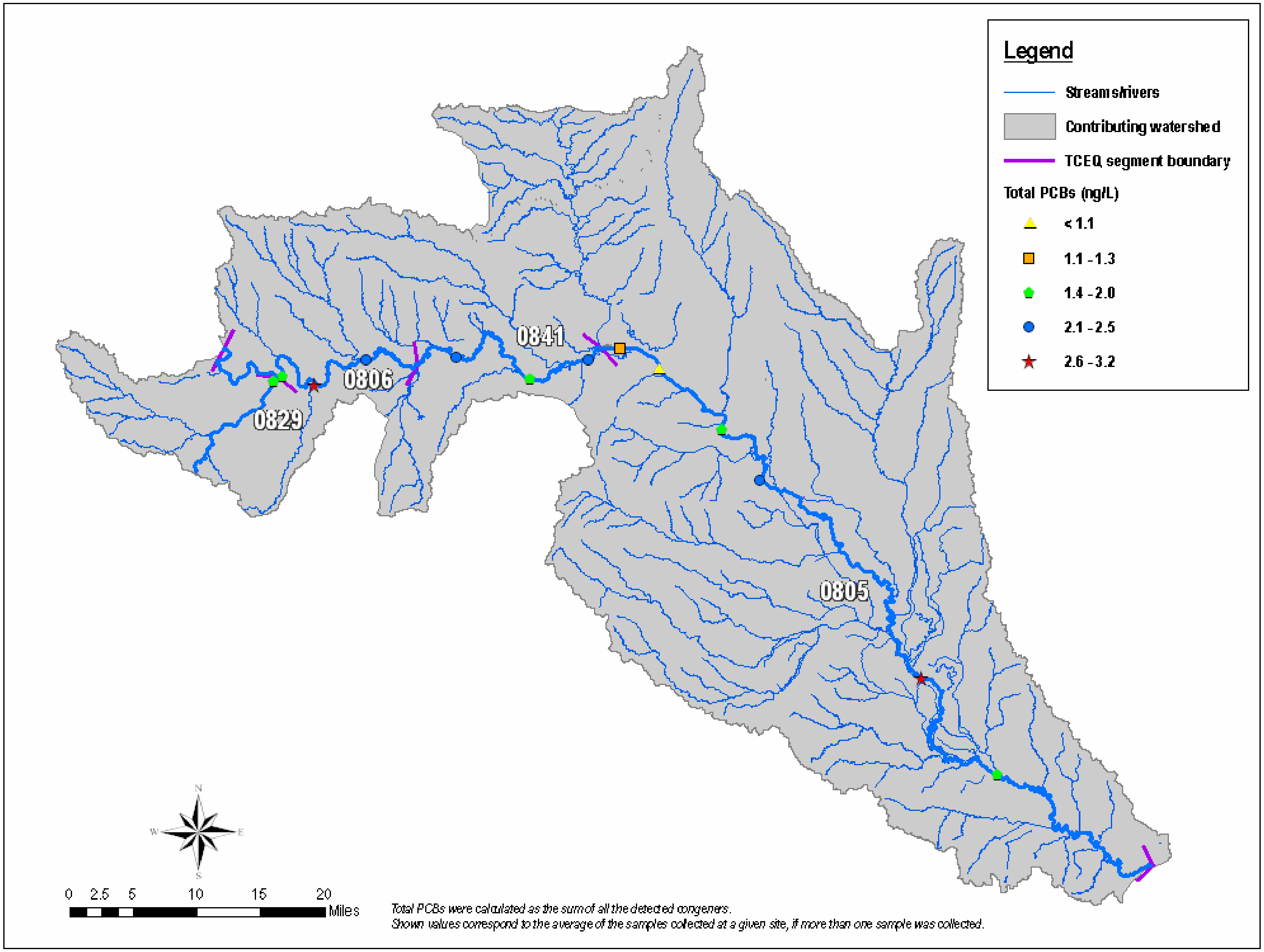
Total PCB concentrations measured in 2008 are compared to historical levels measured during the 1970s and 1980s in Figure 2.10. PCB levels in sediment appear to have declined since in Segment 0805 and 0841, but perhaps not in Segment 0806.

A database that includes results for the individual congeners is provided in Appendix C.

Table 2.1 Summary of Ambient Water Sampling Results

Station ID	Station Description	AU	Sample Date	Volume Sampled (L)	Total PCBs (ng/L)[a]			TSS (mg/L)
					Dissolved	Suspended	Total	
16119	Clear Fork Trinity River at Purcey St	0829_01	3/12/2008	216	0.46	0.96	1.42	17
	Clear Fork Trinity River at Purcey St field duplicate		3/12/2008	279	0.44	1.00	1.44	17
20336	West Fork Trinity River above Nutt Dam	0806_01	3/11/2008	227	0.72	0.62	1.34	26
20336	West Fork Trinity River above Nutt Dam field duplicate		3/11/2008	221	0.76	0.69	1.44	35
10938	West Fork Trinity River at Beach St.		3/13/2008	247	1.50	1.67	3.17	24
16120	West Fork Trinity River at Handley-Ederville Rd.		4/1/2008	149	0.73	1.43	2.16	46
11087	West Fork Trinity River at FM 157	0841_02	4/1/2008	155	0.85	2.57	3.42	60
11087	West Fork Trinity River at FM 157		8/5/2008	206	0.77	0.39	1.16	28
11081	West Fork Trinity at Belt Line Rd	0841_01	4/2/2008	205	0.64	1.09	1.73	43
11089	West Fork Trinity River at West Loop 12		3/31/2008	189	1.01	1.03	2.04	57
10937	Trinity River at Westmoreland Rd	0805_04	3/31/2008	138	0.56	0.67	1.23	57
10936	Trinity River at Commerce St.	0805_04	4/3/2008	154	0.43	0.63	1.05	72
10934	Trinity River at South Loop 12	0805_03	4/1/2008	172	0.62	1.54	2.16	84
10934	Trinity River at South Loop 12	0805_03	8/12/2008	200	0.81	0.21	1.02	51
10932	Trinity River at Dowdy Ferry Road	0805_06	4/2/2008	166	0.64	1.88	2.52	125
10925	Trinity River at SH 34	0805_02	5/1/2008	117	0.83	2.02	2.85	189
10924	Trinity River at FM 85	0805_01	4/30/2008	133	0.65	1.89	2.54	225
10924	Trinity River at FM 85	0805_01	8/6/2008	196	0.57	0.10	0.67	96

[a] *Reported concentrations correspond to the sum of detected congeners*



Total PCBs were calculated as the sum of all the detected congeners.
Shown values correspond to the average of the samples collected at a given site, if more than one sample was collected.

Figure 2.1 Map of Total PCB Concentrations in Trinity River Water

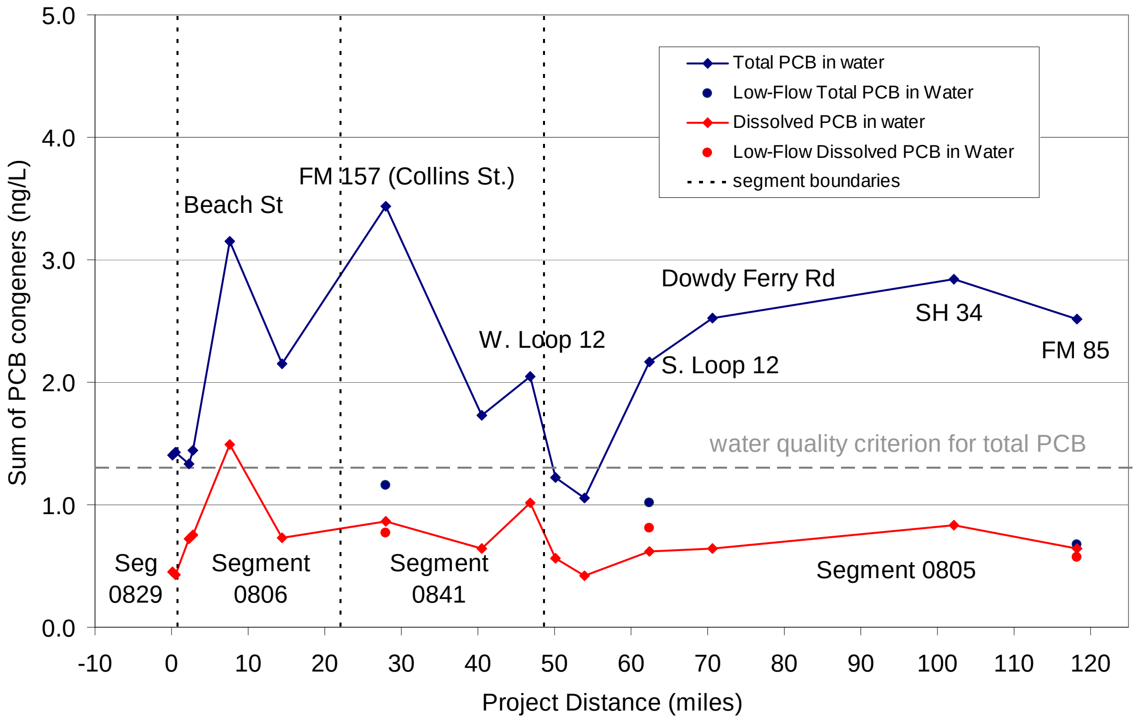


Figure 2.2 Longitudinal Profile of Total PCB Concentrations in the Trinity River

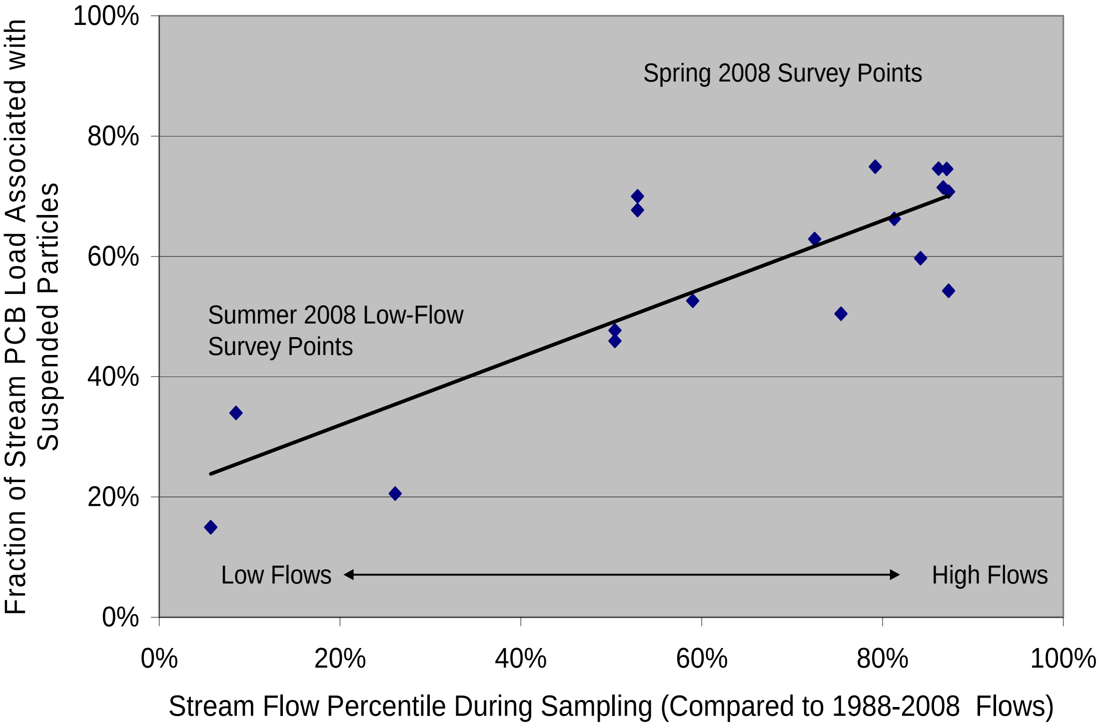


Figure 2.3 Flow Dependence of Suspended PCB Levels

Table 2.2 Summary of Bed Sediment Sampling Results

Station ID	Description	AU	Sample Date	Total PCBs (ng/g)[a]	TOC (%)	Grain size distribution			
						Gravel	Sand	Silt	Clay
11044	Clear Fork Trinity River at Rogers Rd.	0829 U/S[b]	3/12/2008	18.20	2.7	0	40.9	46.0	13.1
18456	Clear Fork Trinity River at Rosedale	0829 U/S	3/12/2008	9.52	1.5	0	55.7	31.9	12.4
16122	Clear Fork Trinity River 275 m downstream of IH-30	0829 U/S	7/30/2008	3.69	1.2	0	84.3	10.1	5.6
20427	Clear Fork Trinity River 235 m upstream of Lancaster Ave.	0829_01	7/30/2008	13.81	1.2	0	54.6	30.0	15.4
16119	Clear Fork Trinity River at Purcey St	0829_01	3/12/2008	38.67	2.8	64.0	30.2	5.8[d]	
20425	West Fork Trinity River 360 m upstream of Meandering Road	0806_ U/S	7/30/2008	0.47	0.31	0	68.6	25.3	6.0
20424	West Fork Trinity River 180 m south of intersection of Scott Rd and Nursery Ln.	0806_ U/S	7/30/2008	4.18	1.5	0	32.0	47.3	20.7
18460	West Fork Trinity River at University Dr.	0806_ U/S	3/12/2008	15.48	0.64	8.0	85.2	6.8[d]	
20336	West Fork Trinity River above Nutt Dam	0806_01	3/11/2008	26.39	1.3	40.0	43.6	16.4[d]	
20336 FD[c]	West Fork Trinity River above Nutt Dam	0806_01	3/11/2008	247.87	0.94	0.0	71.9	19.9	8.2
20336	West Fork Trinity River above Nutt Dam	0806_01	7/29/2008	36.67	1.4	0.0	48.7	35.2	16.1
20336 FD	West Fork Trinity River above Nutt Dam	0806_01	7/29/2008	28.38	0.83	0.0	47.8	36.3	15.9
20422	West Fork Trinity River 80 m upstream of North Side Drive Dam #3	0806_01	7/29/2008	14.91	0.76	0.0	60.7	26.9	12.3
20422 FD	West Fork Trinity River 80 m upstream of North Side Drive Dam #3	0806_01	7/29/2008	19.06	1.2	0.0	53.1	31.5	15.4
17368	West Fork Trinity River above Fourth Street dam	0806_01	5/14/2008	36.97	2.5	0.0	0.0	74.0	26.0
10938	West Fork Trinity River at Beach St.	0806_01	3/13/2008	50.56	1.9	0.0	10.2	63.6	26.3

Station ID	Description	AU	Sample Date	Total PCBs (ng/g)[a]	TOC (%)	Grain size distribution			
						Gravel	Sand	Silt	Clay
17662	West Fork Trinity River at East 1st St.	0806_01	7/23/2008	3.41	1.4	0.0	87.9	8.2	3.9
16120	West Fork Trinity River at Handley-Ederville Rd.	0806_01	3/27/2008	2.55	0.3	0.0	0.0	60.9	39.1
11085	West Fork Trinity River at Precinct Line Rd.	0806_01	5/20/2008	7.56	0.32	8.3	65.7	25.9[d]	
17160	West Fork Trinity River at Greenbelt Rd.	0841_02	7/22/2008	20.14	0.25	0.0	13.5	48.7	37.8
11087	West Fork Trinity River at FM 157	0841_02	5/20/2008	2.66	0.18	0.0	0.0	51.5	48.5
11084	West Fork Trinity River at SH 360	0841_02	3/17/2008	1.29	0.15	0.0	93.5	6.5	
17669	West Fork Trinity River at Roy Orr Blvd	0841_01	7/28/2008	2.60	0.25	0.0	65.1	22.9	12.0
11081	West Fork Trinity at Belt Line Rd	0841_01	5/20/2008	4.62	0.13	0.0	97.6	2.4[d]	
11089	West Fork Trinity River at West Loop 12	0841_01	6/3/2008	4.04	0.28	0.0	72.4	17.29	10.33
10937	Upper Trinity River at Westmoreland Rd	0805_04	5/2/2008	7.57	0.54	0.0	26.6	46.8	26.5
10936	Upper Trinity River at Commerce St.	0805_04	4/3/2008	11.35	0.39	0.0	58.6	26.9	14.5
10935	Upper Trinity River at I-45	0805_03	6/3/2008	18.16	1.4	0.0	5.7	43.7	50.6
10935	Upper Trinity River at I-45	0805_03	8/19/2008	26.09	1	0.0	9.8	54.0	36.2
20444	Upper Trinity River 170 m downstream of South Central Expressway	0805_03	8/19/2008	19.05	0.47	0.0	45.4	29.0	25.6
10934	Upper Trinity River at South Loop 12	0805_03	4/2/2008	24.94	0.48	0.0	19.5	54.8	25.7
10934	Upper Trinity River at South Loop 12	0805_03	8/19/2008	24.60	0.6	0.0	32.1	41.1	26.8
20567	Upper Trinity River 2.25 km upstream of IH-20	0805_03	8/19/2008	17.33	0.45	0.0	36.2	35.5	28.3
10932	Upper Trinity River at Dowdy Ferry Road	0805_06	4/2/2008	20.17	0.44	0.0	23.7	51.2	25.1
20566	Upper Trinity River 275 m upstream of Tenmile Creek	0805_06	8/5/2008	0.81	0.51	0.0	15.1	37.2	47.8

Station ID	Description	AU	Sample Date	Total PCBs (ng/g)[a]	TOC (%)	Grain size distribution			
						Gravel	Sand	Silt	Clay
10925	Trinity River at SH 34 northeast of Ennis	0805_02	5/1/2008	3.31	0.3	0.0	0.0	41.7	58.3
10924	Trinity River at FM 85 west of Seven Points	0805_01	4/30/2008	4.64	0.53	0.0	0.0	41.6	58.4
17126	Unnamed tributary to Clear Fork Trinity River at Purcey Street drain	Trib 0829_01	7/29/2008	35.88	3.1	NA	NA	NA	NA
17370	Marine Creek at Northeast 23rd St.	Trib 0806_01	3/11/2008	59.21	1.7	36.5	57.3	6.2[d]	
20428	Marine Creek at Marine Creek Park	Trib 0806_01	7/29/2008	78.50	2.1	NA	NA	NA	NA
20430	Lebow Creek at Brennan Ave.	Trib 0806_01	7/29/2008	8.99	1.1	NA	NA	NA	NA
17131	Sycamore Creek at Lancaster	Trib 0806_01	3/13/2008	22.05	1	51.1	43.5	5.4[d]	
15613	Sycamore Creek at East Seminary Dr.	Trib 0806_01	7/24/2008	0.30	1.9	0.0	0.7	59.1	40.1
20431	Sycamore Creek at US Highway 287	Trib 0806_01	7/24/2008	15.43	2.8	15.5	65.1	19.4[d]	
20432	Unnamed tributary to West Fork Trinity River at Haltom Rd	Trib 0806_01	7/23/2008	45.93	4.6	0.0	81.1	18.9[d]	
20433	Little Fossil Creek at DART Railroad at dead end of Little Fossil Rd.	Trib 0806_01	7/23/2008	1.86	0.79	19.1	59.0	21.9[d]	
10814	Big Fossil Creek at Hwy 121	Trib 0806_01	3/10/2008	4.34	0.92	0.0	10.5	60.6	28.9
17189	Village Creek at I-30	Trib 0841_02	3/24/2008	0.65	0.68	0.0	44.6	37.9	17.5
20434	Walker Branch at Trammel-Davis Rd.	Trib 0841_02	7/22/2008	1.24	0.63	0.0	9.8	51.0	39.2
20435	Sulphur Branch at Mosier Valley Rd.	Trib 0841_02	7/22/2008	1.87	1.1	0.0	13.8	54.8	31.5
20436	Unnamed tributary to Lower West Fork Trinity River at Mosier Valley Rd	Trib 0841_02	7/22/2008	0.64	0.43	0.0	83.4	12.5	4.1
20437	Unnamed tributary to Lower West Fork Trinity River at S. Main St. in Euless	Trib 0841_02	7/22/2008	0.97	0.25	0.0	84.1	11.1	4.8
17664	Johnson Creek at Carrier Parkway	Trib 0841_01	3/24/2008	1.60	0.38	5.3	90.9	3.9[d]	

Station ID	Description	AU	Sample Date	Total PCBs (ng/g)^a	TOC (%)	Grain size distribution			
						Gravel	Sand	Silt	Clay
17671	Dalworth Creek at W. Palace Parkway	Trib 0841_01	7/31/2008	3.01	0.83	NA	NA	NA	NA
10864	Bear Creek at Hunter-Ferrell Rd	Trib 0841_01	3/25/2008	0.11	0.37	7.4	73.9	18.7^d	
10864 FD	Bear Creek at Hunter-Ferrell Rd	Trib 0841_01	3/25/2008	0.16	0.5	0	0.0	53.9	46.2
10815	Mountain Creek at Singleton Blvd.	Trib 0841_01	6/3/2008	6.11	0.28	0	33.0	42.8	24.2
17682	Mountain Creek at West Jefferson Blvd	Trib 0841_01	7/28/2008	5.48	0.67	NA	NA	NA	NA
15617	Delaware Creek in Fritz Park	Trib 0841_01	7/31/2008	0.94	0.41	NA	NA	NA	NA
18310	Elm Fork Trinity River at East Irving Blvd.	0822	5/20/2008	4.54	0.37	23.0	72.5	4.5^d	
11024	Elm Fork Trinity River above Carrolton Dam and Sandy Lake Rd	0822	7/21/2008	1.02	0.76	0.0	43.0	31.7	25.3
20438	Elm Fork Trinity River at California Crossing	0822	7/21/2008	1.22	0.74	0.0	28.3	46.9	24.8
20340	Dallas storm water canal at pump station Hampton	Trib 0805_04	8/13/2008	122.87	1.1	NA	NA	NA	NA
20447	Dallas storm water canal at pump station Delta	Trib 0805_04	8/13/2008	41.50	2.6	NA	NA	NA	NA
20445	Dallas storm water canal at pump station Baker	Trib 0805_04	8/13/2008	82.20	1.4	NA	NA	NA	NA
20448	Dallas storm water canal at pump station Pavaho	Trib 0805_04	8/13/2008	162.75	1.9	NA	NA	NA	NA
10843	Coombs Creek at pressure sewer intake	Trib 0805_04	8/4/2008	22.49	4.2	NA	NA	NA	NA
20341	Dallas storm water canal at pump station Able	Trib 0805_04	8/13/2008	265.58	2.6	NA	NA	NA	NA
20446	Dallas storm water canal at pump station Charlie	Trib 0805_04	8/11/2008	27.15	2.1	NA	NA	NA	NA
20440	Cedar Creek at East 8th St.	Trib 0805_03	8/4/2008	47.24	4	NA	NA	NA	NA

Station ID	Description	AU	Sample Date	Total PCBs (ng/g)[a]	TOC (%)	Grain size distribution			
						Gravel	Sand	Silt	Clay
20423	Dallas storm water canal at pump station Rochester	Trib 0805_03	8/11/2008	11.32	1.3	NA	NA	NA	NA
18458	White Rock Creek at South 2nd Ave	Trib 0805_03	3/25/2008	5.36	0.94	0	0.0	62.2	37.7
10816	White Rock Creek at US 175	Trib 0805_03	8/6/2008	2.55	2.6	NA	NA	NA	NA
20441	Honey Springs Branch at Solar Lane/ Kiska Street	Trib 0805_03	8/6/2008	5.60	0.68	NA	NA	NA	NA
20443	Elam Creek at Gayglen Drive	Trib 0805_03	8/6/2008	1.35	0.17	NA	NA	NA	NA
20442	Prairie Creek at Dowdy Ferry Rd.	Trib 0805_03	8/5/2008	7.40	1.1	NA	NA	NA	NA
18575	Five Mile Creek at Stuart-Simpson Rd.	Trib 0805_06	3/26/2008	2.60	1.6	0.0	0.0	57.3	42.7
20339	Ten Mile Creek below Parkinson Rd.	Trib 0805_02	3/26/2008	0.96	1.7	0.0	0.0	49.9	50.1
10839	Parsons Slough near Davis Rd.	Trib 0805_02	3/25/2008	1.05	1.8	0.0	0.2	66.5	33.3
10839 FD	Parsons Slough near Davis Rd.	Trib 0805_02	3/25/2008	0.99	1.4	7.4	72.6	18.7[d]	
10990	East Fork Trinity at FM 3039	Trib 0805_02	5/20/2008	0.23	0.59	0.0	0.0	42.03	57.97
17506	Red Oak Creek at FM 660	Trib 0805_02	3/26/2008	0.63	0.8	0.0	5.4	65.8	28.8

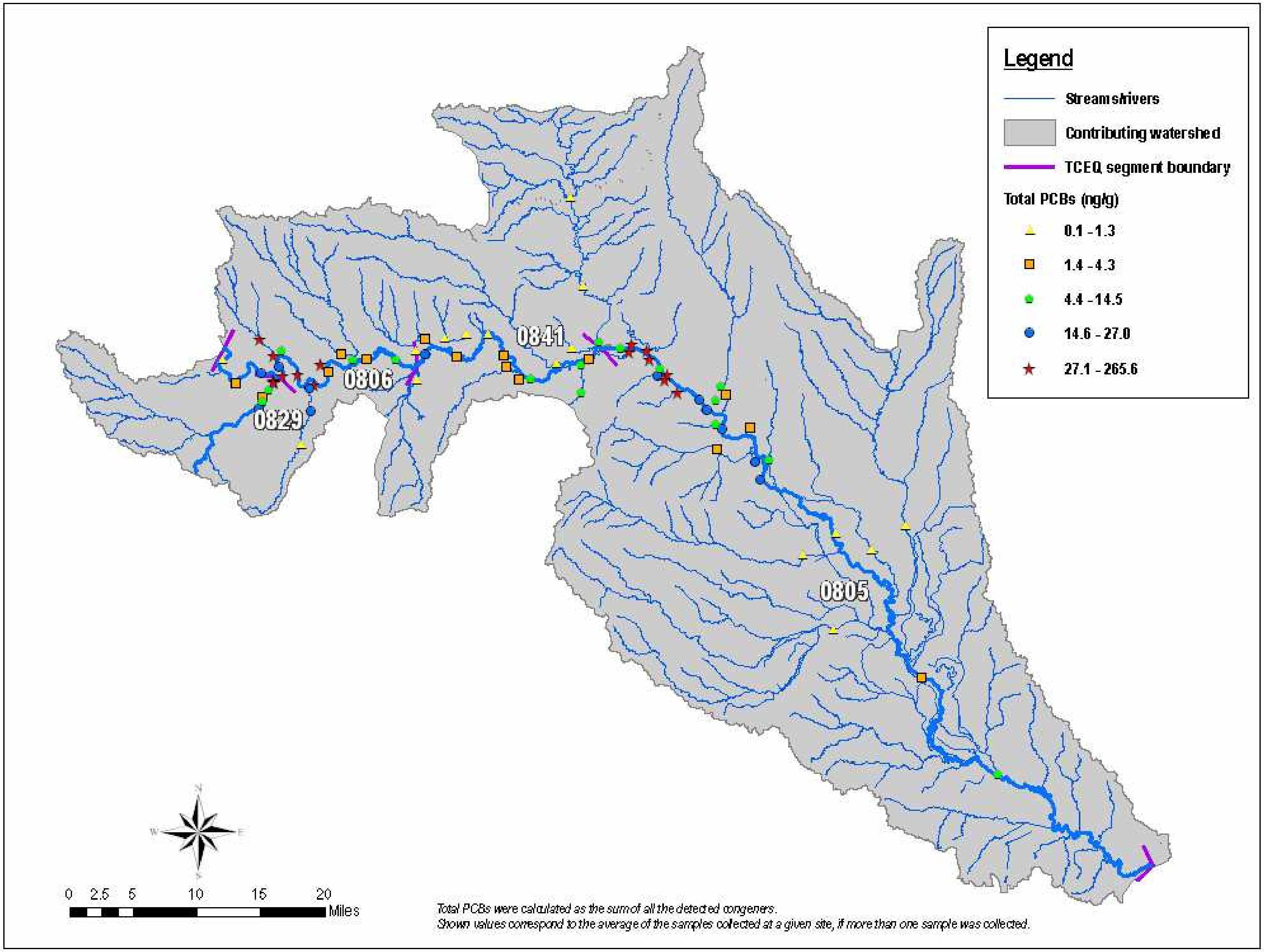
[a] Reported concentrations correspond to the sum of detected congeners

[b] U/S indicates upstream reaches of segment

[c] FD indicates a field duplicate sample

[d] silt and clay could not be separately determined on these samples

NA = not analyzed



Total PCBs were calculated as the sum of all the detected congeners.
Shown values correspond to the average of the samples collected at a given site, if more than one sample was collected.

Figure 2.4 Map of Total PCB Concentrations in Sediments of the TMDL Study Area

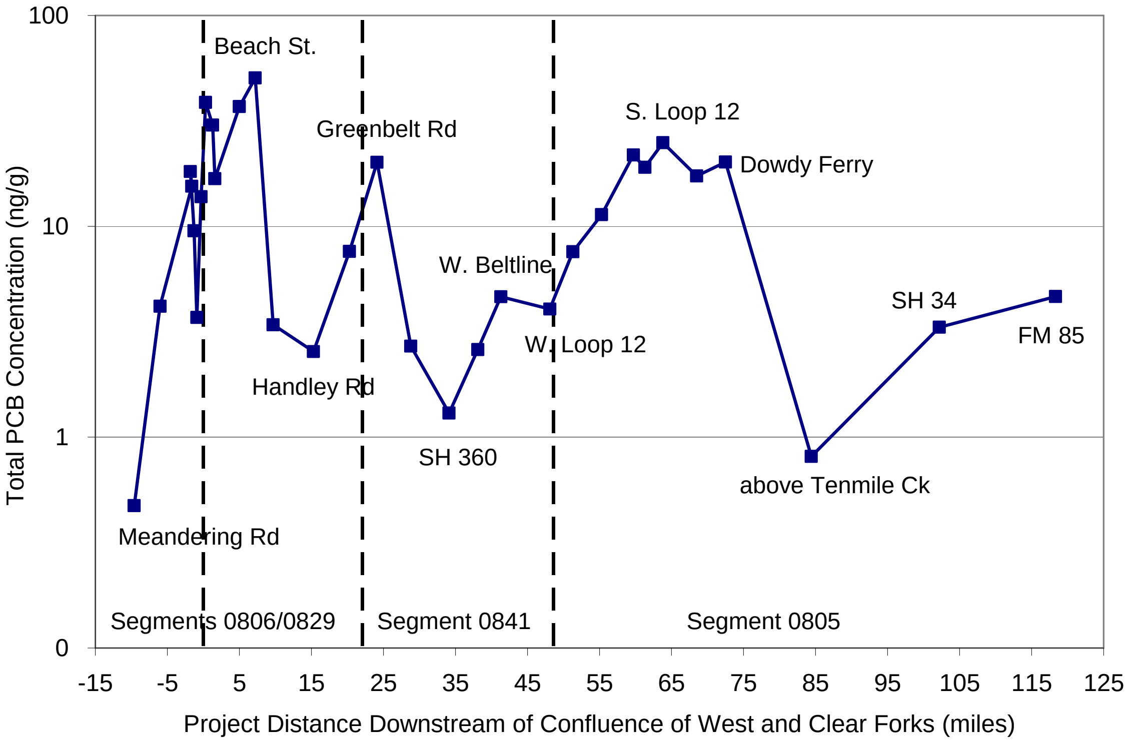


Figure 2.5 Longitudinal Profile of Total PCB Concentrations in Trinity River Sediments

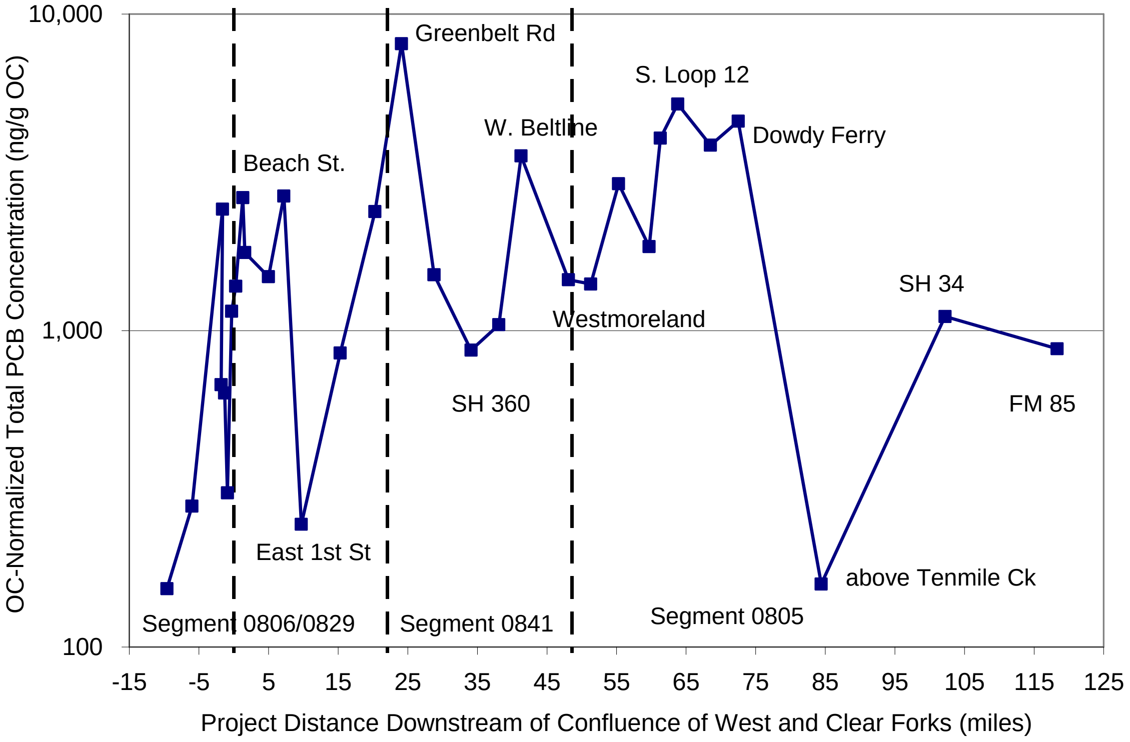


Figure 2.6 Longitudinal Profile of Organic Carbon-Normalized Total PCB Concentrations in Trinity River Sediments

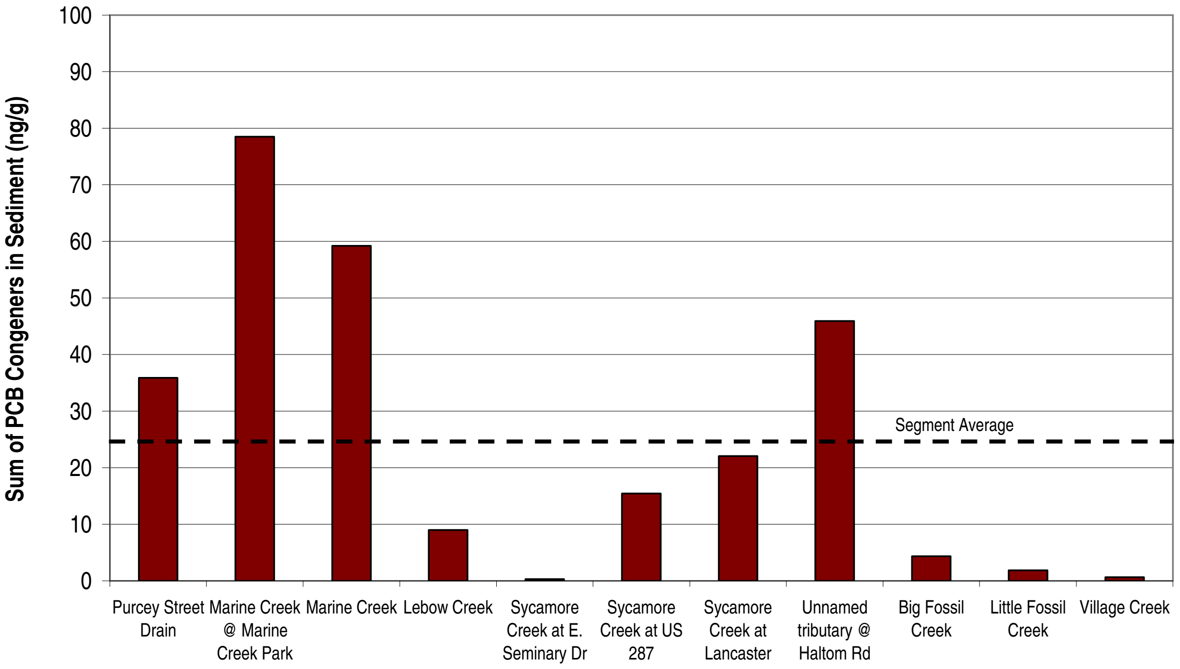


Figure 2.7 PCB Levels in Bed Sediments of Tributaries to Segments 0806 and 0829

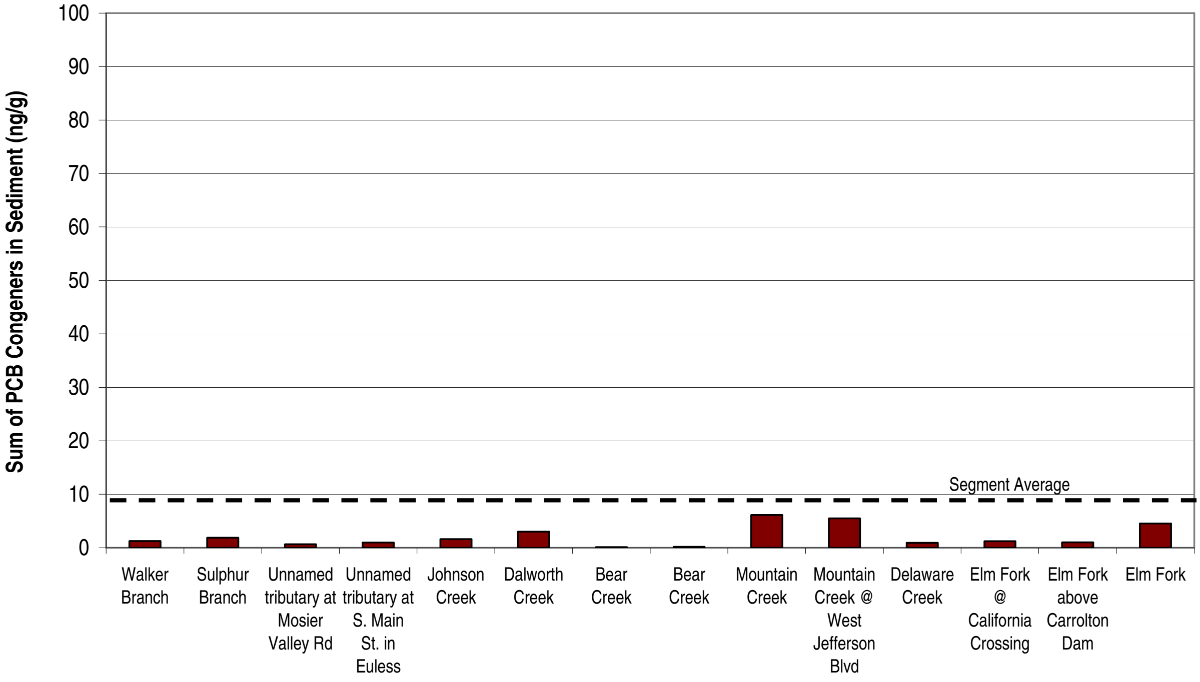


Figure 2.8 PCB Levels in Bed Sediments of Tributaries to Segment 0841

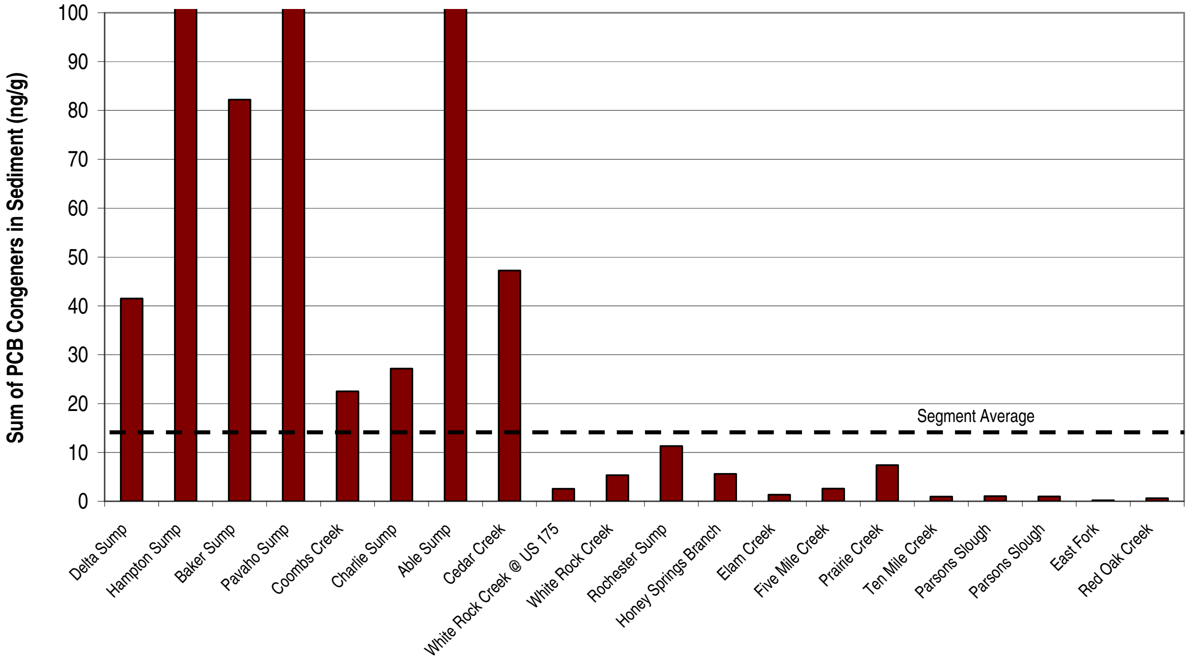


Figure 2.9 PCB Levels in Bed Sediments of Tributaries to Segment 0805

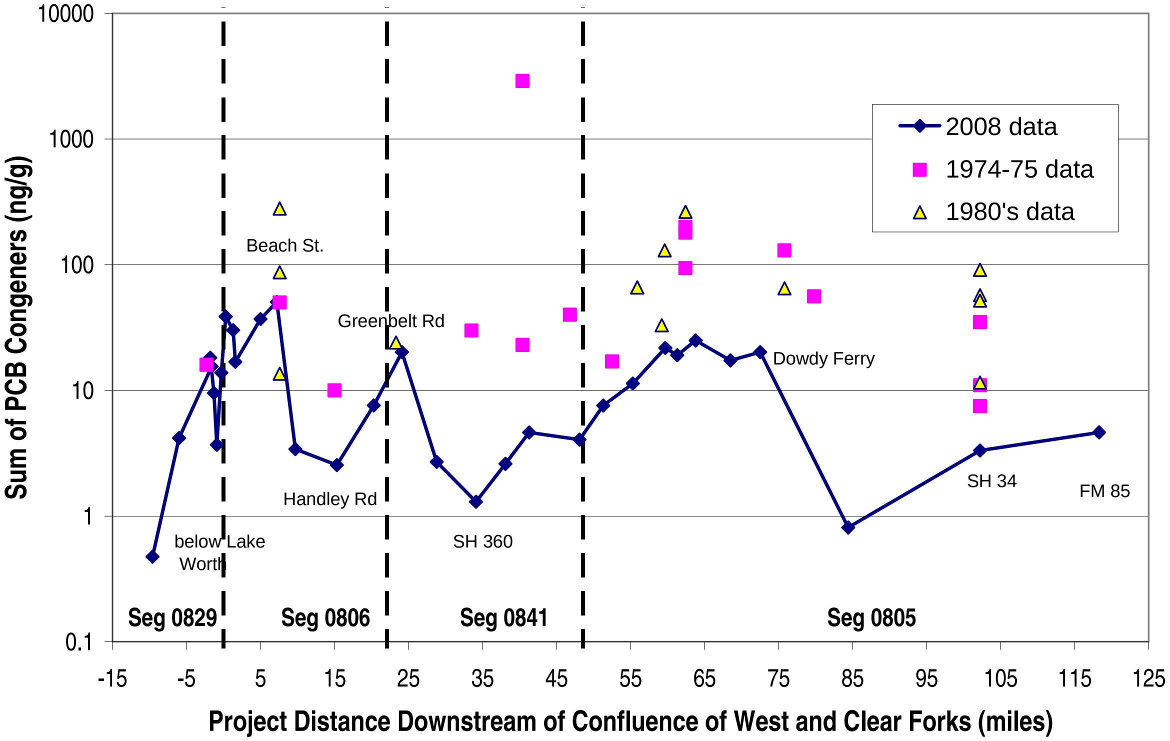


Figure 2.10 Comparison of 2008 and Historical Sediment PCB Levels

2.4.3 Wastewater

Four large domestic facilities treat and discharge almost all of the wastewater effluent discharged to the impaired segments. These facilities include the Fort Worth Village Creek WWTF, Trinity River Authority Central WWTF, Dallas Central WWTF, and Dallas Southside WWTF. PCB concentrations in the final effluent from these four facilities were each measured on two independent dates. Total PCB concentrations in wastewater samples ranged from 0.35 to 1.42 ng/L (Table 2.3). Total PCB levels in wastewater effluent were generally lower than ambient levels in the river and, except for one sample, were below the in-stream water quality criterion. WWTF effluents comprise much of the flow in the Trinity River during low flow periods and, thus, the load to the system is significant.

Appendix C provides results for individual congeners from the eight effluent samples.

2.4.4 Storm Water

Eight storm water runoff events were sampled for PCB concentrations at five sites. Three of the five sites were sampled twice in two separate events (Table 2.4). Due to the typically unpredictable nature of rainfall in this area, and the fact that high-volume water samplers must be operated manually over several hours, small neighborhood-scale streams were not sampled, but only major tributaries and storm water outfalls and pump stations. This helped ensure that when runoff occurred, the flow and runoff influence at these sites persisted for sufficient time for sampling deployment and collection. The Purcey Street storm water drain discharges to AU 0829_01, and drains much of downtown Fort Worth. The Able and Hampton storm water pumping stations drain portions of the Dallas central business district and discharge across the Trinity river levee to AU 0805_04. Samples from these pumping stations were collected immediately in front of the pump bar screens when the pumps were operating, and thus should reflect what is being discharged to the Trinity River. Big Fossil Creek was sampled near SH 121 following a one inch rain event. The watershed of Big Fossil Creek drains parts of north and northeast Fort Worth, Haltom City, Watauga, Richland Hills, North Richland Hills, Haslet, Eagle Mountain, and Keller. Land use is mixed and includes industrial areas, but is primarily residential and undeveloped land. Parsons Slough drains a primarily rural watershed in southeast Dallas county and western Kaufman county.

A summary of storm water PCB levels is presented in Table 2.4. Total PCB concentrations in storm water ranged from 0.28 to 51.6 ng/L. Total PCB levels in storm water tended to be high in sites draining older, more concentrated urban areas, possibly indicating that historical soil contamination may be a major source of PCBs to the Trinity River. PCB levels in storm water runoff in Big Fossil Creek and Parsons Slough were relatively low, even though these watersheds contain more recently developed residential and industrial areas.

Table 2.3 Summary of Wastewater Treatment Facility Effluent Sampling Results

WQ Permit	Facility Name	AU	Sample Date	Volume Sampled (L)	Total PCBs (ng/L)[a]			TSS (mg/L)
					Dissolved	Suspended	Total	
WQ0010494-013	Ft. Worth Village Creek WWTF	0841_02	5/14/2008	210	0.73	0.06	0.79	<4
WQ0010494-013	Ft. Worth Village Creek WWTF	0841_02	7/10/2008	211	0.95	0.06	1.01	<4
WQ0010303-001	TRA Central WWTF	0841_01	5/15/2008	251	0.30	0.06	0.35	7
WQ0010303-001	TRA Central WWTF	0841_01	7/9/2008	204	0.86	0.05	0.91	<4
WQ0010060-001	City of Dallas Central WWTF	0805_03	5/13/2008	206	0.57	0.61	1.18	6
WQ0010060-001	City of Dallas Central WWTF	0805_03	7/8/2008	212	0.81	0.61	1.42	<4
WQ0010060-006	City of Dallas Southside WWTF	0805_06	5/12/2008	208	0.41	0.05	0.46	6
WQ0010060-006	City of Dallas Southside WWTF	0805_06	7/7/2008	209	0.81	0.12	0.92	<4

[a] *Reported concentrations correspond to the sum of detected congeners*

Table 2.4 Summary of Storm Water Sampling Results

Station ID	Description	WQ Segment	Sample Date	Volume	Total PCBs (ng/L)[a]			TSS (mg/L)
					Dissolved	Suspended	Total	
17126	Fort Worth Purcey Street drain	0829_01	3/18/2008	145	1.16	7.83	8.99	57
17126	Fort Worth Purcey Street drain	0829_01	7/29/2008	100	1.44	1.01	2.45	42
10814	Big Fossil Creek at Hwy 121	0806_01	3/10/2008	154	0.26	0.36	0.62	260
10814 FD[b]	Big Fossil Creek at Hwy 121	0806_01	3/10/2008	143	0.34	0.49	0.83	326
20340	City of Dallas Hampton sump	0805_04	3/19/2008	160	2.89	10.30	13.19	76
20340	City of Dallas Hampton sump	0805_04	8/20/2008	97	2.54	3.39	5.93	49
20341	City of Dallas Able sump	0805_04	3/19/2008	208	1.74	5.41	7.15	41
20341	City of Dallas Able sump	0805_04	8/20/2008	106	12.60	39.00	51.60	50
10839	Parsons Slough near Davis Rd.	0805_02	4/10/2008	129	0.17	0.11	0.28	88

[a] *Reported concentrations correspond to the sum of detected congeners*
[b] *FD = field duplicate*

2.5 Data Analysis

2.5.1 PCB Phase Partitioning between Suspended Sediments and the Dissolved Phase in Water

Under equilibrium conditions, the partitioning between the suspended and dissolved phases can be quantitatively described by a linear partition coefficient, K_p, or by the partitioning constants derived either from the Freundlich or Langmuir sorption equations (Mansour 1993). The partition coefficient describes the ratio of a chemical's concentration in sediment (suspended or bed sediment) and the dissolved phase in water:

$$C_s = K_p * C_{w,d}$$

where C_s is the concentration of the chemical in the solid phase, in ng/kg, and $C_{w,d}$ is the dissolved concentration in water, in ng/L. Thus, K_p is typically expressed in units of L/kg. Figure 2.11 illustrates the measured phase partitioning of PCBs in the Trinity River system, including ambient stream, storm water, and wastewater samples. A geometric mean[3] K_p value of 2.6×10^4 L/kg was calculated, and is displayed on the figure. While there is clearly a relationship between dissolved and suspended total PCB concentrations, it was noted that the linear partition coefficient did not fit the observed data particularly well in many cases. Measured K_p values appear to decline with an increasing concentration of suspended solids (Figure 2.12). Thus, we attempted an alternate fit to observed suspended-dissolved partitioning relationships using the Freundlich sorption equation:

$$C_s = K * C_{w,d}^{1/n}$$

where K is the adsorption constant and $1/n$ is another constant providing a rough estimate of the intensity of adsorption (Mansour 1993). The linear partitioning approach is equivalent to the Freundlich equation with an exponent ($1/n$) of 1. A Freundlich exponent significantly different from 1 suggests that processes other than simple hydrophobic partitioning to sediment organic carbon are affecting the magnitude of sorption. The Freundlich equation with fit values of K = 2.86×10^4 L/kg and n = 0.7 provided a slightly better fit to the observed data, with a r^2 value of 0.60 (Figure 2.11).

Some samples exhibited anomalous relationships between total PCB concentrations in suspended sediment and water. This is likely caused by non-equilibrium conditions, perhaps caused by resuspension of bed sediments into the water column, or by fluxes of PCBs from sediment pore water to the dissolved phase in the water column.

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[3] The geometric mean is often considered a better estimate of the central tendency of a set of data than the arithmetic mean (average) when the data are highly variable, such that the average is dominated by relatively few of the data that are much larger than the others. For example, the average of 1,2,3,4,5,6,7,8,9,10 and 100 is ~14, while the geometric mean of 6 is a better measure of central tendency.

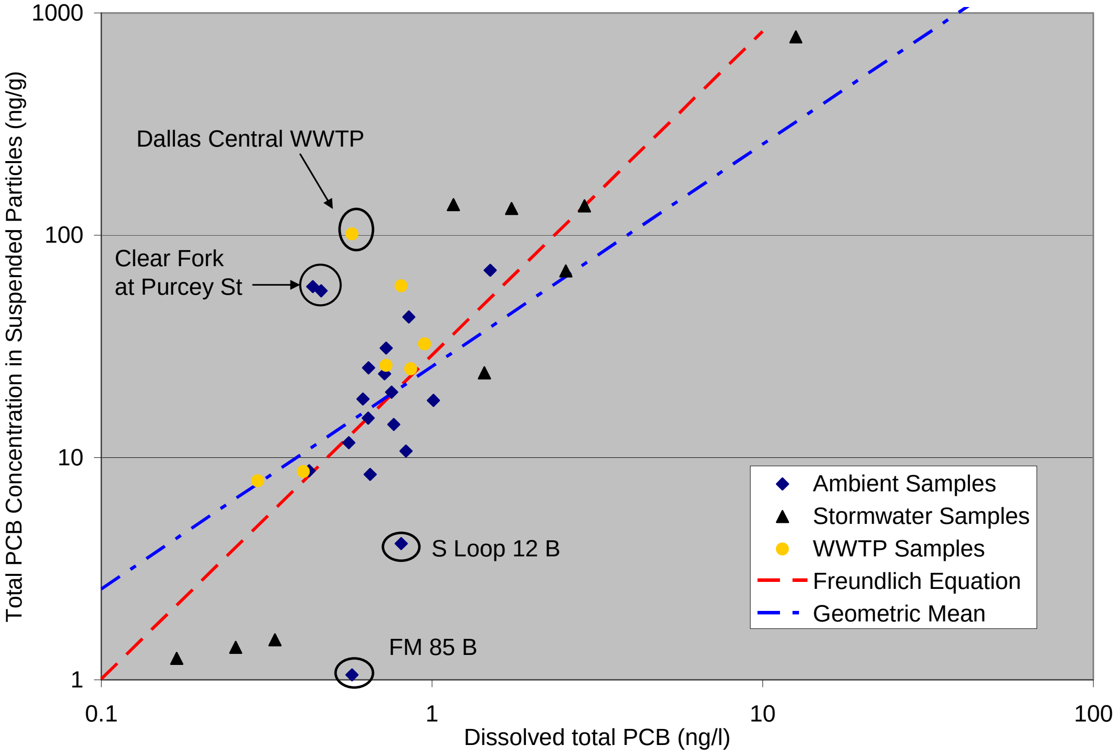


Figure 2.11 Suspended Sediment - Dissolved Phase Partitioning of PCBs in Water Samples

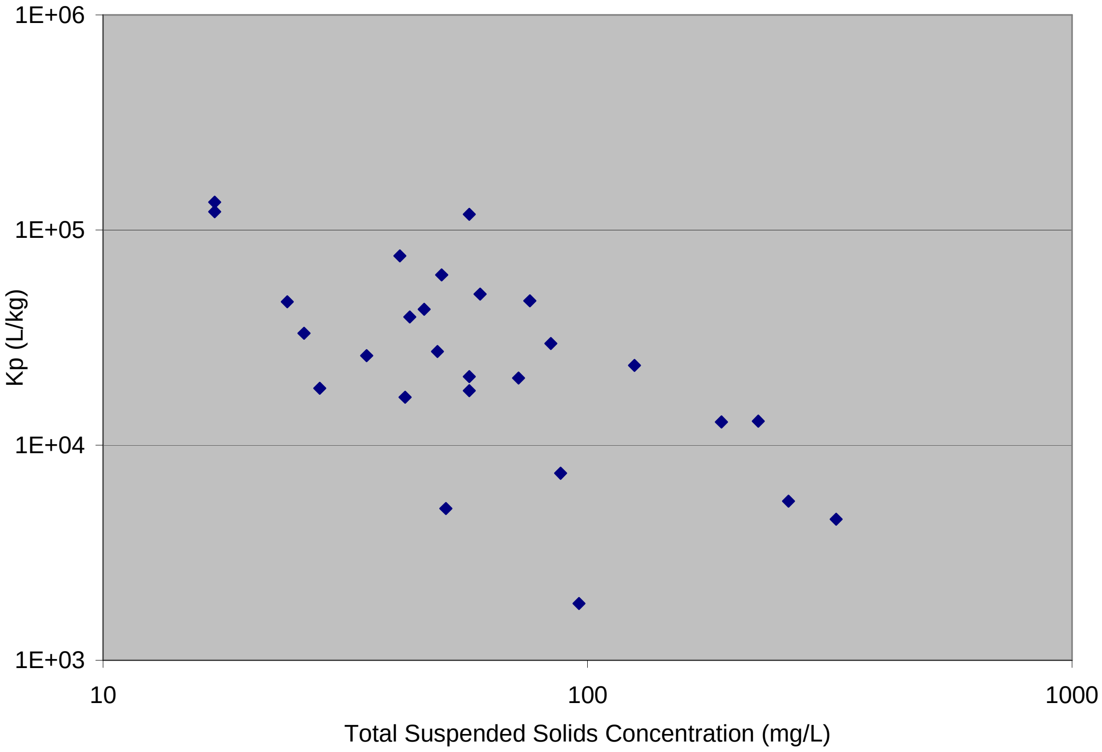


Figure 2.12 Decline in PCB Partition Coefficient with Suspended Solids Concentration

2.5.2 PCB Phase Partitioning between Bed Sediments and the Dissolved Phase

While K_p varies with the properties of the sediment phase, many studies have shown that for minimally soluble nonpolar organic molecules such as PCBs in dilute solution, it is linearly proportional to the organic carbon content of the sediment phase, when the organic carbon content exceeds approximately 0.1% (Karickhoff 1981). The organic carbon partition coefficient, K_{oc}, is considered a property of the chemical solute.

$$K_p = K_{oc} * f_{oc}$$

While a total PCB concentration is a composite of many different chemical compounds with different K_{oc} values, a composite K_p or K_{oc} for total PCBs may be applicable if the mixture of congeners comprising total PCBs does not vary substantially.

Figure 2.13 illustrates the dependence of sediment-water Total PCB K_p values on the organic carbon content of the sediment in the Trinity River. A log K_{oc} value of 6.4 provided a good fit to the observed data across all assessment units. The sediment organic carbon content explained 63% of the variance in observed variation in sediment-water partition coefficients, which is surprising given that at many sites, the water and sediment samples were collected on different dates. This fit implies that PCB concentrations dissolved in water are generally in equilibrium with those in bed sediments.

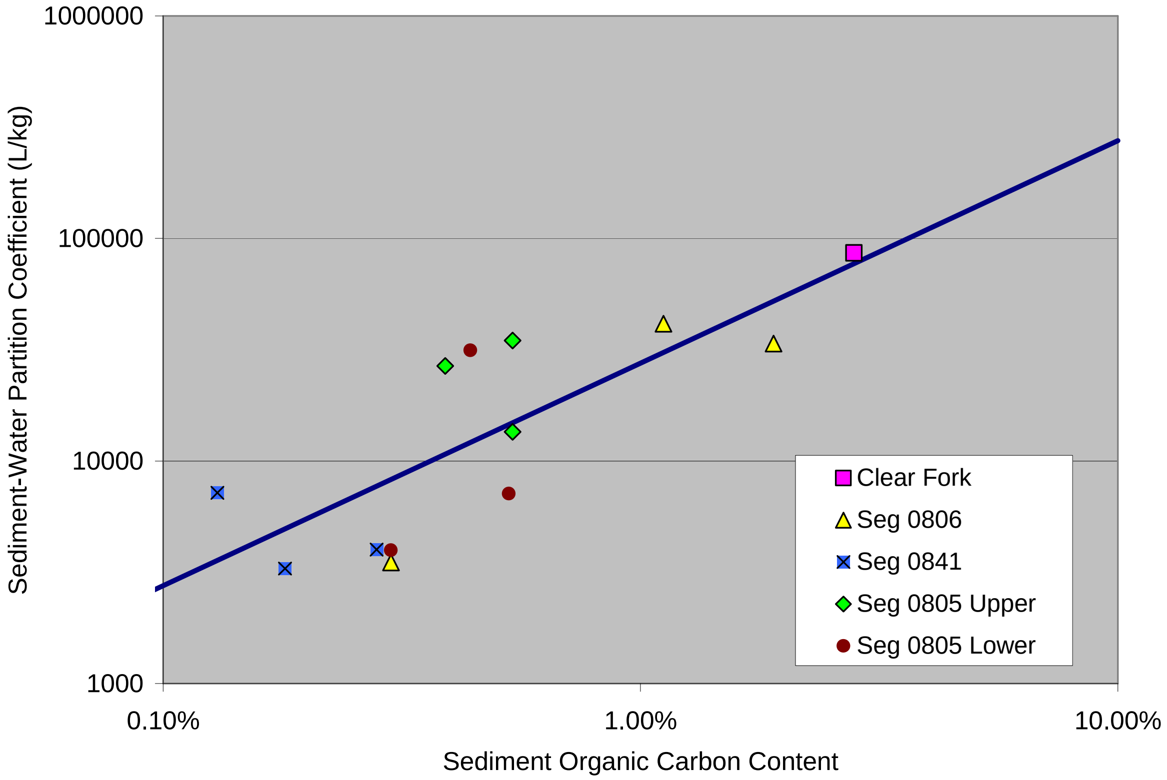


Figure 2.13 Relationship Between Sediment-Water Partition Coefficient and Sediment Organic Carbon Content

The line corresponds to a log Koc value of 6.4

2.5.3 Bioaccumulation Factors

During the summer of 2008, the TDSHS collected additional fish tissue samples to further evaluate health risks associated with consumption of fish from the Trinity River. These measurements were independent from this project; thus a description of the results is beyond the scope of this report. However, because the ultimate goal of the TMDL is removal of the fish advisory, an evaluation of the bioaccumulation of PCBs may be useful to ensure that reaching the TMDL water quality target will permit achievement of this goal.

Fish were collected according to TDSHS procedures, and included twenty-three smallmouth buffalo (*Ictiobus bubalus*), twenty-one channel catfish (*Ictalurus punctatus*), eleven flathead catfish (*Pylodictis olivarus*), twenty blue catfish (*Ictalurus furcatus*), thirteen longnose gar (*Lepisosteus osseus*), three spotted gar (*Lepisosteus oculatus*), twelve common carp (*Cyprinus carpio*), ten freshwater drum (*Aplodinotus grunniens*), ten largemouth bass (*Micropterus salmoides*), four white bass (*Morone chrysops*), and three spotted bass (*Micropterus punctulatus*). Fish size ranged from a 330 g channel catfish to a 15 kg smallmouth buffalo. Average species lipid content ranged from 0.89% for spotted bass to 18.7% for smallmouth buffalo. The overall average lipid content for all specimens analyzed was 10.1%. PCB congeners were analyzed by the Texas A&M University Geochemical and Environmental Research Group using a low resolution gas chromatography / mass spectrometry method. Because the analytical column differed from that used for water and sediment samples, congeners eluted from the column in somewhat different orders and different congeners co-eluted together from the column. This made interpretation of bioaccumulation difficult for individual congeners. An attempt was made to match congeners from the two methods, based on the reported most abundant congener in a co-eluting congener group, but some inaccuracies were inevitable using this approach.

The bioaccumulation factor (BAF) is defined by the USEPA (2003b) as the ratio (in liters per kilogram of tissue) of the concentration of a chemical in the tissue of an aquatic organism (C_{tissue}) to its concentration in water (C_{water}), in situations where both the organism and its food are exposed and the ratio does not change substantially over time.

$$BAF = \frac{C_{tissue}}{C_{water}}$$

This BAF is often referred to as a total BAF because it is based on total concentrations in water and tissue. BAFs were calculated in accordance with EPA guidance for derivation of site-specific BAFs (USEPA, 2009). First, baseline BAFs were calculated. A baseline BAF is defined by the USEPA as a BAF calculated from the concentration of the chemical in the lipid fraction of tissue within the organism and the freely dissolved concentration of the chemical in water (USEPA, 2009). Use of lipid-normalized concentrations in fish and freely dissolved concentrations in water reduces the variance in bioaccumulation between sites and species (USEPA 2009).

$$Baseline\ BAF = \frac{C_{tissue} / F_{lipid}}{C_{water} * F_{diss}} - \frac{1}{F_{lipid}}$$

where F_{lipid} is the lipid fraction of the tissue by weight and F_{diss} is the truly dissolved fraction of the contaminant concentration in water.

Congener-specific baseline BAFs were calculated for all congeners for which five or more paired samples in both water and tissue were quantified above the detection limit (Figure 2.14). Baseline BAFs tended to increase with level of chlorination, and ranged from 9.4×10^4 L/kg for PCB 16 (4,4'-dichlorobiphenyl) to 3.7×10^8 L/kg for PCB 184 (2,2',3,4',5,6,6'-heptachlorobiphenyl). For total PCBs (sum of congener concentrations) the average baseline BAF was 6.28×10^6 L/kg.

Water quality criteria and site-specific water quality targets for organic contaminants are typically expressed as total concentrations in water. Thus, the baseline BAFs were then converted back to total BAFs using the average dissolved PCB fraction (44%) and a fish lipid content of 3% (to be consistent with Texas Surface Water Quality Standards). Using these assumptions, the average site-specific BAF for total PCBs was 8.3×10^4 L/kg. For comparison purposes, the BAF for total PCBs that is currently used in Texas SWQS to calculate water quality criteria for human health is 3.1×10^4 L/kg. A site-specific water quality target for PCBs, based on the measured average BAF, was presented in Section 1.2.

2.5.4 Biota-Sediment Accumulation Factors

The biota-sediment accumulation factor (BSAF) is defined by the USEPA (2003b) as the ratio (in kilograms of sediment organic carbon per kilogram of lipid) of the lipid-normalized concentration of a chemical in the tissue of an aquatic organism to its organic carbon-normalized concentration in surface sediment, in situations where the ratio does not change substantially over time, both the organism and its food are exposed, and the surface sediment is representative of average surface sediment in the vicinity of the organism.

$$BSAF = \frac{C_{tissue} / F_{lipid}}{C_{sed} / F_{oc}}$$

where F_{oc} is the organic carbon fraction of the sediment by weight.

Congener-specific BSAFs were calculated for all congeners for which five or more paired samples in both sediment and tissue were quantified above the detection limit (Figure 2.15). Most BSAFs fell between 0.1 and 10, and there was no systematic increase in BSAF with degree of chlorination of the congener. Average BSAFs ranged from 0.31 for PCB 46 (2,2',3,6'-tetrachlorobiphenyl) to 20.7 for PCB 68 (2,3',4,5'-tetrachlorobiphenyl). For total PCBs (sum of congener concentrations) the average BSAF was 2.3.

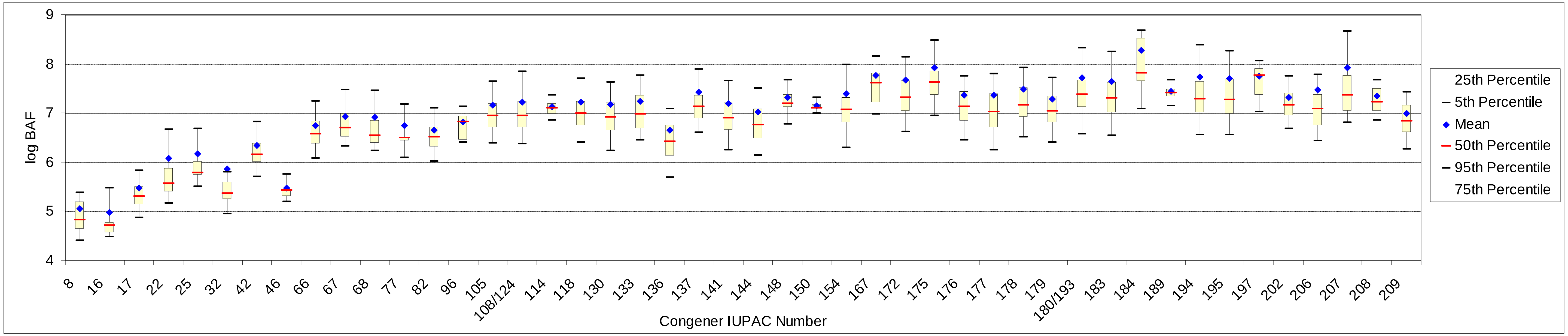


Figure 2.14 Baseline Bioaccumulation Factors for Individual PCB Congeners to Trinity River Fish

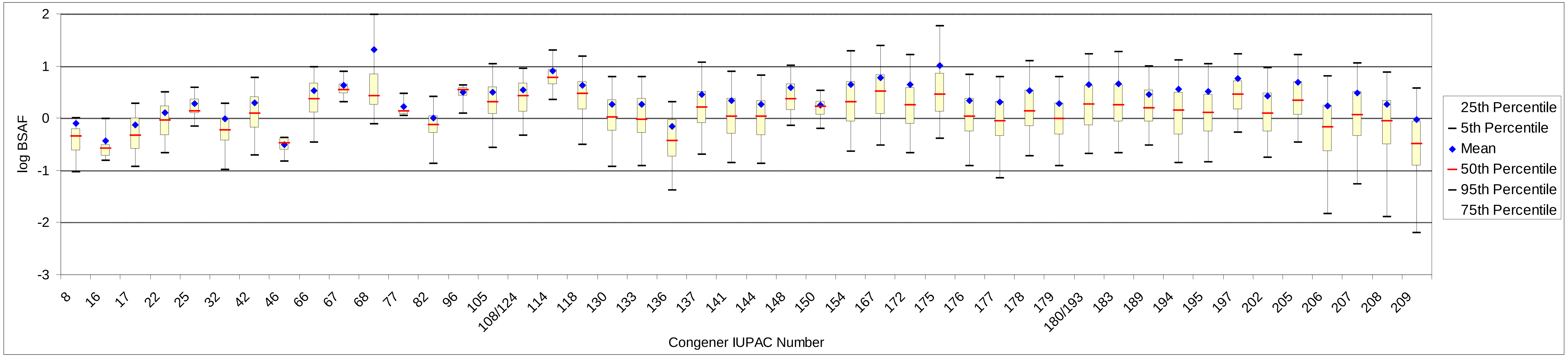


Figure 2.15 Biota-Sediment Accumulation Factors for Individual PCB Congeners to Trinity River Fish

2.5.5 PCB Fingerprinting/Pattern Analysis

As noted earlier, PCBs are comprised of 209 individual congeners. Some chlorination configurations are more energetically favorable than others. Thus, while there are 209 possible congeners, many of these were produced in only very trace amounts. Typically only about 160 congeners were considered present at measurable concentrations in commercial Aroclor mixtures.

The individual congeners have different physical and chemical properties. These different properties result in environmental weathering of the PCB mixtures over time, with the relative abundance of the individual congeners in the environmental different from that of the original source. In general, PCB congener solubility in water and tendency to volatilize from water decline with increasing chlorination, while their tendency to sorb to solids increases with degree of chlorination. Degradation mechanisms can also cause changes in the relative abundance of PCB congeners (Bzdusek et al., 2006). Some heavier congeners are preferentially dechlorinated to lighter congeners through anaerobic dechlorination.

In addition to its high sensitivity and accuracy, one of the advantages of the high-resolution GC/MS method applied for PCB analysis is its ability to provide concentrations for many individual congeners, or groups of a few congeners. Co-eluting congener groups occur when the chromatography-based analytical method does not provide sufficient resolution between two or more congeners to allow them to be quantified reliably separately. Of the 209 congeners, the analytical method was able to determine 133 congeners individually. There were also 22 co-eluting groups comprised of two congeners that cannot be resolved individually, six groups of three co-eluting congeners, two groups of four co-eluting congeners, and a single group of six co-eluting congeners. Thus, the PCB analysis provided concentrations of 164 congeners and congener groups for each sample, as well as a total PCB concentration calculated as the sum of congener concentrations exceeding the detection limit.

It is possible to examine the pattern of relative concentrations of the congeners as a “fingerprint” to identify samples with similar sources. Due to environmental weathering, it is often not possible to directly link the observed congener fingerprint to an original Aroclor source, but similarities among various samples can be ascertained to infer a similar source.

We applied a multivariate statistical method known as positive matrix factorization (PMF) to investigate the PCB congener fingerprints in sediment samples. PMF is a form of factor analysis (Norris et al., 2008), which serves to reduce the dimensionality in a dataset with many variables (e.g., congeners) to identify a smaller number of source profiles. The relative contributions of these sources are then quantified for each individual sample. PMF takes into account the uncertainty in analytical results for each individual congener and sample. This allows inclusion of the full range of measured PCB congeners, including values near or below the analytical quantitation limit. PMF has been used widely in air receptor modeling, and has recently been applied by others to PCB measurements in sediments (Bzdusek et al., 2006). The PMF software (version 3.0) was developed by Sonoma Technology, Inc., and is obtainable from the U.S. EPA at http://www.epa.gov/scram001/receptorindex.htm.

We excluded from the analysis 62 congeners and congener groups with concentrations less than the detection limit in more than 80% of the samples. Another 42 congeners and congener groups with concentrations less than the detection limit in more than 40% of the samples were set as “weak” species in the PMF model, leaving 60 “strong” congeners and congener groups in the model. PMF includes the weak species in the model, but assigns less weight to them in the model fitting procedure.

Uncertainties in analytical results were assumed to result primarily from 2 components. First, an error fraction (typically between 10 and 30% of the measured concentration) was estimated from the average relative percent deviation of seven field duplicate sediment samples for each analyzed congener or congener group. A second component of analytical uncertainty was assumed to prevail at low concentrations near and below the analytical quantitation limit, when the analytical signal of the congener was near to background noise. This uncertainty was calculated in PMF as the method quantitation limit (MQL) for each congener or congener group. The overall uncertainty for each sample and congener was then calculated by PMF as:

$$\text{Uncertainty} = \sqrt{(\text{Concentration} \times \text{error fraction})^2 + \text{MQL}^2}$$

PMF identified three major source factors. A PMF model with three factors fit the data well, with the exception of a few samples and congeners as discussed below. Inclusion of additional factors did not substantially improve model fit for most congeners and samples. The solutions were stable and not heavily influenced by outliers. For total PCB, the model explained 99.7 percent of the variance in observed concentrations (Figure 2.16). The model explained more than 99% of the variability for 25 congeners and congener groups, more than 95% for an additional 51 congeners and congener groups, more than 90% for an additional thirteen congeners and congener groups, and more than 80% for an additional nine congeners and congener groups. Congeners that were not fit well by the model included congener numbers 208, 206, 144, 103, and 11, all of which were “weak” species with a large percentage of measured concentrations below the detection limit. Comparisons between observed and model-predicted concentrations of major PCB congeners are provided in Figure 2.17a-e.

Figure 2.18 illustrates the relative abundance of congeners and congener groups in factors one, two, and three, as well as the uncertainties of those abundances. The uncertainties are estimated by bootstrap analysis, a statistical method which involves random re-sampling of observed data. The raw concentrations in each factor can also be calculated but are not shown here. For comparison purposes, measured relative congener abundances in commercial Aroclor mixtures (Frame et al. 1996) are shown in Figure 2.19. Factor one is comprised primarily of penta- and hexa-chlorobiphenyls. It appears most similar to an Aroclor 1254. Factor two is comprised primarily of the lighter PCB congeners: mono-, di-, tri-, and tetra-chlorobiphenyls. It appears similar to Aroclor 1232 or 1016. Factor three is comprised primarily of the heavier congeners: hepta-, octa-, nona- and deca-chlorobiphenyls. This factor appears most similar to Aroclor 1262.

Two samples were not fit well by the model: those from an unnamed tributary of the West Fork Trinity River at Haltom Road (Station 20432), and from Marine Creek at Marine Creek Park (Station 20428). In the sample from the unnamed tributary at Haltom Road (Figure 2-20), observed concentrations of several penta- and hexa-chlorinated congeners far exceeded those predicted by the PMF model. In the sample from Marine Creek at Marine Creek Park (Figure 2.21), observed concentrations of several tri-, tetra, and penta-chlorinated congeners far exceeded those predicted by the PMF model. It is possible that the excess levels of certain congeners observed in these samples are caused by local sources.

Considering all of the sediment samples collected during the project, 41% of the total observed PCB mass was attributed to factor three (heaviest congeners), 33% to factor one (mid-weight congeners), and 26% to factor two (lightest congeners). Table 2.5 lists the percent contribution of each factor in each sample. Many samples were relatively enriched in one of the three source factors. For example, the lighter PCB congeners comprising factor two tended to be depleted in samples from Trinity River Segments 0841 and especially 0805. The enrichments and depletions may be due to different PCB sources, but also can result from environmental weathering and reductive chlorination. Environmental weathering often selectively depletes lighter congeners, which tend to be more water-soluble and volatile, thereby apparently enriching heavier congeners. Reductive chlorination depletes heavier congeners and enriches lighter congeners.

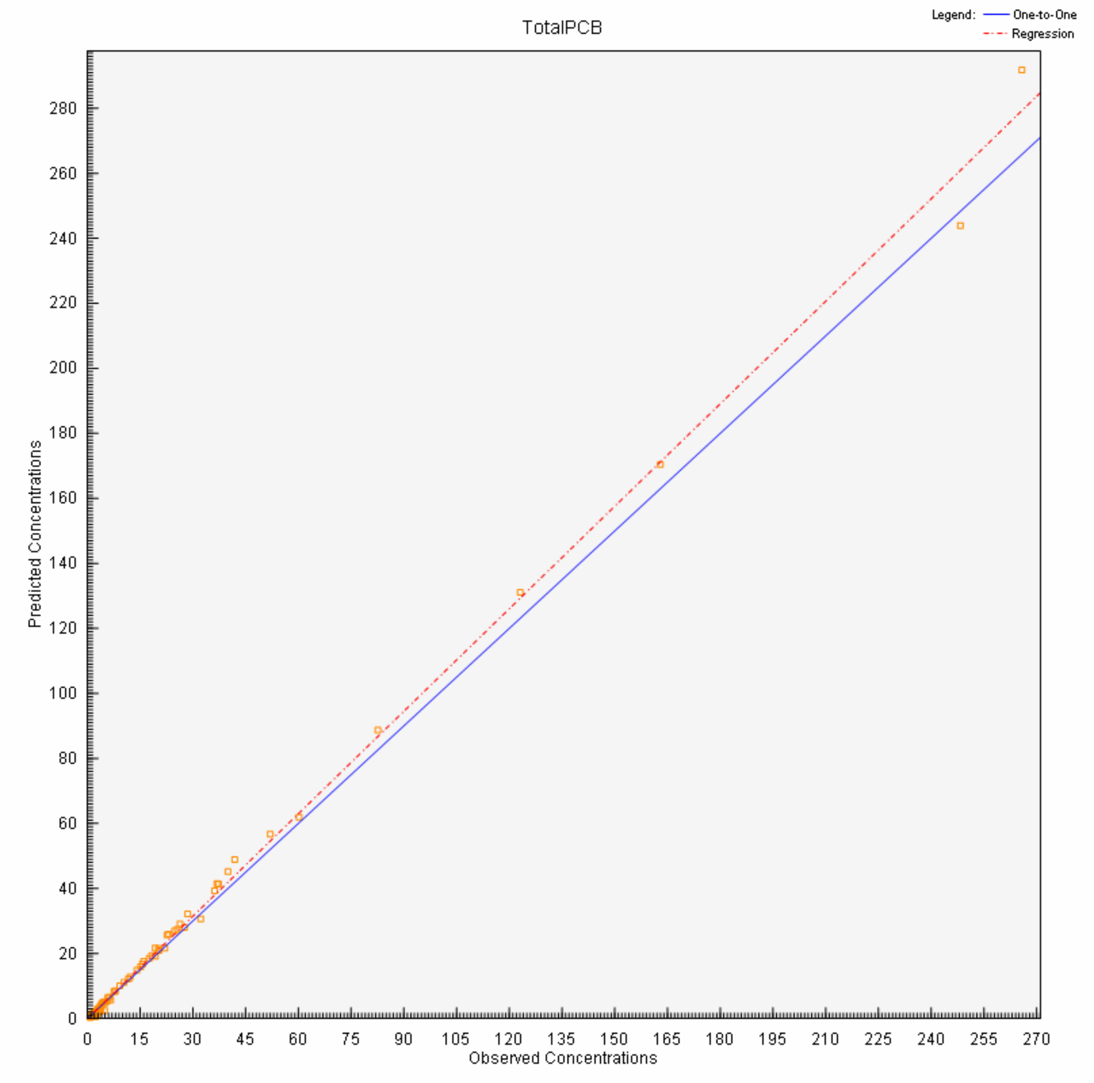


Figure 2.16 Observed Total PCB Concentrations in Sediment (ng/g) Versus Those Predicted by the PMF Model

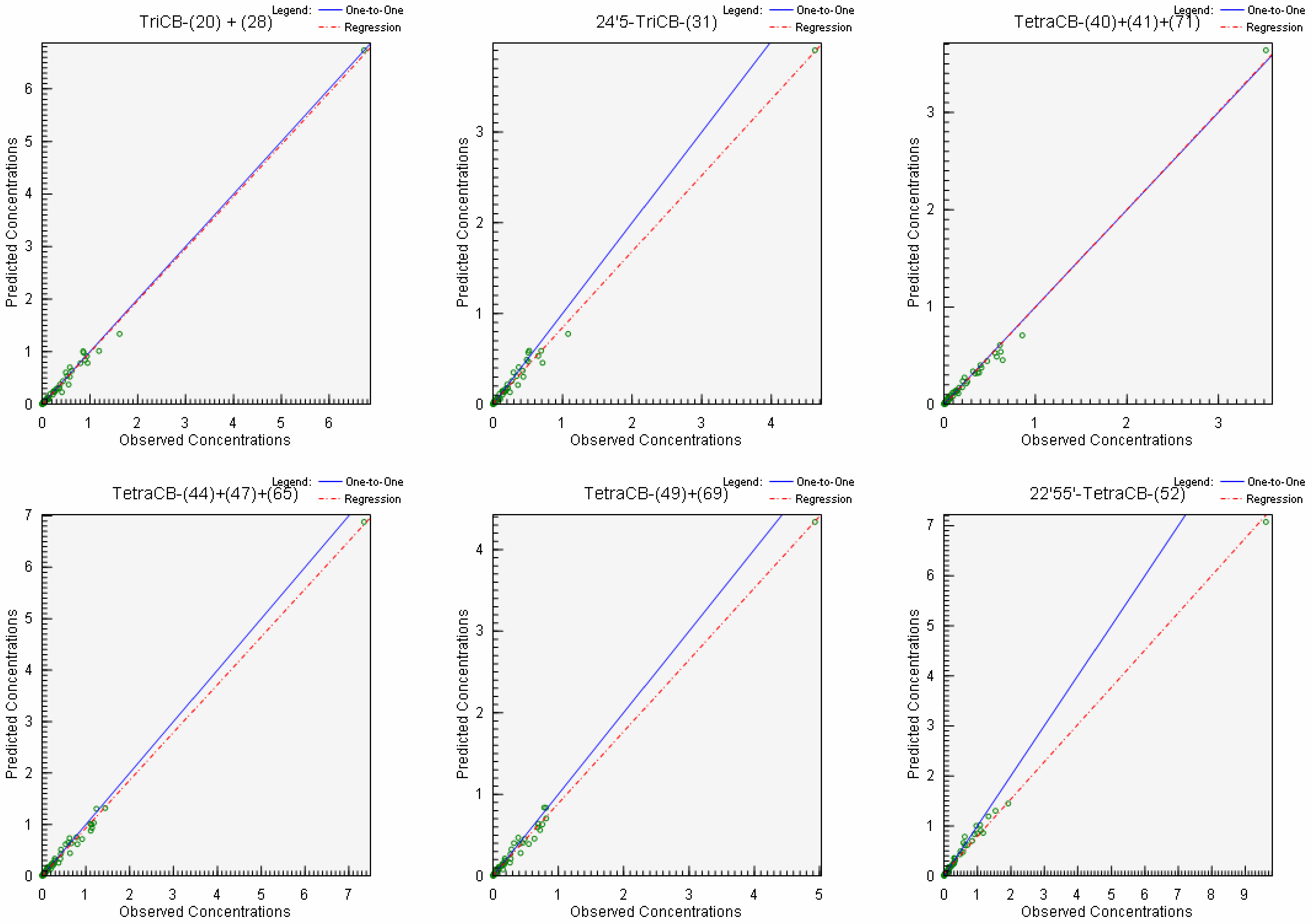


Figure 2.17a Observed and Model-Predicted Concentrations of the Most Abundant Individual PCB Congeners in Sediment Samples

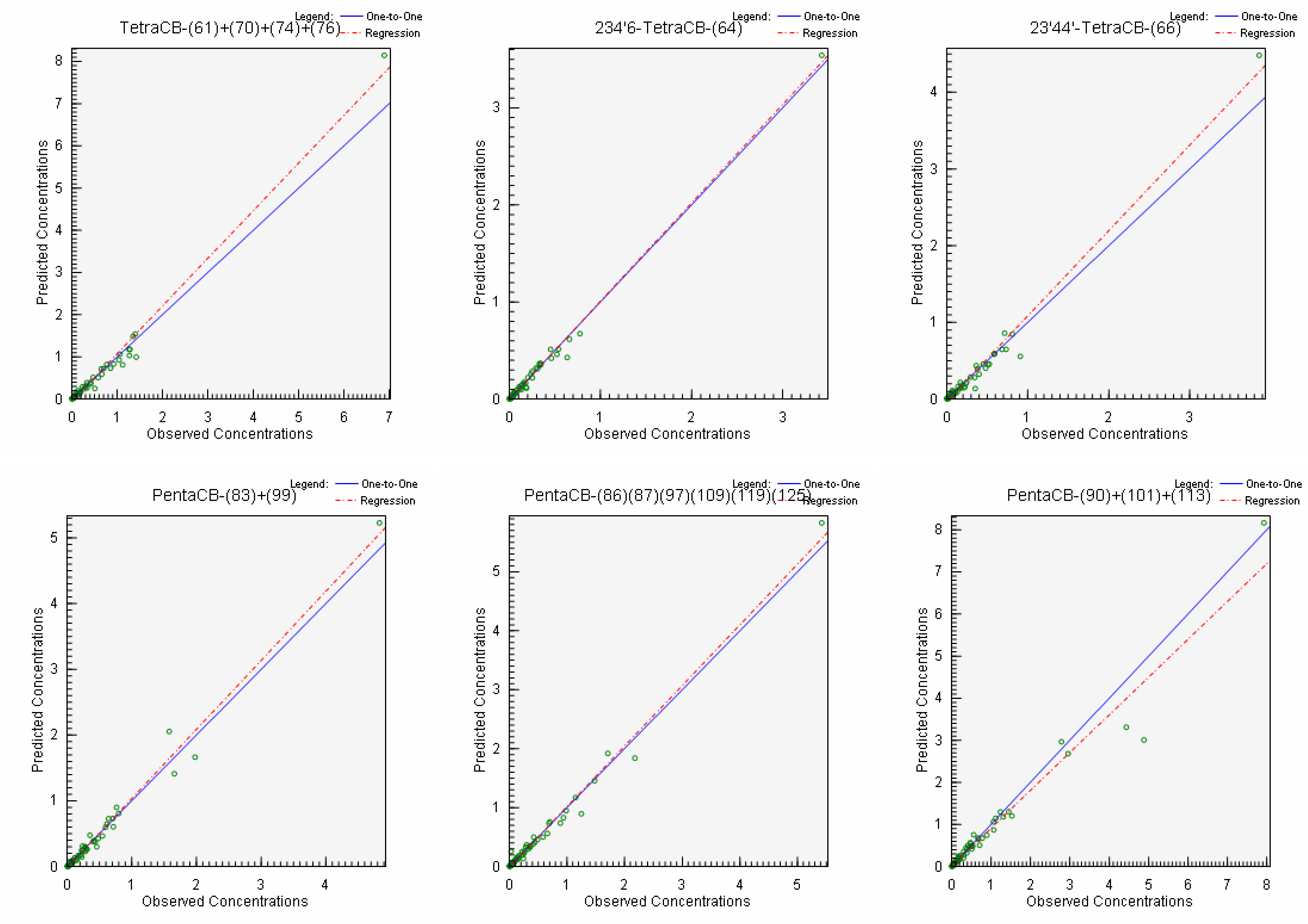


Figure 2.17b Observed and Model-Predicted Concentrations of the Most Abundant Individual PCB Congeners in Sediment Samples

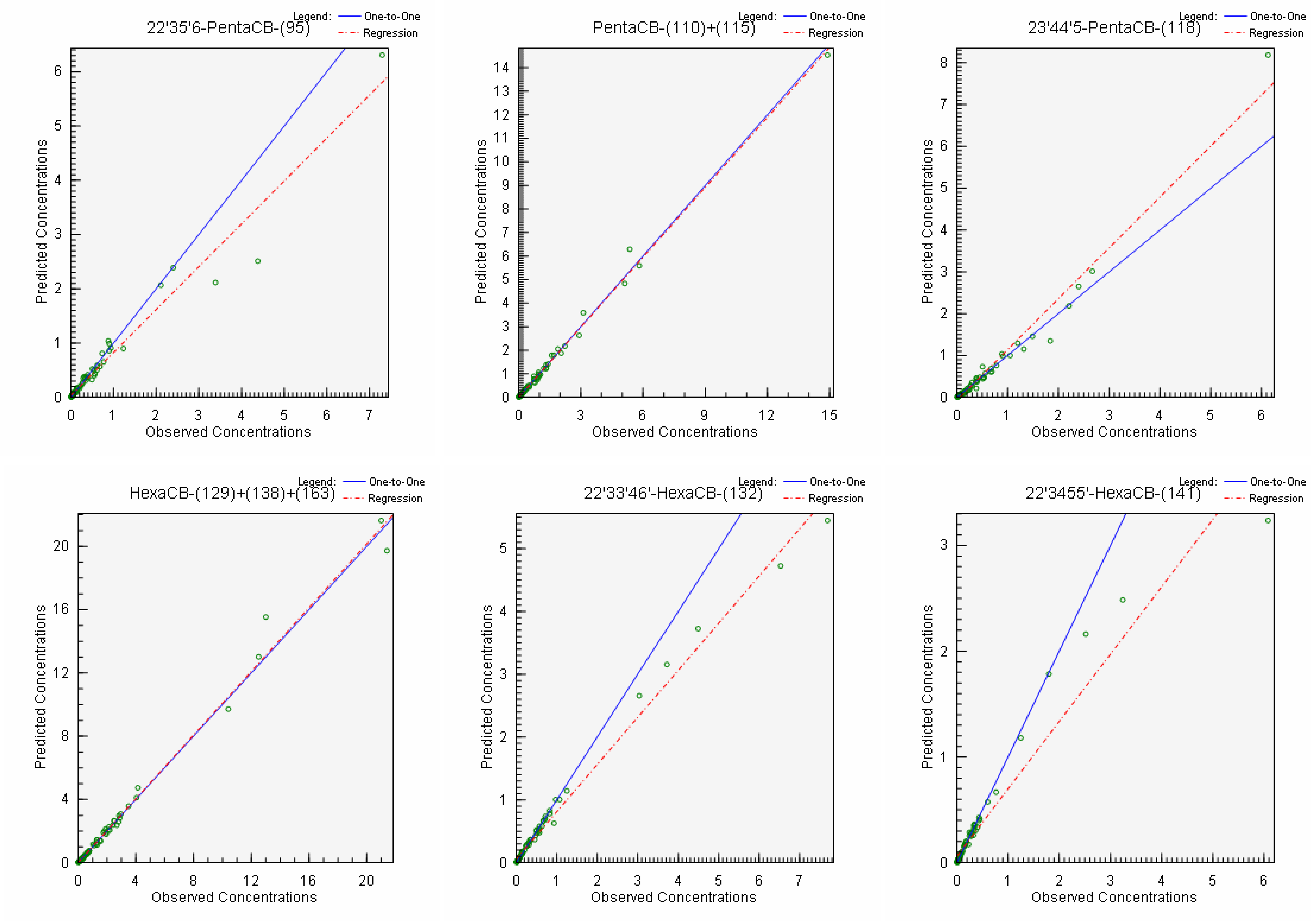


Figure 2.17c Observed and Model-Predicted Concentrations of the Most Abundant Individual PCB Congeners in Sediment Samples

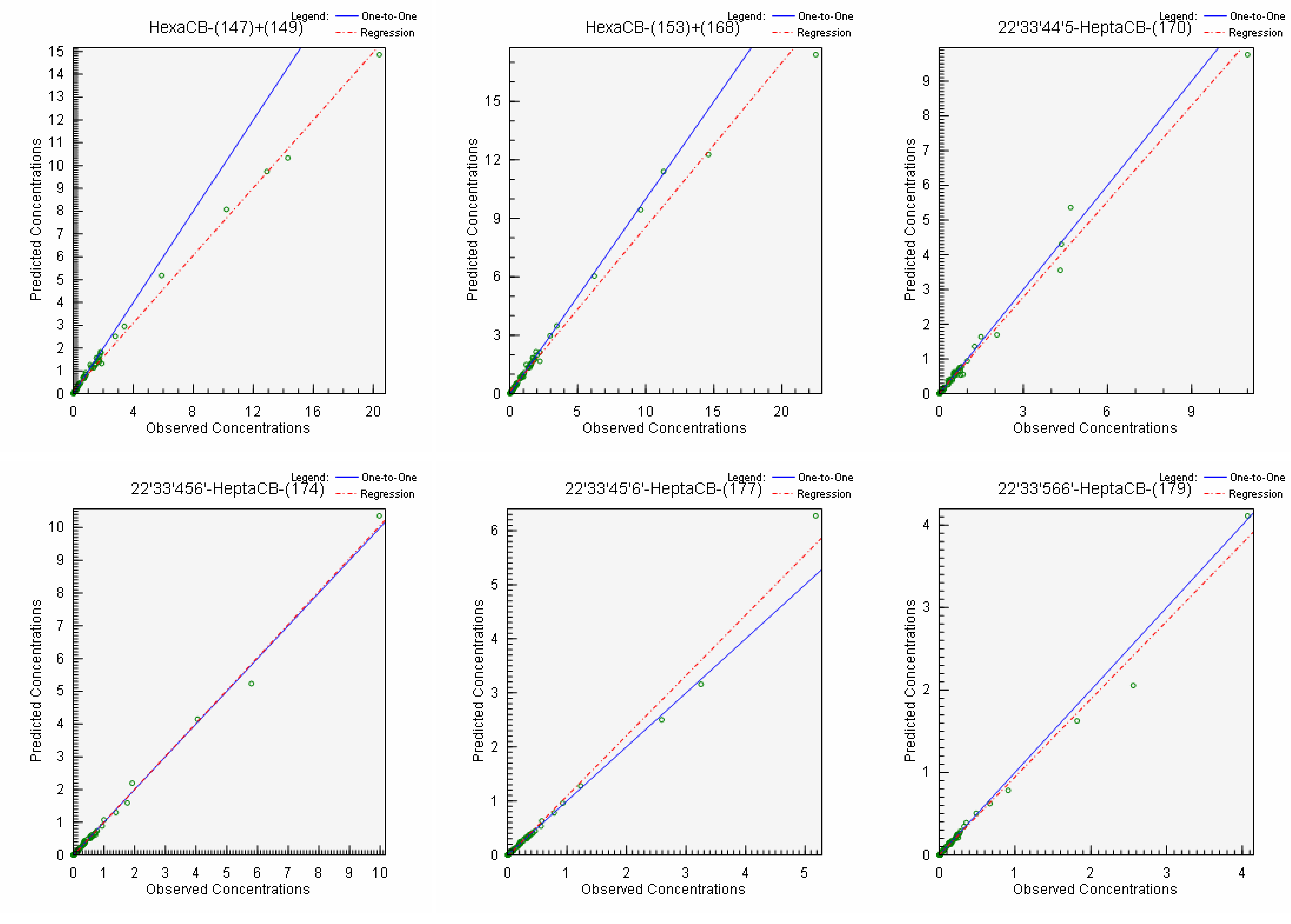


Figure 2.17d Observed and Model-Predicted Concentrations of the Most Abundant Individual PCB Congeners in Sediment Samples

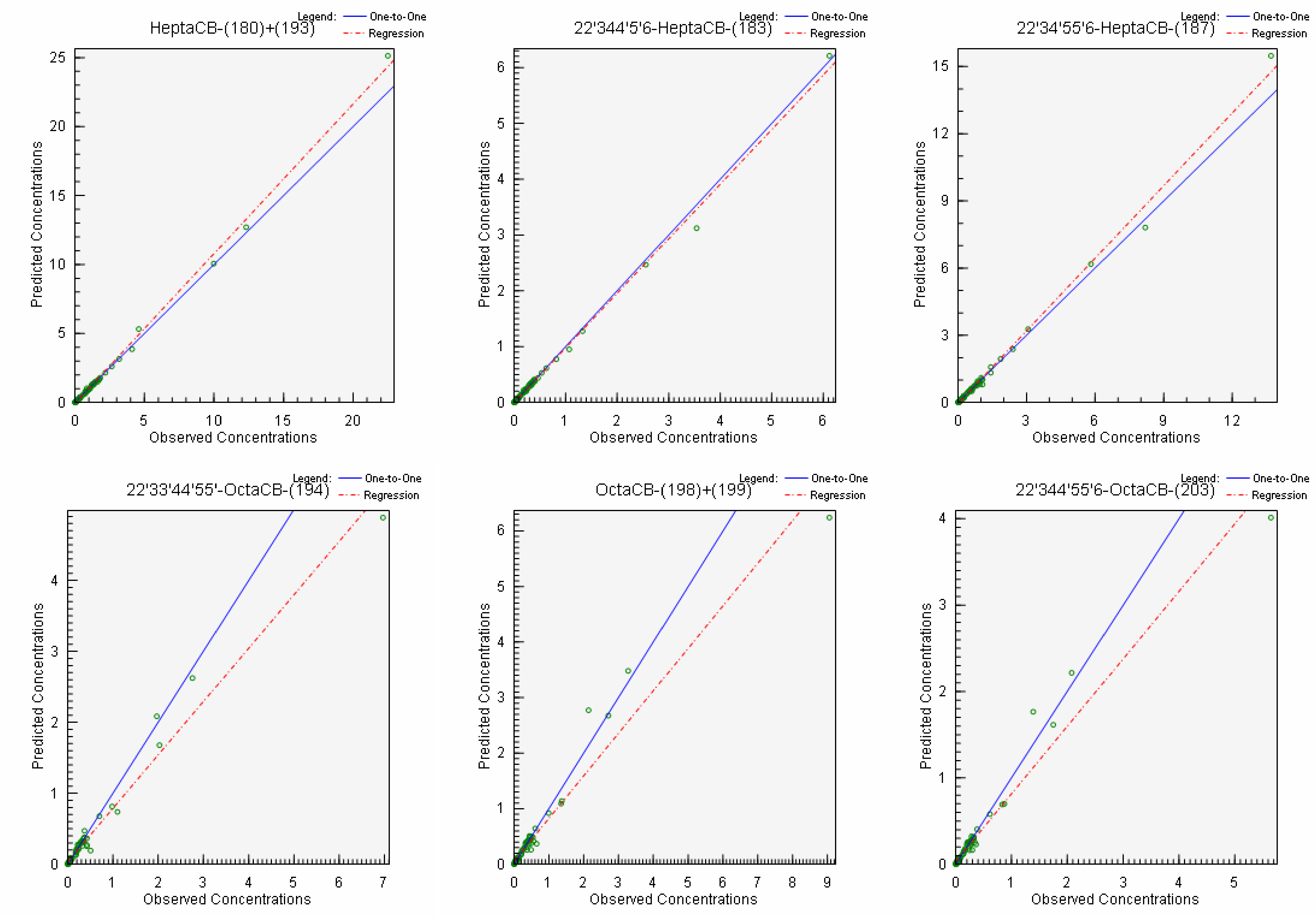
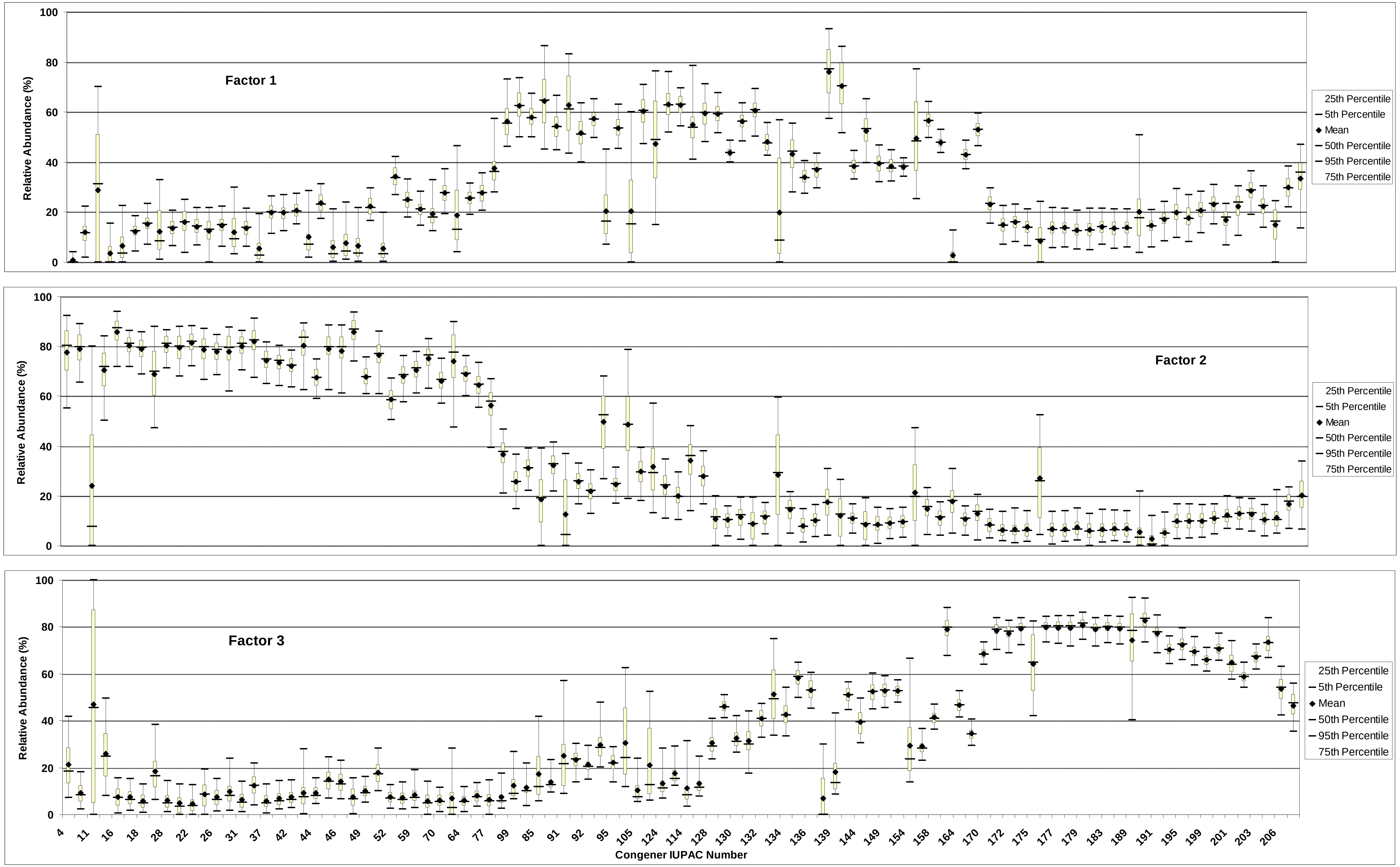
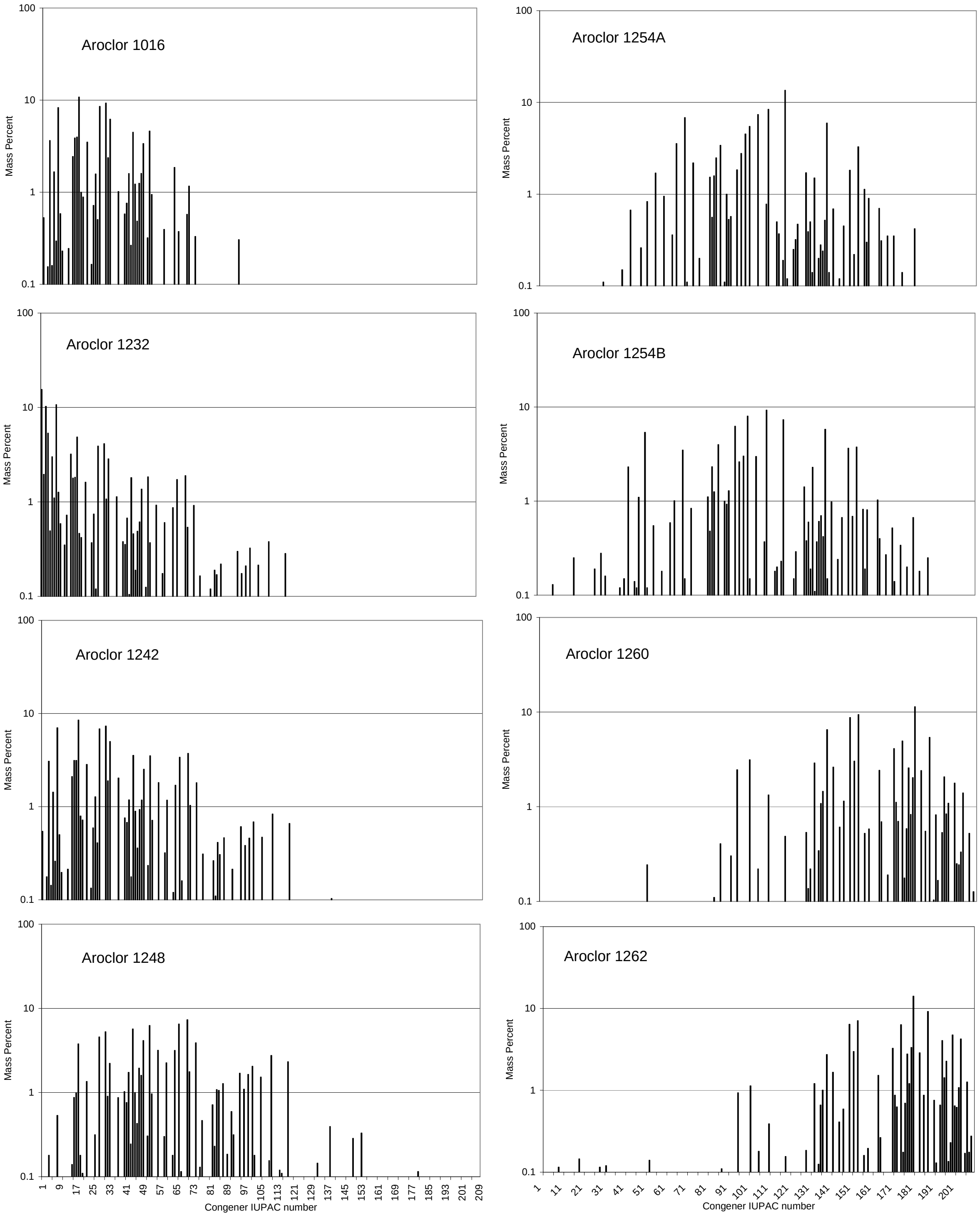


Figure 2.17e Observed and Model-Predicted Concentrations of the Most Abundant Individual PCB Congeners in Sediment Samples



Congeners are listed in elution order. For congener groups, only the main congener of the group is listed.

Figure 2.18 Relative Abundance of Congeners/Congener Groups in Each of the Three Factors of the PMF Model



Congeners are listed in elution order by International Union of Pure and Applied Chemistry (IUPAC) number. Heavier (more chlorinated) congeners are on the right side of each plot. Note that two different "batches" of Aroclor 1254 were identified.

Figure 2.19 Congener Profiles, in Mass Percent, of Selected Commercial Aroclor Mixtures, as Determined by Frame et al. (1996)

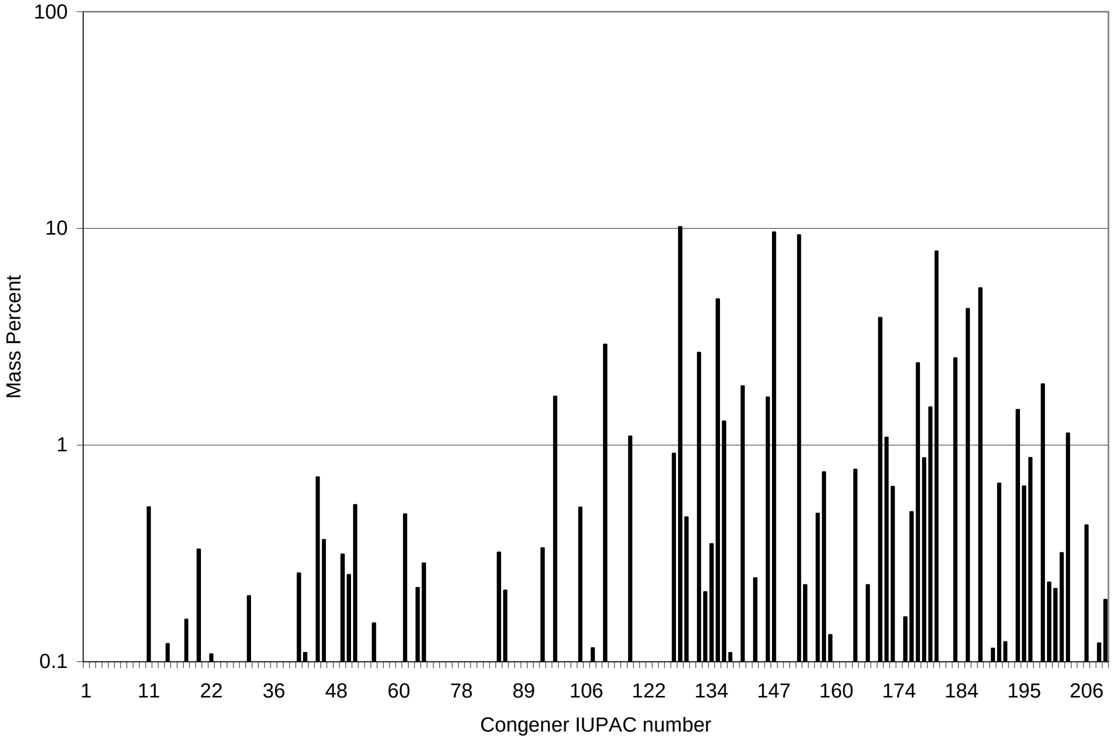


Figure 2.20 PCB Congener Distribution in Sediments from an Unnamed Tributary to the West Fork Trinity River at Haltom Road (Station 20432)

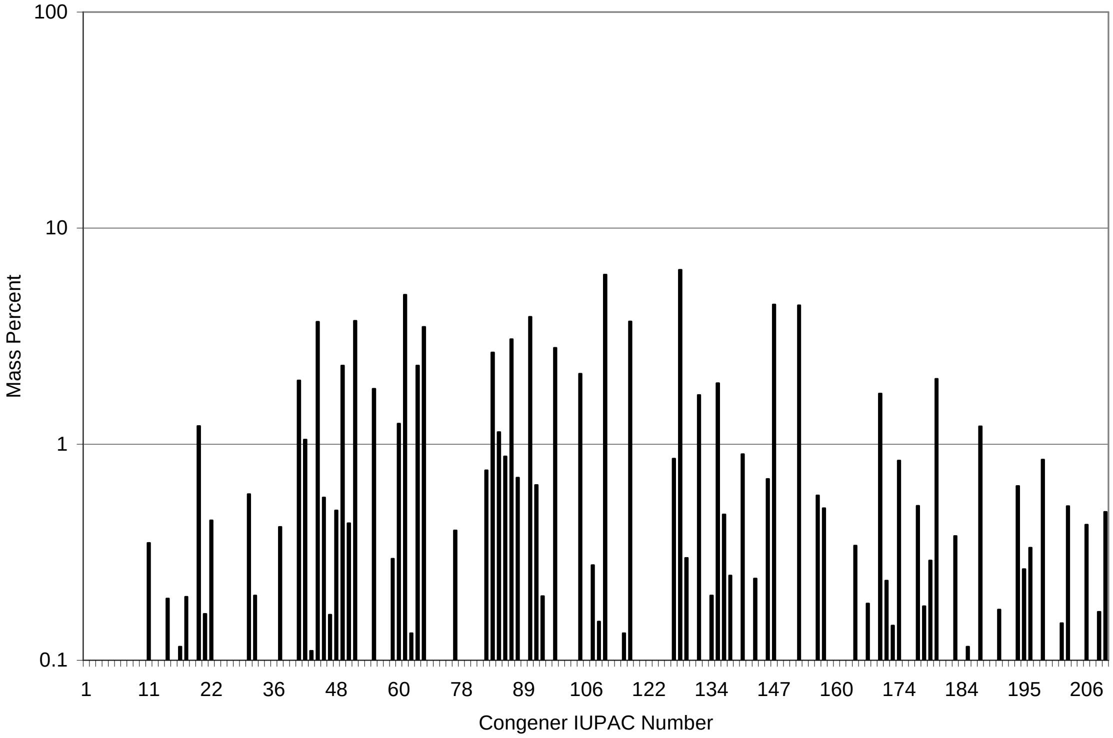


Figure 2.21 PCB Congener Distribution in Sediments from Marine Creek at Marine Creek Park (Station 20428)

Table 2.5 PCB Concentrations Attributed to Source Factors in the Three-Factor Positive Matrix Factorization Model

Station ID	Station Long Description	Factor 1 (mid-weight)	Factor 2 (light)	Factor 3 (heavy)
20425	West Fork Trinity River 360 m upstream of Meandering Rd	49%	24%	27%
20424	West Fork Trinity River 180 m south of intersection of Scott Rd and Nursery Lane	18%	57%	25%
18460	West Fork Trinity River at University Dr.	51%	38%	12%
20336	West Fork Trinity River upstream of Nutt Dam	21%	49%	30%
20336	West Fork Trinity River upstream of Nutt Dam	0%	5%	95%
20336	West Fork Trinity River upstream of Nutt Dam	21%	39%	40%
20336	West Fork Trinity River upstream of Nutt Dam	29%	43%	29%
20422	West Fork Trinity River 80 meters upstream of North Side Drive Dam #3	20%	35%	45%
20422	West Fork Trinity River 80 meters upstream of North Side Drive Dam #3	23%	47%	30%
17368	West Fork Trinity River above Fourth Street dam	32%	57%	10%
10938	West Fork Trinity River at Beach St.	19%	37%	44%
17662	West Fork Trinity River at East 1St Street	4%	31%	65%
16120	West Fork Trinity River at Handley-Ederville Rd.	12%	12%	76%
11085	West Fork Trinity River at Precinct Line Rd.	5%	8%	87%
17160	Lower West Fork Trinity River at Greenbelt Rd.	54%	0%	47%
11087	West Fork Trinity River at FM 157 (Collins St)	0%	12%	88%
11084	Lower West Fork Trinity River at SH 360	15%	34%	51%
17669	Lower West Fork Trinity at Roy Orr Blvd.	21%	11%	68%

Station ID	Station Long Description	Factor 1 (mid-weight)	Factor 2 (light)	Factor 3 (heavy)
11081	Lower West Fork Trinity at Belt Line Rd	35%	8%	57%
11089	West Fork Trinity River at West Loop 12	26%	42%	33%
10937	Upper Trinity River at Westmoreland Rd	13%	22%	65%
10936	Upper Trinity River at Commerce St.	27%	20%	53%
10935	Upper Trinity River at I-45	42%	1%	57%
10935	Upper Trinity River at I-45	43%	14%	43%
20444	Upper Trinity River 170 meters downstream of South Central Expressway	49%	2%	49%
10934	Upper Trinity River at South Loop 12	30%	17%	53%
10934	Upper Trinity River at South Loop 12	51%	4%	46%
20567	Upper Trinity River 2.25 kilometers upstream of IH 20	31%	1%	68%
10932	Upper Trinity River at Dowdy Ferry Road	36%	6%	58%
20566	Upper Trinity River 275 m upstream of the confluence with Ten Mile Creek	39%	16%	45%
10925	Upper Trinity River at SH 34 NE of Ennis	27%	6%	68%
10924	Upper Trinity River at FM 85 West of Seven Points	42%	13%	45%
11044	Clear Fork at Rogers Rd.	21%	58%	21%
18456	Clear Fork Trinity River at Rosedale St.	35%	48%	18%
16122	Clear Fork Trinity River 275 meters downstream of IH-30	30%	40%	30%
20427	Clear Fork Trinity River 235 m upstream of West Lancaster	16%	0%	83%

Station ID	Station Long Description	Factor 1 (mid-weight)	Factor 2 (light)	Factor 3 (heavy)
16119	Clear Fork Trinity River at Purcey St	38%	49%	12%
17126	Purcey Street Drain	78%	22%	0%
17370	Marine Creek at NE 23rd St.	18%	30%	51%
20430	Lebow Creek at Brennan Ave	19%	60%	22%
15613	Sycamore Creek at East Seminary Drive	30%	28%	42%
20431	Sycamore Creek at US Highway 287	43%	23%	34%
17131	Sycamore Creek at I-30	0%	74%	27%
20433	Little Fossil Creek at DART railroad bridge	46%	22%	31%
10814	Big Fossil Creek upstream of confluence with West Fork Trinity River	55%	6%	39%
17189	Village Creek at I-30	24%	12%	64%
20434	Walker Branch at Trammel-Davis Road	35%	37%	28%
20435	Sulphur Branch at Mosier Valley Rd	53%	3%	43%
20436	Unnamed tributary to West Fork Trinity River at Mosier Valley Rd	28%	50%	23%
20437	Unnamed tributary to West Fork Trinity River at South Main St. in Euless	3%	83%	15%
17664	Johnson Creek at North Carrier Parkway	57%	34%	9%
17671	Dalworth Creek at West Palace Parkway	0%	75%	25%
10864	Bear Creek at MacArthur Blvd.	21%	56%	22%
10864	Bear Creek at MacArthur Blvd.	12%	62%	25%

Station ID	Station Long Description	Factor 1 (mid-weight)	Factor 2 (light)	Factor 3 (heavy)
17682	Mountain Creek at West Jefferson Blvd.	100%	0%	0%
10815	Mountain Creek at Singleton Blvd.	15%	85%	0%
15617	Delaware Creek in Fritz Park	18%	50%	32%
11024	Elm Fork Trinity River above Carrollton Dam	30%	62%	8%
20438	Elm Fork Trinity River 335 m upstream of California Crossing Rd.	11%	79%	10%
18310	Elm Fork Trinity River at East Irving Blvd.	25%	24%	51%
20341	Storm water canal at Pump Station "Able"	45%	52%	3%
20447	Storm water canal at Pump Station “Delta”	33%	64%	3%
20445	Storm water canal at Pump Station “Baker”	92%	0%	8%
20448	Storm water canal at Pump Station “Pavaho”	28%	10%	62%
10843	Coombs Creek	29%	25%	46%
20446	Storm water canal at Pump Station “Charlie”	53%	27%	20%
20340	Storm water canal at Pump Station "Hampton"	38%	0%	62%
20440	Cedar Creek at East 8th Street in Moore Park	38%	31%	31%
20423	Storm water canal at Pump Station “Rochester”	21%	4%	75%
10816	White Rock Creek at US Highway 175	53%	10%	37%
18458	White Rock Creek at South 2nd Ave	41%	5%	54%
20441	Honey Springs Branch	20%	68%	12%

Station ID	Station Long Description	Factor 1 (mid-weight)	Factor 2 (light)	Factor 3 (heavy)
20443	Elam Creek at Gayglen Drive	13%	73%	14%
18575	Five Mile Creek at Stuart-Simpson Rd	53%	34%	13%
20442	Prairie Creek at Dowdy Ferry Road	38%	31%	31%
20339	Ten Mile Creek below Parkinson Rd	35%	48%	18%
10839	Parsons Slough near Davis Road south of Combine	26%	32%	42%
10839	Parsons Slough near Davis Road south of Combine	27%	28%	45%
10990	East Fork Trinity River at FM 3039	18%	73%	9%
17506	Red Oak Creek at FM 660	18%	74%	8%

SECTION 3
POLLUTANT SOURCE ASSESSMENT

To support TMDL development, a pollutant source assessment attempts to characterize known and suspected sources of pollutant loading to impaired waterbodies. Pollutant sources within a watershed are categorized and quantified to the extent that information is available. PCBs were produced and sold not as individual congeners, but as mixtures of congeners. They were sold in the U.S. primarily under the trade name Aroclor. Various Aroclor mixtures, varying in the amount of chlorine, were manufactured (e.g., Aroclor 1232, 1242, 1248, 1254, 1260). The last two numbers of each Aroclor mixture indicate the approximate percentage of chlorine by mass in the product. An Aroclor 1260 would have a greater proportion of heavier congeners such as the hexa- to deca-chlorobiphenyls than would an Aroclor 1232. The various commercial Aroclor mixtures were tailored for different applications. For example, a heavier Aroclor mixture was preferred for high temperature applications.

Pollutant loads to waterbodies are commonly classified as either point sources or nonpoint sources (NPS). Point source pollutants are typically delivered to a waterbody through a discrete conveyance such as a pipe or channel, while NPS pollution originates from diffuse locations and is usually transported to waterbodies in rainfall runoff (storm water). However, loads from storm water are also considered point sources in some cases, as discussed below. Point sources of pollution are regulated by permit, while NPS are not.

The National Pollutant Discharge Elimination System (NPDES) is a federal regulatory program to control discharges of pollutants to surface waters of the United States. The State of Texas assumed the authority to administer the NPDES in Texas in 1998. The TCEQ's Texas Pollutant Discharge Elimination System (TPDES) program now has federal regulatory authority over discharges of pollutants to Texas surface water, with the exception of discharges associated with oil, gas, and geothermal exploration and development activities.

3.1 Point Sources: NPDES/TPDES-Permitted Sources

Under 40 CFR, §122.2, a point source is described as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Under the Texas Water Code, the TCEQ has adopted rules and procedures to issue permits to control the quantity and quality of discharges into or adjacent to waters of the state through the TPDES program. TPDES-permitted facilities classified as point sources that may contribute PCB loading to surface waters include:

- municipal wastewater treatment facilities (WWTFs);
- private domestic WWTFs, such as those serving some mobile home parks;
- industrial WWTFs discharging treated wastewater and/or ground water;
- industrial facilities with individual storm water permits;
- Phase I and Phase II municipal separate storm sewer systems (MS4s); and
- facilities covered under TPDES general permits

3.1.1 Individually Permitted Sources

Twenty-three facilities hold individual TPDES permits to discharge treated wastewater, groundwater, and storm water to the impaired assessment units. These facilities include eight public domestic wastewater (sewage) treatment facilities, three private domestic wastewater (sewage) treatment facilities, and eleven industrial facilities with discharges including process wastewater, storm water, and treated ground water. Additionally, one drinking water treatment facility discharges wastewater from backwashing of filters.

PCB data from point sources gathered as part of this TMDL project during spring and summer 2008 were used to calculate existing daily loadings. For the point sources that were not sampled, the PCB concentration was assumed equal to the average PCB concentration from the four sampled facilities (0.81 ng/L). Because the discharges from these four facilities made up more than 95% of the total wastewater discharges to the Study Area, this assumption is unlikely to greatly affect the estimate of current PCB loading. The loads were calculated based on the average self-reported flows from discharge monitoring reports (as found in the USEPA Permit Compliance System database (www.epa.gov/enviro). Only the previous five years of reports (2004-2008) were used in order to reflect the most recent data. Table 3.1 provides a summary of the individually-permitted facilities (excluding MS4s with individual permits) in each assessment unit.

3.1.2 TPDES Regulated Storm Water

In 1990, the USEPA developed rules establishing Phase I of the NPDES MS4 Storm Water Program, designed to prevent harmful nonpoint sources of pollutants from being washed by storm water runoff into municipal separate storm sewer systems and then discharged into local waterbodies. Phase I of the program required medium and large cities with populations of 100,000 or more, and certain other public entities, to obtain a NPDES permit for their storm water discharges and implement a storm water management program as a means to control polluted discharges. Approved storm water management programs for medium and large permitted discharges are required to address a variety of water quality-related issues, including roadway runoff management, municipal-owned operations, and hazardous waste treatment.

Phase II of the rule extended coverage of the TPDES Storm Water Program to certain small MS4s in urbanized areas. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the TPDES Storm Water program. Phase II requires operators of regulated small MS4s to obtain coverage under a TPDES Phase II MS4 general permit and develop a storm water management program. In most cases, Phase I TPDES permittees obtained individual permits, while Phase II entities were covered under general permits.

It is important to note that for many MS4 cities and counties, only a portion of their incorporated area falls within the definition of an urbanized area and is covered by the TPDES program. An urbanized area is considered to have a population greater than 10,000 people and a population density of greater than 1,000 people per square mile.

Table 3.1 Estimated PCB Loads from Individually Permitted Facilities Discharging to the Impaired Waterbodies

TCEQ Permit #	Name	Facility Name	AU	Permit Category	Effluent Type	Flow (MGD)		Estimated PCB Load (mg/day)[b]
						Permitted	Average self-reported[d]	
WQ0002831-000	Reagent Chemical & Research, Inc	Reagent Chemical & Research, Inc	0806_01	Industrial	Treated Wastewater	[a]	<0.00001	<0.001
WQ0003730-000	Chevron USA, Inc.	Chevron USA, Inc.		Industrial	Treated Wastewater	[a]	0.0025	0.008
WQ0010494-013	City of Fort Worth	Village Creek WWTP	0841_02	Public Domestic	Treated Wastewater	166	108.4	371
WQ0003993-000	Citgo Products Pipeline Company	Arlington Pump Station		Industrial	Treated Wastewater	[a]	0.006	0.020
WQ0010303-001	Trinity River Authority of Texas	Central Regional WWTP	0841_01	Public Domestic	Treated Wastewater	189	137.2	328
WQ0011032-001	Andrews, Chester Alan	Alta Vista Mobile Home Park		Private Domestic	Treated Wastewater	0.008	0.005	0.017
WQ0012982-001	Regency Conversions Inc	Regency Conversions		Private Domestic	Treated Wastewater	0.005	0.003	0.010
WQ0001250-000	Extex LaPorte LP	Mountain Creek Steam Electric Station		Industrial	Storm Water	[a]	0.022	0.073
WQ0003446-000	Hanson Pipe & Precast, Inc.	Grand Prairie Pressure Pipe Plant		Industrial	Treated Wastewater, Storm Water	[a]	1.06	3.53
WQ0001441-000	Dallas-Fort Worth International Airport Board	Dallas-Fort Worth International Airport		Industrial	Storm Water	[a]	None reported	
WQ0014699-001	Dallas County Park Cities MUD	Dallas County Park Cities Municipal Utility District Water Treatment Plant	0805_04	Public	Treated Filter Backwash	0.72	0.122	0.41
WQ0004161-000	2200 Ross LP	Chase Tower		Industrial	Treated Ground Water, Storm Water	0.155	0.166	0.55
WQ0004663-000	Buckley Oil Co.	Buckley Oil Co. WWTP		Industrial	Storm Water	[a]	0.022	0.073
WQ0004765-000	IPC Dallas I, LP	San Jacinto Tower Office		Industrial	Treated Ground Water	0.029092	None reported	0.089
WQ0010060-001	City of Dallas	Central WWTP	0805_03	Public Domestic	Treated Wastewater	200	122.5	602
WQ0010060-006	City of Dallas	Southside WWTP	0805_06	Public Domestic	Treated Wastewater	110	64.5	169
WQ0004687-000	Univar USA, Inc.	Univar USA, Inc.		Industrial	Storm Water	[a]	None reported	
WQ0014628-001	D-BAR-B Water-Wastewater Supply Corporation	D-BAR-B Water-Wastewater Supply Corporation		Private Domestic	Treated Wastewater	0.024	0.0015	0.005
WQ0010984-001	Trinity River Authority	Ten Mile Creek Plant	0805_02	Public Domestic	Treated Wastewater	24	14.9	49.6
WQ0013415-001	Trinity River Authority	Red Oak Creek Regional WWTP		Public Domestic	Treated Wastewater	6	2.58	8.59
WQ0014795-001	City of Palmer	City of Palmer WWTF		Public Domestic	Treated Wastewater	0.226	0.154	0.51
WQ0002519-000	Hanson Aggregates West, Inc.	Hanson Aggregates West, Inc.		Industrial	Storm Water	0.3	0	0
WQ0014471-001	Scurry-Rosser ISD	Scurry-Rosser WWTP	0805_01	Public Domestic	Treated Wastewater	0.04	None reported	0.067[c]

a Intermittent and flow variable

b For the four sampled facilities, PCB load was calculated using measured PCB concentrations and self-reported flows, for the remainder, loads were calculated using average PCB from 4 major facilities (0.88 ng/L) times self-reported flows

c Half of the permitted flow was used for load calculations due to lack of self-reporting data

d from January 2004 to December 2008

The TPDES MS4 program is designed to reduce discharges of pollutants to the “maximum extent practicable,” protect water quality, and satisfy appropriate water quality requirements of the Clean Water Act. Small MS4 storm water programs must address the following minimum control measures:

- public education and outreach;
- public participation/involvement;
- illicit discharge detection and elimination;
- construction site runoff control;
- post- construction runoff control; and
- pollution prevention/good housekeeping.

The MS4s in the watersheds of each assessment unit are listed in Tables 3.2 to 3.9. There are no MS4s in assessment unit 0805_01.

In addition to the MS4 program, storm water discharges from individual facilities involved in certain activities are required to be covered under TPDES general permits. These statewide general TPDES permits include:

- TXR050000 – multi-sector industrial facilities
- TXR150000 – construction activities disturbing more than 1 acre
- TXG110000 – concrete production facilities
- TXG130000 – aquaculture production facilities
- TXG340000 – petroleum bulk stations and terminals
- TXG670000 – hydrostatic test water
- TXG830000 – water contaminated by petroleum fuel or petroleum substances
- TXG920000 – concentrated animal feeding operations
- WQG20000 – livestock manure compost operations
- TXG500000 – quarries in the John Graves scenic riverway

The facilities covered under TPDES general permits in the watersheds of each assessment unit are listed in Table 3.10, with the exception of construction activities. Facilities covered under construction activities were not listed because they are very numerous and short-term in nature.

Pollutant loads in storm water runoff originating from portions of the watershed covered by a TPDES discharge permit are considered a point source, while storm water runoff loads from portions of the watershed not covered by a permit are considered NPS pollutants. Thus, to characterize pollutant loads from storm water runoff, it is necessary to segregate storm water runoff into two categories: 1) TPDES-permitted storm water, which is storm water originating from a TPDES-permitted Phase I or Phase II urbanized area (MS4 permittees) or a facility permitted under a TPDES general permit; and 2) non-permitted storm water, which is storm water originating from any area not covered by a TPDES permit. Considerable portions of most of the assessment units in the TMDL Study Area are covered under one or more MS4 discharge permits. The approximate jurisdictional boundaries of the MS4 permits are from a map provided by the USEPA (http://www.epa.gov/npdes/pubs/ua_tx_dallasfortwortharlington.pdf) and provided in Figure 3.1. The approximate contributing watersheds to each assessment unit were delineated based on digital elevation models at 30 meter resolution from the National Elevation Dataset (http://ned.usgs.gov/).

Table 3.2 MS4s in the Watershed of Assessment Unit 0829_01

Permit Number	MS4 Permittee	Approximate Area under MS4 Permit (mi^2)	Percent of AU under MS4 Permit	NPS Percent of AU Area
WQ0004350-000	City of Fort Worth	40	43%	48%
TXR040083	City of Benbrook	8	9%	
TXR040052	Tarrant County	1	1%	
TXR040184	Texas DOT	†	†	

Total watershed area is 94 square miles, including watershed of entire Segment 0829
† precise area cannot be determined

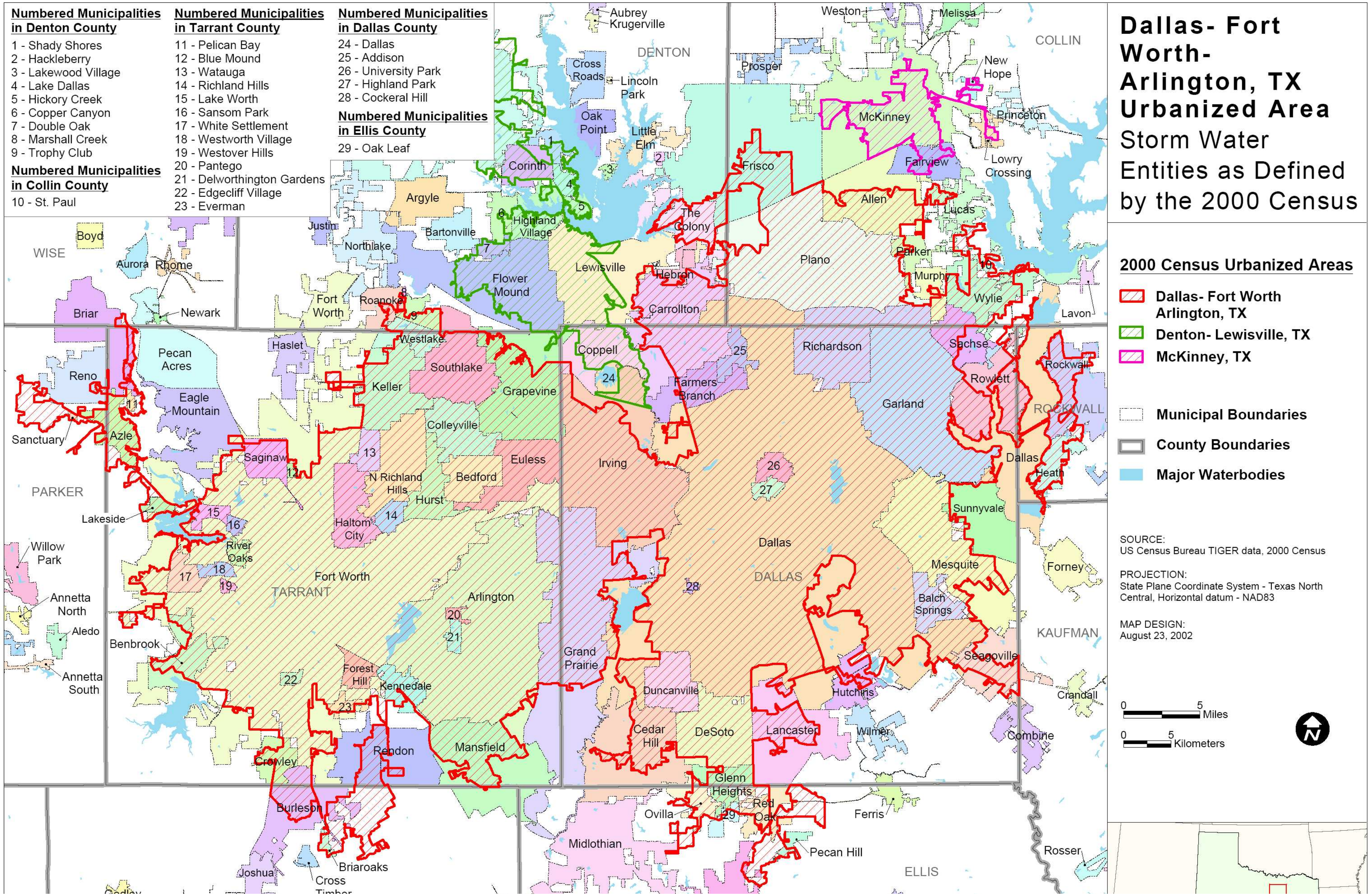


Figure 3.1 USEPA Map of Municipal Separate Storm Sewer System Areas in the Dallas-Fort Worth-Arlington Urbanized Area

Table 3.3 MS4s in the Watershed of Assessment Unit 0806_01

Permit Number	MS4 Permittee	Approximate Area under MS4 Permit (mi^2)	Percent of AU under MS4 Permit	NPS Percent of AU Area
WQ0004350-000	City of Fort Worth	120	60%	18%
TXR040100	City of Haltom City	12	6%	
TXR040145	City of Saginaw	7	4%	
TXR040275	City of Watauga	4	2%	
TXR040113	City of North Richland Hills	4	2%	
TXR040125	City of White Settlement	4	2%	
TXR040089	City of Richland Hills	3	1%	
TXR040146	City of River Oaks	2	1%	
TXR040378	City of Westworth Village	2	1%	
TXR040004	Town of Edgecliff Village	1	<1%	
TXR040376	City of Sansom Park	1	<1%	
TXR040052	Tarrant County	<1	<1%	
TXR040093	City of Blue Mound	<1	<1%	
TXR040017	City of Keller	<1	<1%	
TXR040039	City of Hurst	<1	<1%	
TXR040192	Tarrant County College NW	<1	<1%	
TXR040389	Federal Bureau of Prisons	< 1	<1%	
TXR040099	City of Lake Worth	<1	<1%	
TXR040091	City of Forest Hill	<1	<1%	
TXR040184	Texas DOT	†	†	
TXR040232	Dallas Area Rapid Transit	†	†	

Total watershed area is 201 square miles, including watershed of entire Segment 0806
† precise area cannot be determined

Table 3.4 MS4s in the Watershed of Assessment Unit 0841_02

Permit Number	MS4 Permittee	Approximate Area under MS4 Permit (mi^2)	Percent of AU under MS4 Permit	NPS Percent of AU Area
WQ0004635-000	City of Arlington	47	43%	0%
WQ0004350-000	City of Fort Worth	19	17%	
TXR040113	City of North Richland Hills	10	9%	
TXR040039	City of Hurst	9	8%	
TXR040119	City of Bedford	8	7%	
TXR040211	City of Euless	5	5%	
TXR040065	City of Grand Prairie	6	5%	
TXR040015	City of Dalworthington Gardens	2	2%	
TXR040052	Tarrant County	1	1%	
TXR040325	Town of Pantego	1	1%	
TXR040006	City of Kennedale	<1	<1%	
TXR040207	City of Mansfield	<1	<1%	
TXR040089	City of Richland Hills	<1	<1%	
TXR040380	Tarrant County College NE	<1	<1%	
TXR040023	City of Colleyville	<1	<1%	
TXR040184	Texas DOT	†	†	
TXR040232	Dallas Area Rapid Transit	†	†	

Total assessment unit watershed area is 109 square miles
† precise area cannot be determined

Table 3.5 MS4s in the Watershed of Assessment Unit 0841_01

Permit Number	MS4 Permittee	Approximate Area under MS4 Permit (mi^2)	Percent of AU under MS4 Permit	NPS Percent of AU Area
WQ0004691-000	City of Irving	28	19%	5%
TXR040065	City of Grand Prairie	19	13%	
WQ0004635-000	City of Arlington	17	11%	
TXR040017	City of Keller	14	9%	
TXR040044	Dallas Fort Worth International Airport	14	9%	
TXR040023	City of Colleyville	13	9%	
TXR040007	City of Southlake	9	6%	
TXR040114	City of Grapevine	6	4%	
TXR040211	City of Euless	6	4%	
WQ0004396-000	City of Dallas	6	4%	
TXR040113	City of North Richland Hills	4	3%	
WQ0004350-000	City of Fort Worth	2	1%	
TXR040119	City of Bedford	2	1%	
TXR040052	Tarrant County	1	<1%	
TXR040039	City of Hurst	1	<1%	
TXR040120	Dallas County	<1	<1%	
TXR040255	Dallas County Flood Control District 1	‡	‡	
TXR040184	Texas DOT	†	†	
TXR040232	Dallas Area Rapid Transit	†	†	
WQ0004401-000	North Texas Tollway Authority [a]	†	†	

Total assessment unit watershed area is 149 square miles

† precise area cannot be determined

‡ area cannot be determined, but included within area of the City of Grand Prairie

Table 3.6 MS4s in the Watershed of Assessment Unit 0805_04

Permit Number	MS4 Permittee	Approximate Area under MS4 Permit (mi^2)	Percent of AU under MS4 Permit	NPS Percent of AU Area
WQ0004396-000	City of Dallas	70	91%	0%
TXR040025	City of University Park	4	5%	
TXR040050	City of Highland Park	2	3%	
TXR040274	City of Cockrell Hill	<1	<1%	
WQ0004691-000	City of Irving	<1	<1%	
TXR040184	Texas DOT	†	†	
TXR040232	Dallas Area Rapid Transit	†	†	
WQ0004401-000	North Texas Tollway Authority	†	†	

Total assessment unit watershed area is 77 square miles
† precise area cannot be determined

Table 3.7 MS4s in the Watershed of Assessment Unit 0805_03

Permit Number	MS4 Permittee	Approximate Area under MS4 Permit (mi^2)	Percent of AU under MS4 Permit	NPS Percent of AU Area
WQ0004396-000	City of Dallas	51	100%	0%
WQ0004641-000	City of Mesquite	<1	<1%	
TXR040104	City of Hutchins	<1	<1%	
TXR040184	Texas DOT	†	†	
TXR040232	Dallas Area Rapid Transit	†	†	

Total assessment unit watershed area is 51 square miles
† precise area cannot be determined

Table 3.8 MS4s in the Watershed of Assessment Unit 0805_06

Permit Number	MS4 Permittee	Approximate Area under MS4 Permit (mi^2)	Percent of AU under MS4 Permit	NPS Percent of AU Area
WQ0004396-000	City of Dallas	60	62%	29%
TXR040104	City of Hutchins	4	4%	
TXR040071	City of Lancaster	1	1%	
TXR040072	City of Duncanville	1	1%	
WQ0004641-000	City of Mesquite	1	1%	
TXR040213	City of Balch Springs	1	1%	
TXR040120	Dallas County	<1	<1%	
TXR040073	City of DeSoto	<1	<1%	
TXR040184	Texas DOT	†	†	
TXR040232	Dallas Area Rapid Transit	†	†	

Total assessment unit watershed area is 96 square miles
† precise area cannot be determined

Table 3.9 MS4s in the Watershed of Assessment Unit 0805_02

Permit Number	MS4 Permittee	Approximate Area under MS4 Permit (mi^2)	Percent of AU under MS4 Permit	NPS Percent of AU Area
TXR040073	City of DeSoto	21	5%	82%
TXR040280	City of Cedar Hill	12	3%	
TXR040071	City of Lancaster	10	2%	
WQ0004396-000	City of Dallas	10	2%	
TXR040072	City of Duncanville	9	2%	
TXR040213	City of Balch Springs	6	1%	
TXR040038	City of Glenn Heights	5	1%	
TXR040366	City of Red Oak	4	1%	
TXR040120	Dallas County	3	1%	
TXR040064	City of Seagoville	2	<1%	
TXR040328	City of Waxahachie	1	<1%	
TXR040020	City of Ovilla	1	<1%	
TXR040124	Ellis County	<1	<1%	
TXR040184	Texas DOT	†	†	
TXR040232	Dallas Area Rapid Transit	†	†	

Total assessment unit watershed area is 456 square miles

† precise area cannot be determined

Table 3.10 Facilities Permitted under TPDES State General Permits for Storm Water Discharges (Other than MS4)

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0829_01	TXR05U142	Waste Management Of Texas Inc
Multi-Sector	0829_01	TXR05U142	Waste Management Of Texas Inc
Multi-Sector	0829_01	TXR05U402	Colorado River Concrete LP
Multi-Sector	0829_01	TXR05W488	GMD Environmental Technologies Inc
Multi-Sector	0829_01	TXR05Y108	Texsand Distributors LP
Multi-Sector	0829_01	TXR05Y470	Seaboard International Inc
Multi-Sector	0806_02	TXR05M667	SPM Flow Control Inc
Multi-Sector	0806_02	TXR05P988	US Department Of The Navy
Multi-Sector	0806_02	TXR05U851	SPM Flow Control Inc
Multi-Sector	0806_02	TXR05Y291	Marco Display Specialists GP LP
Concrete Production	0806_01	TXG110126	Tarrant Concrete Co Inc
Concrete Production	0806_01	TXG110174	TXI Operations LP
Concrete Production	0806_01	TXG110177	TXI Operations LP
Concrete Production	0806_01	TXG110229	Lattimore Materials Company LP
Concrete Production	0806_01	TXG110352	Charleys Concrete Co Ltd
Concrete Production	0806_01	TXG110418	Southern Star Concrete Inc
Concrete Production	0806_01	TXG110449	Southern Star Concrete Inc
Concrete Production	0806_01	TXG110474	Southern Star Concrete Inc
Concrete Production	0806_01	TXG110477	Southern Star Concrete Inc
Concrete Production	0806_01	TXG110480	Southern Star Concrete Inc
Concrete Production	0806_01	TXG110762	Redi-Mix LLC

Permit Type	Assessment Unit	Permit Number	Permittee Name
Concrete Production	0806_01	TXG110904	Paisano Redi-Mix Inc
Concrete Production	0806_01	TXG110912	True Grit Redi Mix Ltd
Concrete Production	0806_01	TXG110990	Cowtown Redi Mix Inc
Hydrostatic Test Water	0806_01	TXG670044	Chevron USA Inc
Hydrostatic Test Water	0806_01	TXG670103	Semmaterials LP
Multi-Sector	0806_01	TXR05K559	Five Star Custom Foods Ltd
Multi-Sector	0806_01	TXR05L149	Fort Worth Landfill TX LP
Multi-Sector	0806_01	TXR05M630	PVI Industries LLC
Multi-Sector	0806_01	TXR05M793	United Parcel Service Inc
Multi-Sector	0806_01	TXR05N066	D & J Technologies Inc
Multi-Sector	0806_01	TXR05N114	Royal Baths Manufacturing Company Ltd
Multi-Sector	0806_01	TXR05Q218	Texas Galvanizing Inc
Multi-Sector	0806_01	TXR05R056	DSM Nutritional Products Inc
Multi-Sector	0806_01	TXR05S713	American Ironhorse Motorcycle Company Inc
Multi-Sector	0806_01	TXR05T653	Dillard Texas Operating Limited Partnership
Multi-Sector	0806_01	TXR05U706	Bana Inc
Multi-Sector	0806_01	TXR05U896	Fedex National Ltl Inc
Multi-Sector	0806_01	TXR05U923	Hubbard Feeds Inc
Multi-Sector	0806_01	TXR05U933	Barry Rubin dba Two Amigos Pull N Save
Multi-Sector	0806_01	TXR05V208	Paquin Energy & Fuel LLC
Multi-Sector	0806_01	TXR05V345	Jesse Small Ltd
Multi-Sector	0806_01	TXR05V423	Metroplex Sand & Gravel Ltd

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0806_01	TXR05V660	Westex Iron & Metal Company
Multi-Sector	0806_01	TXR05W058	American Iron Works Of Ft Worth Inc
Multi-Sector	0806_01	TXR05W062	Michael Garrett dba Northside Salvage & Scrap Metals
Multi-Sector	0806_01	TXR05W105	Crist Industries Inc
Multi-Sector	0806_01	TXR05W246	MMW Fabrication Ltd
Multi-Sector	0806_01	TXR05W313	Welbilt Walk-Ins LP
Multi-Sector	0806_01	TXR05W386	Landers Machine Co
Multi-Sector	0806_01	TXR05W486	Pavement Services Corporation
Multi-Sector	0806_01	TXR05W695	Specialty Adhesives Inc
Multi-Sector	0806_01	TXR05X234	Kimrick LP
Multi-Sector	0806_01	TXR05X340	GST Manufacturing Ltd
Multi-Sector	0806_01	TXR05X469	Fieldtech Avionics And Instruments Inc
Multi-Sector	0806_01	TXR05X472	Beltex Corporation
Multi-Sector	0806_01	TXR05X474	Gomez, Diego
Multi-Sector	0806_01	TXR05X555	Conagra Foods Packaged Foods LLC
Multi-Sector	0806_01	TXR05X583	North Texas Steel Company Inc
Multi-Sector	0806_01	TXR05X711	AAA Crains Auto Salvage LLC
Multi-Sector	0806_01	TXR05X732	Metroplex Wood Products Ltd
Multi-Sector	0806_01	TXR05X781	North American Steel Corporation
Multi-Sector	0806_01	TXR05X938	Corning Cable Systems LLC
Multi-Sector	0806_01	TXR05X944	Musket Corporation
Multi-Sector	0806_01	TXR05Y029	GP Rubber LP

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0806_01	TXR05Y109	Texsand Distributors LP
Multi-Sector	0806_01	TXR05Y124	Hanson Roof Tile Inc
Multi-Sector	0806_01	TXR05Y147	Crimstone AAA Operating Company LP
Multi-Sector	0806_01	TXR05Y151	US Lime Company
Multi-Sector	0806_01	TXR05Y160	Durham, Curtis Edward
Multi-Sector	0806_01	TXR05Y264	Agrana Fruit US Inc
Multi-Sector	0806_01	TXR05Y274	QSO Inc
Multi-Sector	0806_01	TXR05Y379	Chazaq Inc
Multi-Sector	0806_01	TXR05Y437	Buzbee Feed Mill LLC
Multi-Sector	0806_01	TXR05Y481	Semmaterials Energy Partners LLC
Multi-Sector	0806_01	TXR05Y536	Marco Display Specialists GP LC
Multi-Sector	0806_01	TXR05Y636	Rubin, Bernard
Multi-Sector	0806_01	TXR05Y725	Modern Forge Texas LLC
Multi-Sector	0806_01	TXR05Y833	Duckett, Lawrence
Multi-Sector	0841_02	TXR05O332	City Of Fort Worth
Multi-Sector	0841_02	TXR05P294	US Corrugated Inc
Multi-Sector	0841_02	TXR05R458	Big City Crushed Concrete Lp
Multi-Sector	0841_02	TXR05U907	Republic Waste Services Of Texas Ltd
Multi-Sector	0841_02	TXR05V504	Nestle Waters North America Inc
Multi-Sector	0841_02	TXR05V814	Shred Tech Inc
Multi-Sector	0841_02	TXR05V914	Cowtown Redi Mix Inc
Multi-Sector	0841_02	TXR05X239	Eddie Zavala dba Arlington Auto Salvage
Multi-Sector	0841_02	TXR05X460	Dallas Fort Worth Rail Terminal LLC

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0841_02	TXR05X780	Stratoflex Inc
Multi-Sector	0841_02	TXR05X878	Momentive Performance Materials USA Inc
Multi-Sector	0841_02	TXR05Y346	TXI Operations LP
CAFO	0841_01	TXG920884	Lone Star Park
Concrete Production	0841_01	TXG110173	TXI Operations LP
Concrete Production	0841_01	TXG110351	Charleys Concrete Co Ltd
Concrete Production	0841_01	TXG110448	Southern Star Concrete Inc
Concrete Production	0841_01	TXG110475	Southern Star Concrete Inc
Concrete Production	0841_01	TXG110476	Southern Star Concrete Inc
Concrete Production	0841_01	TXG110531	Southern Star Concrete Inc
Concrete Production	0841_01	TXG110585	Metroplex Retaining Walls Inc
Concrete Production	0841_01	TXG110608	Southern Star Concrete Inc
Concrete Production	0841_01	TXG110629	Hanson Pipe & Precast Inc
Concrete Production	0841_01	TXG110853	Ant Enterprises Incorporated
Hydrostatic Test Water	0841_01	TXG670030	ConocoPhillips Company
Multi-Sector	0841_01	TXR05L044	DFW Printing Company Inc
Multi-Sector	0841_01	TXR05L487	Trinity River Authority Of Texas
Multi-Sector	0841_01	TXR05L960	Palestine Concrete Tile Company LP
Multi-Sector	0841_01	TXR05M736	Solo Cup Operating Corporation
Multi-Sector	0841_01	TXR05M818	General Magnaplate Texas Inc
Multi-Sector	0841_01	TXR05N065	Pioneer Paper Stock Company Of Texas
Multi-Sector	0841_01	TXR05N886	PCA Arlington

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0841_01	TXR05N912	Martin Sprocket & Gear Inc
Multi-Sector	0841_01	TXR05P159	City Of Arlington
Multi-Sector	0841_01	TXR05P271	Ups Ground Freight Inc
Multi-Sector	0841_01	TXR05P350	Pavestone Company LP
Multi-Sector	0841_01	TXR05P783	Extex Laporte Limited Partnership
Multi-Sector	0841_01	TXR05P829	Macs Snacks
Multi-Sector	0841_01	TXR05Q490	City Of Grand Prairie
Multi-Sector	0841_01	TXR05Q692	Rheaco Inc
Multi-Sector	0841_01	TXR05S110	U Buy Right Auto Salvage LLC
Multi-Sector	0841_01	TXR05S305	Dallas Oil Service Inc
Multi-Sector	0841_01	TXR05T805	American Airlines Inc
Multi-Sector	0841_01	TXR05U021	Dallas Fort Worth International Airport Board
Multi-Sector	0841_01	TXR05U096	Midwest Airlines Inc
Multi-Sector	0841_01	TXR05U189	US Airways Inc
Multi-Sector	0841_01	TXR05U316	Iware Inc
Multi-Sector	0841_01	TXR05U343	Integrated Airline Services Inc
Multi-Sector	0841_01	TXR05U859	United Parcel Service Inc
Multi-Sector	0841_01	TXR05V294	Mesrdad Farahani dba Arcadia Auto Parts
Multi-Sector	0841_01	TXR05V783	Regency Conversions LLC
Multi-Sector	0841_01	TXR05V894	GC Precasting & Welding Inc
Multi-Sector	0841_01	TXR05V951	Nustar Logistics LP
Multi-Sector	0841_01	TXR05W045	Southern Mail Service Inc

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0841_01	TXR05W126	ABX Air Inc
Multi-Sector	0841_01	TXR05W368	Bimbo Bakeries USA Inc
Multi-Sector	0841_01	TXR05X018	Nustar Logistics LP
Multi-Sector	0841_01	TXR05X222	No Name Given
Multi-Sector	0841_01	TXR05X268	Alamo Pallet Recyclers Inc
Multi-Sector	0841_01	TXR05X298	Farris Auto Salvage Inc
Multi-Sector	0841_01	TXR05X393	G P Ambassador Aviation LLC
Multi-Sector	0841_01	TXR05X436	DHL Express USA Inc
Multi-Sector	0841_01	TXR05X573	Old Dominion Freight Line Inc
Multi-Sector	0841_01	TXR05X822	Iscar Metals Inc
Multi-Sector	0841_01	TXR05X873	Flight Services & Systems Inc
Multi-Sector	0841_01	TXR05X892	Arrowhead Rebar LP
Multi-Sector	0841_01	TXR05X893	Champion Waste Services LLC
Multi-Sector	0841_01	TXR05X956	Nestle Waters North America Inc
Multi-Sector	0841_01	TXR05X960	Saia Motor Freight Line LLC
Multi-Sector	0841_01	TXR05X976	Q-Tech Heat Treat Inc
Multi-Sector	0841_01	TXR05X998	Williams Brothers Construction Co Inc
Multi-Sector	0841_01	TXR05Y233	Stair Builders LLC
Multi-Sector	0841_01	TXR05Y275	MTV Transportation Inc
Multi-Sector	0841_01	TXR05Y321	Abs Like New Import Auto Salvage LLC
Multi-Sector	0841_01	TXR05Y520	Escarzaga Jose Antonio dba Tonny S Auto Salvage
Multi-Sector	0841_01	TXR05Y539	Taylor Farms Texas Inc

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0841_01	TXR05Y567	Lone Star Foxhall LLC
Multi-Sector	0841_01	TXR05Y595	Lone Star Foxhall LLC
Multi-Sector	0841_01	TXR05Y599	A-1 Parts Stop Inc
Multi-Sector	0841_01	TXR05Y714	DFW Auto Parts Inc
Multi-Sector	0841_01	TXR05Y777	General Motors Company
Multi-Sector	0841_01	TXR05Y825	M-Works Steel Company Inc
Multi-Sector	0841_01	TXR05Y829	LNS Legacy National Signs Inc
Petroleum Bulk Stations and Terminals	0841_01	TXG341602	Dallas Fort Worth International Airport Board
Petroleum Bulk Stations and Terminals	0841_01	TXG341607	Nustar Logistics LP
Petroleum Bulk Stations and Terminals	0841_01	TXG341616	Nustar Logistics LP
Multi-Sector	0805_04	TXR05M221	Comet Steel Inc
Multi-Sector	0805_04	TXR05O196	American Permanent Ware Company
Multi-Sector	0805_04	TXR05O249	Dallas Area Rapid Transit
Multi-Sector	0805_04	TXR05O291	Natrod I Ltd
Multi-Sector	0805_04	TXR05P812	Dallas Airmotive Inc
Multi-Sector	0805_04	TXR05Q723	Rudolph Foods Company Inc
Multi-Sector	0805_04	TXR05R132	Natrod IV Ltd
Multi-Sector	0805_04	TXR05R381	Latinos Ready Mix Concrete Contractors
Multi-Sector	0805_04	TXR05R794	Con-Way Freight Inc
Multi-Sector	0805_04	TXR05S797	Veronica Cuevas dba Horseshoe Trucking
Multi-Sector	0805_04	TXR05S820	Midwest Engine Inc

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0805_04	TXR05T340	Commercial Metals Company
Multi-Sector	0805_04	TXR05T341	Commercial Metals Company
Multi-Sector	0805_04	TXR05T342	Commercial Metals Company
Multi-Sector	0805_04	TXR05T502	Dal-Chrome Company
Multi-Sector	0805_04	TXR05T825	Palladium Exchange LLC
Multi-Sector	0805_04	TXR05U471	Allied Alloys LP
Multi-Sector	0805_04	TXR05U590	Rock-Tenn Converting Company
Multi-Sector	0805_04	TXR05V218	USA Shade & Fabric Structures Inc
Multi-Sector	0805_04	TXR05V603	Bluebonnet Waste Control Inc
Multi-Sector	0805_04	TXR05V698	Plastics Rescue Inc
Multi-Sector	0805_04	TXR05V719	Glasfloss Industries GP LLC
Multi-Sector	0805_04	TXR05V907	Akidco Inc
Multi-Sector	0805_04	TXR05V954	Duggan Industries Inc
Multi-Sector	0805_04	TXR05W565	Mirage Auto Sales
Multi-Sector	0805_04	TXR05X103	CF Chefs Inc
Multi-Sector	0805_04	TXR05X243	Krugjohann Ken dba Motors
Multi-Sector	0805_04	TXR05X428	Learjet Inc
Multi-Sector	0805_04	TXR05X489	New Thermos-Serv Ltd
Multi-Sector	0805_04	TXR05X799	E-Z Wall Concentrate Inc
Multi-Sector	0805_04	TXR05X890	Allied Construction Supplies LP
Multi-Sector	0805_04	TXR05X955	Ifco Systems North America Inc
Multi-Sector	0805_04	TXR05X977	Republic Sheet Metal And Manufacturing
Multi-Sector	0805_04	TXR05X980	Mayco Inc

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0805_04	TXR05Y031	Bridgford Foods Of Texas
Multi-Sector	0805_04	TXR05Y155	Mag Stone & Marble
Multi-Sector	0805_04	TXR05Y164	Holman Boiler Works Inc
Multi-Sector	0805_04	TXR05Y201	Countertop Etc Inc
Multi-Sector	0805_04	TXR05Y576	Delossatos Rena dba Mid City Recycling
Multi-Sector	0805_04	TXR05Y635	Pallet Repair Services Inc
Multi-Sector	0805_04	TXR05Y711	Schwerman Trucking Co
Multi-Sector	0805_04	TXR05Y750	RPR Environmental Services LLC
Multi-Sector	0805_04	TXR05Y770	Commercial Metals Company
Multi-Sector	0805_04	TXR05Y780	Apperson, Jack
Multi-Sector	0805_04	TXR05Y835	Southeastern Freight Lines Inc
Concrete Production	0805_04	TXG110171	TXI Operations LP
Concrete Production	0805_04	TXG110456	Southern Star Concrete Inc
Concrete Production	0805_04	TXG110689	Lattimore Materials Company LP
Concrete Production	0805_04	TXG110753	Redi-Mix LLC
Concrete Production	0805_04	TXG110969	Ramtex Concrete Corporation
Multi-Sector	0805_03	TXR05L685	Quime Aparicio dba A & A Pallet Repair Company
Multi-Sector	0805_03	TXR05M791	Stevens Transport Inc
Multi-Sector	0805_03	TXR05N916	Haymarket Auto Parts
Multi-Sector	0805_03	TXR05O043	United Parcel Service Inc
Multi-Sector	0805_03	TXR05R811	Milk Products LP
Multi-Sector	0805_03	TXR05S348	Alejandro Dominguez dba Dallas Pallet Recycle

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0805_03	TXR05U810	Dallas Cast Stone Ii Corp
Multi-Sector	0805_03	TXR05U973	Triple S Dynamics Inc
Multi-Sector	0805_03	TXR05V227	Lone Star Auto Crushers Inc
Multi-Sector	0805_03	TXR05V290	Effiom Archibong dba Northwest Metals Recycling
Multi-Sector	0805_03	TXR05V593	Selman, Donald
Multi-Sector	0805_03	TXR05W293	Jerry Aaman dba Gold Auto Parts Recycling
Multi-Sector	0805_03	TXR05W449	LKQ Best Automative Corp
Multi-Sector	0805_03	TXR05X089	Erect-A-Line Inc
Multi-Sector	0805_03	TXR05X137	Billy Hendersons Auto Parts Inc
Multi-Sector	0805_03	TXR05Y018	Omni Marble
Multi-Sector	0805_03	TXR05Y426	Continental Electronics Corporation
Multi-Sector	0805_03	TXR05Y478	Herdez Trucking Co
Multi-Sector	0805_03	TXR05Y493	Dallas Pick-A-Part
Multi-Sector	0805_03	TXR05Y495	Continental Electronics Corporation
Multi-Sector	0805_03	TXR05Y668	R-N-R Ready Mix LLC
Multi-Sector	0805_06	TXR05L895	City Of Dallas
Multi-Sector	0805_06	TXR05O219	Mizkan Americas Inc
Multi-Sector	0805_06	TXR05P254	LKQ Auto Parts Of North Texas LP
Multi-Sector	0805_06	TXR05P589	Schneider National Carriers Inc
Multi-Sector	0805_06	TXR05R564	Western Cabinets Inc
Multi-Sector	0805_06	TXR05S457	JL Steel LP
Multi-Sector	0805_06	TXR05S898	W & S Precision Finishing Company

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0805_06	TXR05T210	Mobile Mini Texas Limited Partnership
Multi-Sector	0805_06	TXR05T514	Best Bumper Supply Inc
Multi-Sector	0805_06	TXR05V273	Allied Waste Systems Inc
Multi-Sector	0805_06	TXR05V363	Highway 310 Auto Salvage Inc
Multi-Sector	0805_06	TXR05V413	City Of Dallas
Multi-Sector	0805_06	TXR05V499	No name provided
Multi-Sector	0805_06	TXR05W243	Recycle To Conserve TX Inc
Multi-Sector	0805_06	TXR05W307	Longhorn Fabrication & Design Inc
Multi-Sector	0805_06	TXR05W332	Ted Alvarez Trucking Inc
Multi-Sector	0805_06	TXR05W447	LKQ Best Automative Corp
Multi-Sector	0805_06	TXR05X162	Alkel Prime Pack
Multi-Sector	0805_06	TXR05X199	Tucker Fuel & Oil Co Inc
Multi-Sector	0805_06	TXR05X376	Clinton Garland dba Garland Auto Recyclers & Auto Parts
Multi-Sector	0805_06	TXR05X385	Covenant Transport Inc
Multi-Sector	0805_06	TXR05Y175	Hope Agri Products Of Texas Ltd
Multi-Sector	0805_06	TXR05Y380	City Of Dallas
Multi-Sector	0805_06	TXR05Y381	Post Oak Grinding LLC
Multi-Sector	0805_06	TXR05Y398	Air Products And Chemicals Inc
Multi-Sector	0805_06	TXR05Y403	Southwest Shingle Recycling LLC
Multi-Sector	0805_06	TXR05Y423	Indians Wrecking Yard
Multi-Sector	0805_06	TXR05Y443	Storopack Inc
Multi-Sector	0805_06	TXR05Y479	Herdez Trucking Co

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0805_06	TXR05Y514	Stop & Pull Auto Parts & Salvage
Multi-Sector	0805_06	TXR05Y779	M & H Specialties Inc
Multi-Sector	0805_06	TXR05Y788	Southwest Freight Distributors Inc
Concrete Production	0805_06	TXG110699	Williams Concrete Products
Concrete Production	0805_02	TXG110187	TXI Operations LP
Concrete Production	0805_02	TXG110459	Southern Star Concrete Inc
Concrete Production	0805_02	TXG110469	Southern Star Concrete Inc
Concrete Production	0805_02	TXG110558	B & B Ready Mix Inc
Concrete Production	0805_02	TXG110761	Redi-Mix LLC
Multi-Sector	0805_02	TXR05K393	Mesquite Landfill TX LP
Multi-Sector	0805_02	TXR05L518	Trinity River Authority Of Texas
Multi-Sector	0805_02	TXR05L947	Trinity River Authority Of Texas
Multi-Sector	0805_02	TXR05M553	Bilco Corporation
Multi-Sector	0805_02	TXR05O399	Georgia-Pacific Corporation
Multi-Sector	0805_02	TXR05R226	Cox Industries Inc
Multi-Sector	0805_02	TXR05S356	Bailey Tool & Manufacturing Company
Multi-Sector	0805_02	TXR05V752	Harsco Corporation
Multi-Sector	0805_02	TXR05V902	Georgia-Pacific Corporation
Multi-Sector	0805_02	TXR05W385	Display Source Alliance LLC
Multi-Sector	0805_02	TXR05W460	Potter Concrete Ltd
Multi-Sector	0805_02	TXR05X647	Coal City Cob Company Inc
Multi-Sector	0805_02	TXR05X757	City Of Lancaster
Multi-Sector	0805_02	TXR05X879	BASF Construction Chemicals LLC

Permit Type	Assessment Unit	Permit Number	Permittee Name
Multi-Sector	0805_02	TXR05Y206	County Line Classics LLC
Multi-Sector	0805_02	TXR05Y451	Park Environmental Equipment Ltd
Multi-Sector	0805_02	TXR05Y826	Alcaraz, Refugio
Petroleum Fuel or Petroleum Substances	0805_02	TXG830327	No name provided
Multi-Sector	0805_01	TXR05K392	Ellis County Landfill TX LP
Multi-Sector	0805_01	TXR05X093	Seven Points Sand & Gravel Inc
Multi-Sector	0805_01	TXR05X154	Seven Points Sand & Gravel Inc
Multi-Sector	0805_01	TXR05Y343	Lattimore Materials Company LP
Multi-Sector	0805_01	TXR05Y388	Hanson Aggregates LLC
Multi-Sector	0805_01	TXR05Y785	C & M Trailers LLC
Petroleum Fuel or Petroleum Substances	0805_01	TXG830330	Terra-Max Engineering Inc
Petroleum Fuel or Petroleum Substances	0805_01	TXG830330	One Stop Express

Runoff volumes and suspended sediment loads were modeled using the Generalized Watershed Loading Function (GWLF). See Section 4 for a detailed description of GWLF setup and results. Dissolved PCB concentrations in runoff were estimated based using the average organic carbon-normalized PCB concentration in sediment of Trinity River tributaries draining the watershed, divided by a log K_{oc} value of 6.4. For example, in the Johnson Creek watershed in Arlington, a measured sediment PCB level of 1.6 ng/g and 0.38% organic carbon content in Johnson Creek resulted in an organic carbon-normalized PCB concentration of 420 μg per kg of organic carbon. Dividing by a K_{oc} value of 2.5×10^6 L per kg organic carbon (see derivation of log K_{oc} value of 6.4 in Section 2.5.2) results in an estimated dissolved PCB concentration in runoff of 0.17 ng/L. Suspended PCB concentrations in runoff were then calculated from the dissolved total PCB concentration, the suspended solids concentration from GWLF, and a partition coefficient of 2.4×10^4 L/kg (see section 2.5.1). The resulting PCB daily loads by assessment unit are summarized in Table 3.11. The estimated loads were further split into permitted loads and nonpoint source loads using the percent of each watershed area covered by MS4 permits.

Table 3.11 Runoff Loads to TMDL Assessment Units

Assessment Unit	Average Flow [a] (cms)	Total PCB Load (mg/day)	% of Watershed Addressed Under TPDES Permits	PCB Load in TPDES-Permitted Runoff (mg/day)[b]	PCB Load in NPS Runoff (mg/day)[c]
0829_01	2.7	296	52%	154	142
0806_01	7.7	853	81%	691	162
0841_02	4.5	113	100%	113	0
0841_01	5.8	217	95%	206	11
0805_04	4.0	1673	100%	1673	0
0805_03	2.4	162	100%	162	0
0805_06	4.2	116	72%	84	32
0805_02	11.7	110	18%	20	90
0805_01	4.8	78	0%	0	78
Overall	47.8	3,618		3,103	515

[a] *Runoff flows from the GWLF*

[b] *Total PCB load times the percent of watershed covered by MS4 permits*

[c] *Total PCB load minus MS4-permitted PCB load*

3.2 Non-Regulated Sources: Storm Water, Air Deposition, and Bottom Sediment

Nonpoint source pollutant loading often enters the impaired waterbody through distributed locations and is usually not regulated. Nonpoint sources of PCBs can include runoff that is not regulated under TPDES, direct air deposition of pollutants to the water body, and contaminated benthic sediments.

3.2.1 Nonpoint Runoff

Estimated NPS runoff loads are summarized in Table 3.11. The total non-point PCB loads discharged via runoff to the TMDL segments is estimated to be 727 mg/day.

3.2.2 Dry and Wet Air Deposition

Most of the pollutant load from air deposition enters the impaired water bodies via storm water runoff and, thus, is included in the storm water runoff load calculations (permitted and non-permitted). Direct deposition to the water surface is considered insignificant due to the relatively small surface area of the impaired waterbodies, and was included in the watershed areas in GWLF. However, direct deposition of PCBs from the atmosphere has not been measured in the Trinity River watershed.

3.2.3 Contaminated Benthic Layer

Contaminated bottom sediments can act as an “internal” source of PCBs to the water column through two mechanisms: sediment resuspension and direct fluxes from sediment porewater to the water column. A mass-balance analysis completed using an in-stream model allowed the estimation of the relative contribution of PCB fluxes from sediments to the water column. A more detailed description of the procedure employed to estimate internal PCB loading from sediments is presented in Section 4 of this report.

3.3 Inflows from Upstream Segments

Inflows from upstream designated segments represent a final source of PCBs to the impaired waterbodies. The magnitude of these loads was calculated using daily gaged flow data from the USGS, or reported daily releases from dams, together with the measured organic carbon-normalized PCB concentration in tributary sediments and a log K_{oc} value of 6.4 L/kg, as described in Section 3.1.2.

3.4 Loading Summary

Loads are summarized by assessment unit and source type in Table 3.12. Point source loads are divided into WWTFs and runoff point source (TPDES-permitted runoff) categories. Loads from segments upstream of the model domain include upstream portions of segments 0829 and 0806, the Elm and East Forks of the Trinity River, and releases from Lake Arlington, Mountain Creek Reservoir, and White Rock Lake. The flux to and from sediments was then calculated as the load required to account for the difference between the average load at the downstream boundary of an AU and the sum of other loads to an AU. A negative flux indicates that PCB flux goes from water to sediment in that assessment unit. While this calculation does not explicitly account for PCBs lost to volatilization and degradation, these losses were predicted to be relatively minor, averaging 62 mg/day for the impaired assessment units.

For the overall TMDL study area, and thus excluding loads from upstream PCB-impaired assessment units, fluxes from sediments are estimated to represent 63% of the PCB load to the impaired assessment units, followed by 20% from runoff, 10% from upstream segments, and 8% from WWTFs.

Table 3.12 Summary of Existing Average PCB Loads to Impaired Trinity River Assessment Units

Assessment Unit	Average Daily Loads (mg/day)							
	External Loads					Internal Load	Sum of External Loads to AU[c]	Load at Downstream Boundary of AU
	WWTFs	PS Runoff	NPS Runoff	Upstream Sources [a]		Sediment Exchange dS[b]		
				Non-Impaired	Impaired			
0829_01	0	154	142	34[d]	0	518	330	848
0806_01	0.008	691	162	151[e]	848	-6	1,852	1,846
0841_02	371	113	0	10[f]	1,846	6,960	2,340	9,300
0841_01	332	206	11	607[g]	9,300	-2,186	10,456	8,270
0805_04	0.49	1,673	0	694[h]	8,270	2,371	10,637	13,008
0805_03	602	162	0	130[i]	13,008	10,064	13,902	23,966
0805_06	169	84	32	0	23,966	1,437	24,251	25,688
0805_02	59	20	90	183[j]	25,688	-2,220	26,040	23,820
0805_01	0	0	78	0	23,820	-5,097	23,898	18,801
Overall	1,533	3,103	515	1,809		11,841		
	8%	17%	3%	10%		63%		

a upstream non-impaired designated Segments and impaired AUs
b Negative numbers indicate areas where there is net deposition of PCBs to sediments
c includes WWTFs, PS runoff, NPS runoff, upstream sources, and immediate upstream impaired AU
d Lake Benbrook (Segment 0830)
e Lake Worth (Segment 0807)
f Lake Arlington (Segment 0828)
g Mountain Creek Lake (Segment 0841A)
h Elm Fork Trinity River (Segment 0822)
i White Rock Lake (Segment 0827)
j East Fork Trinity River (Segment 0819)

SECTION 4
MODEL ANALYSIS FOR LINKAGE BETWEEN SOURCES AND RECEIVING WATERS

4.1 Introduction

Establishing the relationship between instream water quality and the sources of pollutant loadings is an important component of TMDL development. It allows for the evaluation of management options that will achieve the desired endpoint.

For these TMDLs, the modeling approach included 1) a watershed model to simulate flow and sediment loadings from runoff, and 2) an instream water quality model to simulate flows and instream behavior of sediments and PCBs.

4.2 Watershed Model

Runoff flows and sediment loadings in the modeled domain of the Trinity River watershed were simulated using the Generalized Watershed Loading Function (GWLF) of Haith et al. (1992). These runoff flows and sediment loads were then used in the instream water quality model of the TMDL Study Area.

GWLF is a mechanistic model that estimates sediment and dissolved and total nutrient loads in streamflow from complex watersheds. The model accounts for point sources, ground water, and urban and rural runoff. The model computes runoff volumes using the NRCS Curve Number equation. Eroded sediment is calculated using the Universal Soil Loss Equation (USLE), which considers soil and land cover properties. Monthly sediment yield is calculated by multiplying erosion loads by a delivery ratio, which is a function of watershed size.

For modeling purposes, the Trinity River watershed modeled domain was divided into 45 subwatersheds, as shown in Figure 4.1. The subwatersheds were developed from a digital elevation model at 30-meter resolution, the National Elevation Dataset (USGS 1999a). Most of the subwatersheds correspond to a single major tributary each, either a creek or fork of the Trinity River, and range in size from 3.5 to 232 square miles. Note that portions of the watersheds above major flood control reservoirs are not included because outflows from these reservoirs could not be simulated with a watershed model. Instead daily measurements or estimates of water releases from the reservoirs were obtained from the U.S. Army Corps of Engineers, U.S. Geological Survey, or Tarrant Regional Water District. These reservoirs included Lake Worth, Benbrook Lake, Mountain Creek Lake, Lake Arlington, Lake Grapevine, Lake Lewisville, and Lake Ray Hubbard. The 45 subwatersheds modeled include six watersheds that contributed directly to other non-impaired designated segments but were downstream of dams or flow gages: two subwatersheds contributing to the Elm Fork Trinity River (Segment 0822) downstream of Lake Grapevine and Lake Lewisville, two subwatersheds contributing to the East Fork Trinity River (Segment 0819) downstream of Lake Ray Hubbard, and two subwatersheds contributing to White Rock Lake (Segment 0827).

The models were run for each subwatershed separately using a 23-year period, starting in January 1986 and ending December 2008. Results for the first two years of the simulation were ignored to eliminate effects of arbitrary initial conditions, as recommended in the GWLF Manual (Haith et al., 1992).

4.2.1 GWLF Input Data

The GWLF model requires the user to generate three input files: a weather file, a transport file, and a nutrient file.

Weather

Weather information required by the model includes daily precipitation and temperature data. Daily records for the period 1986-2008 were acquired from the Texas A&M Agrilife Research Center at Beaumont (iAIMS climate data) at: http://beaumont.tamu.edu/climaticdata/ for the following weather stations: Arlington, Bardwell, Benbrook, Corsicana. DFW, Ferris, Joe Pool, Richardson, Rockwall, and Rosser. Weather station locations are also shown in Figure 4.1. Each of the 45 subwatersheds was assigned weather data from the closest weather station as listed in Table 4.1.

Transport

Transport parameters include subwatershed areas, runoff curve numbers for antecedent moisture condition, and the erosion product K_kLSCP (Universal Soil Loss Equation parameters) for each runoff source. Soil properties needed to simulate transport were obtained from the State Soil Geographic (STATSGO) Database compiled by the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture. Land use and land cover data for the Modeled Domain was compiled from county-level vector geospatial data provided by the North Central Texas Council of Governments (http://www.dfwmaps.com/clearinghouse/). Metadata provided with the geospatial data indicates the land use data was derived from aerial photographs collected during the years 2003 to 2005. It was the most recent land use data available.

STATSGO and land use data were compiled into an electronic geographic information system and electronically overlaid. For each land use/soil type combination within each subwatershed, area-weighted NRCS curve number (CN), length (L), slope gradient (S), and soil erodibility factors (K_k) were calculated based on land use and soil properties. Land use data is summarized for each subwatershed in Table 4.2. A summary of estimated CN, L, S, and K_k values for the 45 subwatersheds is provided in Table 4.3. Values for individual subwatersheds can be found in the transport input files in Appendix D. Ground cover factors (C) were used as a calibration parameter (see next section for final values) and a supporting practice factor (P) of 1 was used for all source areas based on the GWLF manual recommendation for non existing conservation practices (urban areas).

Other required watershed transport parameters were assumed constant for all subwatersheds as summarized in Table 4.4.

The final components of the transport file are the monthly coefficients listed in Table 4.5. With the exception of the evaporation coefficient, which was used as a calibration parameter, all the monthly values were assumed constant for all subwatersheds.

Nutrients

Nutrients were not simulated for the Trinity River. However, because the model requires a nutrient input file, a file with default values was prepared.

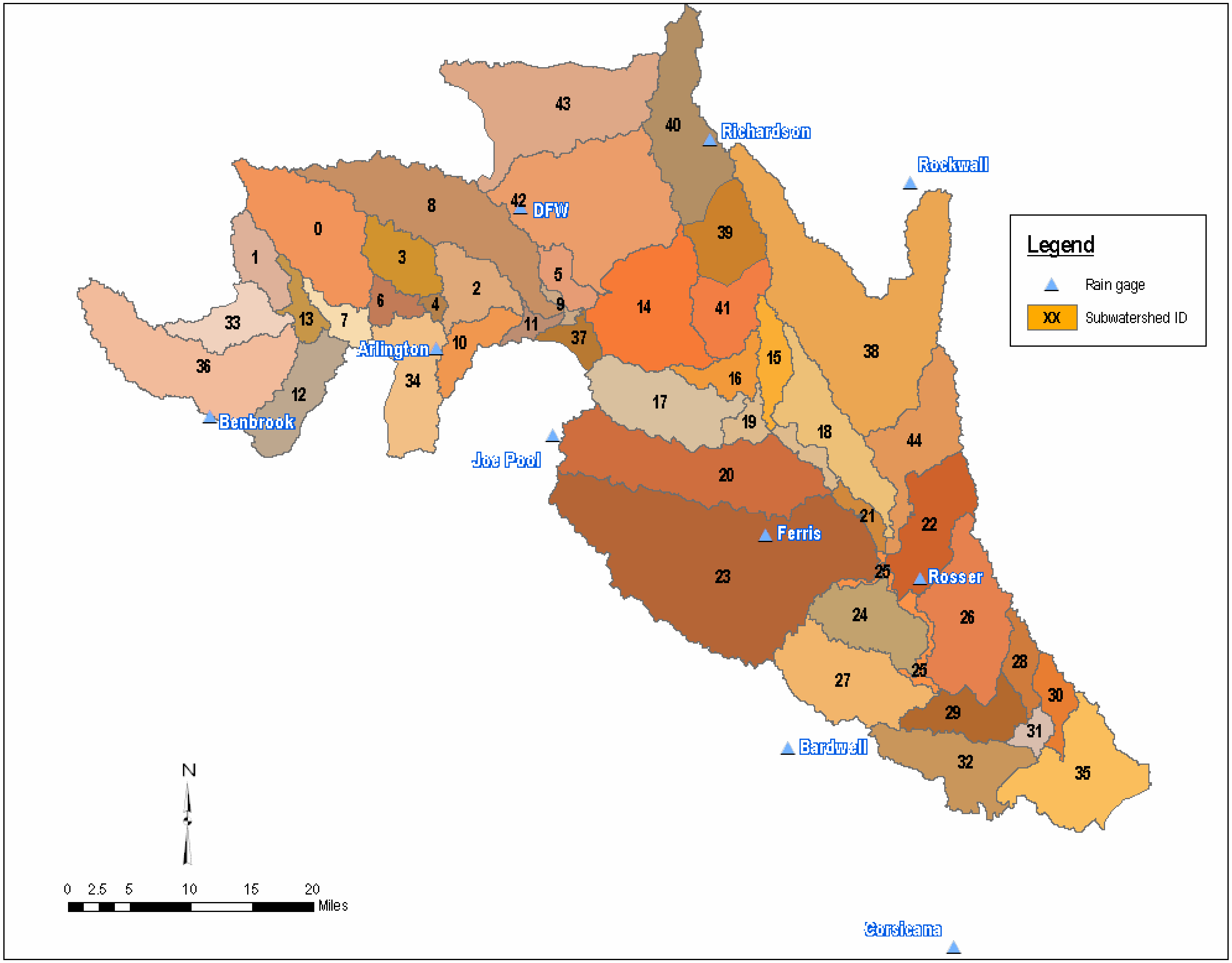


Figure 4.1 Trinity River Subwatersheds in the Modeled Domain

Table 4.1 Weather Stations used for GWLF Modeling

Subwatershed ID	Name	Weather Station
0	Big Fossil Creek	Arlington
1	Marine Creek	Benbrook
2	West Fork Trinity River between Sulphur Branch and Johnson Creek	Arlington
3	Sulphur Branch	Arlington
4	West Fork Trinity River between Village Creek and Sulphur Branch	Arlington
5	West Fork Trinity River between Mountain Creek and Elm Fork	DFW
6	West Fork Trinity River between Fossil and Village Creeks	Arlington
7	West Fork Trinity River between Sycamore and Fossil Creeks	Arlington
8	Bear Creek	DFW
9	West Fork Trinity River between Bear and Mountain Creeks	DFW
10	Johnson Creek	Arlington
11	West Fork Trinity River between Johnson and Bear Creeks	Arlington
12	Sycamore Creek	Benbrook
13	West Fork Trinity River between Clear Fork and Sycamore Creek	Arlington
14	Upper Trinity River between Elm Fork and White Rock Creek	Richardson
15	Prairie Creek	Richardson
16	Upper Trinity River between White Rock and Fivemile Creeks	Joe Pool
17	Fivemile Creek	Joe Pool
18	Parsons Slough	Rosser
19	Upper Trinity River between Fivemile and Tenmile Creeks	Ferris
20	Tenmile Creek	Joe Pool
21	Upper Trinity River between Tenmile Creek and East Fork Trinity River	Rosser
22	Old Channel East Fork Trinity River	Rosser
23	Red Oak Creek	Ferris
24	Smith Creek	Rosser
25	Upper Trinity River between East Fork and Walker Creek	Rosser
26	Bois d'Arc / Cottonwood Creek	Rosser
27	Walker / Village Creek	Bardwell
28	Caney Creek	Rosser
29	Upper Trinity River below Bois d'Arc / Cottonwood Creek	Rosser
30	Bridge Creek	Rosser
31	Upper Trinity River above Grays Creek	Rosser
32	Grays Creek	Bardwell
33	West Fork Trinity River below Lake Worth	Benbrook
34	Village Creek below Lake Arlington	Arlington
35	Upper Trinity River between Grays and Cedar Creek Reservoir discharge canal	Corsicana
36	Clear Fork Trinity River	Benbrook
37	Mountain Creek below Mountain Creek Reservoir	Joe Pool
38	East Fork Trinity River below Lake Ray Hubbard above Crandall gage*	Rockwall
39	White Rock Creek between White Rock Lake and Greenville gage*	Richardson
40	White Rock Creek above Greenville gage*	Richardson
41	White Rock Creek below White Rock Lake	Richardson
42	Elm Fork Trinity River below Carrolton gage*	DFW
43	Elm Fork Trinity above Carrolton gage below Lakes Lewisville and Grapevine*	DFW
44	East Fork Trinity River below Crandall gage*	Rosser

** Included in watershed model but contribute to a non-impaired designated segment*

Table 4.2 Land Use in Project Subwatersheds (areas in square miles)

Subwatershed ID	Residential	Government & Education	Commercial	Industrial	Transportation & Parking	Vacant	Under Construction	Parks & Flood Control	Water	Utilities	Other
0	19.73	2.26	2.86	4.67	0.30	29.95	1.86	2.46	0.55	0.51	0.46
1	4.44	0.75	0.31	1.00	1.53	8.64	0.74	0.66	0.45	0.19	0.98
2	6.48	1.03	2.17	2.47	5.31	8.61	0.28	2.50	1.13	0.08	0.70
3	11.49	1.79	2.42	0.94	0.12	4.39	0.16	0.79	0.17	0.15	0.26
4	1.07	0.12	0.26	0.33	1.40	0.86	0.04	0.37	0.51	0.87	0.02
5	6.04	1.19	0.77	0.70	1.53	1.18	0.01	0.80	0.15	0.04	2.08
6	1.90	0.18	0.41	0.82	0.23	5.58	0.16	0.30	0.70	0.19	0.69
7	6.00	0.55	1.45	3.31	1.04	2.81	0.01	1.81	0.26	0.08	0.52
8	30.50	2.89	2.66	0.37	1.02	24.74	1.43	3.09	1.04	0.47	0.89
9	1.95	0.07	0.99	2.61	0.81	0.72	0.02	0.05	0.43	0.14	0.70
10	4.94	1.30	1.69	0.21	0.11	2.17	0.00	1.11	0.07	0.05	0.34
11	1.72	0.22	0.49	2.00	0.67	2.89	0.42	0.14	0.43	0.01	1.42
12	12.39	2.06	1.72	1.68	8.12	7.61	0.03	2.08	0.10	0.13	0.00
13	5.19	0.54	2.20	8.95	1.05	2.34	0.28	0.73	0.18	0.15	0.00
14	18.89	3.02	2.85	0.89	0.37	7.83	0.20	6.31	1.02	0.89	0.00
15	7.76	1.17	0.54	0.71	0.40	4.32	0.03	0.87	0.42	0.14	0.00
16	6.16	0.59	0.73	2.40	0.50	4.91	0.83	0.68	0.97	0.11	0.00
17	15.34	2.83	1.94	1.46	0.12	18.53	0.26	2.29	0.13	0.50	0.00
18	10.12	1.41	0.46	0.91	0.08	27.80	0.01	0.83	2.55	1.51	0.00
19	2.25	0.09	0.61	2.15	0.39	12.79	2.18	0.28	2.04	0.94	0.00
20	21.29	2.83	2.87	0.01	0.30	53.06	0.82	2.98	1.34	1.45	0.00
21	0.82	0.14	0.05	1.28	0.26	7.06	0.51	0.55	0.61	0.14	0.00
22	4.91	1.54	0.68	0.00	0.14	43.56	0.56	0.79	0.68	0.00	0.00
23	26.42	0.01	0.36	0.01	0.48	184.43	0.47	0.34	2.14	0.35	0.00
24	1.47	0.11	0.65	0.27	0.17	41.15	0.00	0.43	0.96	0.00	0.00
25	3.51	0.49	0.64	1.06	0.40	10.60	1.00	0.16	0.08	0.00	0.00
26	5.22	0.28	2.81	0.90	0.23	62.81	0.07	0.04	0.74	0.01	0.00

Subwatershed ID	Residential	Government & Education	Commercial	Industrial	Transportation & Parking	Vacant	Under Construction	Parks & Flood Control	Water	Utilities	Other
27	6.04	0.15	2.14	0.99	0.21	57.65	0.63	2.59	0.80	0.13	0.00
28	4.98	1.69	4.41	0.46	0.25	13.17	0.29	3.26	0.09	0.43	0.00
29	4.60	2.02	1.74	7.00	0.33	31.38	0.84	4.24	0.14	0.68	0.00
30	1.58	2.18	7.11	1.66	0.13	15.27	0.37	2.03	0.01	0.69	0.00
31	4.61	0.70	1.98	1.05	0.00	8.28	0.00	5.56	0.00	1.70	0.00
32	3.59	4.88	9.64	0.64	0.00	50.60	0.00	3.22	0.04	0.21	0.00
33	8.11	1.65	3.62	13.91	0.00	4.64	0.00	4.60	0.34	0.39	0.00
34	19.16	3.73	3.96	3.10	0.00	8.64	0.00	3.69	0.30	0.49	0.00
35	1.31	1.34	3.80	0.03	0.00	67.07	0.00	8.29	0.00	1.51	0.00
36	17.65	4.73	0.11	0.00	0.00	46.98	0.00	5.59	0.68	0.49	0.00
37	1.30	3.33	0.00	0.00	0.00	2.96	0.00	0.44	0.19	0.03	0.00
38	36.51	0.21	0.00	0.00	0.00	90.22	0.00	0.00	2.95	0.00	0.00
39	12.57	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.38	0.00	0.00
40	21.94	0.00	0.00	0.00	0.00	6.97	0.00	0.00	0.30	0.00	0.00
41	10.47	0.00	0.00	0.00	0.00	5.42	0.00	0.00	0.53	0.00	0.00
42	23.96	0.00	0.00	0.00	0.00	17.28	0.00	0.00	3.89	0.00	0.00
43	23.63	0.00	0.00	0.00	0.00	36.59	0.00	0.00	1.79	0.00	0.00
44	3.84	0.00	0.00	0.00	0.00	43.48	0.00	0.00	1.04	0.00	0.00

Table 4.3 Summary of GWLF Transport Parameters by Land Use Category

Land Use	**CN**		**K_k**		**LS**	
	Range	**Average**	**Range**	**Average**	**Range**	**Average**
Single family residential	76 - 87	84.6	0.16 - 0.43	0.32	0.84 - 15	4.73
Multi-family residential	85 - 92	90.6	0.12 - 0.43	0.3		
Mobile homes	85 - 92	90.7	0.1 - 0.43	0.32		
Government/education group quarters	72 - 82	79.4	0.1 - 0.43	0.3		
Commercial: office	92 - 95	94.4	0.12 - 0.43	0.31		
Commercial: retail	92 - 95	94.3	0.11 - 0.43	0.31		
Government/education institutional	92 - 95	94.4	0.17 - 0.43	0.32		
Commercial: hotel/motel	92 - 95	94.1	0.11 - 0.43	0.3		
Industrial	88 - 93	91.7	0.15 - 0.43	0.3		
Transportation	98 - 98	98	0.11 - 0.43	0.3		
Roadway	98 - 98	98	0.1 - 0.32	0.21		
Utilities	58 - 78	72.8	0.17 - 0.43	0.31		
Airports	98 - 98	98	0.1 - 0.32	0.3		
Parking garage	98 - 98	98	0.1 - 0.43	0.28		
Airport: runway	98 - 98	98	0.11 - 0.32	0.3		
Commercial: large stadium	98 - 98	98	0.1 - 0.43	0.28		
Commercial: mixed use	85 - 92	89	0.24 - 0.32	0.29		
Parks	61 - 80	74	0.14 - 0.43	0.31		
Landfill	69 - 84	81.1	0.1 - 0.43	0.31		
Under construction	79 - 89	86.5	0.13 - 0.43	0.31		
Flood control	86 - 94	90.5	0.27 - 0.33	0.31		
Undeveloped: vacant	62 - 80	76.2	0.12 - 0.43	0.32		
Undeveloped: parking (central business district)	98 - 98	98	0.21 - 0.32	0.26		
Undeveloped: expanded parking	89 - 93	92.1	0.1 - 0.43	0.28		
Water	100	100	0.11 - 0.43	0.31		
Transportation: right of way	98	98	0.1 - 0.43	0.28		

Table 4.4 Constant GWLF Transport Parameters

Parameter	**Value**
Recession coefficient (unitless)	0.05[a]
Seepage coefficient of basin (unitless)	0
Initial unsaturated storage (cm)	10
Initial saturated storage (cm)	0
Initial snow cover (cm)	0
Unsaturated water capacity (cm)	10
Antecedent rain + melt for days -1 to -5 (cm)	0

[a] *Calculated from long-term hydrograph at USGS gage at Clear Fork*

Table 4.5 Monthly Coefficients for the GWLF Transport Dataset

Month	Evapotranspiration cover coefficient	Mean daylight hours[a]	Growing season[b]	Erosivity coefficient[c]
January	Varies by subwatershed	10.2	0	0.28
February		10.9	0	0.28
March		11.8	0	0.28
April		12.8	1	0.37
May		13.6	1	0.37
June		14.0	1	0.37
July		13.8	1	0.37
August		13.3	1	0.37
September		12.2	1	0.37
October		11.2	0	0.28
November		10.4	0	0.28
December		10.0	0	0.28

[a] *Average daylight hours for latitude 32° were obtained from the GWLF manual (originally reported by Mills et al., 1985)*

[b] *1 if the month corresponds to the growing season, 0 otherwise*

[c] *Coefficients for Rainfall Erosivity Zone 23 (Selker et al., 1990)*

4.2.2 GWLF Calibration and Output Data

The model was calibrated in two steps: flow and sediment yield.

Flow

The main calibration parameter for flow was the evapotranspiration coefficient. The parameter was varied in a trial-and-error fashion until flow data measured at the White Rock Creek at Greenville gage (USGS 08057200) was reasonably well matched. The resulting calibrated evapotranspiration cover coefficient for this “reference” subwatershed was 0.1. Subsequently, cover coefficients were estimated for the remaining 44 subwatersheds using the ratio of percent impervious of a given subwatershed to the percent impervious of the reference subwatershed. This is because evapotranspiration should increase when the percent pervious increases. Table 4.6 summarizes the evapotranspiration cover factors for the 45 subwatersheds.

Table 4.6 Calibrated GWLF Evapotranspiration Cover Factors

Subwatershed ID	Percent impervious	Evapotranspiration Cover Coefficient
0	32	0.14
1	34	0.13
2	35	0.13
3	43	0.11
4	31	0.15
5	41	0.11
6	27	0.17
7	37	0.12
8	38	0.12
9	31	0.15
10	52	0.09
11	31	0.15
12	41	0.11
13	51	0.09
14	50	0.09
15	37	0.12
16	30	0.15
17	36	0.12
18	21	0.21
19	15	0.3
20	24	0.19
21	14	0.32
22	7	0.68
23	11	0.4
24	4	0.90[a]
25	6	0.7
26	8	0.59
27	8	0.59
28	8	0.59
29	3	0.90[a]
30	3	0.90[a]
31	3	0.90[a]
32	3	0.90[a]
33	41	0.11
34	38	0.12
35	4	0.90[a]
36	27	0.17
37	40	0.11
38	27	0.17
39	49	0.09
40	45	0.1
41	39	0.12
42	48	0.09
43	32	0.14

Subwatershed ID	Percent impervious	Evapotranspiration Cover Coefficient
44	10	0.46

[a] *Coefficient calculated using ratio of impervious percentages is greater than 1, so a value of 0.9 was assumed.*

Figure 4.2 presents a comparison of modeled and measured average annual flows for USGS gages on White Rock Creek at Greenville, on the Clear Fork Trinity River at Fort Worth, and on Prairie Creek at US Hwy 175. Figure 4.2 also includes modeled and measured monthly flows for Bear Creek at SH 183 for the period of record (Nov-02 to Apr-04)[4]. In addition, validation was completed using data from the Mary's Creek at Benbrook gage (results shown in Figure 4.2). Note that the corresponding drainage area for the Mary's Creek gage is part of subwatershed 36-Clear Fork Trinity River, thus, a separate watershed delineation was needed. Results from the Mary's Creek GWLF model were not directly input to the mass-balance model, but included in the input from subwatershed 36. Data in Figure 4.2 indicate that model results are in reasonable agreement with measured values, especially for White Rock Creek and Clear Fork.

In addition to the plots previously presented, a variety of model statistics were calculated to measure model performance. These are discussed in Stow *et al*. (2003) and Legates and McCabe (1999) and include:

1. *the correlation coefficient of model predictions and observations,* r*:*

$$r = \frac{\sum_{i=1}^{n}(O_i - \overline{O})(P_i - \overline{P})}{\sqrt{\sum_{i=1}^{n}(O_i - \overline{O})^2 \sum_{i=1}^{n}(P_i - \overline{P})^2}} \tag{1}$$

2. *the index of agreement,* d*:*

$$d = 1.0 - \frac{\sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}\left(\left|P_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right)^2} \tag{2}$$

3. *the root mean squared error,* RMSE*:*

$$RMSE = \frac{\sqrt{\sum_{i=1}^{n}(P_i - O_i)^2}}{n} \tag{3}$$

where n*=number of observations,* O_i=i*th of* n *observations,* P_i=i*th of* n *predictions, and* $\overline{O}$ *and* $\overline{P}$ *=observation and prediction averages, respectively.*

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[4] Data were available for a limited period, thus, annual averages could not be calculated.

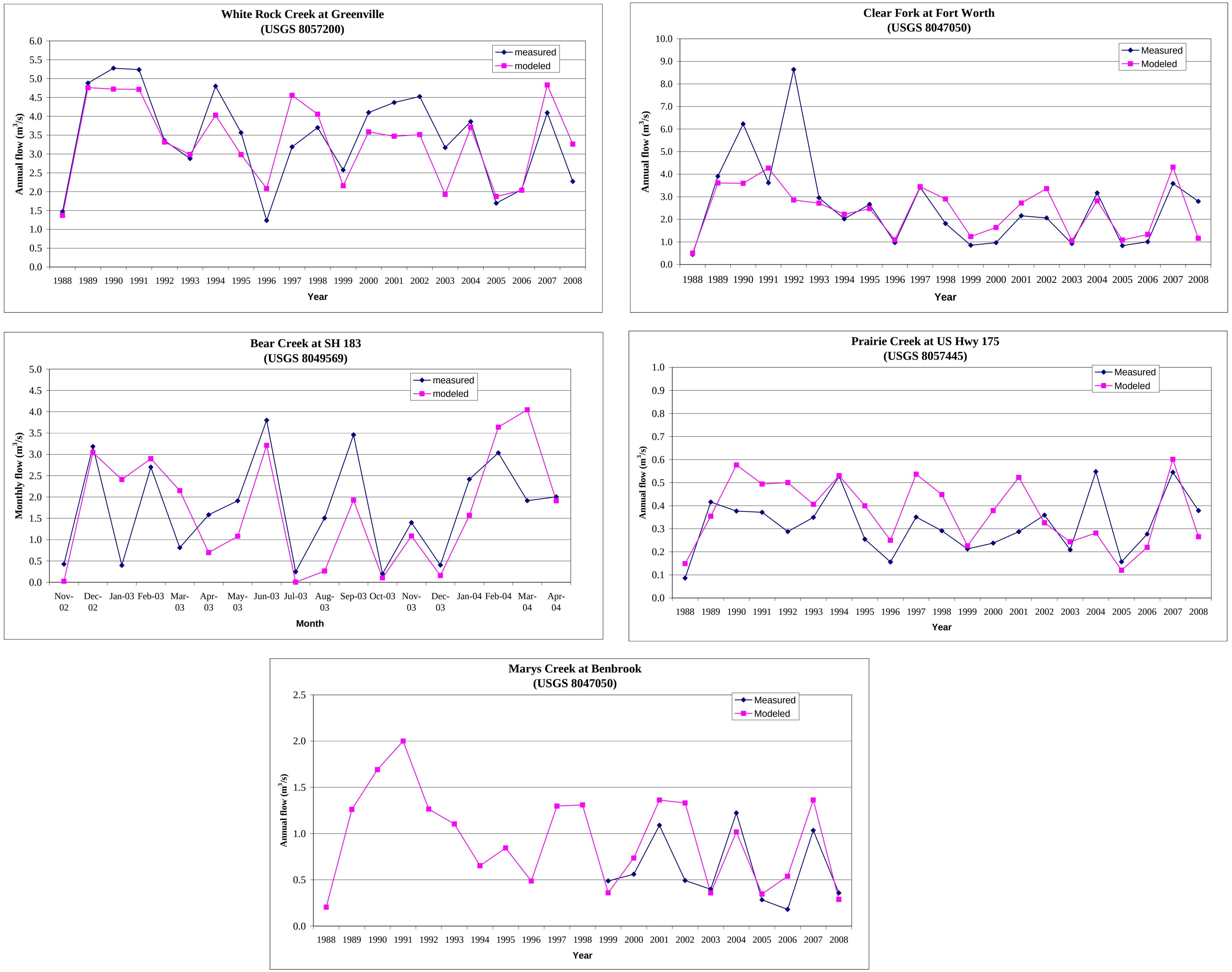


Figure 4.2 Measured and Modeled Annual Flows

The correlation coefficient, r, ranges from –1 to 1 and measures the tendency of the predicted and observed values to vary together linearly; a value close to 1 indicates a good match between observations and model predictions. The index of agreement, d, varies from 0 to 1, with higher values indicating better agreement between the model and observations. Finally, the root mean squared error, RMSE, measures the magnitude of the discrepancies between predicted and observed values, with values close to zero indicating a good match. Table 4.7 presents a summary of the different statistics calculated for the various gages. Results indicate a very good level of agreement between predicted and observed values.

Table 4.7 Goodness-of-Fit for GWLF Flow Predictions

Statistic	White Rock at Greenville	Clear Fork at Fort Forth	Bear Creek at SH 183	Prairie Creek at US Hwy 175	Marys Creek at Benbrook
r	0.831	0.626	0.677	0.589	0.740
d	0.903	0.708	0.815	0.731	0.813
RMSE (m^3/s)	0.148	0.331	0.233	0.029	0.050
RMSE (%)[a]	4%	13%	14%	9%	7%

[a] *RMSE (in cms)/* $\overline{O}$ **100%*

Also of interest was to evaluate model performance on a seasonal basis. To do so, observed and modeled average flows by month (12 values) were compared in Figure 4.3. As can be seen, the model seems to capture most of the patterns throughout the year, with the exception of the spring months for Bear Creek and the summer and fall months for Mary's Creek.

Sediment Yield

The GWLF model calculates sediment yield loads based on erosion and delivery ratios. Annual sediment yield loads for the various subwatersheds were converted to concentrations (using the calibrated flows). Ground cover factors (C) were used as a calibration parameter. Various alternatives for C (in KLSCP) were evaluated. Some weighted C by percent impervious (for each land use) or normalized by percent pervious compared to the White Rock subwatershed (calibration). The final calibrated values were 0.006 for land uses with more than 70% pervious cover and 0.0015 for the remaining more impervious land uses (perviousness between 0 and 70%). The pervious and impervious percents for each of the land uses as well as their resulting C values are included in Table 4.8.

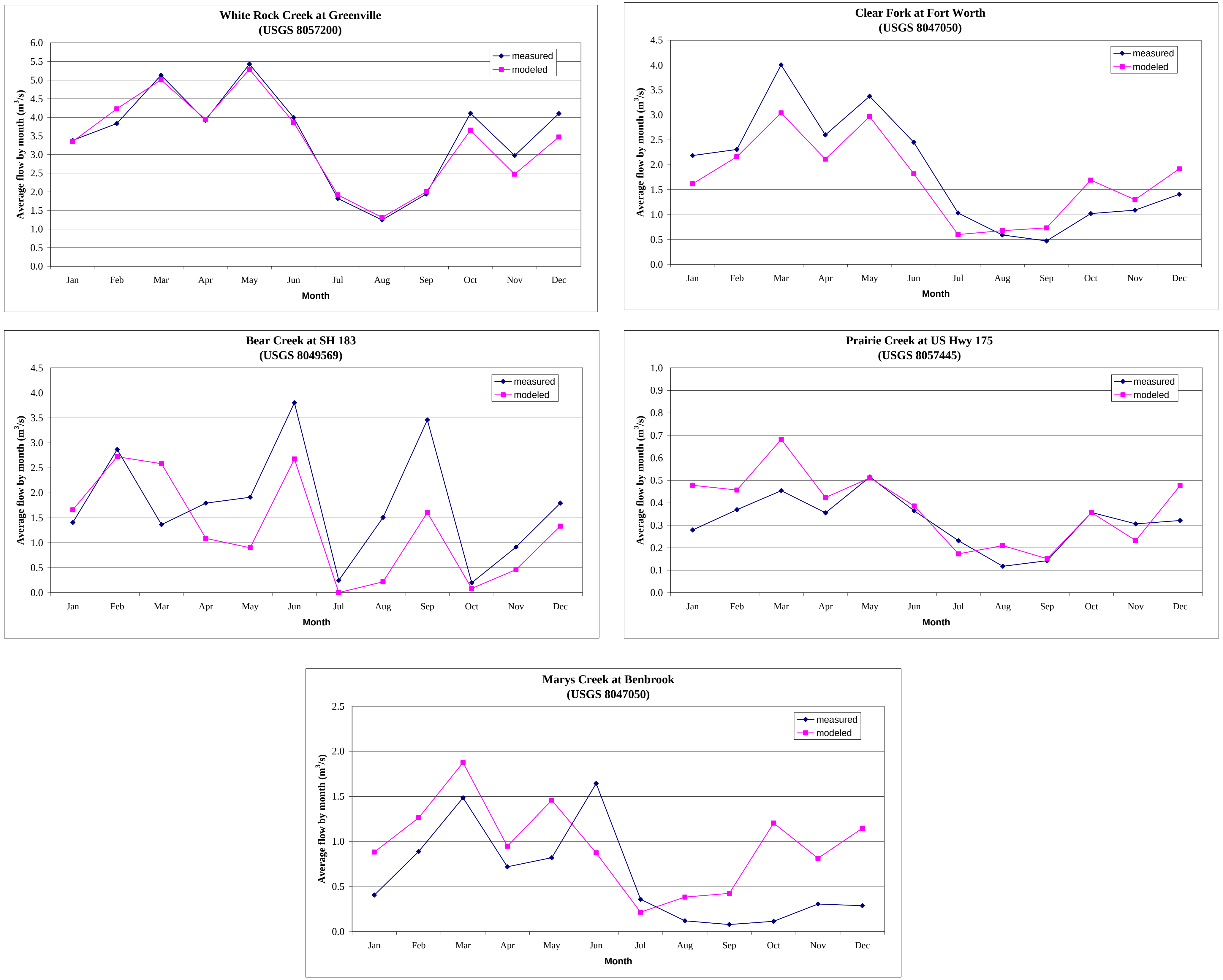


Figure 4.3 Measured and Modeled Flows by Month

Table 4.8 GWLF Ground Cover Factors by Land Use

Land Use	Percent pervious	Percent impervious	C
Single family residential	70	30	0.0015
Multi-family residential	70	30	0.0015
Mobile homes	70	30	0.0015
Government/education group quarters	15	85	0.0015
Commercial: office	15	85	0.0015
Commercial: retail	15	85	0.0015
Government/education institutional	70	30	0.0015
Commercial: hotel/motel	15	85	0.0015
Industrial	28	72	0.0015
Transportation	10	90	0.0015
Roadway	10	90	0.0015
Utilities	28	72	0.0015
Airports	10	90	0.0015
Parking garage	10	90	0.0015
Airport: runway	10	90	0.0015
Commercial: large stadium	15	85	0.0015
Commercial: mixed use	15	85	0.0015
Parks	97	3	0.006
Landfill	97	3	0.006
Under construction	70	30	0.006
Flood control	97	3	0.006
Undeveloped: vacant	97	3	0.006
Undeveloped: parking (CBD)	97	3	0.006
Undeveloped: expanded parking	97	3	0.006
Water	0	100	0.006
Transportation: right of way	10	90	0.0015

Total suspended solids data for five subwatersheds in the study area were retrieved from the TCEQ Surface Water Quality Monitoring (SWQM) database. Measured TSS data were scarce, with very few measurements for most of the years as summarized in Table 4.9. Therefore, calibration of GWLF was focused on attaining the order of magnitude of the average of measurements for each subwatershed, rather than on matching individual data points. For the White Rock Creek subwatershed, it was possible to calculate annual average TSS loads from measured data and compare them to modeled loads (Figure 4.4). The modeled loads are in reasonable agreement with the measured loads. It is noted that the goal was to match patterns rather than values, due to the paucity of daily measured data. Finally, a comparison of total average TSS concentrations for the five subwatersheds is shown in Figure 4.5. The model under-predicted TSS concentrations in White Rock and Johnson Creeks, while it over-predicted average values in Clear Fork, Delaware Creek and Bear Creek. However, the modeled average concentrations are within the order of magnitude of the observed values, which indicates that the model is predicting reasonable values for solids loads/concentrations.

Table 4.9 Summary of Available Total Suspended Solids Data

Subwatershed	Year	Number of TSS Samples	Average TSS (mg/L)
Bear Creek	2002	3	14.0
	2003	13	31.9
	2004	7	64.0
	2005	2	19.5
	2006	3	15.3
	Total	*28*	*35.4*
Clear Fork	1989	1	8.0
	1990	1	9.0
	1992	1	16.0
	1993	3	25.7
	1994	4	77.3
	1995	3	22.0
	1996	2	35.0
	1997	1	19.0
	1998	4	17.0
	1999	4	28.8
	2000	5	18.4
	2001	4	19.3
	2002	4	7.0
	2003	4	15.8
	2004	4	18.0
	2005	4	27.0
	2006	4	21.5
	2007	3	20.0
	2008	2	26.0
	Total	*58*	*24.1*
Delaware Creek	1986	5	38.8
	2001	10	26.0
	2002	35	10.8
	2003	55	25.2
	2004	46	10.5
	Total	*151*	*17.9*
Johnson Creek	1973	3	20.3
	1977	11	36.5
	1978	7	20.0
	1979	7	39.1
	1980	7	21.1
	1981	9	29.3
	1982	7	14.6
	1983	5	8.6
	1984	7	53.0
	1999	1	7.0
	Total	*70*	*28.3*

Subwatershed	Year	Number of TSS Samples	Average TSS (mg/L)
White Rock Creek	1995	6	46.8
	1998	4	38.8
	1999	12	49.3
	2000	12	37.8
	2001	12	26.7
	2002	21	14.5
	2003	18	32.6
	2004	9	22.2
	2005	6	19.7
	2006	8	51.4
	2007	16	49.6
	Total	*124*	*34.0*

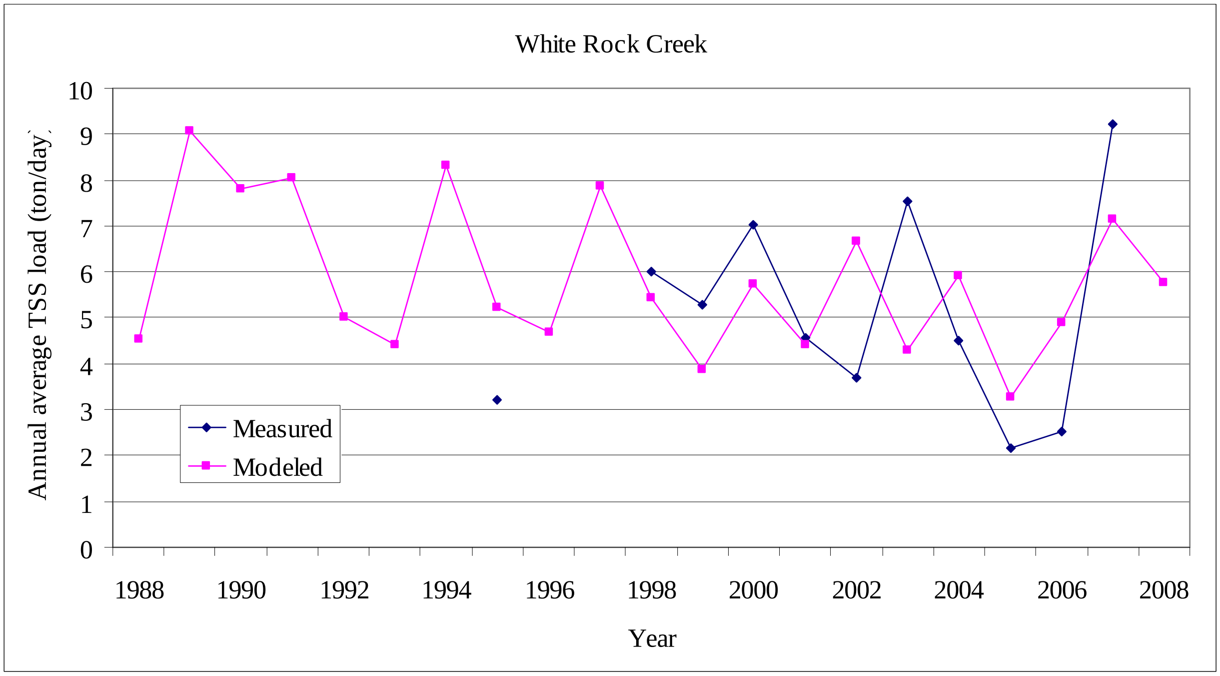


Figure 4.4 Measured and Modeled Annual TSS Loads for White Rock Creek

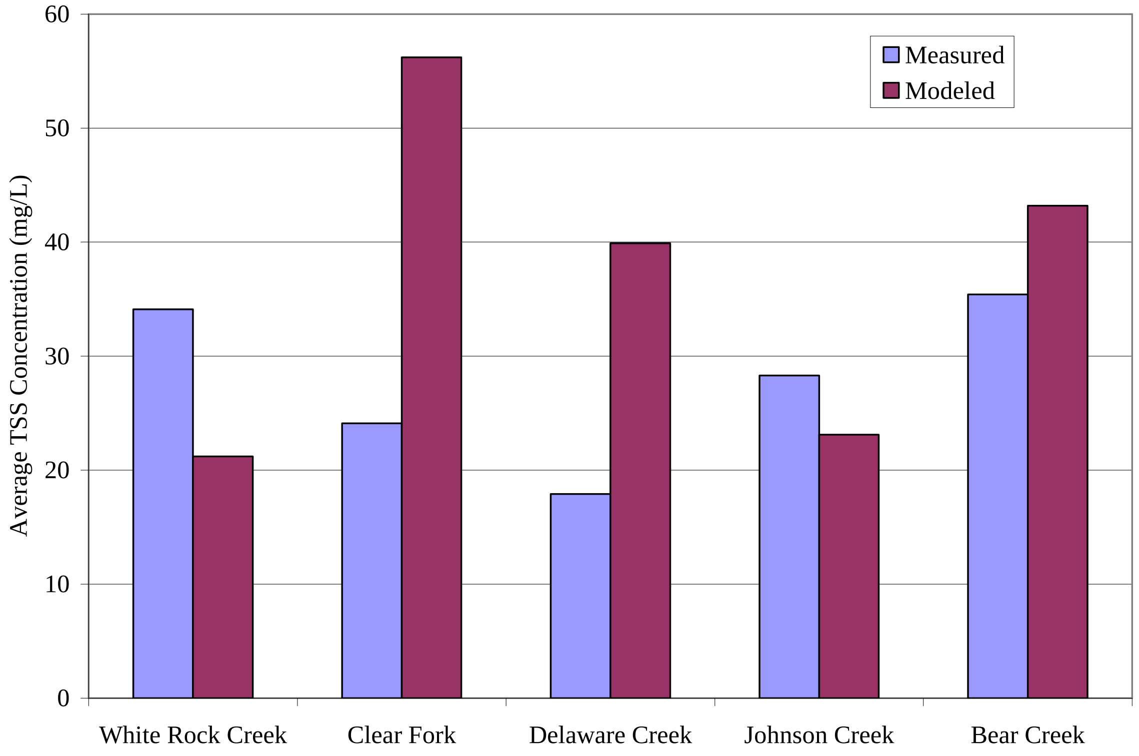


Figure 4.5 Modeled and Measured Average TSS Concentrations

4.3 Instream Model

The TMDL development approach used here is based upon a simple multiple-box, mass balance analytical model. The system is divided into multiple boxes or calculational elements, with different boxes for water and sediment for each reach of the river. The model accounts for the flux in and out of each calculational element, partitioning the PCB between dissolved and particulate phases and then calculates the fate and transport separately for each phase.

The model is not a numerical simulation model, rather it is basically a flux accounting model. Several simplifying assumptions were made to allow the use of simpler analytical solutions rather than rely upon more complex numerical simulation techniques to solve the state equations. The primary simplifying assumption is that each of the equations describing fate and transport in each phase for the various sinks and sources are assumed to be independent. Additionally, the major PCB sources and removal mechanisms are treated as first-order processes.

The model was developed in REALbasic, a cross-platform rapid prototyping and development environment that is an implementation of the BASIC programming language. The model relies upon the PostgreSQL database server as a mechanism to both store and manipulate model output and parts of the input. PostgreSQL is a free open source database. The model includes a graphical user interface (GUI) and two main program modules, one of which is a utility module for creating the input time series upon which the model depends from the various input sources such as USGS records and GWLF watershed model output. Figure 4.6 is a generalized process flow diagram for the model. The three main parts or modules that comprise the model are shown in the figure. In the center is the GUI, or graphical user interface, to the right is the TSGen time series processing module and the main processing module for PCBs is shown to the left.

4.3.1 Model Input

The GUI module not only serves as the interface between the user and the program, but also processes the model input. Following the process flow shown in Figure 4.6, at the beginning of the program the user selects an input file and the GUI module reads and processes the file. The input file is a comma delimited file containing blocks of input data arranged in a fashion loosely inspired by the input format of the QUAL-TX model. The input is arranged in 13 blocks that provide various types of input including:

1. TITLE Block - The first field in the block is the name to be used for the output table, while the second field is and arbitrary descriptive title.
2. TIME Block - The time information, start date, stop date and the time step are specified in this block.
3. RATES Block - The rates for the fate kinetics are specified here.
4. REACH Block - This block describes the physical arrangement of the model schematic, designates the calculational elements that comprise each model reach, sets both reach and element lengths, etc.
5. HDWTR Block - This block specifies the element numbers that constitute the headwaters of the main stem and each tributary.
6. JCTN Block - The junction block provides the element number of each junction or confluence element where tributaries and/or the main stem conjoin.
7. HYDRO Block - This block provides the coefficient for the hydraulic equations described below.
8. INITIAL Block - The initial conditions for the model are described in this block.
9. TEMP Block - Temperatures to be used during the simulation are described here.
10. EVAP Block - Evaporation rates to be used during the simulation are described here.
11. QLOAD Block - This block provides the filenames for the USGS time series records and GWLF output files that are processed to become the input flow and load time series.
12. WATUSE Block - This block describes water use and withdrawals from the system that must be included in the accounting.
13. OUTPUT Block - This block is where the element numbers for which model output is stored in the output table are described.

The GUI reads these data and stores them internally, subsequently prompting the user for a time series name. The user has the option of using a previously generated time series, since the time series table contains flow and loading data that may not change from run to run. If a name is specified that does not correspond to a time series already stored in the database, the GUI executes the TSGen time series module. The TSGen module pre-processes all of the inflows from gaged tributaries as well as GWLF watershed input files specified in the QLOAD block of the input file. The module reads all of the input files and generates an array of inflow and loads for each time step for each element which has inflow. These arrays are stored in the time series table in the database to foster the efficient retrieval of the loading data during the simulation.

4.3.2 Model Operational Theory

The main model process module illustrated to the left in Figure 4.6 is the overall calculational loop for the model. Basically this module loads the selected time series table and creates the output table. The module then starts an outer loop through time starting at the specified start date progressing by a specified time step to the end date. On each time step the model starts the inner loop that performs the transport and kinetics calculations for each of the several hundred calculational elements. Both of these loop structures are illustrated in Figure 4.6.

The inner or spatial loop is called for each calculational element for each time step. Immediately prior to the initiation of the inner loop the input flows and loads are retrieved from the time series table for all elements that have inflows. The loop then executes each of the seven hydraulic and kinetic routines and subsequently stores the results in the output table.

Model Domain

Figures 4.7 through 4.12 illustrate the spatial layout of the Trinity River model. The model extends from the Lake Worth dam on the West Fork downstream to the USGS gage at SH 31 near Navidad, downstream of the impaired assessment units. The model was divided into 66 reaches based on the locations of major tributaries, subwatershed boundaries, monitoring locations, and assessment unit boundaries. The reaches were further divided into one-kilometer long computational elements. There are a total of 315 computational elements.

Hydraulics

The hydraulic routine is the first of the seven routines in the calculation loop to be executed. The inner or spatial loop is called for each computational element for each time step. All inflows (from upstream, tributaries, and discharges) are added, and withdrawals are removed. The resulting flow in the element is used to calculate flow velocity, depth, channel width, element residence time, element cross-sectional area and element volume. The principal relationships are for flow velocity and depth. Since the length of the element is specified, the other parameters can be calculated from flow velocity, depth, and flow. The equations used to derive flow velocity and depth are the same equations used in the TCEQ’s QUAL-TX models:

$$U = aQ^b$$

$$D = dQ^e + f$$

$$W = gQ^h + i$$

where:

Q = flow, m^3/s

U = average flow velocity, m/s

D = average depth, m

W = average width at surface, m

The values for the coefficients a, b, d, e, f, g, h, and i were taken from the TCEQ calibrated QUAL-TX models of Segments 0805, 0806, and 0841 (TWC, 1986), and are specified for each model reach. The QUAL-TX models are used by the TCEQ in determining waste load evaluations for dissolved oxygen, and were obtained from Mark Rudolph of the TCEQ's Water Quality Division.

PCB Phase Partitioning

The next step in the model calculations is partitioning the total PCB in the element between the dissolved and particulate phases. The total PCB in the element is calculated by summing both dissolved and particulate sources from upstream, tributaries, and discharges. The resultant total PCB is partitioned by the distribution equation below:

$$PCB_d = PCB_t / [1 + (K_p * TSS /1000000)]$$

$$PCB_s = PCB_t - PCB_d$$

Where:

PCB_t = total PCB in element, ug/m^3

PCB_d = dissolved PCB in element, ug/m^3

PCB_s = particulate PCB in element, ug/m^3

K_p = PCB partition coefficient between suspended solids and the dissolved phase in water, L/kg

TSS = total suspended solids concentration, g/m^3

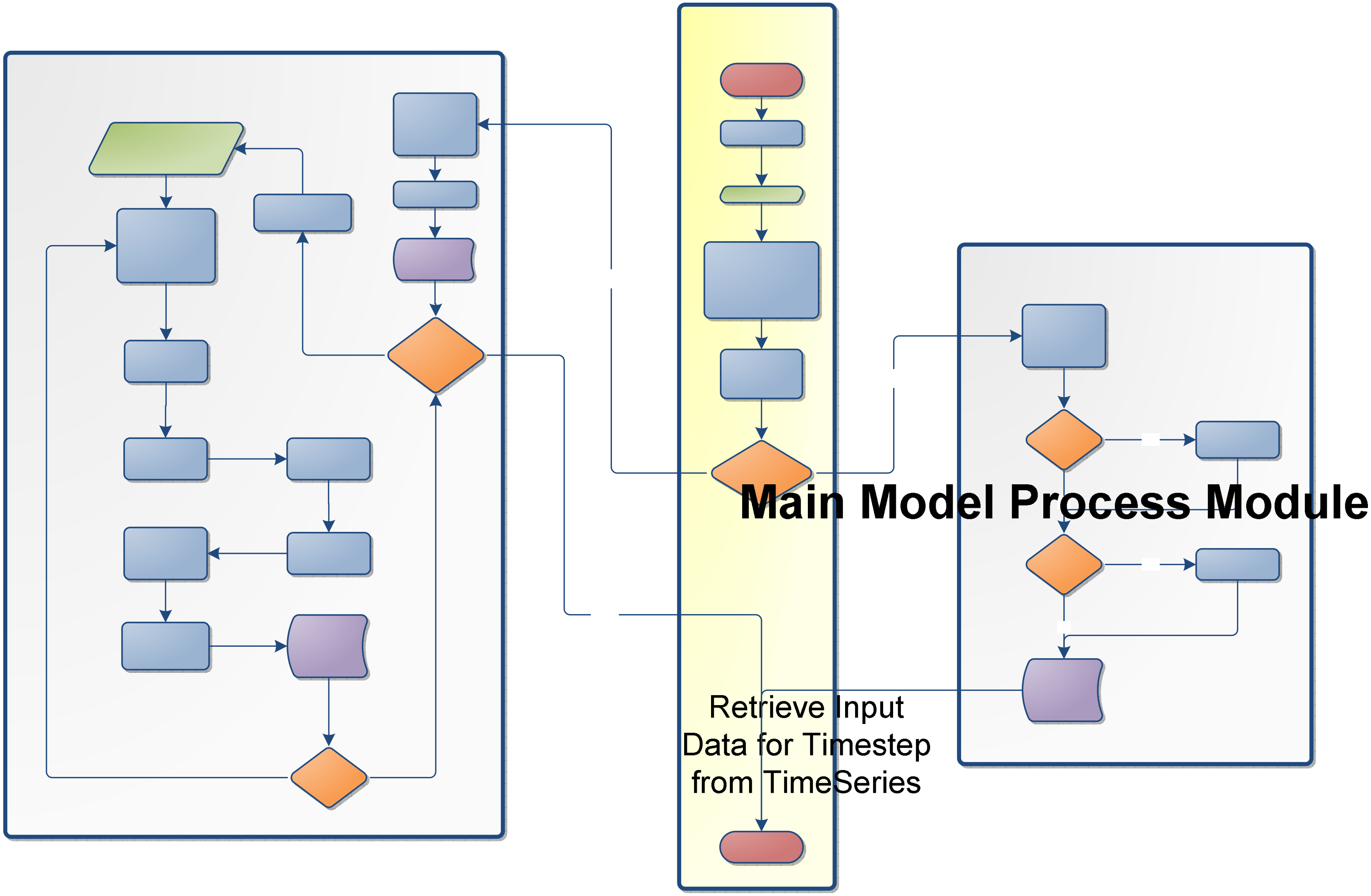


Figure 4.6 Generalized Process Flow Model for the Instream Model

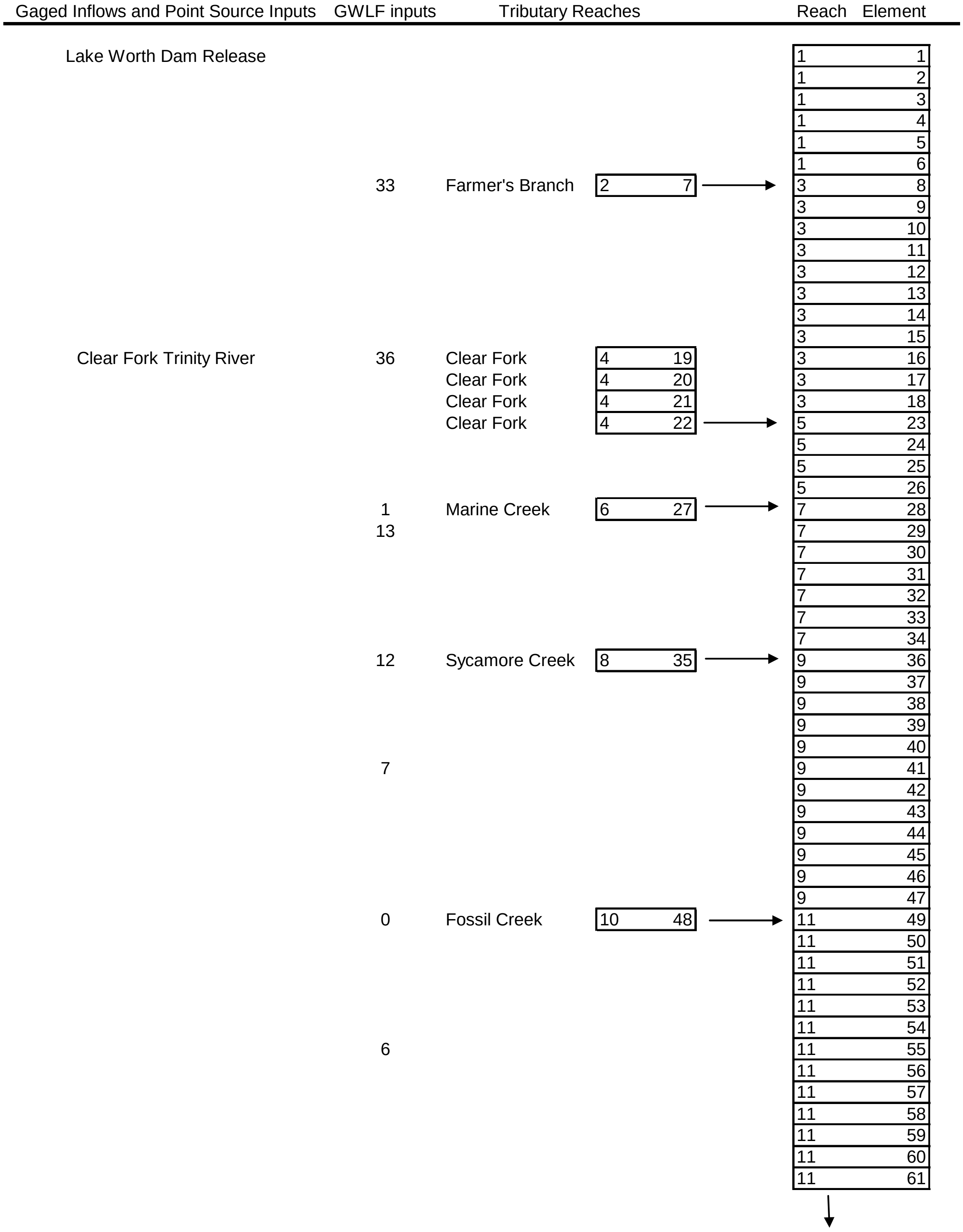


Figure 4.7 Model Schematic of Assessment Units 0806_02, 0806_01, and 0829_01

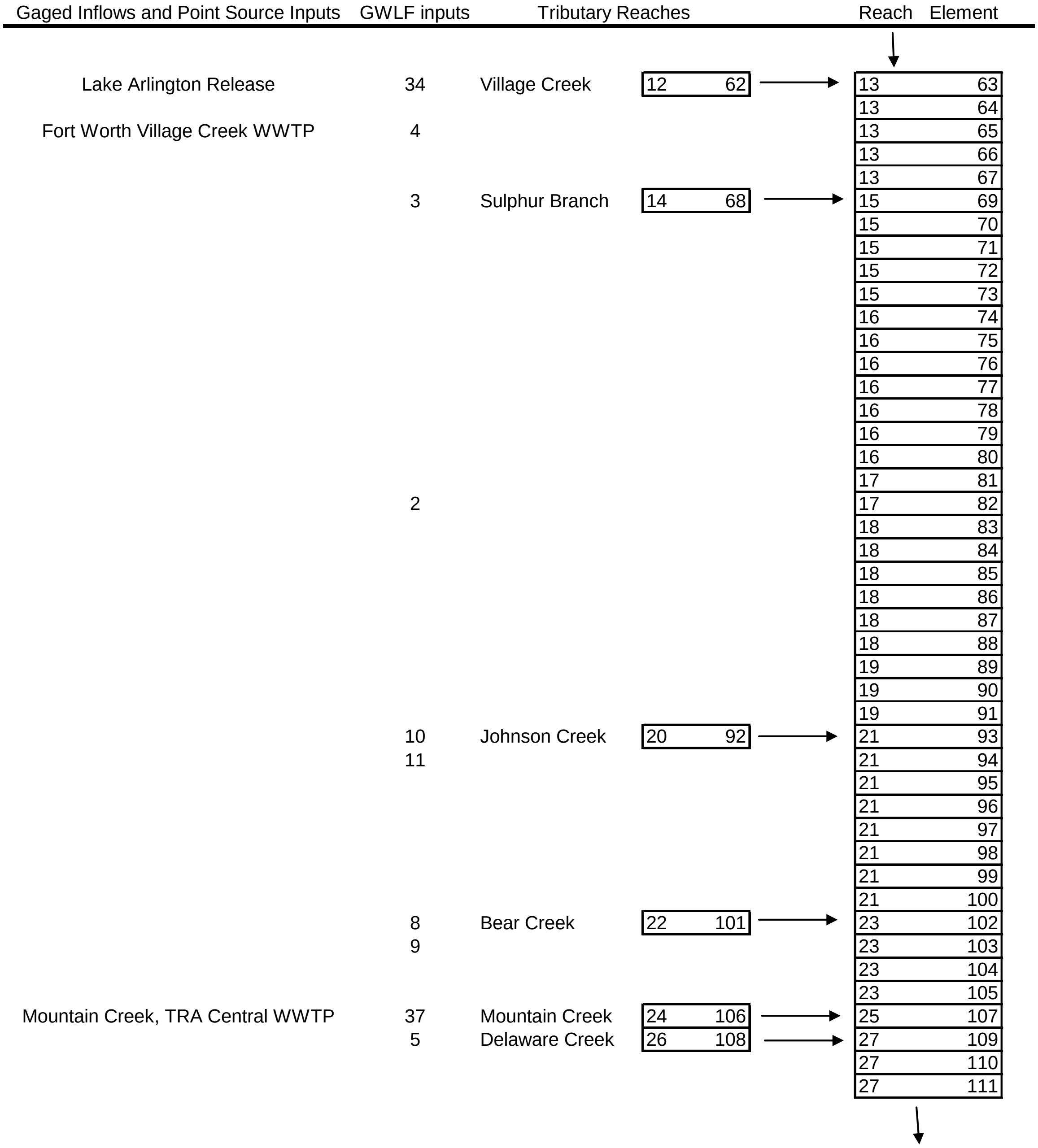
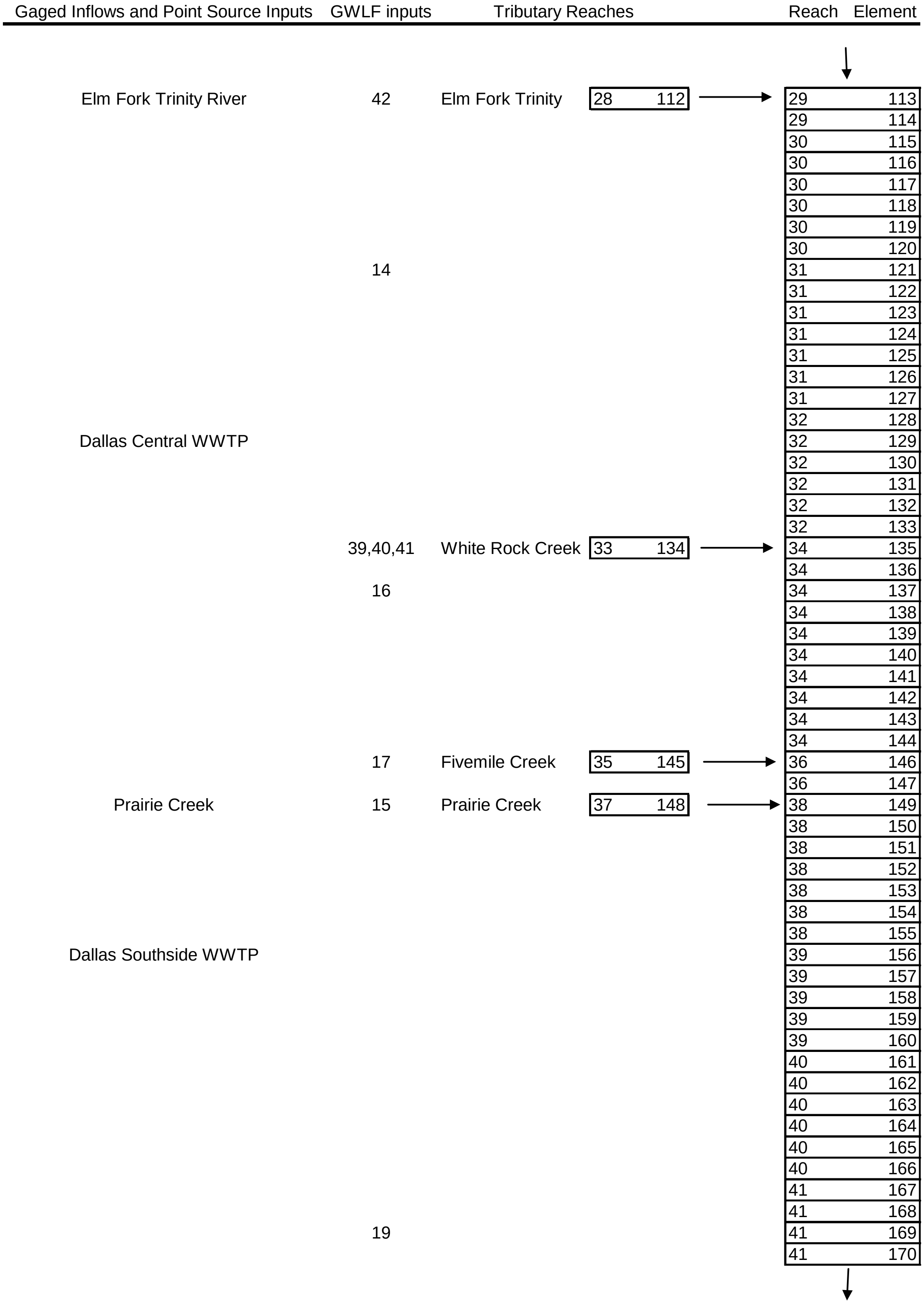
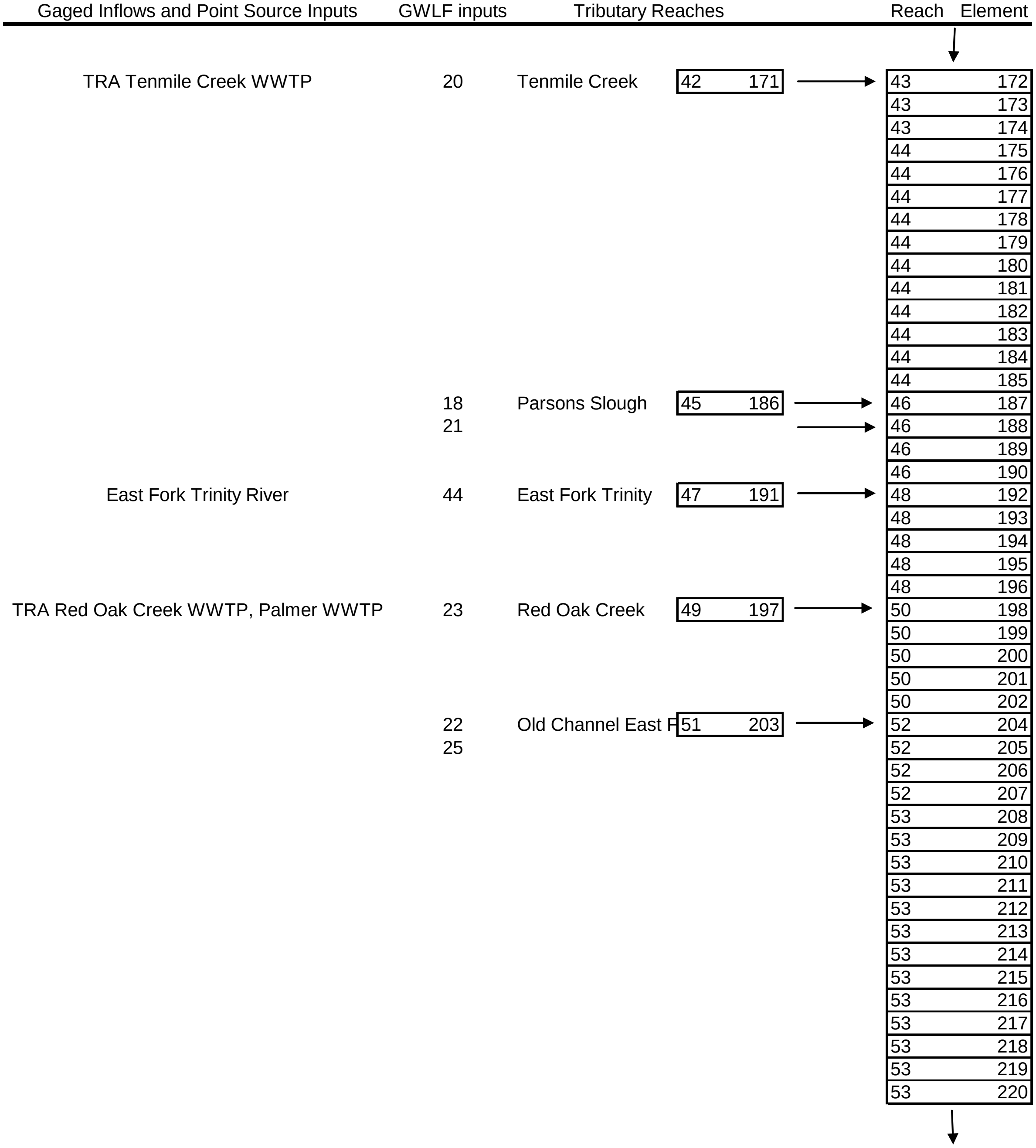


Figure 4.8 Model Schematic of Assessment Units 0841_02 and 0841_01



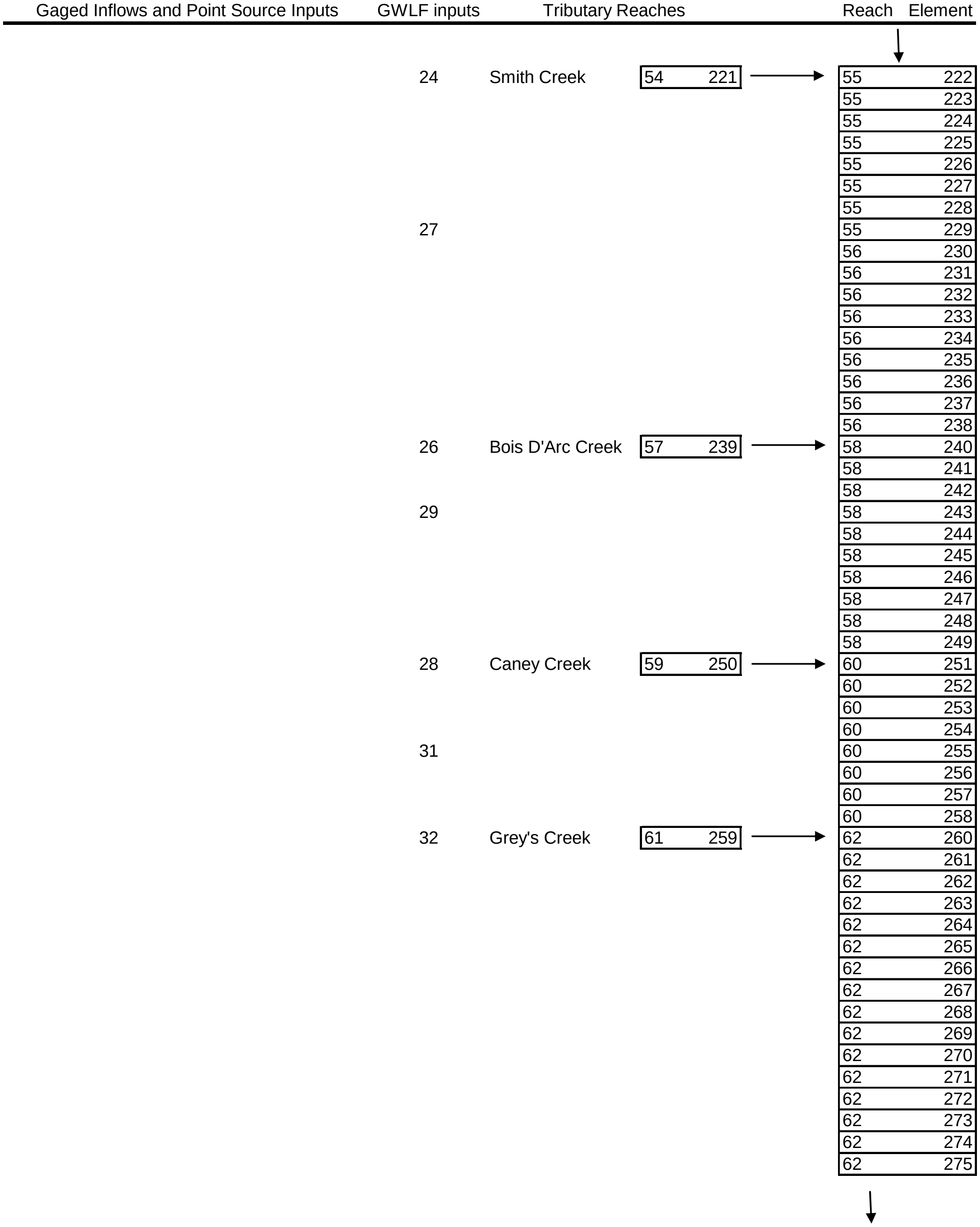
Gaged Inflows and Point Source Inputs	GWLF inputs	Tributary Reaches			Reach	Element
Elm Fork Trinity River	42	Elm Fork Trinity	28	112	29	113
					29	114
					30	115
					30	116
					30	117
					30	118
					30	119
					30	120
	14				31	121
					31	122
					31	123
					31	124
					31	125
					31	126
					31	127
					32	128
Dallas Central WWTP					32	129
					32	130
					32	131
					32	132
					32	133
	39,40,41	White Rock Creek	33	134	34	135
					34	136
	16				34	137
					34	138
					34	139
					34	140
					34	141
					34	142
					34	143
					34	144
	17	Fivemile Creek	35	145	36	146
					36	147
Prairie Creek	15	Prairie Creek	37	148	38	149
					38	150
					38	151
					38	152
					38	153
					38	154
					38	155
Dallas Southside WWTP					39	156
					39	157
					39	158
					39	159
					39	160
					40	161
					40	162
					40	163
					40	164
					40	165
					40	166
					41	167
					41	168
	19				41	169
					41	170

Figure 4.9 Model Schematic of Assessment Units 0805_04, 0805_03, and 0805_06



Gaged Inflows and Point Source Inputs	GWLF inputs	Tributary Reaches			Reach	Element
TRA Tenmile Creek WWTP	20	Tenmile Creek	42	171	43	172
					43	173
					43	174
					44	175
					44	176
					44	177
					44	178
					44	179
					44	180
					44	181
					44	182
					44	183
					44	184
					44	185
	18	Parsons Slough	45	186	46	187
	21				46	188
					46	189
					46	190
East Fork Trinity River	44	East Fork Trinity	47	191	48	192
					48	193
					48	194
					48	195
					48	196
TRA Red Oak Creek WWTP, Palmer WWTP	23	Red Oak Creek	49	197	50	198
					50	199
					50	200
					50	201
					50	202
	22	Old Channel East F	51	203	52	204
	25				52	205
					52	206
					52	207
					53	208
					53	209
					53	210
					53	211
					53	212
					53	213
					53	214
					53	215
					53	216
					53	217
					53	218
					53	219
					53	220

Figure 4.10 Model Schematic of Assessment Unit 0805_02



Gaged Inflows and Point Source Inputs	GWLF inputs	Tributary Reaches			Reach	Element
	24	Smith Creek	54	221	55	222
					55	223
					55	224
					55	225
					55	226
					55	227
					55	228
	27				55	229
					56	230
					56	231
					56	232
					56	233
					56	234
					56	235
					56	236
					56	237
					56	238
	26	Bois D'Arc Creek	57	239	58	240
					58	241
					58	242
	29				58	243
					58	244
					58	245
					58	246
					58	247
					58	248
					58	249
	28	Caney Creek	59	250	60	251
					60	252
					60	253
					60	254
	31				60	255
					60	256
					60	257
					60	258
	32	Grey's Creek	61	259	62	260
					62	261
					62	262
					62	263
					62	264
					62	265
					62	266
					62	267
					62	268
					62	269
					62	270
					62	271
					62	272
					62	273
					62	274
					62	275

Figure 4.11 Model Schematic of Upstream Portions of Assessment Unit 0805_01

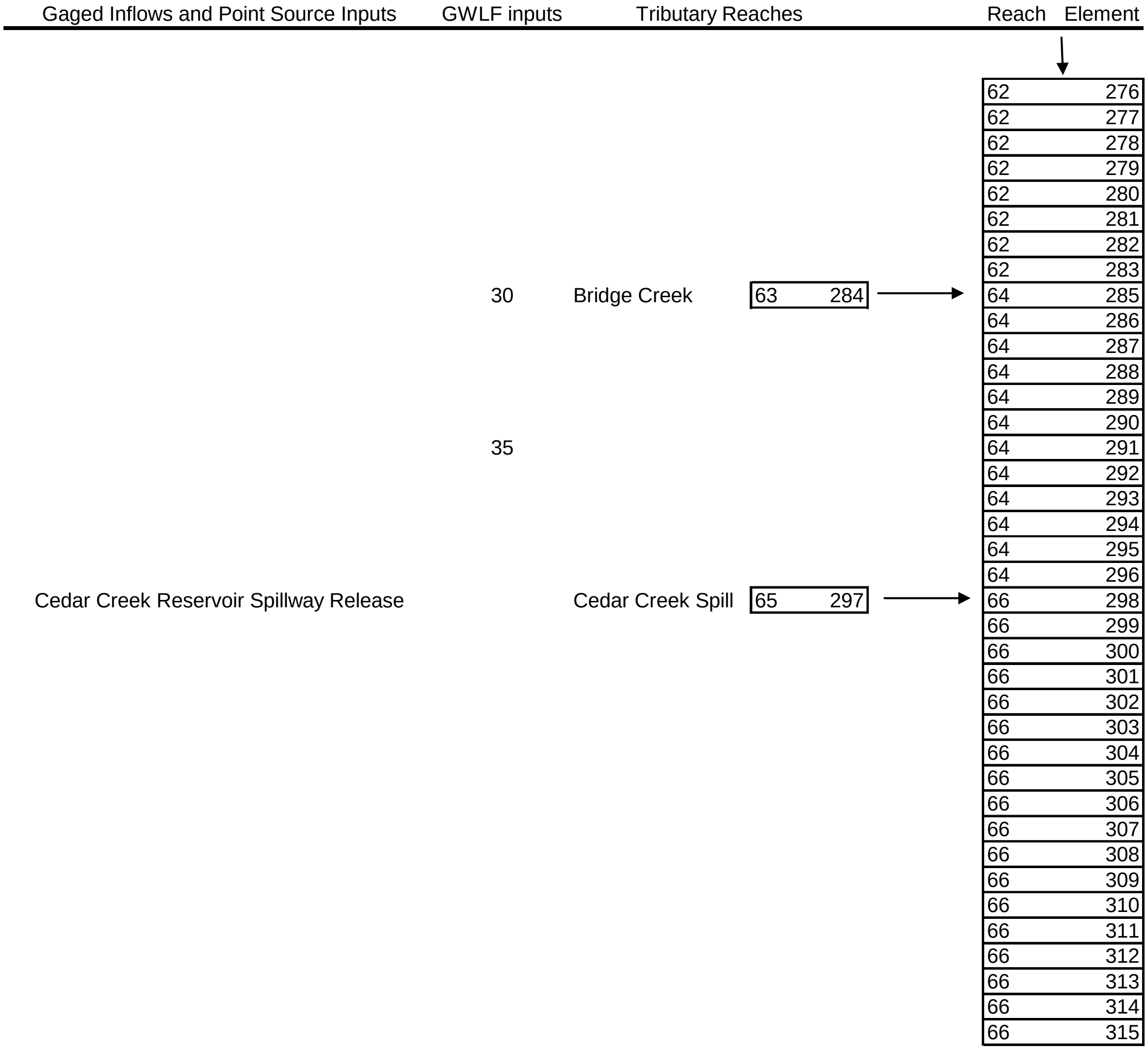


Figure 4.12 Model Schematic of Downstream Portions of Assessment Unit 0805_01, as well as Additional Downstream Reaches to State Highway 31

PCB Volatilization

PCB volatilization from the water phase to air occurs from the dissolved phase. In the model, it was treated as a first order process.

$$C = C_0 \times \exp(-K_{OL} t / D)$$

Where:

C = PCB concentration at time t

C_0 = initial PCB concentration

D = water depth

K_{OL} = overall volatilization mass transfer coefficient (distance/time)

The two-film resistance model of Liss and Slater (1974) is commonly used to estimate the volatilization mass transfer coefficient from water to air. It includes mass transfer coefficients in the liquid (K_L) and gas (K_G) phases:

$$1/K_{OL} = 1/K_L + RT/HK_G$$

Where:

R = the gas constant and

H = Henry's Law coefficient for PCBs

T = absolute temperature.

K_L and K_G depend on turbulence levels in air and water, on temperature, and on properties of the PCB such as molecular size. Based on field and laboratory measurements, Mackay and Yeun (1983) derived the following equations to estimate K_L and K_G :

$$K_L = 34.1\text{x}10^{-6} * (6.1 + 0.63*U_{10})^{0.5} * U_{10} * Sc_L^{-0.5}$$

$$K_G = 46.2\text{x}10^{-5} * (6.1 + 0.63*U_{10})^{0.5} * U_{10} * Sc_L^{-0.67}$$

Where:

U_{10} = wind speed at 10 meters height, and

Sc_L = Schmidt number of the water body

The Schmidt number can in turn be calculated from the dynamic viscosity (μ) and density (ρ) of water, and the molecular diffusivity (D) of the PCB:

$$ScL = \mu / (\rho * D)$$

$$\mu = 2.414 \text{ x } 10\text{-}5 \text{ x } 10247.8/(T_K - 140)$$

Where T_K = water absolute temperature (Kelvin)

$\rho = 1000.1 + 0.0107 * T_C - 0.0052 * T_C^2$

Where T_C = water temperature in Celsius

The molecular diffusivity D of a dilute solute such as a PCB in water was calculated from the Wilke-Chang (1955) equation:

$D = 7.4 \times 10^{-8} * (\varphi M_B)^{0.5} * T / (\mu (V_A)^{0.6})$

Where φ = a solvent association factor (2.6 for water),

T = absolute temperature (Kelvin)

M_B = molecular weight of water (18 g/mol), and

V_A = molar volume of the solute (289 m^3/mol for a penta-chlorinated PCB).

In the model, the wind speed was held constant at the annual average of 3.2 m/s. Alternately, a daily average wind speed time series could be read in. The model also assumed a Henry's Law constant of 3×10^{-4} atm/m^3-mol, which is typical for a penta-chlorinated PCB, although the overall range is large. Daily volatilization losses from each model element were adjusted for retention time in the element.

PCB Water Column Decay

Decay of PCB in the water column is modeled as a first order decay from the dissolved phase, utilizing the equation below:

$$C = C_0 \times \exp(-k_{PCB} t)$$

Where:

C = dissolved PCB concentration at time t

C_0 = initial dissolved PCB concentration

k_{PCB} = dissolved phase PCB decay rate, 1/day

t = time, day

Daily decay losses from each model element were adjusted for retention time in the element.

Suspended Sediment Settling

The equation chosen to approximate the settling rate in the model is an empirical equation adapted from the Environmental Fluid Dynamics Code (Tetra Tech 2002):

$$w = w_0 * (TSS / TSS_R)^{order}$$

Where:

w = suspended solid settling velocity, m/day

w_0 = user-specified reference settling velocity at TSS_R, m/day

TSS = TSS concentration, g/m^3

TSS_R = user-specified reference TSS concentration, g/m^3

order = user-specified adjustable equation order

This equation accounts for the fact that at higher TSS concentrations, sedimentation rates of cohesive solids are enhanced due to particle coagulation. The applied settling velocity is calculated for every element for each time step and the TSS and PCB settled for that time step (day) is added to the sediment array for that element. The sediment array is a first in – first out array that stores the TSS and PCB settled for each day of the simulation. The maximum size of the array is 10,000 elements. As a result each individual daily sedimentation is stored for each element for up to 10,000 days (more than 27 years). The storage of the daily sedimentation is used in the subsequent resuspension calculations.

Bed Sediment Resuspension

The daily sediment resuspension rate per unit surface area, ε, (g/m^2-day) was computed according to the formula of Gailani et al (1991) as:

$$\varepsilon = \frac{a_0}{t_d^m} * \left(\frac{\tau - \tau_o}{\tau_o} \right)^n$$

Where:

t_d = time after deposition in days

τ = shear stress in dynes/cm^2

τ_o = effective critical shear stress in dynes/cm^2

a_0 = a site specific coefficient with units of grams/m2

m = a unitless site-specific consolidation exponent coefficients

n = a unitless coefficient (it is not Manning’s n)

Values of a_0 and n have been measured in several systems. The average and 95% confidence interval for a_0 is 2.1 ± 2.0 g/m^2. The average and 95% confidence interval for the exponent n is 2.6 ± 0.3. In the absence of measured data, these average values were used for the Trinity River model. Values of the consolidation exponent, m, range from 0.5 for high energy systems to 2 for low energy systems. The Trinity River was considered a higher-energy system, thus a value of 0.5 was used for m.

This formulation accounts for the consolidation that occurs over time in deposited cohesive sediments that resists resuspension. It is assumed that freshly deposited sediments occur in an easily resuspendable water-rich layer, and that over time due to gravity and biological activity the sediments become more resistant to resuspension.

The shear stress, τ, is calculated as:

$$\tau = f * \rho_w * \mathrm{U}^2 / 2$$

Where:

τ = shear stress in dynes/cm^2

f = Fanning friction factor

ρ_w = water density, g/cm^3

U = average flow velocity, cm/s

The Fanning friction factor can be calculated as:

$$f = 2 * n^2 * g / R^{1/3}$$

Where:

n = Manning's roughness coefficient, unitless

g = gravitational acceleration constant, m/s^2

R = Hydraulic radius, m

The hydraulic radius is calculated as the ratio of channel area to wetted perimeter. For a rectangular channel, the hydraulic radius is:

$$R = D*W/(W+2D)$$

Where:

R = Hydraulic radius, m

D = average depth, m

W = average width at surface, m

As described above, settled sediments are added in daily-deposited layers to the bed sediment pool for a maximum of 10,000 days. The oldest sediment layer is moved each day from the active sediment matrix to a buried sediment pool. When sediments are resuspended, they (and their associated PCBs) are removed from the bed sediment pool on a layer-by-layer basis and added to the overlying water column. The most recently deposited bed sediments are resuspended first. Resuspension of only a fraction of a daily sediment layer is permitted.

PCB Fluxes Across the Sediment-Water Interface

The model accounts for PCB transfer between the sediment pore water and the overlying water column. The transfer is based upon the total PCB concentrations in the active sediment array. Pore water concentrations are calculated using the equation below:

$$PCB_{PW} = (PCB_{BS} * 1000) / (K_{OC} * F_{OC})$$

Where:

PCB_{PW} = PCB pore water concentration, ug/m^3 or ng/L

PCB_{BS} = average sediment PCB concentration, ug/kg

K_{OC} = PCB distribution coefficient between pore water and sediment organic carbon, L/kg

F_{OC} = organic carbon content of sediments g/g

The areal PCB flux (F_{PCB})from the sediment (ug/m^2/day) is then calculated by:

$$F_{PCB} = K_{st} * (PCB_{pw} - PCB_{d}) * T_r$$

Where:

K_{st} = user-specified PCB pore water flux factor, m/day

PCB_{pw} = PCB pore water concentration, ug/m^3

PCB_{d} = dissolved PCB concentration in overlying water column, ug/m^3

T_r = element retention time, day

The resulting PCB flux is added to the water column concentration and deducted from the active sediment layers, beginning with the uppermost sediments first and proceeding as deep as required.

4.3.3 Model Database Structure

As described previously, the model relies upon a PostgreSQL database to store, retrieve and manipulate the output and parts of the input data. The database is comprised of three schemas. The *system* schema contains a single database, *system.timeseries.* The structure for this table is illustrated in Figure 4.13. The table stores the names and creation dates of the various input time series. The input time series themselves are stored in the *timeseries* schema.

The *timeseries* schema contains a variable number of tables including *timeseries.template* and the individual time series tables named by the user. The *timeseries.template* table is used to create a new time series table by the TSGen module and the structure of the table is shown in

Figure 4.13. The model output is stored in tables in the *output* schema. The *output* schema contains a variable number of tables including *output.template* and the individual output tables named via the input file. The *output.template* table is used to create a new output table by the main model process module.

4.4 Model Inputs and Calibration

The model was based on total PCB concentrations, that is, the sum of all congeners. Average values of K_p ($2.6x10^4$ L/kg) and K_{oc} ($2.5x10^6$ L/kg) calculated from field measurements were used in all model reaches. Measured sediment PCB and organic carbon concentrations in each reach were used to initialize the model's sediment layers. The Fanning friction factor was held constant at 0.0035.

Permitted water withdrawals were spatially allocated to model elements using a TCEQ GIS shapefile of water rights permit holders. Permitted annual water withdrawals from the TCEQ water rights permits database were distributed based on water use category. For industrial use, water withdrawals were distributed evenly across all months. For irrigation and recreational use, annual water withdrawals were distributed based on monthly average evapo-transpiration in excess of rainfall, For municipal uses, half of annual water use was distributed evenly and half was distributed as for irrigation use.

The model used average monthly evaporation measured at Lake Grapevine from 1988 to 2008, and average monthly water temperatures measured in Segments 0805, 0806, 0829, and 0841, also from 1988 to 2008.

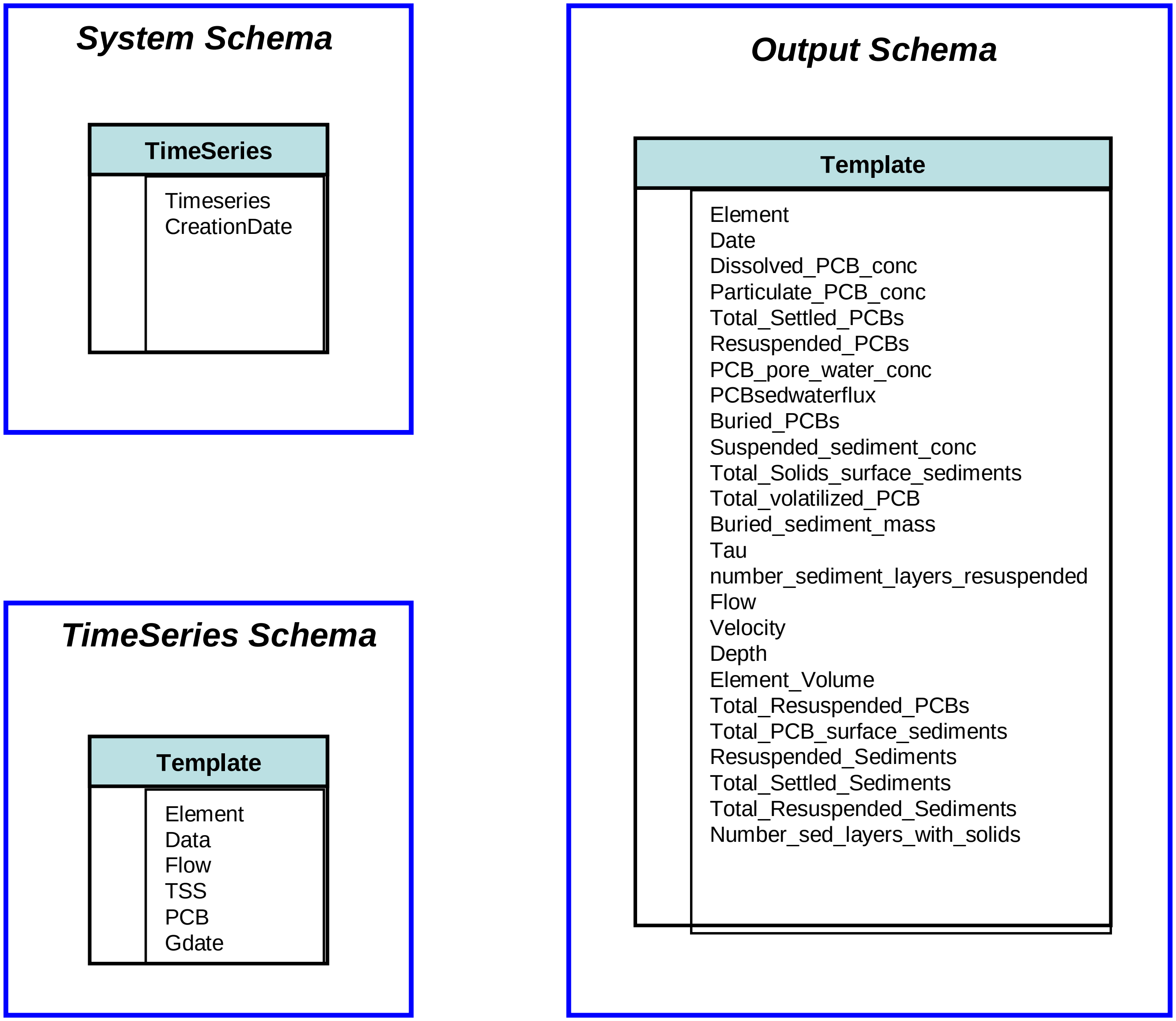


Figure 4.13 Model Database Structure

Flows were not calibrated in the instream model. Monthly average model-predicted flows at elements where USGS flow gages are present in the model domain are compared to the gaged flows for 1988 through 2008 in Figure 4.14. Average percent differences between measured and modeled flow ranged from -6% (an under-prediction) at West Fork at Fort Worth (USGS 08048000), to +13% (an over-prediction) at Trinity River at Dallas (USGS 08057000). The model is not intended to accurately simulate flows at shorter time steps. Under low flow conditions, there were some indications of model over-prediction of flows downstream of the Beach Street gage in Fort Worth. We hypothesize that the Trinity River may "lose" some water to the Woodbine aquifer outcrop in this area. However, lacking data or independent reports to confirm this, we made no corrections to the model flow predictions.

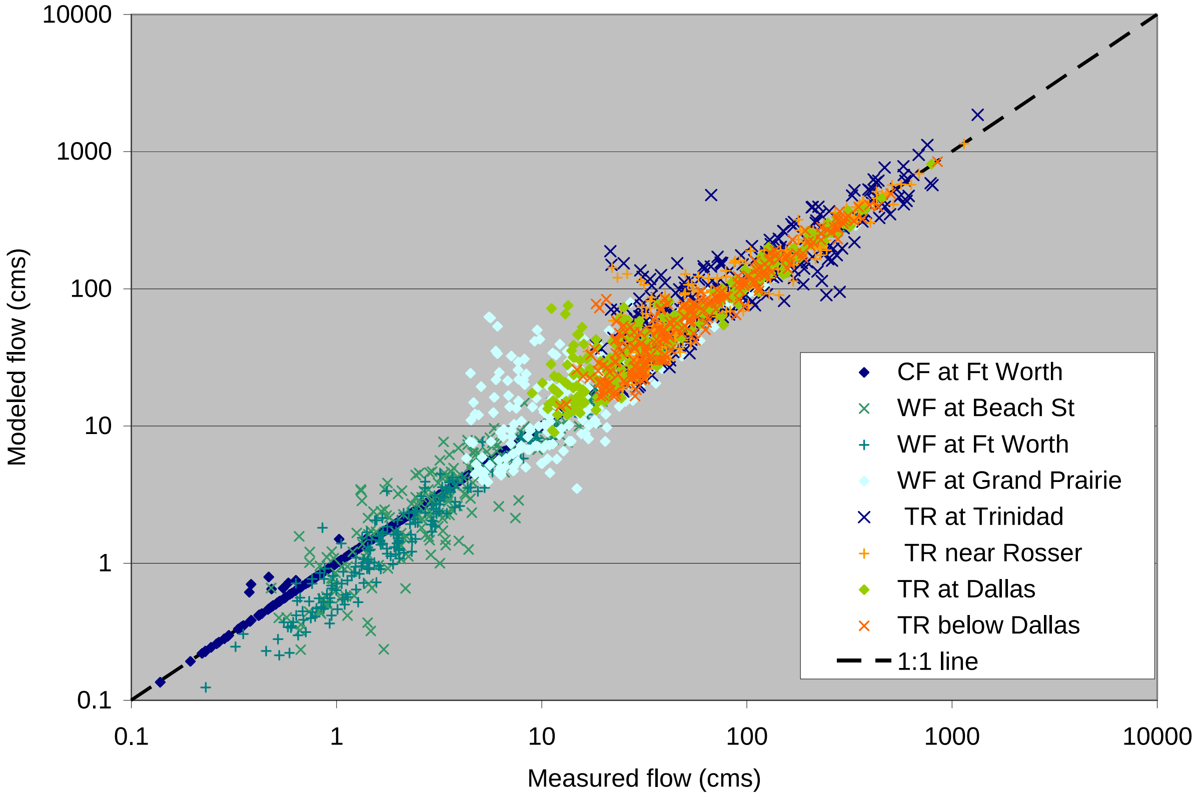


Figure 4.14 Comparison of Model-Predicted and Measured Monthly Average Flows, 1988-2008

Suspended solids in the model were calibrated using the reference TSS concentration, the reference solids settling rate, the order, and the critical shear stress. These model parameters were not allowed to vary on a reach-specific basis, but were held uniform for the entire model domain. A limited dataset of TSS measurements was available for calibration: 531 individual grab samples were collected from stations within the model domain from 1988 to 2008. TSS concentrations can vary quite dynamically in response to runoff and other short-term flow events. Model runoff sediment loads were based on monthly sediment loads and runoff flows from the GWLF model. The model is not capable of simulating suspended sediment dynamics on a daily or finer time scale. Rather than trying to fit individual TSS measurements, the calibration approach involved attempting to match the median measured TSS concentration from each site with twenty or more TSS measurements. Figure 4.15 illustrates the results of this calibration, with sites ordered from upstream to downstream.

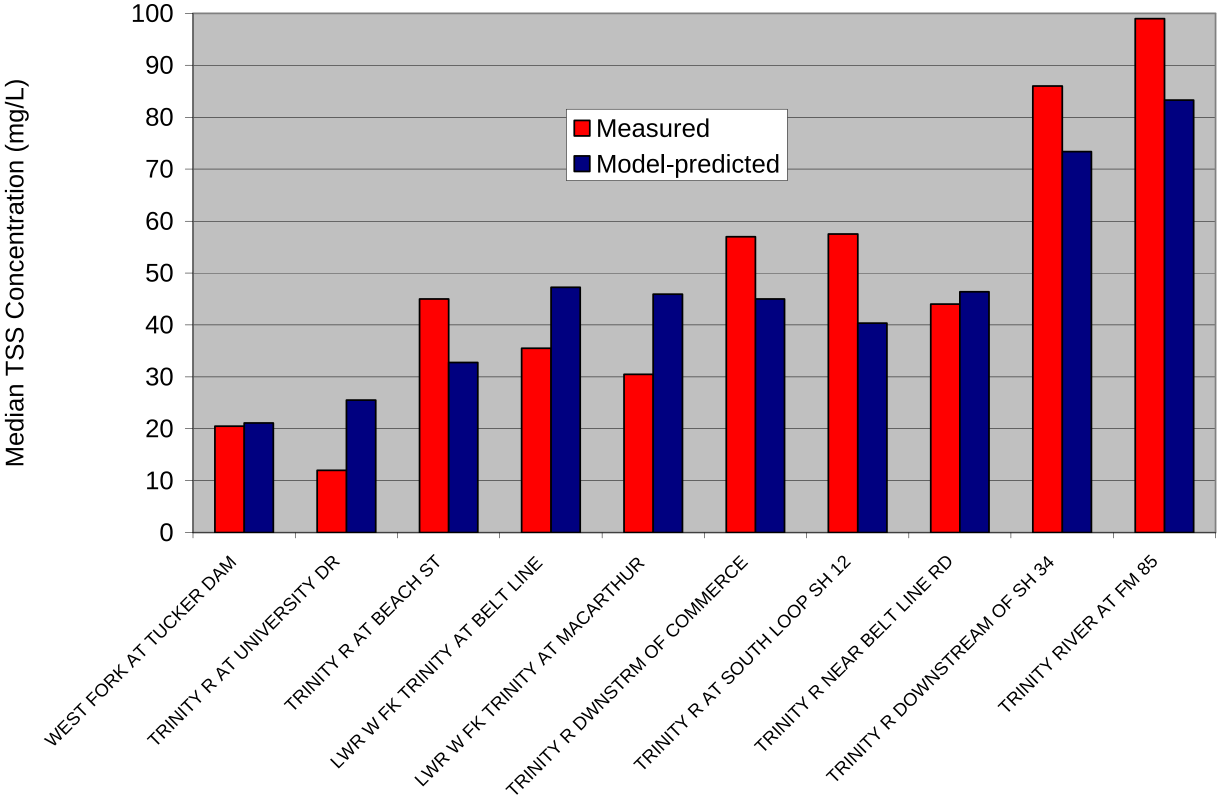


Figure 4.15 Comparison of Model-Predicted and Measured Median TSS Concentrations, 1988-2008

Daily model-predicted PCB concentrations in water were calibrated to concentrations measured in the spring of 2008 at thirteen sites. The PCB decay rate was considered minimal and held constant at 0.01% per day. Calibration was performed by adjusting K_{st}, the rate constant for PCB flux from sediments, on a model-wide basis. Figure 4.16 shows the results of the calibrated model for the thirteen sites, from upstream to downstream. The solid line indicates the model substantially under-predicted total PCB concentrations at Beach Street, and over-predicted those at West Beltline Road, but generally captured the observed ranges and spatial trends in PCB levels. The model performed less well under the very low flow conditions of August, when it over-predicted PCB concentrations in water (Figure 4.17). With long residence times in each element under these conditions, the model may be overestimating flux rates from sediment or underestimating volatilization losses.

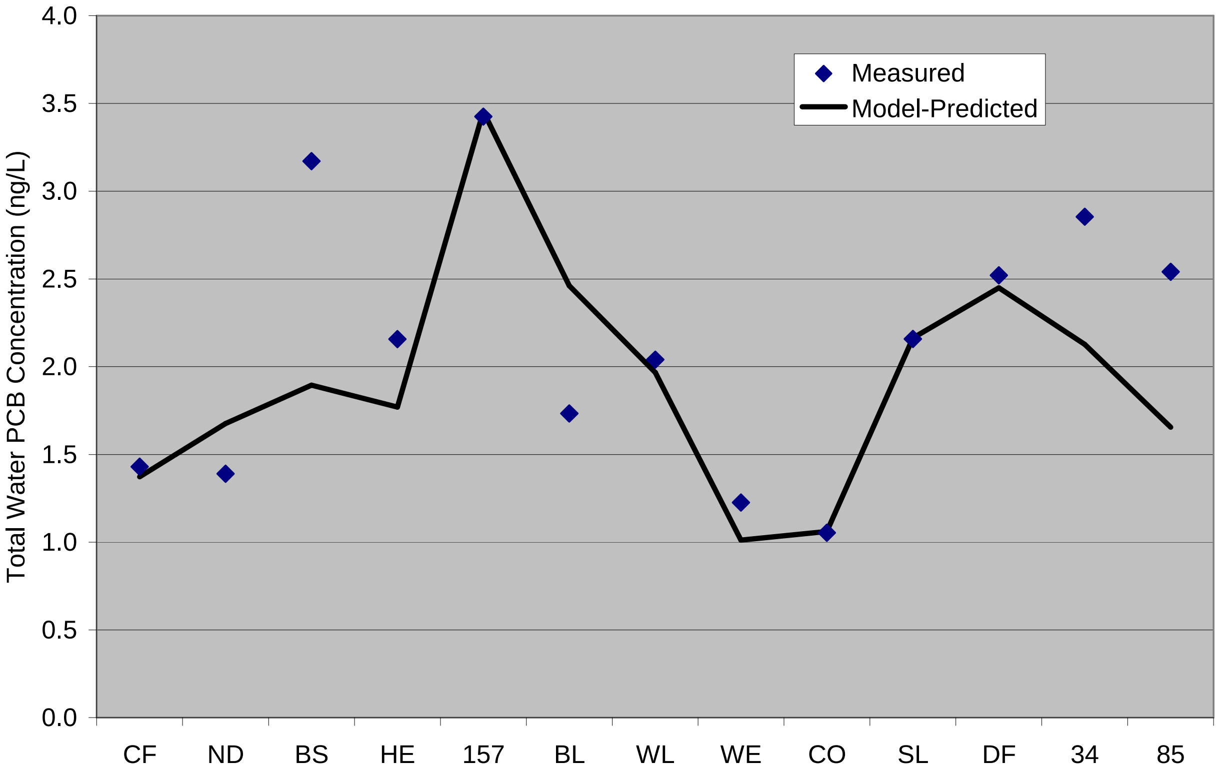


Figure 4.16 Model-Predicted Total PCB Concentrations in Water are Compared to Concentrations Measured in Spring 2008, from Upstream to Downstream.

CF = Clear Fork Trinity River at Purcey Street, ND = West Fork at Nutt Dam, BS = West Fork at Beach Street, HE = West Fork at Handley-Ederville Rd, 157 = West Fork at FM 157, BL = West Fork at West Beltline Road, WL = West Fork at West Loop 12, WE = Trinity River at Westmoreland, CO = Trinity River at Commerce, SL = Trinity River at South Loop 12, DF = Trinity River at Dowdy Ferry Road, 34 = Trinity River at SH 34, 85 = Trinity River at FM 85.

4.5 Model Results

Model results for the five year period from January 1, 2004 through December 31, 2008 were taken to indicate current conditions. Predicted average total PCB concentrations by assessment unit ranged from 1.5 to 4.6 ng/L (Table 4.10).

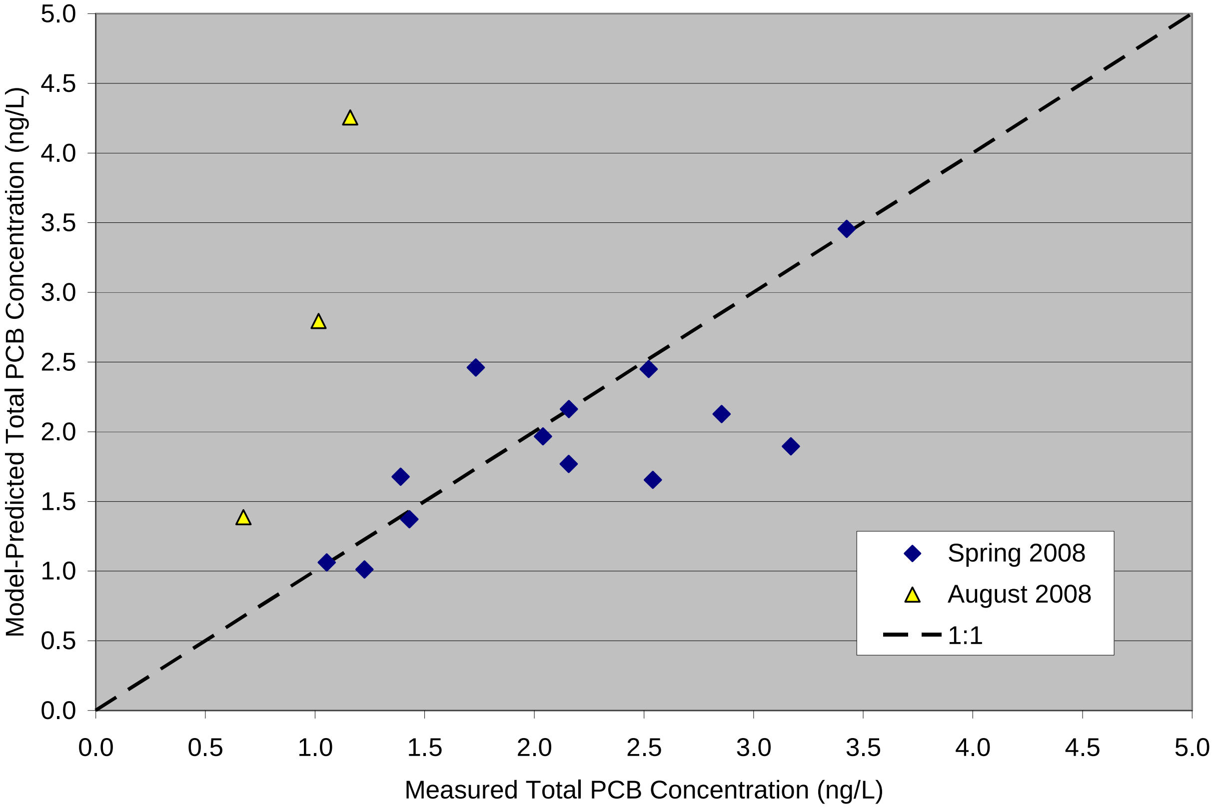


Figure 4.17 Model-Predicted Versus Measured Total PCB Concentrations in Water

Table 4.10 Average Total PCB Concentrations in Water by Assessment Unit Under Existing Conditions, as Predicted by the Water Quality Model

Assessment Unit	Predicted Average Total PCB Concentration (ng/L)
0829_01	1.8
0806_01	1.5 – 2.5 (3 sites)
0841_02	4.6
0841_01	2.1 – 3.4 (2 sites)
0805_04	1.6 – 1.8 (2 sites)
0805_03	2.4
0805_06	3.2
0805_02	2.2
0805_01	1.8

4.6 Required % Reductions

The model was then run under various load reduction scenarios to determine the TMDL. The results indicated that even if PCB loads from external point and runoff sources were eliminated, the water quality target was not achieved in any AU due to internal PCB fluxes from sediments back into the water column. It was assumed the reservoirs of PCB in sediment deposits were accumulated in large part from historical sources. If all external point and nonpoint source PCB loading to the AUs are eliminated, PCB levels in sediments will ultimately decline due to erosion of the contaminated sediment deposits to downstream locations, leaching of PCBs back into the overlying water column, degradation, and dilution through deposition of new “clean” sediment from the watershed. In fact, historical measurements indicate that in some reaches of the Trinity River PCB levels in sediments have declined as much as an order of magnitude since the mid-1970’s (see figure 2.10). Thus, instream sediment PCB levels will ultimately respond to reductions in PCB loading from external point and nonpoint sources, although the time required to achieve this reduction is not known. Considering this, the model was run under various load reduction scenarios with internal PCB loads from sediments reduced proportionally to reductions in the external loads. These scenarios are illustrated by AU in Figures 4.18 through 4.26. The required load reduction to meet the water quality target are then summarized in Table 4.11. The time required to achieve the water quality target after implementation of these load reductions is not known.

Table 4.11 Percent Load Reductions Required to Meet the Water Quality Target

Assessment Unit	Required % Loading Reduction[†]
0829_01	60%
0806_01	76%
0841_02	86%
0841_01	81%
0805_04	64%
0805_03	74%
0805_06	80%
0805_02	71%
0805_01	65%

[†] reductions applied to both external point and nonpoint source loading and internal loading from sediments

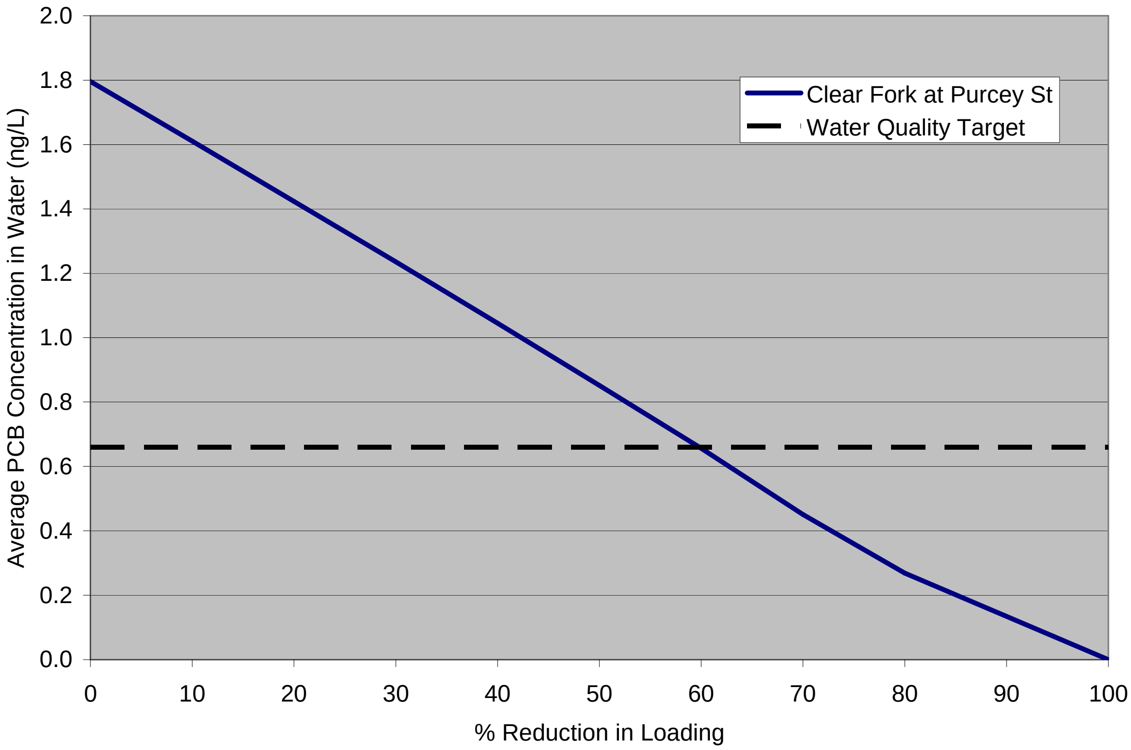


Figure 4.18 Effects of Load Reductions in AU 0829_01.

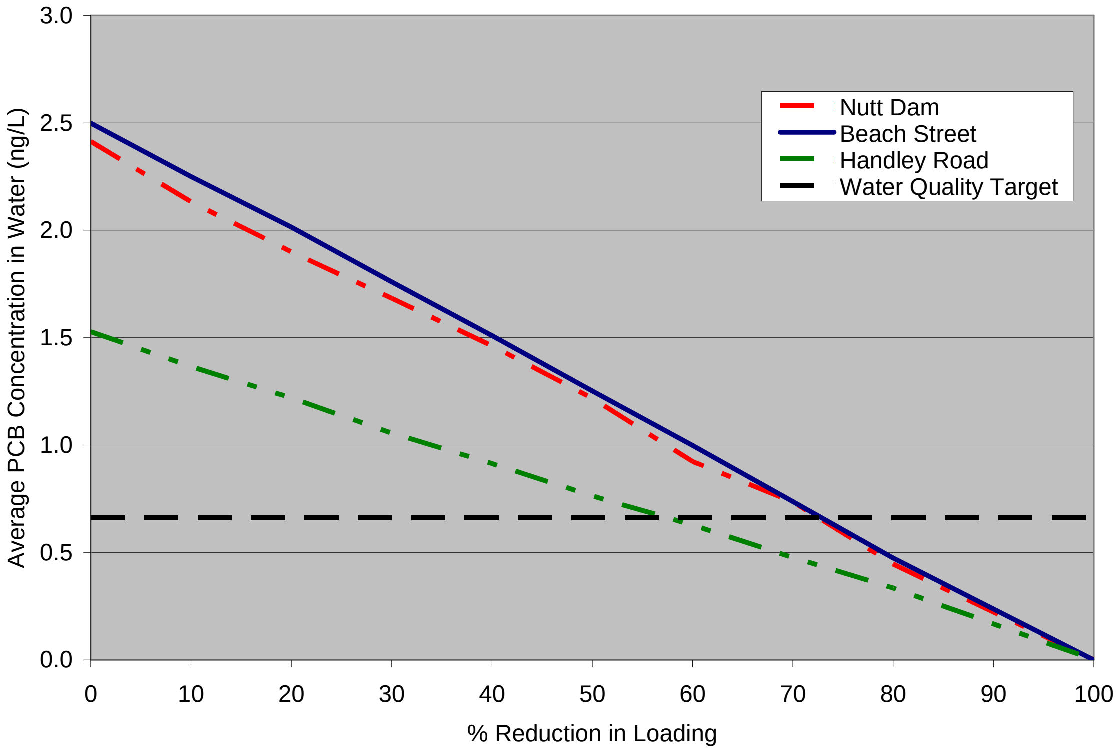


Figure 4.19 Effects of Load Reductions in AU 0806_01.

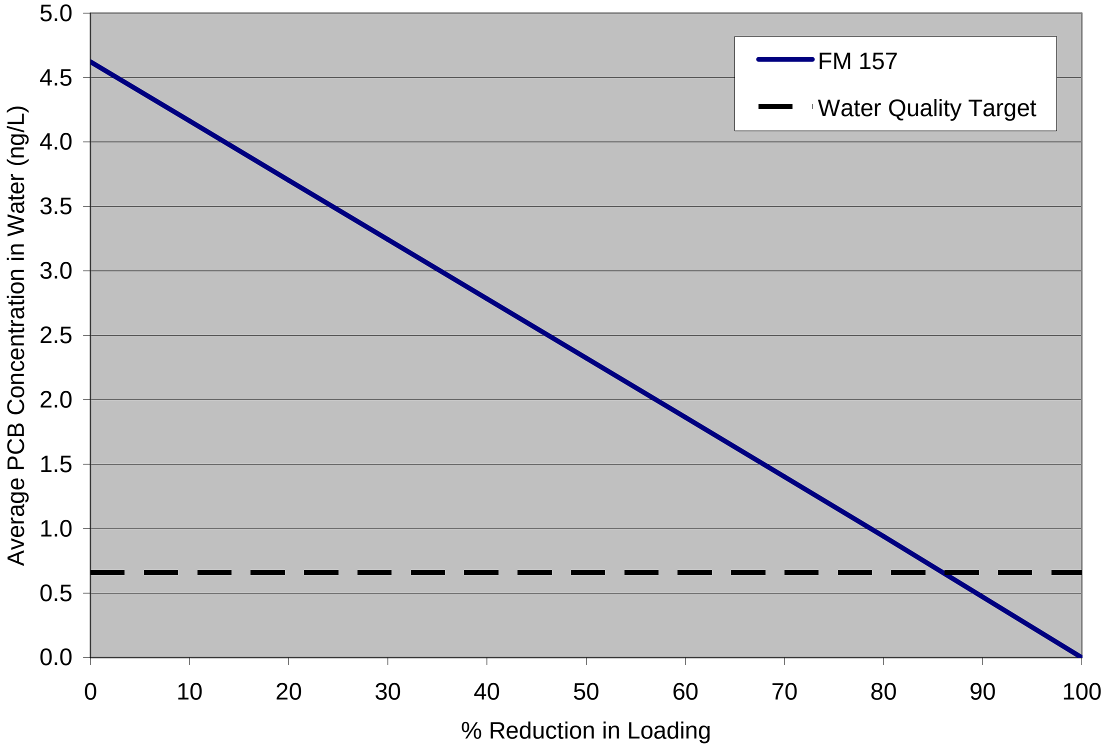


Figure 4.20 Effects of Load Reductions in AU 0841_02.

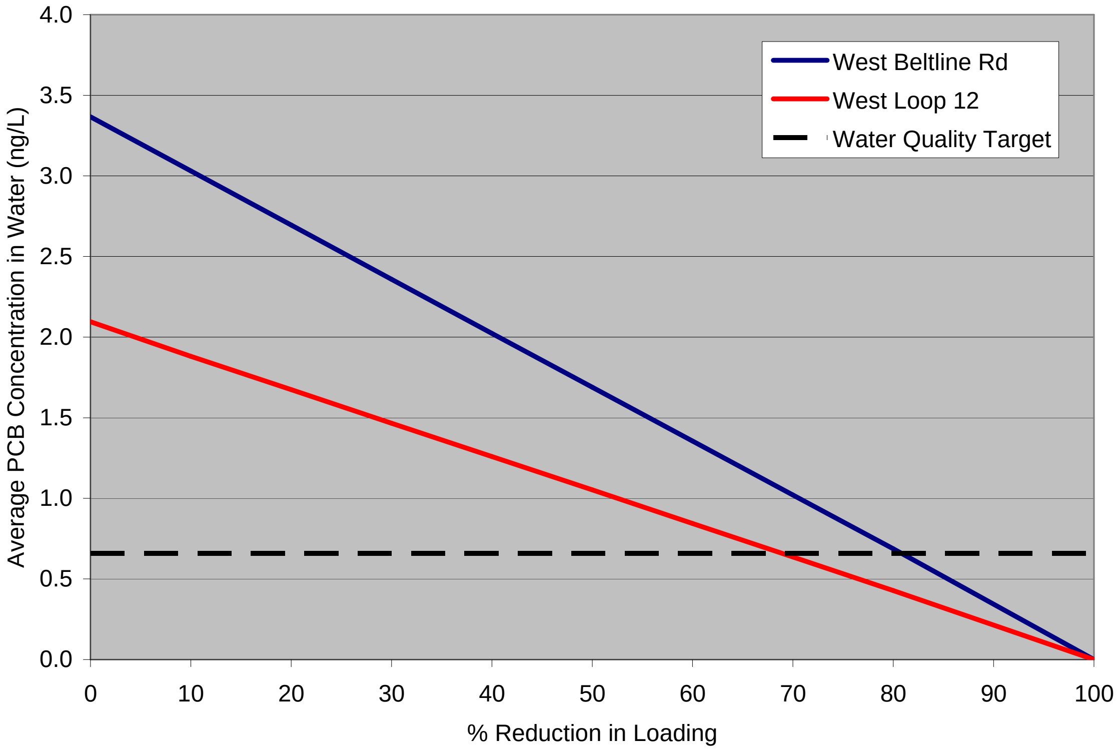


Figure 4.21 Effects of Load Reductions in AU 0841_01 .

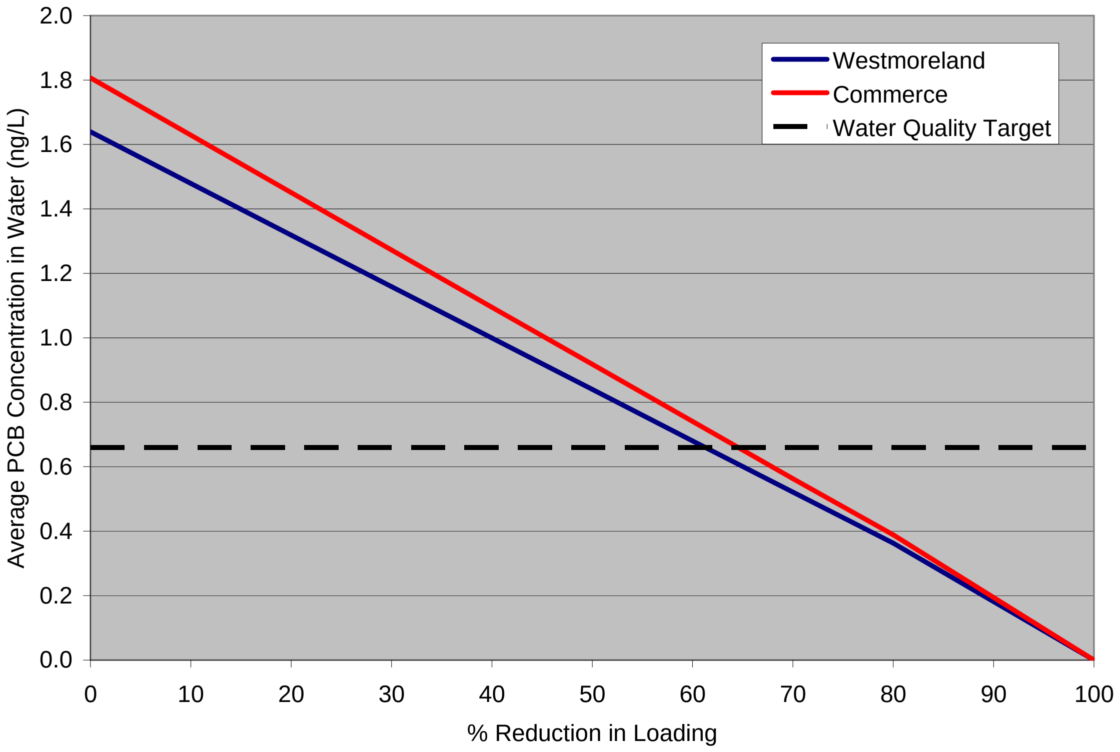


Figure 4.22 Effects of Load Reductions in AU 0805_04.

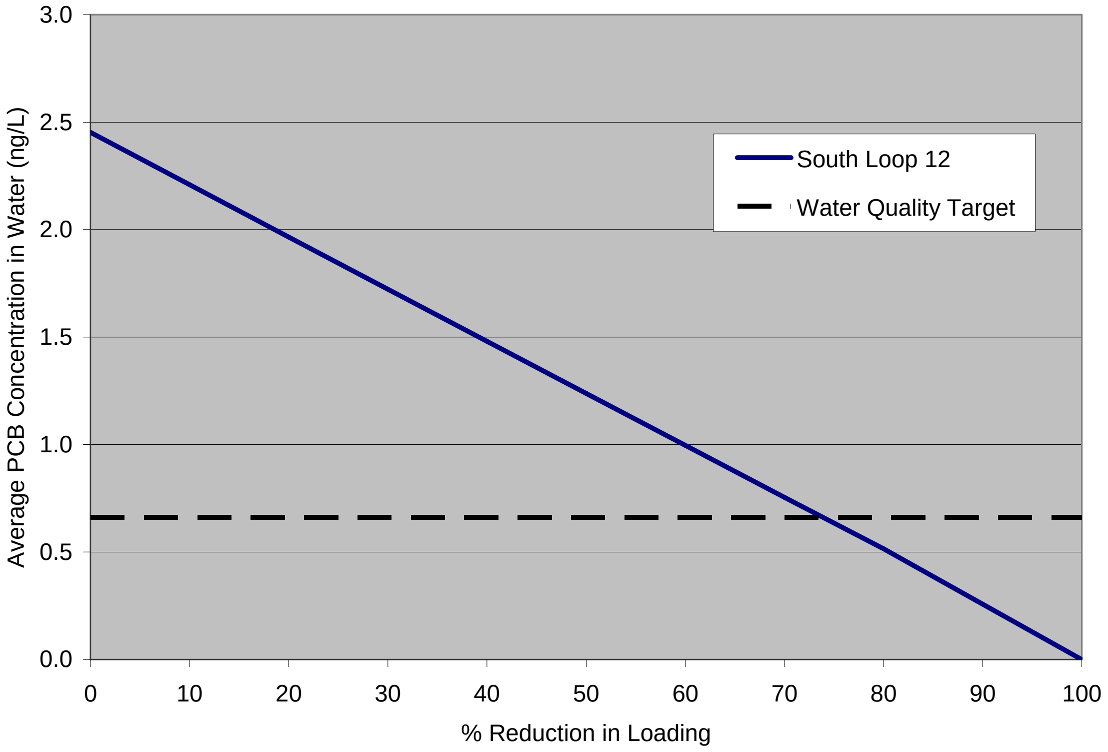


Figure 4.23 Effects of Load Reductions in AU 0805_03.

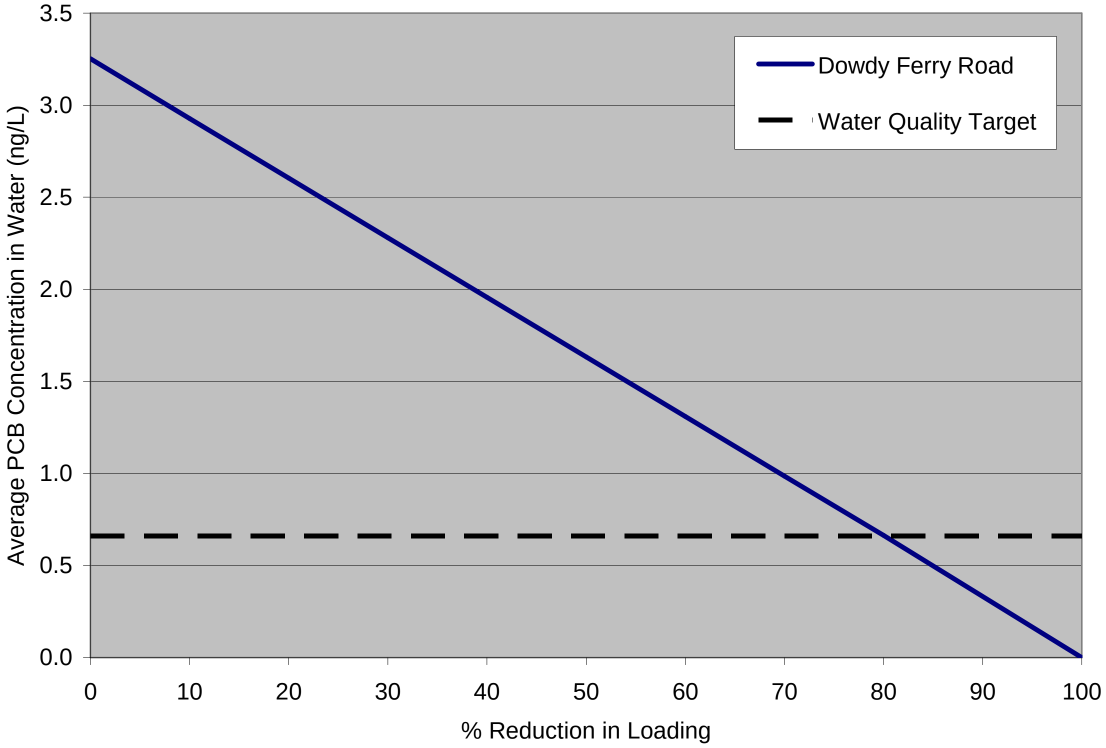


Figure 4.24 Effects of Load Reductions in AU 0805_06.

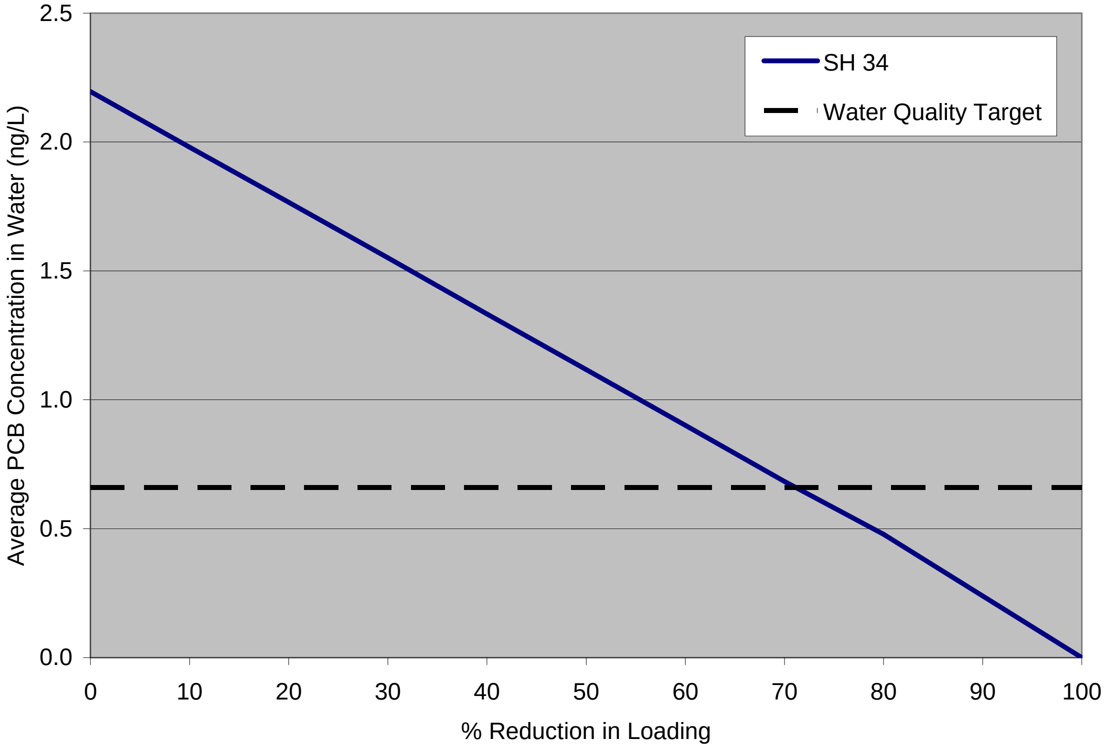


Figure 4.25 Effects of Load Reductions in AU 0805_02.

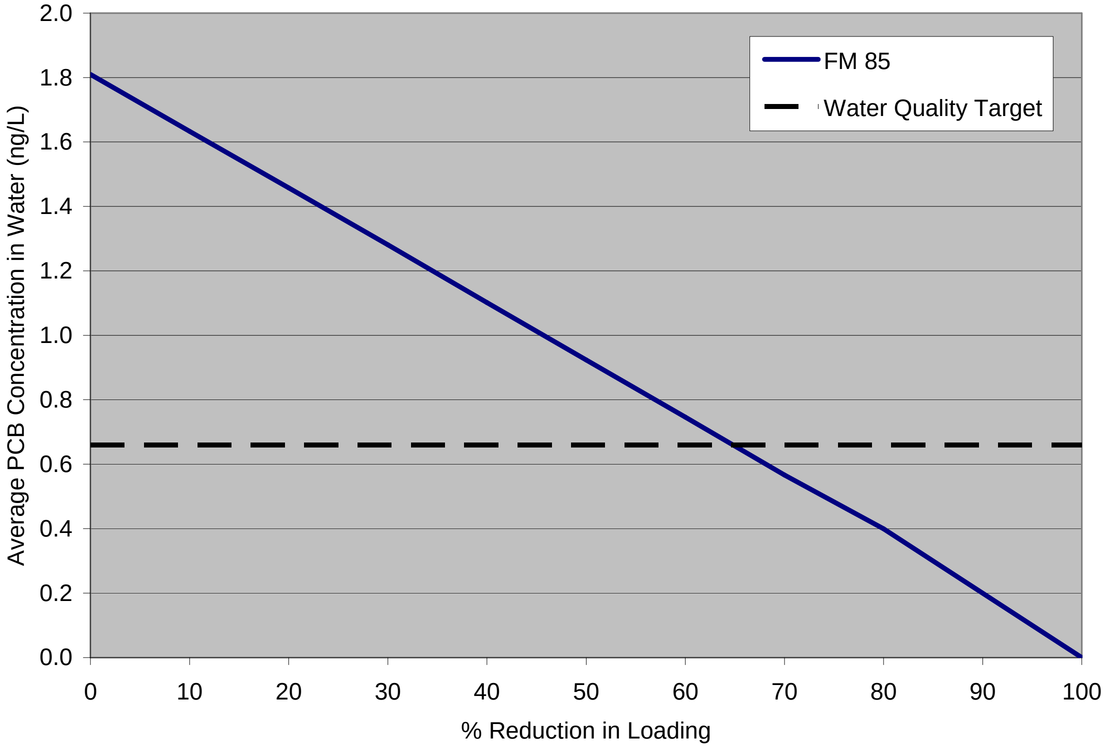


Figure 4.26 Effects of Load Reductions in AU 0805_01.

SECTION 5
TMDL AND LOAD ALLOCATIONS

5.1 Margin of Safety

The margin of safety (MOS) should account for uncertainty in the analysis used to develop the TMDL and thus provide a higher level of assurance that the goal of the TMDL will be met. According to the USEPA (1991), the MOS can be incorporated into the TMDL either by

- implicitly incorporating a MOS using conservative model assumptions to develop allocations, or;
- explicitly reserving a portion of the TMDL as the MOS.

These TMDLs incorporate an implicit MOS due to the following conservative assumptions:

- Load reductions were calculated based on the most contaminated site in an assessment unit, while fish are mobile and also exposed to less contaminated sites.
- The model over-predicts PCB concentrations at some sites, thereby requiring greater reductions than necessarily required.
- The BAF-based water quality target in water is less than 50% of the water quality criterion.
- The TDSHS incorporates conservative assumptions in their risk assessments to ensure that public health will be protected.

5.2 Seasonal Variation

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonal variation was accounted for in these TMDLs by using a time-varying model that simulated conditions over a continuous twenty-one year period (1988 – 2008). TMDL allocations were then based on the most recent five year period (2004 – 2008).

The water quality target for PCBs in these TMDLs is based on human exposure through consumption of contaminated fish over thirty years. There is no data to indicate that PCB levels in Trinity River fish vary significantly on a seasonal basis. With fish exposed to minimally water soluble contaminants such as PCBs over a long period of time, some research suggests a reservoir of contaminant builds up in the tissues that is not released rapidly upon changes in concentration in the external medium. In a review of PCB elimination rates from fish, Barber (2003) suggested that daily elimination rates for PCBs in fish were on the order of 0.1% per day or less. At these rates, short-term or seasonal variations in PCB concentrations in water are unlikely to produce substantial seasonal variations in fish tissue concentrations.

5.3 Pollutant Load Allocations

The estimated maximum allowable loads are calculated as the existing loads minus the required reductions. Table 5.1 lists the TMDLs by assessment unit. Waste load allocations for individually permitted facilities were calculated as their existing permitted discharge flow rate in mgd (or average reported flow rate from Table 3.1 if the permit did not specify a flow) multiplied by the TMDL water quality target of 0.57 ng/L total PCB in water and a conversion factor of 3,785,400 liters per million gallons. In this way, total PCB concentrations in permitted discharges are limited to the instream water quality target.

Table 5.1 TMDL Calculations

Assessment Unit	Existing Load (mg/day)	Overall Required Reduction (%)	TMDL (mg/day)	Adjusted [a] Reduction (%)	Waste Load Allocation (mg/day)		Load Allocation (mg/day)			
					Individually Permitted Facilities	MS4	Upstream Sources		NPS	Internal (Sediment)
							Non-Impaired Segments	Impaired AUs		
0829_01	848	60%	339	63%	0	58	34	0	53	194
0806_01	1,846	76%	443	83%	0.008	119	151	339	28	-194
0841_02	9,300	86%	1,302	87%	359	15	10	443	0	475
0841_01	8,270	81%	1,571	84%	411	33	252[b]	1,302	2	-429
0805_04	13,008	64%	4,683	68%	2	535	694	1,571	0	1,881
0805_03	23,966	74%	6,231	75%	432	40	130	4,683	0	946
0805_06	25,688	80%	5,138	80%	237	17	0	6,231	6	-1,353
0805_02	23,820	71%	6,908	72%	66	6	183	5,138	25	1,490
0805_01	18,801	65%	6,580	65%	0.087	0	0	6,908	27	-355

[a] *adjusted to reflect that load reductions are not expected in non-impaired upstream segments*

[b] *for Mountain Creek Lake, an upstream segment for which a TMDL has been developed, the upstream load was calculated at the average flow and the water quality target of 0.57 ng/L. Current PCB loads exceed this level.*

5.4 Implementation and Reasonable Assurances

To be developed in consultation with the TCEQ.

SECTION 6
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APPENDIX A
QUALITY ASSURANCE PROJECT PLAN

(electronic)

APPENDIX B
DATA VERIFICATION REPORTS

(electronic)

APPENDIX C
PCB SAMPLE RESULTS

(electronic)

APPENDIX D
GWLF INPUT AND OUTPUT FILES

(electronic)