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Occurrence and Concentrations of Selected Trace Elements, Halogenated Organic Compounds, and Polycyclic Aromatic Hydrocarbons in Streambed Sediment and Results of Water-Toxicity Testing in Westside Creeks and the San Antonio River, San Antonio, Texas, 2014

Scientific Investigations Report 2016–5136

U.S. Department of the Interior
U.S. Geological Survey

Front cover:

Left, U.S. Geological Survey scientist collecting a stormwater sample at U.S. Geological Survey station 08178345 Martínez Creek at West Hildebrand Avenue, San Antonio, Texas .

Middle, Looking upstream towards downtown San Antonio from U.S. Geological Survey station 08178465 San Pedro Creek at West Cevallos Street, San Antonio, Texas.

Right, U.S. Geological Survey scientist making field notes at U.S. Geological Survey station 08178310 Alazán Creek at West Laurel Street, San Antonio, Texas.

Back cover:

Top, U.S. Geological Survey station 08178445 Apache Creek at West Commerce Street, San Antonio, Texas.

Bottom, U.S. Geological Survey station 08178345 Martínez Creek at West Hildebrand Avenue, San Antonio, Texas.

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U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
	Volume	
liter (L)	33.81402	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
	Pressure	
kilopascal (kPa)	0.009869	atmosphere, standard (atm)
kilopascal (kPa)	0.01	bar
kilopascal (kPa)	0.2961	inch of mercury at 60°F (in Hg)
kilopascal (kPa)	0.1450	pound-force per inch (lbf/in)
kilopascal (kPa)	20.88	pound per square foot (lb/ft^2)
kilopascal (kPa)	0.1450	pound per square inch (lb/ft^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as °F = (1.8 × °C) + 32.

Datum

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C). Concentrations of chemical constituents in water are given in milligrams per liter (mg/L). Concentrations of chemical constituents in sediment are given in milligrams per kilogram (mg/kg), micrograms per kilogram (µg/kg).

Abbreviations

DDD	Dichlorodiphenyldichloroethane
DDE	Dichlorodiphenyldichloroethylene
DDT	Dichlorodiphenyltrichloroethane
FEQG	Federal Environmental Quality Guidelines established by Environment Canada
IRL	Interim reporting level
NAWQA	National Water-Quality Assessment
NIST	National Institute of Standards and Technology
NWQL	National Water Quality Laboratory
PAH	Polycyclic aromatic hydrocarbons
PBDE	Polybrominated diphenyl ether
PCB	Polychlorinated biphenyl
PEC	Probable effect concentration
PSOC	Potential source of contamination
RPD	Relative percent difference
SARA	San Antonio River Authority
SQG	Sediment quality guideline
TEC	Threshold effect concentration
UV	Ultraviolet
USGS	U.S. Geological Survey

Occurrence and Concentrations of Selected Trace Elements, Halogenated Organic Compounds, and Polycyclic Aromatic Hydrocarbons in Streambed Sediment and Results of Water-Toxicity Testing in Westside Creeks and the San Antonio River, San Antonio, Texas, 2014

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Abstract

Sediment samples and samples for water-toxicity testing were collected during 2014 from several streams in San Antonio, Texas, known locally as the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and from the San Antonio River. Samples were collected during base flow and after periods of stormwater runoff (poststorm conditions) to determine baseline sediment- and water-quality conditions. Streambed-sediment samples were analyzed for selected constituents, including trace elements and organic contaminants such as pesticides, polychlorinated biphenyls (PCBs), brominated flame retardants, and polycyclic aromatic hydrocarbons (PAHs). Potential risks of contaminants in sediment were evaluated by comparing concentrations of contaminants in sediment to two effects-based sediment-quality guidelines: (1) a lower level, called the threshold effect concentration, below which, harmful effects to benthic biota are not expected, and (2) a higher level, the probable effect concentration (PEC), above which harmful effects are expected to occur frequently. Samples for water-toxicity testing were collected from each stream to provide information about fish toxicity in the study area. The trace metal lead was detected at potentially toxic concentrations greater than the PEC in both the base-flow and poststorm samples collected at two sites sampled on San Pedro Creek. The PECs for the pesticides dichlorodiphenyldichloroethane, dichlorodiphenyldichloroethylene, dichlorodiphenyltrichloroethane, and chlordane were exceeded in some of the samples at the same two sites on San Pedro Creek. Brominated flame retardants and polybrominated diphenyl ether (PBDE) 85, 153, and 154 were found in all streambed-sediment samples. Federal Environmental Quality Guidelines established by Environment Canada for PBDE 99 and PBDE 100 were exceeded in all samples in which PBDE 99 was detected and in a majority of the samples in which PBDE 100 was detected; the greatest concentrations occurred in samples collected at the same two sites on San Pedro Creek where the samples containing elevated lead and pesticide concentrations were collected. All concentrations of total PCBs (computed as the sum of the 18 reported PCB congeners) in the individual streambed-sediment samples were less than the threshold effect concentration, but the concentrations were elevated in the two sites on San Pedro Creek compared to concentrations at other sites. At one site on Apache Creek, 6 of the individual PAHs measured in the sample collected during base-flow conditions exceeded the PECs and 8 of the 9 PECs were exceeded in the sample collected during poststorm conditions. The total PAH concentration in the sample collected at the site during poststorm conditions was 3.3 times greater than the PEC developed for total PAHs. Average PAH profiles computed for base-flow samples and poststorm samples most closely resemble the parking lot coal-tar sealcoat dust PAH source profile, defined as the average PAH concentrations in dust swept from parking lots in six cities in the United States that were sealed with a black, viscous liquid containing coal-tar pitch. Six of ten water samples collected during base-flow conditions caused reductions in *Pimephales promelas* (fathead minnow) survival and were considered to be toxic.

Introduction

Elevated concentrations of sediment-associated contaminants often are measured in urban areas (Rice, 1999; Wong and others, 2000; Chalmers and others, 2007). In the area of San Antonio, Texas, the seventh most populous city in the United States (U.S. Census Bureau, 2016), sediment-associated contaminants have been detected and documented in previous studies. For example, Ging (1999) and Ging and others (1999) documented upward trends in zinc, chlordane, and polycyclic aromatic hydrocarbon (PAH) concentrations in relation to sediment cores collected in an urban lake in the San Antonio area. Lead, dichlorodiphenyltrichloroethane (DDT), and polychlorinated biphenyls (PCBs) also were detected in the lake core samples. Wilson (2011) documented concentrations of certain pesticides, PCBs, halogenated organic compounds, and PAHs in streambed and suspended sediment in selected streams in the San Antonio area.

Sediment-associated contaminants can influence the health of aquatic organisms that ingest particulate matter when bioaccumulation of trace elements and organic compounds occurs (Forstner and Wittmann, 1979; Luoma, 1983). The accumulation of trace elements and organic compounds can cause various physiological issues and can ultimately result in death of aquatic organisms. Subsequent ingestion of aquatic organisms by consumers (organisms that eat other organisms) can transfer accumulated fat-soluble (lipophilic) contaminants upward through the food chain resulting in biomagnification (Neely, 1980; Borga and others, 2004).

The Alazán, Apache, Martínez, and San Pedro Creeks in San Antonio, Tex., are part of a network of tributaries to the San Antonio River known locally as the Westside Creeks (fig. 1). The Westside Creeks flow through some of the oldest neighborhoods in San Antonio—an area with a rich cultural history that includes the Alamo, Mission Concepción, and San José Mission. In 1954, a Federal program known as the San Antonio Channel Improvement Project channelized several miles of stream reaches in the Westside Creeks and San Antonio River within the city limits in an effort to reduce urban flooding (San Antonio River Authority, 2016). In 2008, the San Antonio River Authority (SARA) started a community-based effort working to improve the environmental condition of 14 miles of channelized sections of the Alazán, Apache, Martínez, and San Pedro Creeks, while enhancing or maintaining current (2016) flood control functions, and increasing recreational opportunities (San Antonio River Authority, 2016) (fig. 2). It is anticipated the construction activities to improve channelized sections on the 14 miles of stream channel could appreciably disturb stream channel sediments.

There are several constituents of concern in the streambed sediments of the Westside Creeks; the constituents that were selected for analysis included trace elements, pesticides, brominated flame retardants, PCBs, and PAHs. Many of the selected constituents of concern have been used historically for industrial as well as domestic purposes. These chemicals are typically hydrophobic, meaning they do not normally remain in the water column but instead bind to sediments; hence, sediments can serve as long-term repositories of historical contamination. The disruption of sediment during the anticipated large-scale construction activities to improve channelized sections can create the potential to reintroduce these chemicals into the ecosystem where, depending on hydrologic and environmental conditions, they could become bioavailable and toxic to aquatic life. It is important to understand the impact of urbanization on freshwater ecosystems, including the possibility of increased frequency and delivery of contaminants to neighboring ecosystems (Moran and others, 2012). The Westside Creeks are tributaries to the San Antonio River, which drains into bays and estuaries along the Gulf Coast in Texas. Contaminates mobilized from the Westside Creeks during construction activities could affect downstream users of water from the San Antonio River and ultimately the ecological health of these bays and estuaries. Determination of the degree to which contaminants might be present in the sediment in areas of long-term urbanization also is important because almost all population growth through 2050 is expected to occur by expansion of existing urban areas (United Nations, 2015), and the San Antonio area is a prime example of this projection. The degree to which contaminants are present in sediments of San Antonio streams might increase over time as a result of rapid urbanization. By 2040, the population of Bexar County is projected to grow by 1 million, and the urban area of San Antonio is projected to more than double in size from 500 square miles (mi^2) to more than 1,000 mi^2 (San Antonio Express News, 2014). As urbanization increases, infrastructure modifications such as the replacement of aging or undersized bridges and other stream modification projections could lead to mobilization and redistribution of contaminants.

The U.S. Geological Survey (USGS), in cooperation with SARA, collected sediment samples and samples for water-toxicity testing from sites on Alazán, Apache, Martínez, and San Pedro Creeks, and from a site on the San Antonio River as part of an initial characterization of selected contaminants in the study area. Stream samples also were collected to assess toxicity of the streams to fish during base flow and after periods of stormwater runoff.

Purpose and Scope

This report provides an initial characterization of selected contaminants in streambed sediments and water-toxicity testing results within the boundaries of a planned restoration of the Westside Creeks in San Antonio, Tex. (fig. 2). Streambed-sediment samples and samples for water-toxicity testing were collected in 2014 from the Alazán, Apache, Martínez, and San Pedro Creeks, as well as from the main channel of the San Antonio River during two periods of sampling representing different flow conditions. The first period of sampling was during base-flow conditions; the second was completed shortly after a stormflow event.

This report specifically describes the occurrence and quantity of selected constituents in streambed sediments including trace elements, pesticides, polychlorinated biphenyls, brominated flame retardants, and polycyclic aromatic hydrocarbons, and water toxicity for aquatic biota at selected sites in Westside Creeks and the San Antonio River in 2014. Potential risks of contaminants in sediment were evaluated by comparing concentrations of contaminants in sediment to effects-based sediment-quality guidelines. The frequencies with which the organic contaminants were detected in the streambed-sediment samples were assessed, and comparisons of concentrations among sites were made to describe the occurrence and distribution of the contaminants. As an indicator of ecological health in relation to mobilized (and thus, possibly bioavailable) contaminants in disturbed streambed sediments, the toxicity of water samples collected from the same locations as sediment samples to the indicator species *Pimephales promelas* (fathead minnow) was evaluated by using standard 7-day water-toxicity testing. All analytical data are presented in Crow and others (2016).

Description of the Study Area and Sampling Sites

The study area encompasses approximately 95 mi^2 and consists of the drainage area of San Pedro Creek, its tributaries, and one site downstream from the confluence of San Pedro Creek with the San Antonio River (fig. 1). The sites from which streambed-sediment samples and samples for water-toxicity testing were collected were Martínez Creek at West Hildebrand Avenue, San Antonio, Tex., (USGS station 08178345; hereinafter referred to as the “upstream Martínez site”; map identifier MTZ-US); Martínez Creek at West Poplar Street, San Antonio, Tex., (USGS station 08178375; hereinafter referred to as the “downstream Martínez site”; map identifier MTZ-DS); Alazán Creek at West Laurel Street, San Antonio, Tex., (USGS station 08178310; hereinafter referred to as the “upstream Alazán site”; map identifier ALZ-US); Alazán Creek at Tampico Street, San Antonio, Tex., (USGS station 08178410; hereinafter referred to as the “downstream Alazán site”; map identifier ALZ-DS); Apache Creek at West Commerce Street, San Antonio, Tex., (USGS station 08178445; hereinafter referred to as the “upstream Apache site”; map identifier APC-US); Apache Creek at South Brazos Street, San Antonio, Tex., (USGS station 08178460; hereinafter referred to as the “downstream Apache site”; map identifier APC-DS); San Pedro Creek at Santa Rosa Street, San Antonio, Tex., (USGS station 08178100; hereinafter referred to as the “upstream San Pedro site”; map identifier SPD-US); San Pedro Creek at West Cevallos Street, San Antonio, Tex., (USGS station 08178465; hereinafter referred to as the “middle San Pedro site”; map identifier SPD-MD); San Pedro Creek at Probandt Street, San Antonio, Tex., (USGS station 08178504; hereinafter referred to as the “downstream San Pedro site”; map identifier SPD-DS); and San Antonio River at Mission Road, San Antonio, Tex., (USGS station 08178515; hereinafter referred to as the “San Antonio River site”; map identifier SAR) (table 1).

The contributing area and land use in the contributing area in 2011 (fig. 1) of each sampling site are summarized in table 1. The contributing areas range in size from 1.8 for the upstream San Pedro site to 94.9 mi^2 for the San Antonio River site, respectively. The entire study area is highly urbanized with the contributing areas ranging from 94.3 to 100 percent developed land (Homer and others, 2015).

Numerous potential sources of contamination are present in the drainage areas of the Westside Creeks. The top 10 potential sources of contamination (PSOCs) by area in the contributing area of each sampling site (the watershed area that drains to the location of the sampling site) as identified by the Texas Commission on Environmental Quality Source Water Assessment Program are shown in table 2 (Texas Commission on Environmental Quality, 2009). Abandoned municipal solid waste landfills and petroleum storage tanks were the most common PSOCs in the study area. In the six largest contributing areas, abandoned municipal solid waste landfills were the largest PSOCs followed by petroleum storage tanks. Petroleum storage tanks were the largest PSOC in the two smallest contributing areas (to the upstream and middle San Pedro Creek sampling sites [fig. 1; map identifiers SPD–US and SPD–MD]) followed by petroleum chemical industry and auto repair, sales, salvage, and towing, respectively. Petroleum storage tanks also were the largest PSOC in the contributing area of the downstream Martínez site followed by auto repair, sales, salvage, and towing. Abandoned municipal solid waste landfills were the largest PSOC in the contributing area of the upstream Martínez site followed by pipelines (Texas Commission on Environmental Quality, 2009).

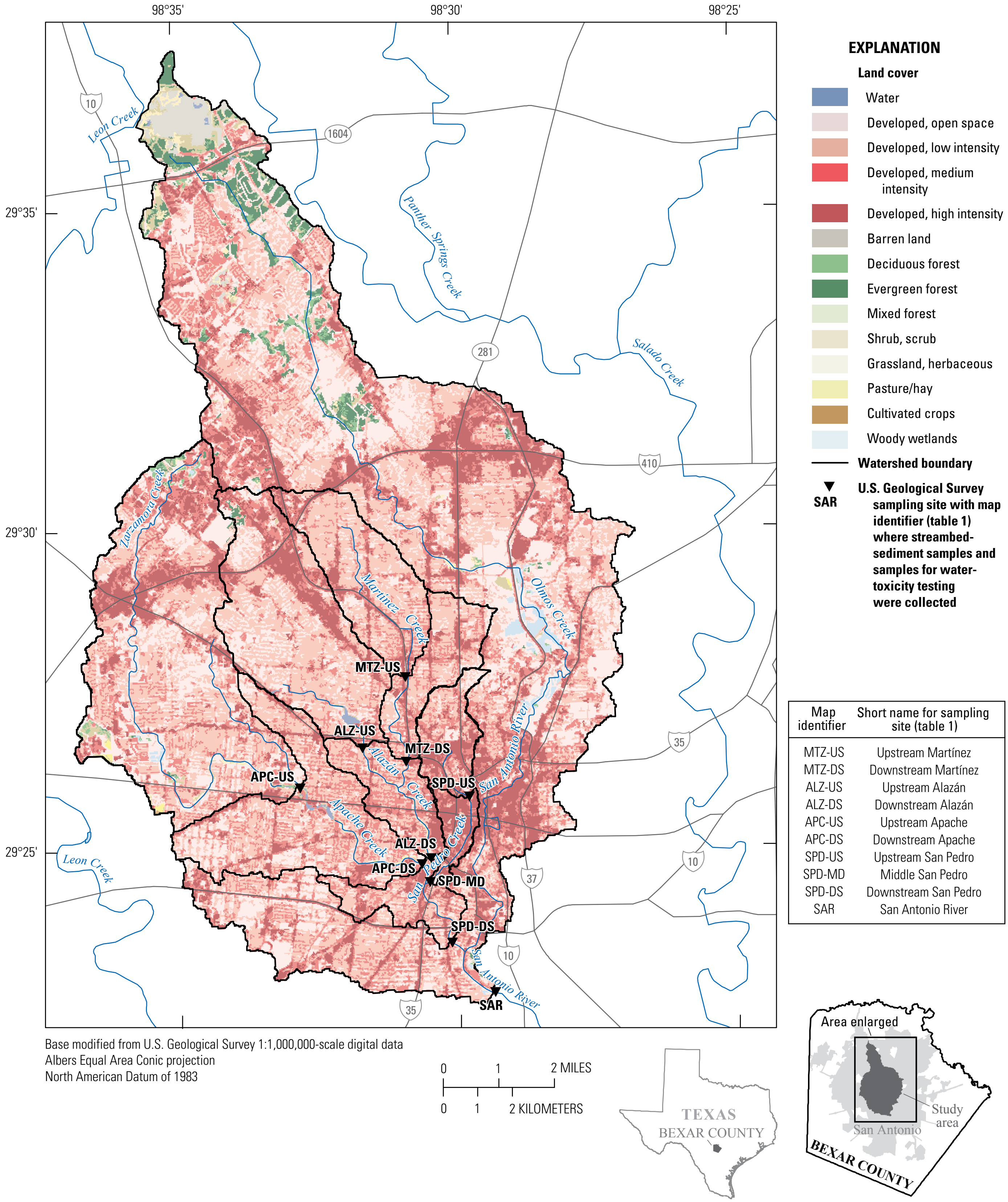
Methods

Streambed Sample Collection

Streambed-sediment and water samples were collected during base-flow conditions in January 2014 and again in May 2014 following a storm event. The streambed-sediment sampling sites were along stream reaches with several depositional zones that could be sampled by wading the stream (fig. 2; table 1). Care was taken to ensure that the streambeds were submerged during the sampling from which streambed-sediment samples were collected because comparison of wet to dry sediment chemistry is unreliable, especially for organic compounds (Shelton and Capel, 1994).

The collection of streambed-sediment samples was based on methods of the USGS National Water-Quality Assessment (NAWQA) program (Shelton and Capel, 1994). The NAWQA streambed-sediment collection guidelines recommend collecting fine-grained particulates from 5 to 10 depositional zones along a reach of stream approximately 100 meters in length. Depositional zones are locations in streams where the energy typically is low and fine-grained particles accumulate in the streambed (Shelton and Capel, 1994). Each sediment sample consisted of 2 to 8 depositional zones along reaches of the sampled streams (each reach was approximately 26 to 1,476 feet in length) (table 1). Some suitable depositional zones were not sampled because they were too deeply inundated to wade, too widely spaced along the stream reach, or inaccessible because of thick vegetation or steep banks.

All sediment samples were collected by wading the stream; each depositional zone was approached by one or two field personnel from the downstream direction so as not to disturb the streambed sediment (fig. 3*A*). After rinsing precleaned sampling equipment with native water, surficial streambed sediment (about 1 centimeter deep) was collected from the multiple depositional zones with a Teflon spoon and composited in a glass container. The total volume (wet) of streambed sediment collected at each stream reach was about 1 liter (L). Streambed-sediment samples were stored on ice immediately after collection and processed in the USGS office in San Antonio.



Map identifier	Short name for sampling site (table 1)
MTZ-US	Upstream Martínez
MTZ-DS	Downstream Martínez
ALZ-US	Upstream Alazán
ALZ-DS	Downstream Alazán
APC-US	Upstream Apache
APC-DS	Downstream Apache
SPD-US	Upstream San Pedro
SPD-MD	Middle San Pedro
SPD-DS	Downstream San Pedro
SAR	San Antonio River

Base modified from U.S. Geological Survey 1:1,000,000-scale digital data
Albers Equal Area Conic projection
North American Datum of 1983

Figure 1. Land cover characteristics of the contributing area associated with each site where streambed-sediment samples and samples for water-toxicity testing were collected from the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014. Land cover data are from Homer and others (2015).

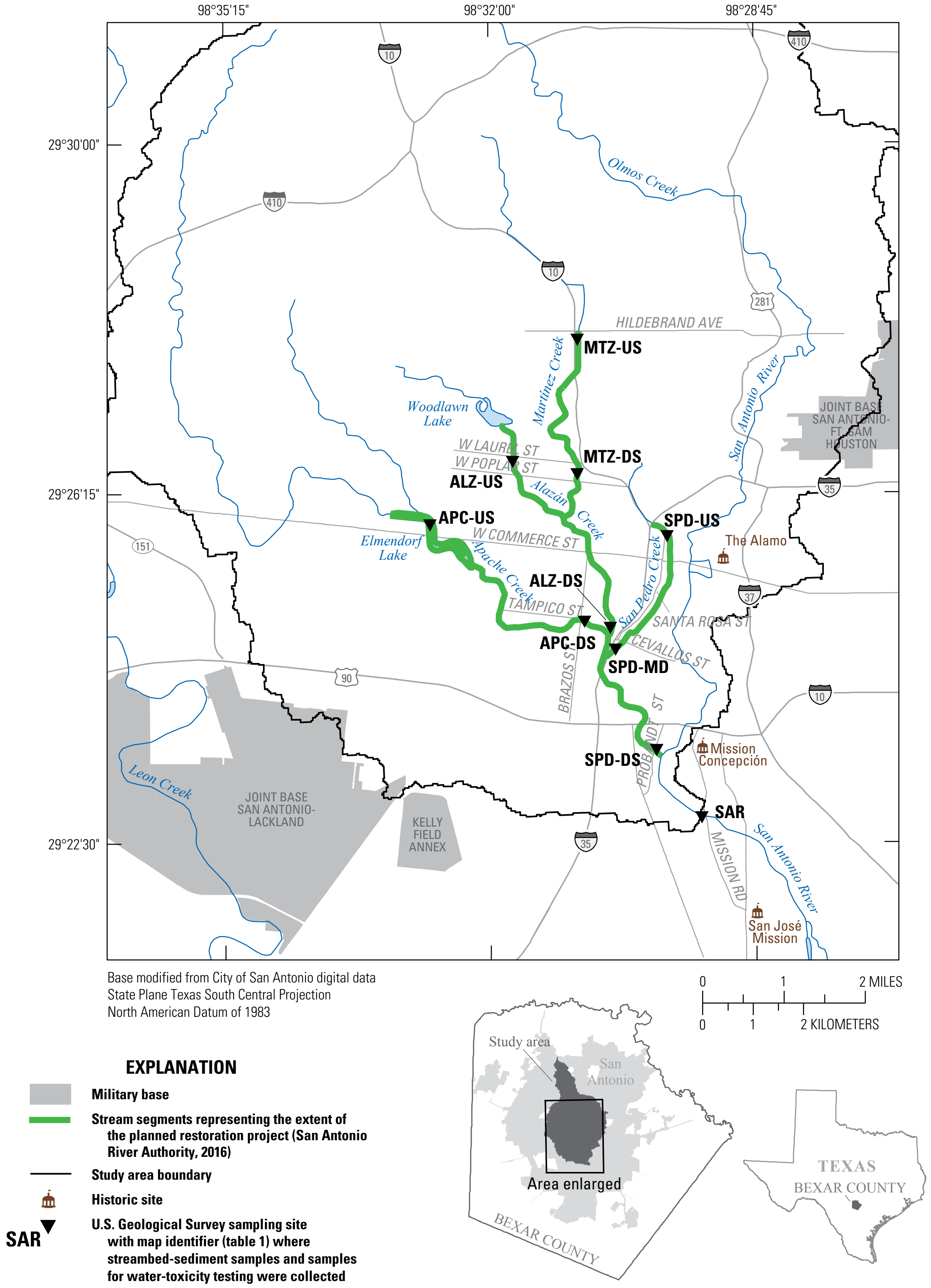
Table 1. Total length of sampled reach, contributing area, and land use of the contributing area to each site where streambed-sediment samples and samples for water-toxicity testing were collected from the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014. Land use data are from the National Land Cover Database (Homer and others, 2015).

[ft, feet; mi^2, square miles]

U.S. Geological Survey station number and name	Short name for sampling site	Map identifier (fig. 1)	Total length of sampled reach (ft)	Number of locations sampled in reach	Contributing area (mi^2)	Land use							
						Developed[1] (percent)	Forest[2] (percent)	Shrub and scrub (percent)	Pasture, hay, and cultivated crops (percent)	Grassland, herbaceous (percent)	Wetland (percent)	Barren (percent)	Water (percent)
08178345 Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1,476	5	4.5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08178375 Martínez Creek at West Poplar Street, San Antonio, Tex.	Downstream Martínez	MTZ-DS	820	6	7.1	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08178310 Alazán Creek at West Laurel Street, San Antonio, Tex.	Upstream Alazán	ALZ-US	755	7	8.2	98.6	0.6	0.2	0.0	0.0	0.0	0.0	0.6
08178410 Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	295	6	17.5	99.1	0.3	0.1	0.0	0.2	0.0	0.0	0.3
08178445 Apache Creek at West Commerce Street, San Antonio, Tex.	Upstream Apache	APC-US	26	2	15.8	96.8	1.3	1.0	0.4	0.3	0.4	0.0	0.0
08178460 Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	266	8	22.6	97.3	0.9	0.8	0.2	0.3	0.3	0.0	0.2
08178100 San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	318	5	1.8	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08178465 San Pedro Creek at West Cevallos Street, San Antonio, Tex.	Middle San Pedro	SPD-MD	384	6	2.7	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
08178504 San Pedro Creek at Probrandt Street, San Antonio, Tex.	Downstream San Pedro	SPD-DS	443	7	44.7	98.3	0.6	0.5	0.1	0.3	0.1	0.0	0.2
08178515 San Antonio River at Mission Road, San Antonio, Tex.	San Antonio River	SAR	30	2	94.9	94.3	2.8	0.9	0.1	0.4	0.6	0.9	0.1

[1] Includes open space and low, medium, and high intensity development.

[2] Includes deciduous, evergreen, and mixed forests.



Base modified from City of San Antonio digital data
State Plane Texas South Central Projection
North American Datum of 1983

Figure 2. Locations of sites where streambed-sediment samples and samples for water-toxicity testing were collected from the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

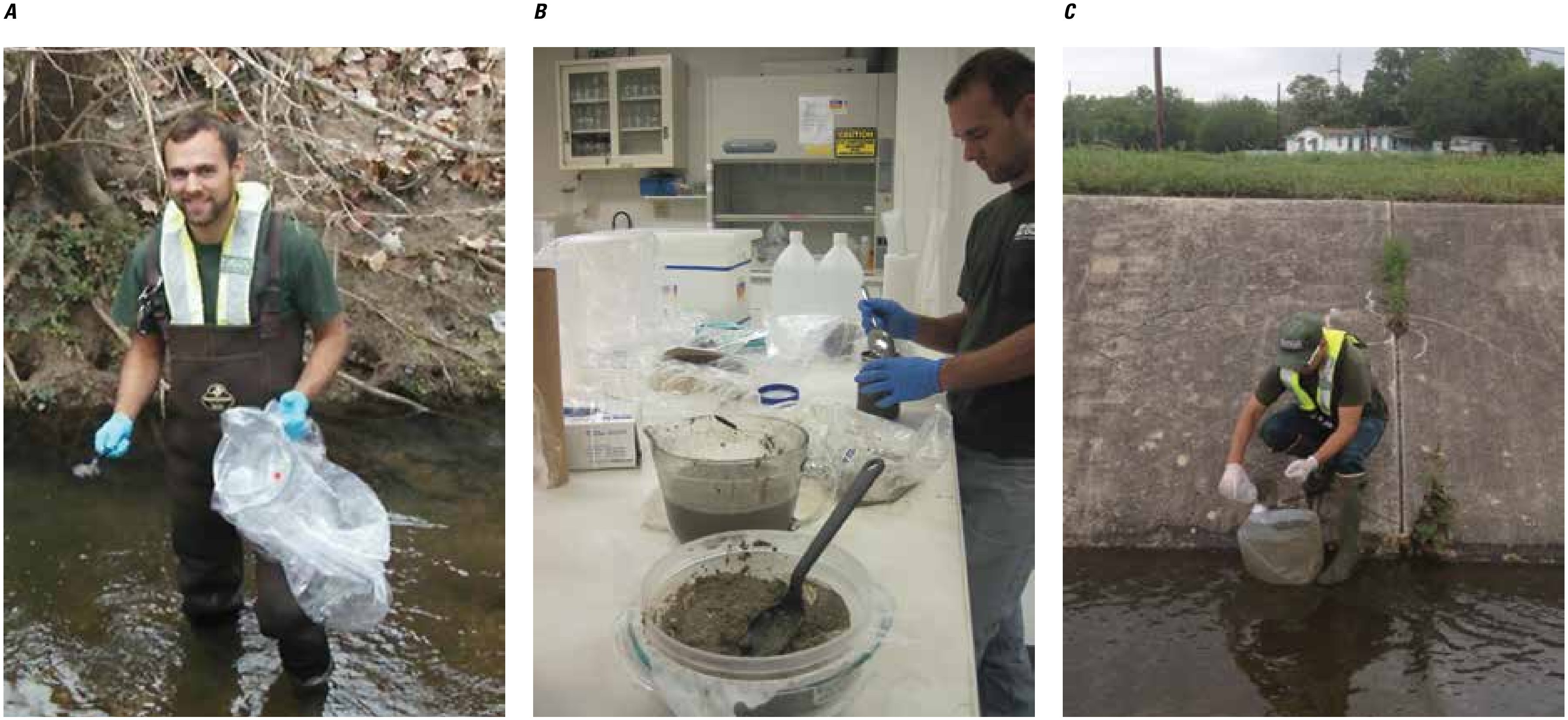


Figure 3. *A*, streambed-sediment sample collection; *B*, processing (from Wilson, 2016); and *C*, collection of water samples for toxicity-testing used at sites in the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

Table 2. Top 10 potential sources of contamination (Texas Commission on Environmental Quality, 2009) in contributing areas of sites where streambed-sediment samples were collected from the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

[mi^2, square miles; ft^2, square feet; TNRCC, Texas Natural Resource Conservation Commission]

Map identifier (fig. 1)	MTZ-US		MTZ-DS		ALZ-US		ALZ-DS		APC-US	
Contributing area (mi^2)	**4.5**		**7.1**		**8.2**		**17.5**		**15.8**	
Rank of source	**Source type**	**Area (ft^2)**	**Source type**	**Area (ft^2)**	**Source type**	**Area (ft^2)**	**Source type**	**Area (ft^2)**	**Source type**	**Area (ft^2)**
1	Municipal solid waste - abandoned	60,000	Petroleum storage tank	95,000	Municipal solid waste - abandoned	180,000	Municipal solid waste - abandoned	240,000	Municipal solid waste - abandoned	540,000
2	Pipeline	56,000	Auto repair, sales, salvage, towing	66,000	Petroleum storage tank	84,000	Petroleum storage tank	226,000	Petroleum storage tank	133,000
3	Petroleum storage tank	52,000	Municipal solid waste - abandoned	60,000	Auto repair, sales, salvage, towing	43,000	Auto repair, sales, salvage, towing	138,000	Pipeline	70,000
4	Auto repair, sales, salvage, towing	28,000	Pipeline	56,000	Pipeline	42,000	Pipeline	98,000	Auto repair, sales, salvage, towing	64,000
5	Confined animal feeding operation	25,000	Confined animal feeding operation	25,000	Mined land: active or abandoned	20,000	Pesticide, fertilizer manufacturing, sale, application	35,000	Mined land: active or abandoned	40,000
6	Pesticide, fertilizer manufacturing, sale, application	13,000	Organic Chemical Industry	25,000	Pesticide, fertilizer manufacturing, sale, application	14,000	Confined animal feeding operation	25,000	Radiochemical site	33,000
7	Tire sales, repair business	5,000	Pesticide, fertilizer manufacturing, sale, application	19,000	Paint shop	10,000	Organic Chemical Industry	25,000	Pesticide, fertilizer manufacturing, sale, application	18,000
8	Paint shop	4,000	Paint shop	7,000	Tire sales, repair business	9,000	Paint shop	22,000	Chemical storage	13,000
9	Pesticide manufacturing, sale, application	3,000	Pesticide manufacturing, sale, application	7,000	New or used oil site	6,000	Mined land: active or abandoned	20,000	Tire sales, repair business	10,000
10	New or used oil site	2,000	Tire sales, repair business	6,000	Chemical storage	5,000	Tire sales, repair business	20,000	New or used oil site	9,000

Table 2. Top 10 potential sources of contamination (Texas Commission on Environmental Quality, 2009) in contributing areas of sites where streambed-sediment samples were collected from the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[mi^2, square miles; ft^2, square feet; TNRCC, Texas Natural Resource Conservation Commission]

Map identifier (fig. 1)	**APC-DS**		**SPD-US**		**SPD-MD**		**SPD-DS**		**SAR**	
Contributing area (mi^2)	**22.6**		**1.8**		**2.7**		**44.7**		**94.9**	
Rank of source	**Source type**	**Area (ft^2)**	**Source type**	**Area (ft^2)**	**Source type**	**Area (ft^2)**	**Source type**	**Area (ft^2)**	**Source type**	**Area (ft^2)**
1	Municipal solid waste - abandoned	660,000	Petroleum storage tank	51,000	Petroleum storage tank	86,000	Municipal solid waste - abandoned	960,000	Municipal solid waste - abandoned	1,560,000
2	Petroleum storage tank	207,000	Petroleum Chemical Industry	25,000	Auto repair, sales, salvage, towing	26,000	Petroleum storage tank	559,000	Petroleum storage tank	1,132,000
3	Auto repair, sales, salvage, towing	114,000	Auto repair, sales, salvage, towing	17,000	Confined animal feeding operation	25,000	Auto repair, sales, salvage, towing	296,000	Pipeline	742,000
4	Pipeline	112,000	Paint shop	5,000	Petroleum Chemical Industry	25,000	Pipeline	280,000	Auto repair, sales, salvage, towing	502,000
5	Mined land: active or abandoned	40,000	Pesticide, fertilizer manufacturing, sale, application	4,000	Organic Chemical Industry	25,000	Pesticide, fertilizer manufacturing, sale, application	61,000	Septic system	282,000
6	Radiochemical site	35,000	Superfund site - TNRCC	4,000	Paint shop	6,000	Mined land: active or abandoned	60,000	Mined land: active or abandoned	200,000
7	Treatment plant	25,000	Tire sales, repair business	3,000	Radiochemical site	5,000	Confined animal feeding operation	50,000	Pesticide, fertilizer manufacturing, sale, application	136,000
8	Pesticide, fertilizer manufacturing, sale, application	21,000	Plastic manufacturing, sales	2,000	Tire sales, repair business	5,000	Radiochemical site	44,000	Industrial wastewater outfall	125,000
9	Chemical storage	19,000	Site discovery - TNRCC	2,000	Pesticide, fertilizer manufacturing, sale, application	4,000	Chemical storage	42,000	Chemical storage	86,000
10	Tire sales, repair business	14,000	Radiochemical site	1,000	Superfund site - TNRCC	4,000	Tire sales, repair business	42,000	Paint shop	75,000

Streambed-sediment sample processing (fig. 3*B*) involved mixing and sieving the wet sediment. Sieving the samples eliminated the grain-size variability that has been shown to affect trace-element and organic-compound concentrations in sediment samples (Horowitz and Elrick, 1987; Smith and others, 1988), allowing for more informative comparisons among samples. About one-half of the sample was sieved using a 63-micrometer (mm) nylon-cloth sieve for analysis of major and trace elements. Sediment greater than 63 mm (the diameter differentiating larger, sand-size particles from smaller, clay- and silt-size particles) (Wentworth 1922; Guy, 1969) was discarded. The fine material (less than 63 mm) was transferred into 125 milliliter (mL) polypropylene jars and transported on ice to the USGS office in Austin where they were freeze-dried, pulverized, and shipped to the USGS Mineral Resources Program Analytical Laboratories in Lakewood, Colorado, for analysis. The other half of the sample was sieved by using a 2.0-millimeter (mm) stainless-steel-mesh sieve on the opening of a 500-mL precleaned glass jar and analyzed for organic compounds. Coarse sediment (greater than 2.0 mm) was discarded. The samples for organic compound analyses were chilled and shipped on ice to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colo., for analysis.

Streambed Sediment Analytical Methods

Streambed-sediment samples were analyzed for major and trace elements, halogenated organic compounds (including pesticides, brominated flame retardants, and PCBs), and PAHs. The USGS Mineral Resources Program Analytical Laboratories in Lakewood, Colo., analyzed the freeze-dried streambed-sediment samples for major and trace elements using a variety of analytical methods. Total and inorganic carbon was determined by using methods described by Taggart (2002). Total carbon was analyzed by combustion with an automated carbon analyzer; inorganic carbon was determined as carbon dioxide by coulometric titration. Organic carbon was then determined as the difference in mass between total and inorganic carbon. The percentage of organic carbon in the sediment sample is reported. Samples for major and trace element analyses were digested completely using a mixture of hydrochloric, nitric, perchloric, and hydrofluoric acids and analyzed by inductively coupled plasma–mass spectrometry (Briggs and Meier, 2002). Concentrations of mercury were determined by continuous flow-cold vapor-atomic fluorescence spectrometry (Hageman, 2007).

The NWQL in Lakewood, Colo., analyzed the wet streambed-sediment samples for halogenated organic compounds and PAHs using a custom analytical method, meaning there was not a published method at the time of sample analysis. The samples were extracted twice using the ASE 200 accelerated solvent extraction system made by Dionex (Sunnyvale, California) at a pressure of 13,800 kilopascals with a water/isopropyl alcohol mixture (50:50, volume-to-volume ratio) at 120 degrees Celsius (°C) and then a water/isopropyl alcohol mixture (20:80, volume-to-volume ratio) at 200 °C for 40 minutes. As explained in Wilson (2016, p. 11) “surrogate compounds were added to the sample prior to extraction to monitor laboratory preparation, matrix effects (Rowe and others, 2005; Geboy and Engle, 2011), and method performance.” The extracts were analyzed by capillary-column gas chromatography/mass spectrometry (GC/MS) by using an Agilent Technologies Model 5975 GS/MS, with the mass spectrometer (MS) operated in the electron capture negative ion mode using ammonia as the reactant gas. The halogenated organic compounds were identified by selected ion monitoring using the ions of interest (Mark Burkhardt and Steven Zaugg, U.S. Geological Survey National Water Quality Laboratory, written commun., July 2007).

Wet streambed-sediment samples also were analyzed for PAHs by the NWQL. The samples were extracted by using the ASE 200 accelerated solvent extraction system (Dionex, Sunnyvale, Calif.) as described previously for the halogenated organic compounds. The constituents of interest then were isolated from the extract by using disposable solid-phase extraction (SPE) cartridges containing divinylbenzene-vinylpyrrolidone copolymer resin. The SPE cartridge was dried partially with nitrogen gas, and sorbed compounds were eluted with a dichloromethane/diethyl ether mixture (80:20, volume-to-volume ratio) and passed through a second SPE cartridge, either a sodium sulfate or Florisil SPE cartridge, to dry and further “clean up” the extract by removing unwanted impurities. The concentrated extract was solvent exchanged into ethyl acetate, the solvent volume reduced, internal standard compounds added, and then analyzed by capillary-column GC/MS on an Agilent Technologies Model 5973, with the MS operated in the electron impact, full scan mode (Zaugg and others, 2006).

Water Quality Toxicity Sample Collection

Water samples for use in toxicity testing were collected from the nine sites on the Westside Creeks and the site on the San Antonio River during base-flow conditions (January 2014) and following a storm event (May 2014). Samples for water-toxicity testing were grab samples collected into new 20-L carboys (fig. 3*C*) that were certified for use in metal analyses. Samples were chilled immediately to about 4 °C and shipped overnight for analysis by the USGS Columbia Environmental Research Center (CERC) in Columbia, Missouri. Water samples were stored in the dark at a temperature of about 4 °C prior to analysis.

Water Quality Toxicity Analytical Methods

Water samples from the nine sites on the Westside Creeks and the site on the San Antonio River were evaluated at the CERC in two rounds of standard 7-day water-toxicity testing as an indicator of ecological health. Water samples collected from the 10 sites during base-flow conditions at the end of

January 2014 were tested in the first round and 10 additional water samples collected in late May 2014 from the same sites were tested in the second round. Toxicity endpoints consisted of the 7-day survival and biomass of *Pimephales promelas* (fathead minnow) that were exposed to either environmental water or diluted or undiluted control water starting with recently hatched fish larvae that were slightly more than 48-hours old (U.S. Environmental Protection Agency, 2002). Water in the tanks holding the test organisms was replaced every 3 days with water from the same sources (and when applicable, diluted in the same manner) as the original water used to fill the tanks for the experiments.

At the end of the 7-day exposure, the surviving fish were placed in clean control water and exposed to 7.5 microWatts per square centimeter (µW/cm^2) ultraviolet radiation (UV) for 4 hours to evaluate the potential lethality associated with photoactivated compounds that may accumulate in the fish tissues (Little and others, 2007). Survival of test organisms was determined after the 4-hour pulse exposure to UV and after a subsequent 20-hour recovery period under ambient laboratory lighting conditions.

Quality Control

Quality-control (QC) samples were collected and analyzed to help assess the amount of variability and bias found in the environmental sample results (Mueller and others, 2015). The QC samples submitted to the analytical laboratories by project personnel included four streambed-sediment sample duplicates and two reference samples. Concurrent duplicate samples were collected, meaning that two samples were collected by using identical methodology and as closely together in time and space as possible (Horowitz and others, 1994). Duplicate sample results can be affected by sample heterogeneity, particularly when sediment is the sample medium (Pirkey and Glodt, 1998). The relative percent difference (RPD) was calculated between each pair of duplicate analyses to provide a measure of variability using the equation:

$$\mathrm{RPD} = \frac{|C_1 - C_2|}{(C_1 + C_2)/2} \times 100\,, \tag{1}$$

where

C_1 is the constituent concentration in the environmental sample, and

C_2 is the constituent concentration in the duplicate sample.

Reference samples contain known concentrations of selected analytes and are used to estimate positive or negative bias (if the measured value is greater than or less than the known concentration). National Institute of Standards and Technology (NIST) reference material 8704 (Buffalo River Sediment; National Institute of Standards and Technology, 2000) for selected trace elements and NIST standard reference material 1941b (Organics in Marine Sediment; National Institute of Standards and Technology, 2015) for selected pesticides, PCBs, and PAHs were analyzed by the USGS laboratories.

Inorganic Analysis

The RPDs calculated for trace element analytes in the four duplicate samples collected in the Westside Creeks during 2014 (table 3, at end of report) are summarized in table 4. The RPDs for the trace element analyses ranged from 0 to 9.7 with a median value of 0.58, indicating low variability between duplicate streambed-sediment samples. Low variability (high precision) between concurrent duplicate samples is indicative of proper sampling techniques, which ensures comparability between sites and sample sets.

Comparisons of reference material 8704 (Buffalo River Sediment) analysis by the USGS Mineral Resources Program Analytical Laboratories to the NIST concentration values

Table 4. Statistical summary of relative percent difference (RPD) between environmental and duplicate streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks), San Antonio, Texas, 2014.

[RPD, relative percent difference]

Category	Number of samples	Minimum RPD	Maximum RPD	Mean RPD	Median RPD
Trace elements	4	0	9.7	0.90	0.58
Halogenated organic compounds					
Pesticides	4	0	37	6.4	4.6
Polychlorinated biphenyls (PCBs)	4	0.26	11	5.4	5.0
Brominated flame retardants	4	0.41	30	5.6	3.3
Polycyclic aromatic hydrocarbons (PAHs)	4	0	17	5.6	3.7
All duplicate samples	4	0	37	3.9	1.9

generally indicate negligible bias in inorganic constituents during environmental sample analyses (table 5, at end of report). Results for the analysis were within the range of uncertainty (known concentration of a constituent in the NIST reference material plus or minus one standard deviation) (table 5) for 11 of 22 analytes, greater than the range of uncertainty for 4 of the 22 analytes, and less than the range of uncertainty for 7 of the 22 analytes. Trace elements for which negative bias was observed (results less than the range of uncertainty) are of concern because there is the potential for false negatives (concentrations reported as less than the applicable reporting level when they were likely greater than the applicable reporting level) and the possibility that the analytes are present in greater, potentially toxic concentrations in the environmental samples than reported by the laboratory. The concentrations of inorganic analytes in the environmental samples were adjusted by factors developed from the results of the reference material analysis. Comparisons of the environmental sample concentrations among sites, sampling events, and to sediment-quality guidelines before and after adjustments indicated that the bias had no apparent effect on the interpretation of the study results. The concentrations of inorganic analytes in the environmental sample results are therefore used in this report as received from the laboratory.

Organic Analysis

The RPDs calculated for the four organic duplicate samples collected in the Westside Creeks during 2014 (tables 6 and 7, at end of report) are summarized in table 4. The comparisons of duplicate sample results indicate greater variability in the halogenated organic compound concentrations (RPDs ranged from 0 to 37) than in the PAH concentrations (RPDs ranged from 0 to 17). From the RPDs calculated for organic compounds, 204 of the 207 (96 percent), including all of those calculated for PCBs and PAHs, were less than 20 percent. One RPD calculated for the antimicrobial pesticide triclosan (RPD of 37.0), and one each RPD for the brominated flame retardants 1,2-bis(2,4,6-tribromophenoxy) ethane (TBE) (RPD of 29.9) and Bis(hexachlorocyclopentadieno) cyclooctane (trade name Dechlorane plus) (RPD of 20.6) exceeded 20 percent, which is not unusual when comparing concurrent duplicate sediment samples. Overall, variability in the analysis of organic compounds was low, which is indicative of proper sampling and analytical processes that allow comparability between sites and sample sets; no organic environmental data were rejected from the dataset based on variability.

Quality control for the NWQL for the halogenated organic compound and PAH analyses consisted of analyzing a laboratory reagent blank (hereinafter called a laboratory set blank) and a laboratory reagent spike (hereinafter called a set spike) with each set of environmental samples. The halogenated organic compound samples collected at the sites in the Westside Creeks and San Antonio River in 2014 were analyzed in six different sets (table 8, at end of report); PAH samples were analyzed in four different sets (table 9, at end of report). Halogenated organic compound and PAH concentrations equal to or greater than their respective interim reporting levels (IRLs) are hereinafter referred to as "detections" or "detected concentrations." The IRL is a temporary reporting level used for new or custom schedules when long-term method detection limit data are unavailable and a laboratory reporting level has not yet been established (U.S. Geological Survey, 2002, table 5).

Laboratory set blank samples are intended to demonstrate processing and analysis by the laboratory are not sources of contamination (Mueller and others, 2015). Five to seven halogenated organic compounds were detected in each of the laboratory set blank samples (table 8). Four to eighteen PAHs were detected in each of the laboratory set blank samples (table 9). Whenever a halogenated organic compound or PAH was detected in its respective laboratory set blank, the quantification of that same compound in the environmental samples in that same set was marked as estimated with an "E" remark code. The value was further qualified with a "v" value-qualifier code indicating the sample was associated with a laboratory blank in which the compound was detected (Childress and others, 1999). Detections of halogenated organic compounds and PAHs in laboratory set blank samples, particularly at concentrations equal to or greater than their IRLs, indicate the possibility of positive bias and false positives during environmental sample analyses. Five of the six detections of PBDE 47 and two of the six detections of PBDE 99 in the halogenated organic compound laboratory set blank samples, and one of the three detections of bis(2-ethylhexyl) phthalate in the PAH laboratory set blank samples were present in concentrations greater than their respective IRLs. The detections of the compounds in the environmental samples were at concentrations of 1.5 to 1,447 times greater than the detected concentrations in their respective laboratory set blanks; therefore, no environmental data were rejected or adjusted on the basis of the results obtained from blank samples. All values marked as estimated (E) on the basis of laboratory set blank detections were used as reported by the laboratory in data analysis including comparisons among sites, sampling events, and to sediment-quality guidelines.

Based on laboratory set spike recoveries, the analytical method performance and potential bias indicate the environmental sample results can be interpreted as reported by the laboratory without adjustment. The overall average spike recovery for the halogenated organic compounds was 70.3 percent and 118 percent for PAHs (tables 8 and 9). The NWQL establishes annually acceptable spike recovery ranges on the basis of historical spike analyses (D.L. Stevenson and A.R. Barnard, U.S. Geological Survey, written commun., 2013). Spike recoveries were within acceptable recovery ranges for 223 of the 234 (95 percent) individual recovery values of the spike samples analyzed for halogenated organic compounds and for 104 of the 114 (91 percent) of the individual recovery values for those analyzed for PAHs. Eight of the eleven spike recoveries that were outside of their acceptable ranges for halogenated organic compound analysis were less than their acceptable ranges (negatively biased), whereas all of the spike recoveries that were outside of their acceptable ranges for PAH analysis were greater than their acceptable ranges (positively biased). The spike recoveries for triclosan in all six laboratory set spikes were less than the lower limit (14 percent) of the acceptable range and ranged from an estimated value of 2.8 percent to an estimated value of 7.6 percent, indicating a possible large negative bias in triclosan concentrations and the possibility of frequent false negatives during environmental sample analyses. For this reason, the four detections of triclosan in the environmental samples were assigned an "E" remark code and further qualified with an "m" value-qualifier code indicating the sample was biased on the basis of an associated laboratory set spike (Childress and others, 1999). Triclosan concentrations are included in the dataset as reported by the laboratory, but the concentrations were not used in data analysis in this report.

The environmental sample results were adjusted for the laboratory set spike recoveries to assess the possible effect of the analytical method performance on the data interpretation. The environmental sample concentrations were raised or lowered as needed to represent a 100-percent spike recovery. Comparisons of the environmental sample concentrations among sites, sampling events, and to sediment-quality guidelines before and after spike adjustments indicated that the spike recovery rates had no apparent effect on the interpretation of the study results; therefore, the environmental sample results are used in this report as received from the laboratory. Because laboratory set spikes are prepared using reagent water (deionized water that is continuously purged at the NWQL with ultrapure nitrogen and assumed to be void of the analytes of interest), any possible matrix effects associated with any organic matter, and (or) constituents other than the target constituent that might be present in the environmental samples, are not accounted for by laboratory set spike recovery rates (Rowe and others, 2005).

One sample of reference material 1941b (Organics in Marine Sediment; National Institute of Standards and Technology, 2015) containing known concentrations of a set of organic compounds was submitted to evaluate laboratory method performance. A single reference sample, while not sufficient to make statistical assessment of overall laboratory performance, can be used as a general indicator of performance. As with all the environmental samples, a set spike was analyzed by the NWQL with the reference material sample. Recoveries from that set spike were within the acceptable ranges for each constituent for the majority of the organic compounds. For completeness, the NIST reference material values were compared to both an unadjusted concentration (as reported by the laboratory analyzing the sample) and an adjusted concentration that was increased or decreased as needed to represent a 100-percent spike recovery. Comparisons of the reference sample concentrations before and after spike adjustments indicated no apparent effect on the overall bias distribution in the datasets; therefore, the concentrations of the organic compounds in the reference sample are used in this report as received from the laboratory.

The reference material (table 5) contained one pesticide (DDT) with NIST certified concentrations less than the laboratory IRLs. Concentrations of the other six pesticides obtained during analysis by USGS laboratories were less than the known concentrations, including false negatives (concentrations reported as less than the applicable reporting level when they were likely greater than the applicable reporting level) in the analysis of dichlorodiphenyldichloroethane (DDD) and dichlorodiphenyldichloroethylene (DDE). Recoveries from USGS laboratory analysis of pesticides in the reference material ranged from approximately 2 percent in *trans*-nonachlor to approximately 19 percent in *cis*-nonachlor, indicating the possibility of substantial negative bias in environmental sample concentrations of these pesticides. Concentrations of 16 PCBs obtained during analysis by USGS laboratories were less than the known concentrations, including false negatives in the analysis of PCB congeners 49, 52, 70, 110, 138, and 146. PCBs consist of as many as 209 theoretically possible chlorinated compounds, called congeners, with various numbers and positions of chlorine atoms attached to the biphenyl structure (U.S. Environmental Protection Agency, 2016b). For identification purposes, each PCB compound (congener) has been assigned a number from 1 to 209; the number generally increases with increasing chlorination of the biphenyl structure (Ballschmiter and Zell, 1980, table 2, p. 21). Recoveries from reference material analysis of the other 10 PCB congeners by the USGS laboratories ranged from approximately 18 percent in PCB congener 101 to approximately 66 percent in PCB congener 170, indicating the possibility of moderate negative bias in environmental concentrations. The reference material contained four PAH compounds with NIST certified values less than their respective laboratory IRLs. Of the other 18 PAH compound concentrations obtained during analysis by USGS laboratories, 11 were greater than the known concentrations, and 5 were less than the known concentrations. Recoveries from USGS laboratory analysis of PAHs in the reference material ranged from approximately 38 percent in indenopyrene to approximately 213 percent in *2,6*-dimethlnaphthalene with a median of approximately 115 percent, indicating a possible positive bias in overall PAH concentrations in environmental samples (table 5).

For completeness and comparison, the concentrations of organic compounds in the environmental samples were adjusted by factors developed from the results of the reference material analysis. Comparisons of the environmental sample concentrations among sites, sampling events, and to sediment-quality guidelines before and after adjustments indicated that the bias could have had an effect on the concentrations of certain halogenated organic compounds. The concentrations of organic compounds in the environmental sample results are used in this report as received from the laboratory, but instances when bias could be a concern are addressed.

Occurrence and Concentrations of Selected Trace Elements, Halogenated Organic Compounds, and Polycyclic Aromatic Hydrocarbons in Streambed Sediment

Concentrations of the contaminants in the streambed-sediment samples were compared to the consensus-based sediment quality guidelines (SQGs) of MacDonald and others (2000) to determine the degree of contamination (table 10). The SQGs evaluate the potential toxicity of bed sediments to benthic biota (sediment-dwelling organisms). Two SQG concentration levels are used: (1) a lower level, called the threshold effect concentration (TEC), below which harmful effects to benthic biota are not expected, and (2) a higher level, the probable effect concentration (PEC), above which harmful effects are expected to occur frequently. Samples with concentrations between the TEC and PEC are not predicted to be toxic or nontoxic to benthic biota. The sediment screening levels used by the Texas Commission for Environmental Quality's Ecological Assessment Program (Texas Commission for Environmental Quality, 2015) are identical to the PECs of MacDonald and others (2000).

Trace Elements

Trace elements are naturally occurring and typically found in sediment samples; they also can be derived from anthropogenic sources. The concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc in the streambed-sediment samples collected in the Westside Creeks and San Antonio River in 2014 were compared to their sediment-quality guidelines (fig. 4). The concentrations of arsenic, cadmium, mercury, and nickel were less than the TEC in all of the samples. Lead and zinc were most frequently detected at concentrations greater than the TEC (90 percent of all analyses). Concentrations of lead in all four samples collected at the upstream San Pedro and middle San Pedro sites were greater than the PEC of 128 mg/kg (fig. 4). Lead is a toxic metal that has been shown to be strongly related to urban land use (Callender and Rice, 2000; U.S. Environmental Protection Agency, 2016a). Prior to regulation efforts, lead was used as a pigment in paint, in water supply pipes, and as a fuel additive. In 2016, the manufacture of automobile components, including lead-acid batteries, is one of the most common uses of lead in the United States (U.S. Environmental Protection Agency, 2016a). Consistent with Callender and Rice (2000), land use in the contributing areas of the upstream and middle San Pedro sites is highly urbanized and typical of the entire study area (table 1). Sources of lead in the contributing areas of these sites might include older petroleum storage tanks that in the past held leaded fuel or possibly from a variety of automobile components used in the numerous automobile-related businesses in the area (table 2). Other trace elements detected at concentrations greater than the TEC but less than the PEC were chromium (65 percent of all analyses) and copper (35 percent of all analyses).

On the basis of the percentages of concentrations greater than the TEC for all eight trace elements during base-flow conditions, the greatest number of trace elements in the

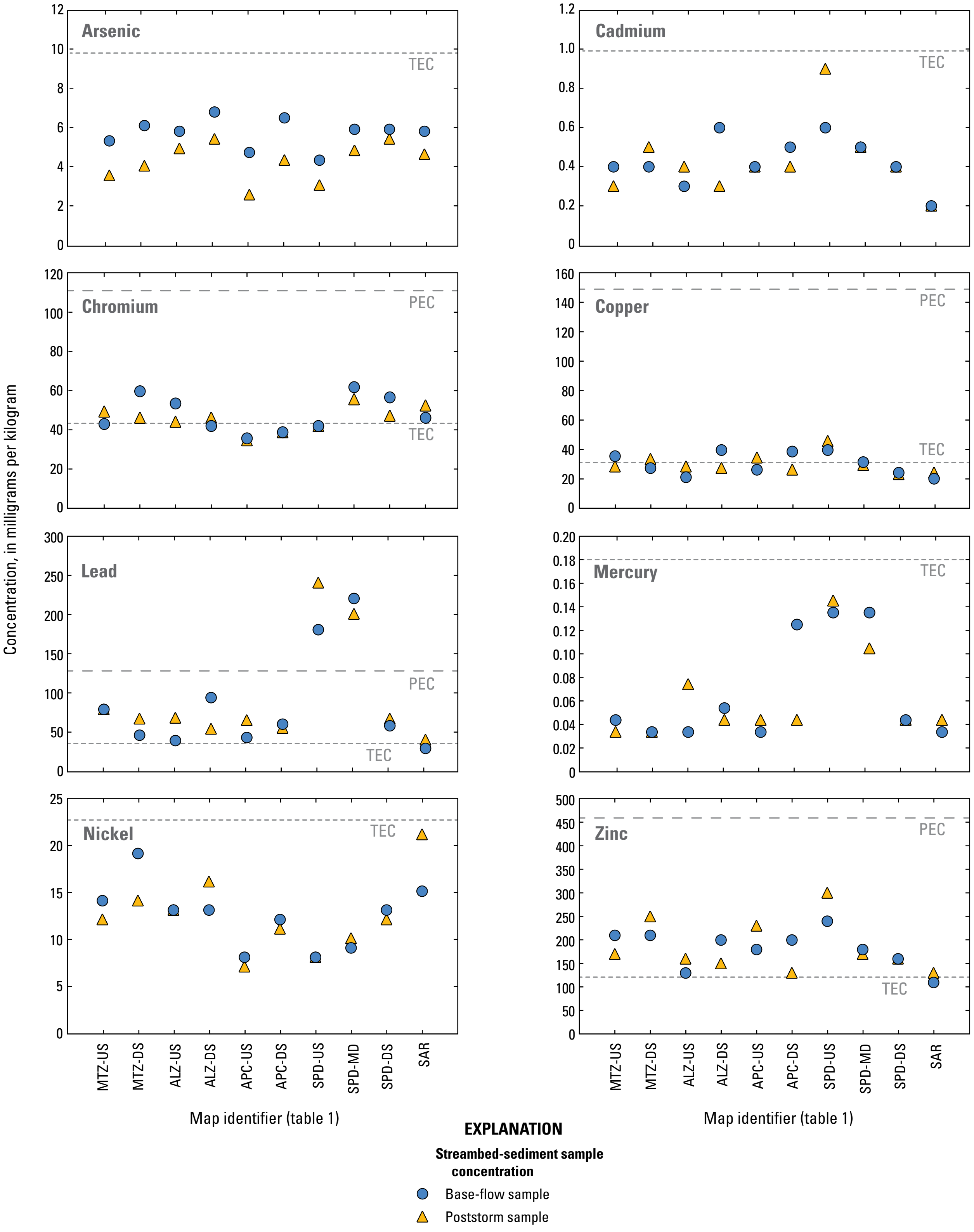
Table 10. Consensus-based sediment-quality guidelines of MacDonald and others (2000) that were used to evaluate the contaminant concentrations in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

[mg/kg, milligrams per kilogram; µg/kg, micrograms per kilogram; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCBs, polychlorinated biphenyls; PAHs, polycyclic aromatic hydrocarbons]

Constituent	Threshold effect concentration[1]	Probable effect concentration[2]
Trace elements (mg/kg)		
Arsenic	9.79	33.0
Cadmium	0.99	4.98
Chromium	43.4	111
Copper	31.6	149
Lead	35.8	128
Mercury	0.18	1.06
Nickel	22.7	48.6
Zinc	121	459
Halogenated organic compounds (µg/kg)		
Chlordane	3.24	17.6
Dieldrin	1.90	61.8
DDD	4.88	28.0
DDE	3.16	31.3
DDT	4.16	62.9
Total PCBs	**59.8**	**676**
Polycyclic aromatic hydrocarbons (µg/kg)		
Anthracene	57.2	845
Benz(a)anthracene	108	1,050
Benzo(a)pyrene	150	1,450
Chrysene	166	1,290
Dibenzo(a,h)anthracene	33.0	none
Fluoranthene	423	2,230
Fluorene	77.4	536
Naphthalene	176	561
Phenanthrene	204	1,170
Pyrene	195	1,520
Total PAHs	**1,610**	**22,800**

[1] Threshold effect concentration is the concentration below which harmful effects to benthic biota are not expected.

[2] Probable effect concentration is the concentration above which harmful effects are expected to occur frequently.



[TEC, threshold effect concentration; PEC, probable effect concentration]

Figure 4. Comparison of consensus-based sediment quality guidelines (MacDonald and others, 2000) with concentrations of trace elements in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

sediments occurred at the upstream Martínez site (50 percent), and the smallest number occurred at the San Antonio River site (12.5 percent) (fig. 4). During poststorm conditions, the greatest number of trace elements in the sediments exceeding a TEC occurred at the downstream Martínez site (50 percent), and the smallest number occurred at the downstream Apache site (25 percent). With the exception of arsenic concentrations, which were greater in all base-flow samples collected at the 10 sites compared to the poststorm samples collected at the same sites, there was no discernable pattern observed in the trace metal concentrations when comparing base-flow and poststorm samples. The reduced concentration of arsenic following the storm event could indicate a consistent source that is either diluted or subject to flushing during storm runoff.

Halogenated Organic Compounds

Unlike trace elements which can occur naturally, the halogenated organic compounds discussed in this report are almost always associated with human activities. The manufacturing, sale, or use of many of these compounds (pesticides, brominated flame retardants, and PCBs) was banned or restricted in the United States because of their persistence in the environment, detrimental effects on plant and animal life, or both (U.S. Environmental Protection Agency, 1997a). However, many other synthetic halogenated organic compounds (pesticides and brominated flame retardants) are currently (2016) being produced and used in the Unites States; selected pesticides in this group were assessed and referred to as “current-use pesticides” in this report.

Many organic compounds are known to sorb to the organic matter in sediments (Chiou and others, 1979; Karickhoff and others, 1979). The percentage of organic carbon in streambed-sediment samples collected during base-flow conditions was greater than the percentages measured in samples collected during poststorm conditions at 60 percent of the sampled sites (fig. 5). The percentage of organic carbon measured during base-flow conditions ranged from 1.2 percent at the

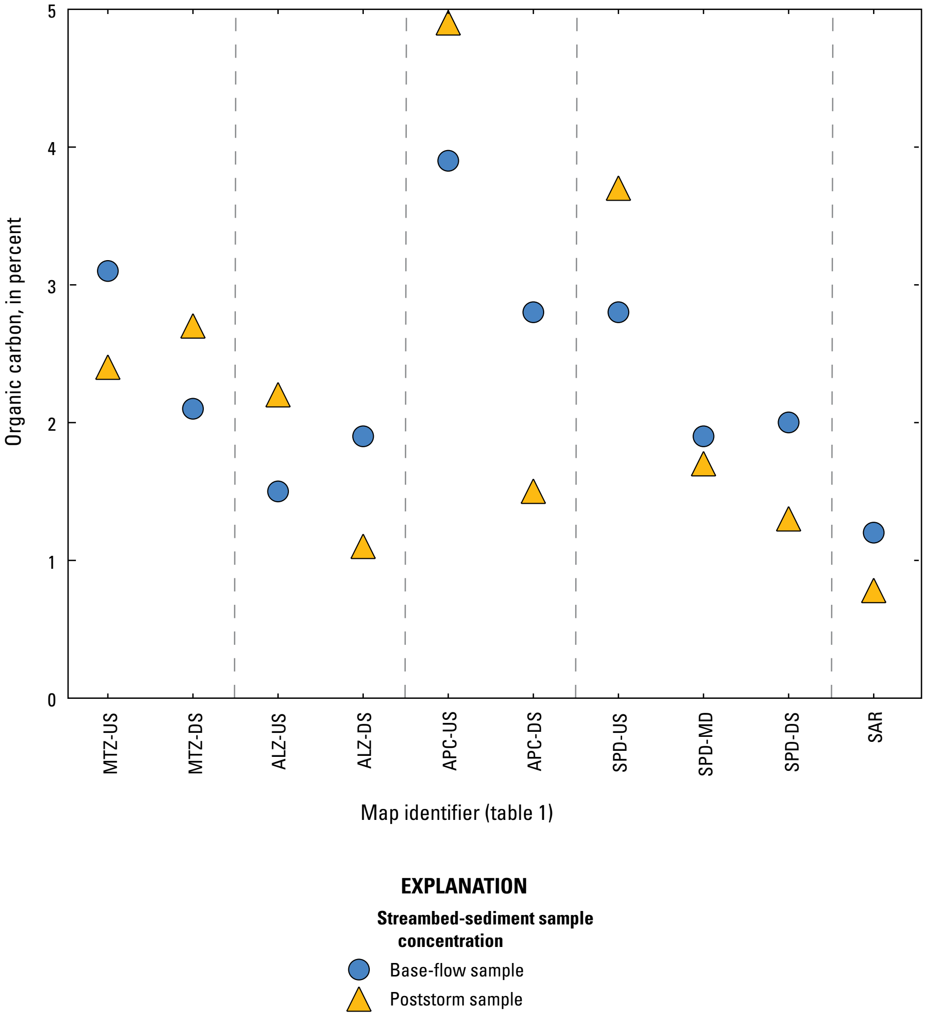


Figure 5. Percentages of organic carbon in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

San Antonio River site to 3.9 percent at the upstream Apache site and from 0.78 percent at the San Antonio River site to 4.9 percent at the upstream Apache site during poststorm conditions, which could affect the organic compound concentrations in the different sample types. Some, but not all, SQGs are based on concentrations normalized to 1 percent organic carbon to overcome differences that could be related to different types of samples. The PBDE concentrations were normalized by dividing them by the percentage of organic carbon in the sample before comparisons among PBDE concentrations were made.

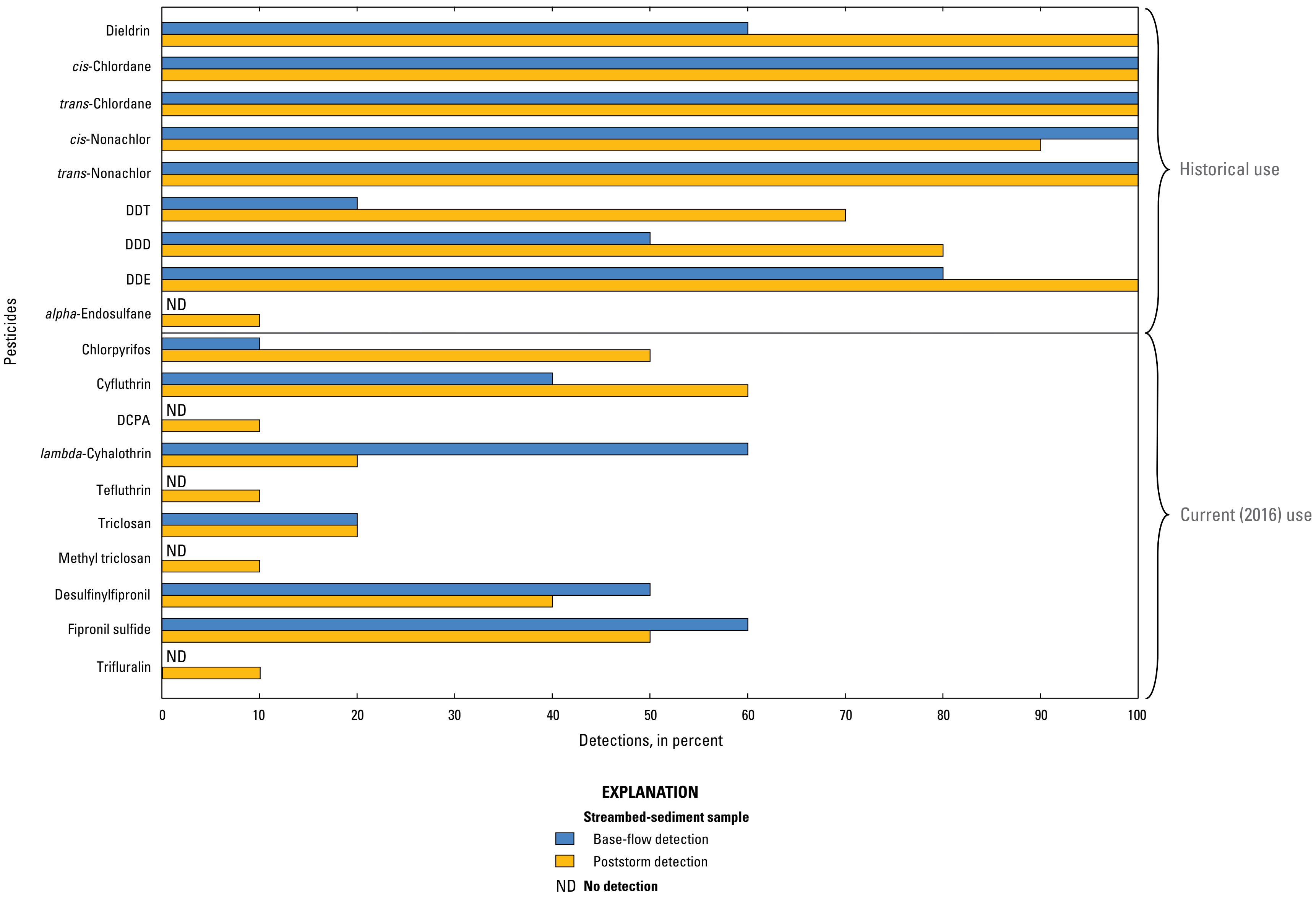
Pesticides

The concentrations in streambed-sediment samples of 9 historical-use and 10 current-use pesticides (all of which are synthetic, halogenated organic compounds) were investigated in this study (fig. 6). The historical-use pesticides discussed in this report are toxic, persistent organic pollutants that have either been banned for production, sale, and use in the United States, or their production, sale, and use are being phased out (Agency for Toxic Substances and Disease Registry, 2016). Historical-use pesticides were more frequently detected in streambed-sediment samples compared to current-use pesticides. Three chlordane compounds (*cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor), which were banned by the U.S. Environmental Protection Agency (EPA) in 1988 (U.S. Environmental Protection Agency, 1997b), were detected in all of the samples collected during both base-flow and poststorm conditions (fig. 6). During base-flow conditions, the number of pesticides detected at each site ranged from 4 in the sample collected from the upstream Apache site to 12 in the sample collected at the downstream Martínez site. During poststorm conditions, the number of pesticides detected at each site ranged from 7 in the sample collected from the upstream Apache site to 13 in the sample collected at the upstream San Pedro site (Crow and others, 2016). The pesticides *alpha*-endosulfane, dimethyl tetrachloroterephthalate (DCPA), tefluthrin, methyl triclosan, and trifluralin were not detected in any samples collected during base-flow conditions but were detected in some samples collected during poststorm conditions. The most frequently detected (60 percent of samples) current-use pesticides in samples collected during base-flow conditions were the insecticides lambda-cyhalothrin and fipronil sulfide. Cyfluthrin, a synthetic pyrethroid insecticide, was the most frequently detected (60 percent of samples) current-use pesticide in samples collected during poststorm conditions.

MacDonald and others (2000) published consensus-based SQGs for chlordane (sum of *cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, and *trans*-nonachlor), dieldrin, DDD, DDE, and DDT (table 10). Most of the pesticide concentrations, as reported by the laboratory, were less than their respective PEC concentrations (fig. 7). Possible negative bias in laboratory results for all four chlordane compounds (*cis*-chlordane, *trans*-chlordane, *cis*-nonachlor, and *trans*-nonachlor), DDD, and DDT indicates that true environmental concentrations could be greater than those reported by the laboratory, meaning the compounds could exist in the environment in greater (possibly more toxic) concentrations than indicated by the reported laboratory values discussed in this report. The majority of the detections of dieldrin (13 of 16) and DDT (6 of 9) were at concentrations less than their respective TECs. The majority of the detections of chlordane (18 of 20) and DDE (15 of 18), as reported by the laboratory, were at concentrations greater than their respective TECs but less than their PECs. Correction for possible negative laboratory bias indicated that the environmental concentrations for chlordane could possibly exceed the PEC in all samples. Pesticides were most frequently detected in concentrations, as reported by the laboratory, greater than their PECs in samples from the upstream San Pedro and middle San Pedro sites. During base-flow conditions, concentrations of DDD, DDE, and DDT exceeded their PECs in the sample collected from the middle San Pedro site. During poststorm conditions, concentrations of chlordane, DDD, and DDE in samples collected at the upstream San Pedro site and concentrations of DDD and DDE in samples collected at the middle San Pedro site exceeded their PECs. Correction for possible negative laboratory bias indicated that the number and distribution of environmental concentrations exceeding the PEC did not change for DDD; however, the concentrations of DDE in as many as seven additional samples (five collected during base-flow and two collected during poststorm conditions) could have exceeded the PEC.

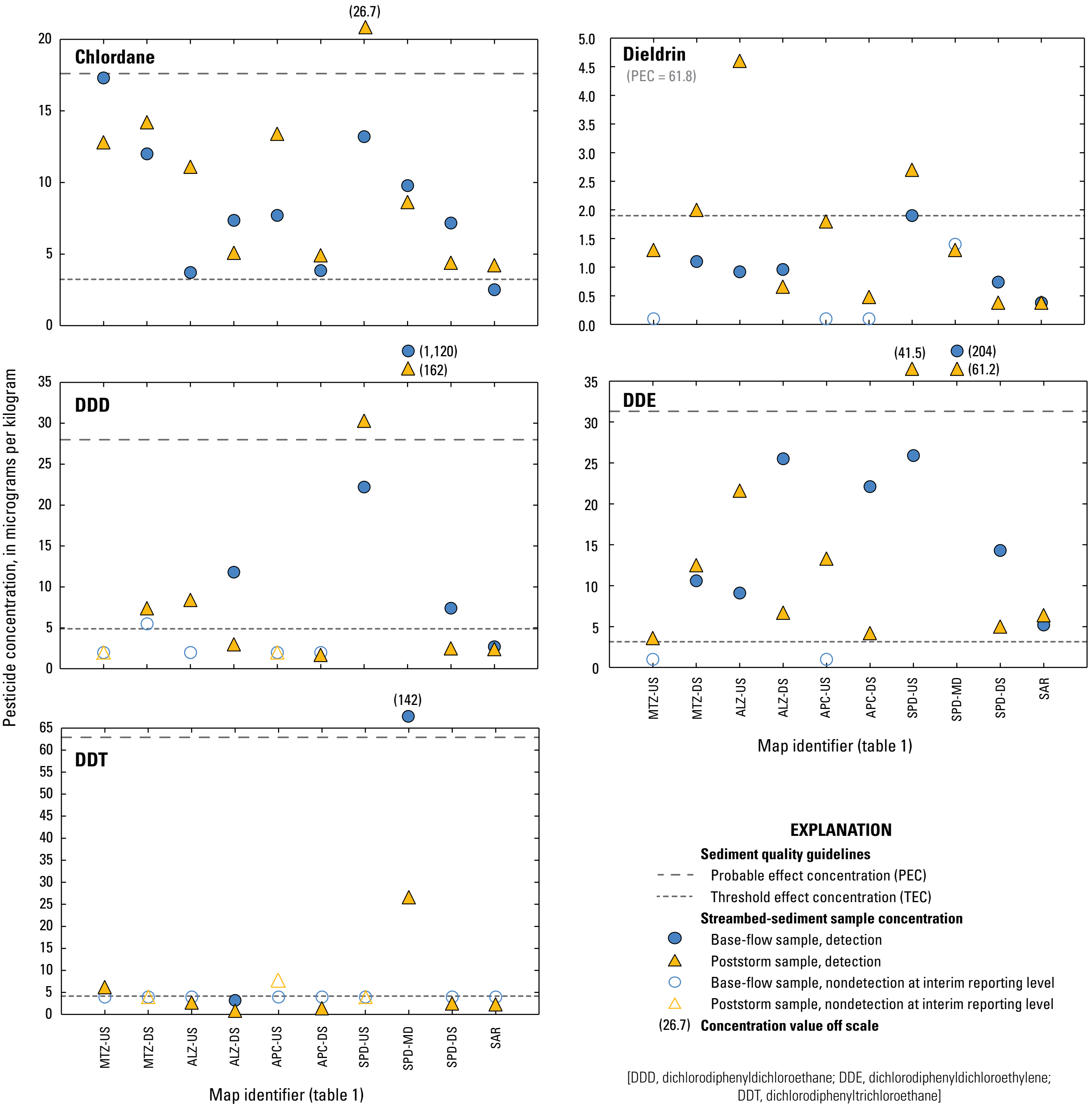
Brominated Flame Retardants

Brominated flame retardants are halogenated organic compounds that are added to plastics, foams, and fabrics to increase the fire resistance of products such as electronics, automobiles, clothing, and furniture. The chemicals are not chemically bound to the products to which they are added, making them likely to leach out of these products (Shaw and others, 2010). Brominated flame retardants are persistent in the environment and have been shown to be toxic and to bioaccumulate (U.S. Environmental Protection Agency, 2010). In 2005, the EPA restricted the manufacturing, importing, or processing of pentabromodiphenyl ether (pentaBDE) and octabromodiphenyl ether (octaBDE), which are commercial mixtures of PDBE congeners (U.S. Environmental Protection Agency, 2015). The streambed-sediment samples collected from the Westside Creeks and San Antonio River in 2014 were analyzed for several polybrominated diphenyl ether (PBDE) congeners plus three other brominated flame retardants: Dechlorane Plus, pentabromotoluene, and 1,2-bis (2,4,6-tribromophenoxy) ethane (TBE). Brominated flame retardants were found at every site where streambed-sediment samples were collected (fig. 8). PBDEs 85, 153, and 154 were found in all streambed-sediment samples. Brominated flame



[DDT, dichlorodiphenyltrichloroethane; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DCPA, dimethyl tetrachloroterephthalate]

Figure 6. Detection frequencies of pesticides in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.



[DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane]

Figure 7. Comparison of consensus-based sediment quality guidelines (MacDonald and others, 2000) with concentrations of pesticides in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

retardants were more frequently detected in samples collected during poststorm conditions (75 percent of the analyses) than in those collected during base-flow conditions (67 percent of the analyses), with the greatest increase in the number of brominated flame retardants detected when comparing samples collected from the San Pedro Creek sites during base-flow and poststorm conditions.

To protect benthic and pelagic aquatic life, Environment Canada has established guidelines referred to as “Federal Environmental Quality Guidelines” (FEQGs) for the concentrations of PBDE 99 and PBDE 100 in stream sediments. According to Environment Canada (2013, p. 2), the FEQGs “provide benchmarks for the quality of the ambient environment. Where the FEQG is met there is low likelihood of adverse effects on the aquatic life or the wildlife that may consume them.” The FEQGs (normalized to 1 percent organic carbon in sediments) for PBDE 99 and PBDE 100 are 0.4 mg/kg (Environment Canada, 2013). The concentrations of PBDE 99 and PBDE 100 measured in the sediment samples collected during this study were normalized to 1 percent organic carbon to compare them to the FEQGs. The organic-carbon normalized concentrations of PBDE 99 exceeded the FEQG in the 19 streambed-sediment samples in which PBDE 99 was detected (fig. 9). Organic-carbon normalized concentrations of PBDE 99 ranged from 0.5 mg/kg in the sample collected during base-flow conditions at the middle San Pedro site to 8.5 mg/kg in the sample collected during base-flow conditions at the upstream Apache site (fig. 9). The organic-carbon normalized concentrations of PBDE 100 exceed the FEQG in 13 of the 19 streambed-sediment samples in which PBDE 100 was detected. Similar to the results for PBDE 99 and PBDE 100, the remaining brominated flame retardants that were analyzed were also found in the streambed sediments collected from all 10 sites at similar concentrations. The organic-carbon normalized concentrations of the three most frequently

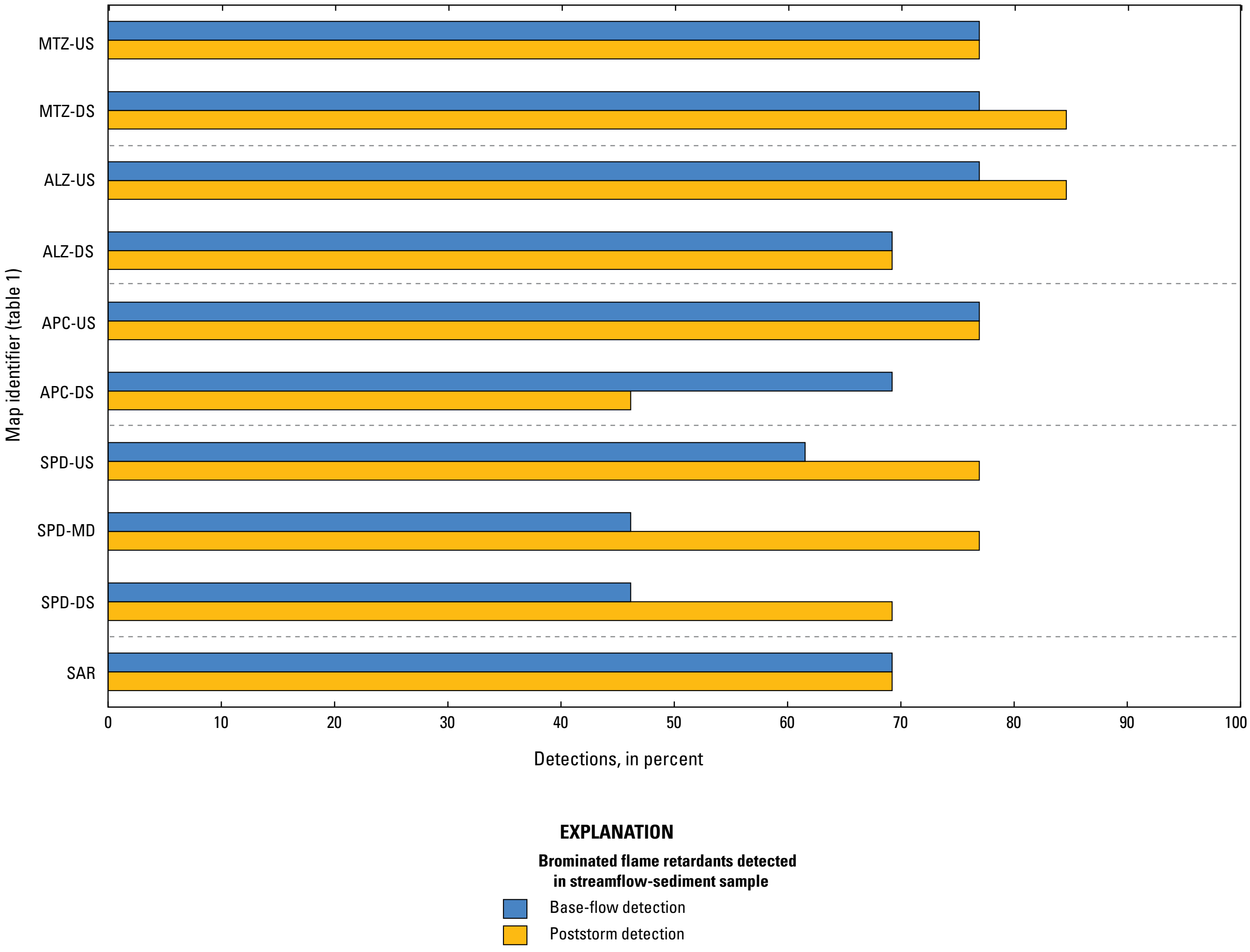


Figure 8. Detection frequencies of 13 brominated flame retardants in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

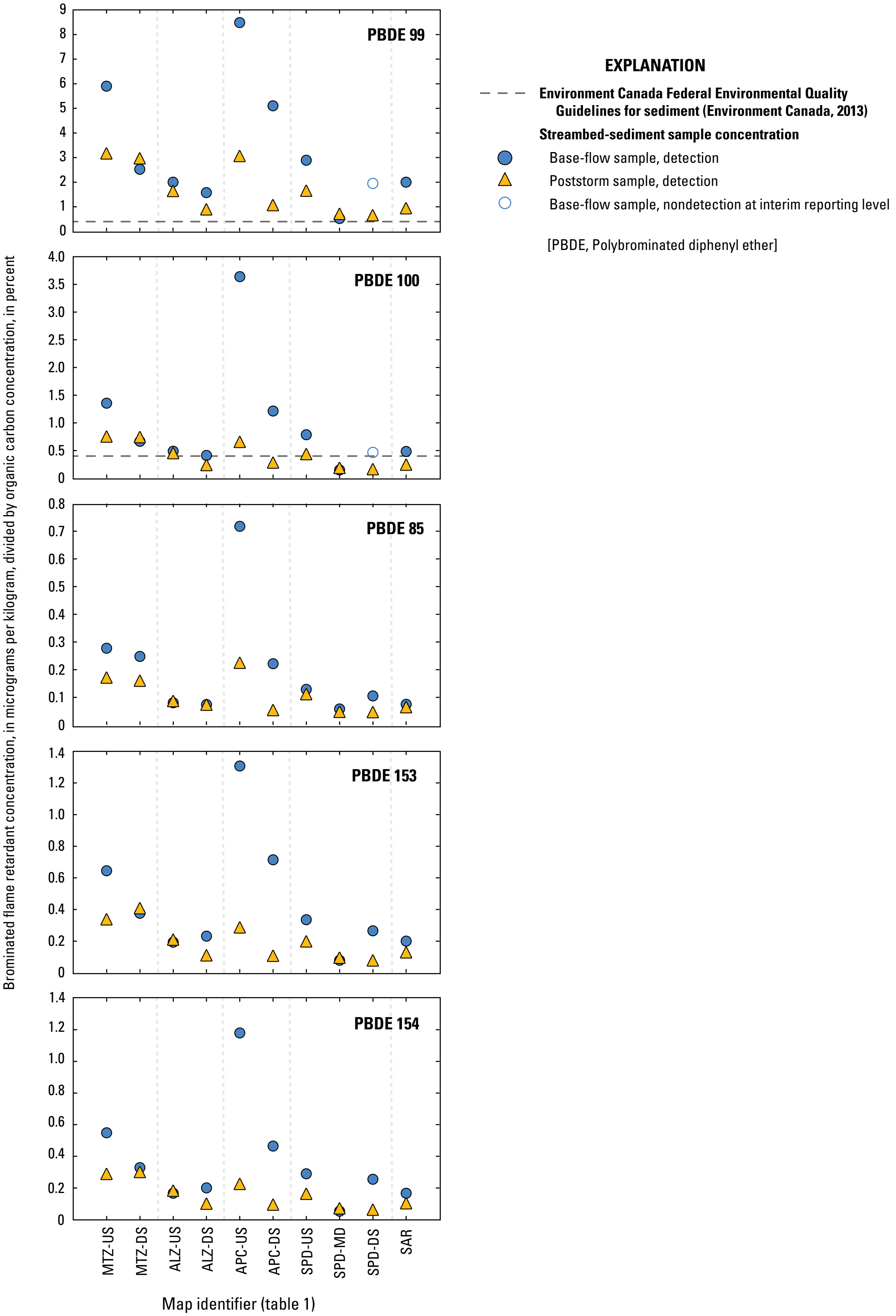


Figure 9. Comparison of select organic-carbon normalized brominated flame retardant concentrations and Environment Canada Federal Environmental Quality Guidelines (FEQGs) for sediment (Environment Canada, 2013) in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

detected compounds, PBDE 85, PBDE 153, and PBDE 154, were compared among the sample collection sites (fig. 9). The concentration variations of PBDEs 85, 153, and 154 were similar to those of PBDE 99 and PBDE 100. The greatest concentrations of organic-carbon normalized PBDEs 85, 99, 100, 153, and 154 were observed in samples collected during base-flow conditions at the upstream Apache site. Concentrations of these compounds in the samples collected at the same site during poststorm conditions were substantially reduced from the base-flow sample concentrations, possibly indicating a source that is diluted during rainfall events.

Polychlorinated Biphenyls

Polychlorinated biphenyls were first synthesized in the early 1930s and have had widespread industrial uses, primarily as plasticizers, hydraulic lubricants, and dielectric fluids in electrical capacitors (Smith and others, 1988). Adverse human health effects and cancer in animals have been associated with exposure to PCBs. Polychlorinated biphenyls have not been manufactured in the United States since 1977, and their use was generally banned in 1979 (the EPA issues exemptions that allow the importation of PCBs by a petition process) (Agency for Toxic Substances and Disease Registry, 2000). The tendency for PCB congeners to volatilize or sorb strongly to solids depends on the degree of chlorination. The larger numbered PCB congeners with at least four chlorine atoms tend to sorb strongly to solids such as sediments, whereas the smaller numbered PCB congeners with three chlorine atoms or less are more likely to volatilize (Eisenreich and others, 1983; Eisenreich and others, 1992; Pearson and others, 1996; Puri and others, 1997).

The NWQL quantified 18 common PCB congeners in the streambed-sediment samples collected from the Westside Creeks and San Antonio River in 2014. The two smallest PCB congeners (49 and 52) were not detected in any of the streambed-sediment samples (Crow and others, 2016). Polychlorinated biphenyl 70 was detected in only two samples collected during base-flow conditions (upstream and downstream Apache sites) (fig. 10). Polychlorinated biphenyls 174, 187, and 194 were found in every streambed-sediment sample collected during both base-flow and poststorm conditions. The median number of detections of the 18 common PCB congeners in the individual samples collected during both base-flow and poststorm conditions was 12.5; the number of detections ranged from 5 in the sample collected from the upstream Apache site during base-flow conditions to 15 in the sample collected from the middle San Pedro site during poststorm conditions.

MacDonald and others (2000) published a consensus-based SQG for total PCBs (table 10). Total PCBs in streambed-sediment samples collected from the Westside Creeks and San Antonio River in 2014 were computed as the sum of the 18 reported congeners (Crow and others, 2016) by using the Kaplan-Meier method for computing summations that include nondetections (Helsel, 2009). The Kaplan-Meier method is a nonparametric statistical method that was developed for evaluating right-censored survival data of people older than a certain age in medical and industrial statistics that has been modified for left-censored environmental data where nondetections are common. Total environmental PCB concentrations adjusted for negative bias (on the basis of organic reference material analysis) indicated that although some adjusted concentrations could possibly exceed the TEC (59.8 mg/kg; table 10) for total PCBs, the negative bias was not great enough to cause adjusted concentrations to exceed the PEC (676 mg/kg; table 10) and thus be possibly toxic to aquatic biota. All concentrations of total PCBs in the individual streambed-sediment samples were less than the TEC (fig. 11). The concentrations of total PCBs in the samples collected during base-flow conditions ranged from an estimated 2.9 mg/kg in the sample collected at the upstream Alazán site to an estimated 35 mg/kg at the middle San Pedro site; the median concentration of total PCBs was an estimated 7.5 mg/kg (Crow and others, 2016). During poststorm conditions, the concentrations of total PCBs in the samples ranged from an estimated 3.8 mg/kg in the sample collected at the downstream Apache site to an estimated 49 mg/kg in the sample collected at the upstream San Pedro site, and the median total PCB concentration was an estimated 6.6 mg/kg. The concentrations of total PCBs in the samples collected during base-flow and poststorm conditions from the upstream and middle San Pedro sites were greater than the concentrations in the samples collected from the other study sites.

Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons are ubiquitous in the urban environment and are derived from numerous sources. Common sources in urban settings include coal-tar-based sealcoat; automobile exhaust; used motor oil; automobile tire particles; and burning wood, oil, coal, or other combustibles for cooking, heating, or energy production. Coal-tar-based sealcoat contains elevated concentrations of PAHs and has been identified as the predominant source of PAHs in many urban environments (Mahler and others, 2005; Van Metre and Mahler, 2010). PAHs rarely occur in the environment as individual compounds but are present as complex mixtures. PAHs are potential human health hazards; several PAH compounds, known as B2 PAHs, have been identified as probable carcinogens (U.S. Environmental Protection Agency, 1993). In this report, total PAH is the sum of 12 compounds: acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene (Ingersoll and others, 2001; 2-methylnaphthalene not included because not measured by the NWQL). The greatest total PAH concentration (99,000 µg/kg) was measured in the poststorm sample

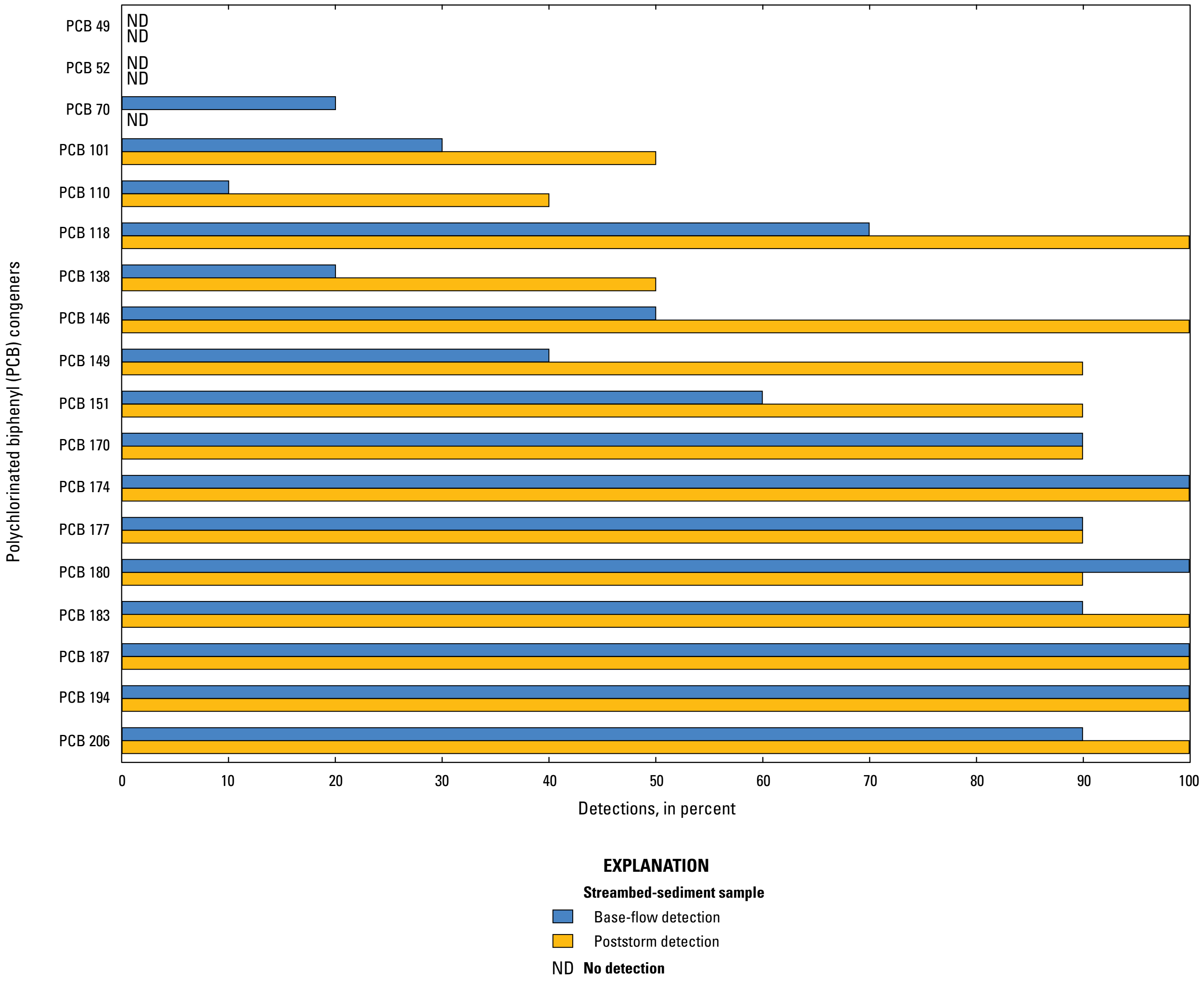
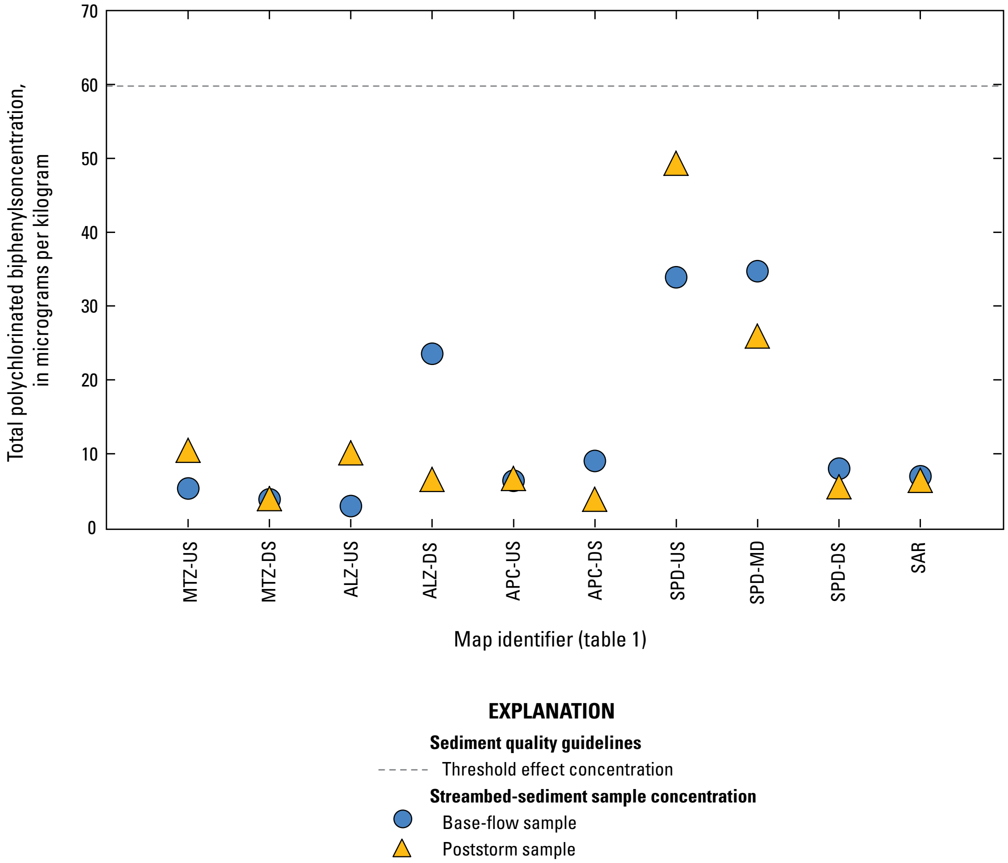


Figure 10. Detection frequencies of polychlorinated biphenyls (PCBs) in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.



[Probable effect concentration of 676 migrograms per kilograpm is not shown on graph]

Figure 11. Comparison of consensus-based sediment quality guidelines (MacDonald and others, 2000) with concentrations of polychlorinated biphenlys (PCBs) in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

collected at the upstream Apache site (Crow and others, 2016). The total PAH concentration in the sample collected at the same site during base-flow conditions (20,000 µg/kg) was also the greatest total PAH concentration measured during base-flow conditions. Land use in the contributing area of the upstream Apache site is typical of the study area (table 1) and therefore provides no insight to the relatively high PAH concentrations measured in the streambed-sediment samples collected from the site compared to all the other sites. The smallest total PAH concentration (750 µg/kg) was measured in the poststorm sample collected at the downstream San Pedro site (Crow and others, 2016).

Streambed-sediment samples were compared to the consensus-based SQGs developed for several individual PAH compounds (anthracene, benz(a)anthracene, benzo(a)pyrene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, naphthalene, phenanthrene, and pyrene) and total PAHs (MacDonald and others, 2000) (fig. 12). Total PAHs and each of the 10 individual PAHs were analyzed in 20 samples resulting in a total of 220 analyses. The TECs of the PAHs for which SQGs were developed were exceeded in 161 of 220 analyses (73 percent); PECs were exceeded in 30 of 220 analyses (14 percent), of which 9 (30 percent) were analyses from the sample collected during poststorm conditions at the upstream Apache site. At the upstream Apache site, 6 of the individual PAHs measured in the sample collected during base-flow conditions exceeded the 9 PECs developed by MacDonald and others (2000) and 8 of the 9 PECs were exceeded in the sample collected during poststorm conditions. The total PAH concentration in the sample collected during poststorm conditions (99,000 mg/kg) at the upstream Apache Creek site was 3.3 times greater than the PEC developed for total PAHs (22,800 mg/kg), making it the most contaminated site in regards to total PAHs in the study area. In general, TECs were exceeded in a greater number of analyses in samples collected during base-flow conditions (76 percent) than in those collected during poststorm conditions (70 percent). The PECs were exceeded in a greater number of analyses during poststorm conditions (17 percent) than in those collected during base-flow conditions (11 percent). The

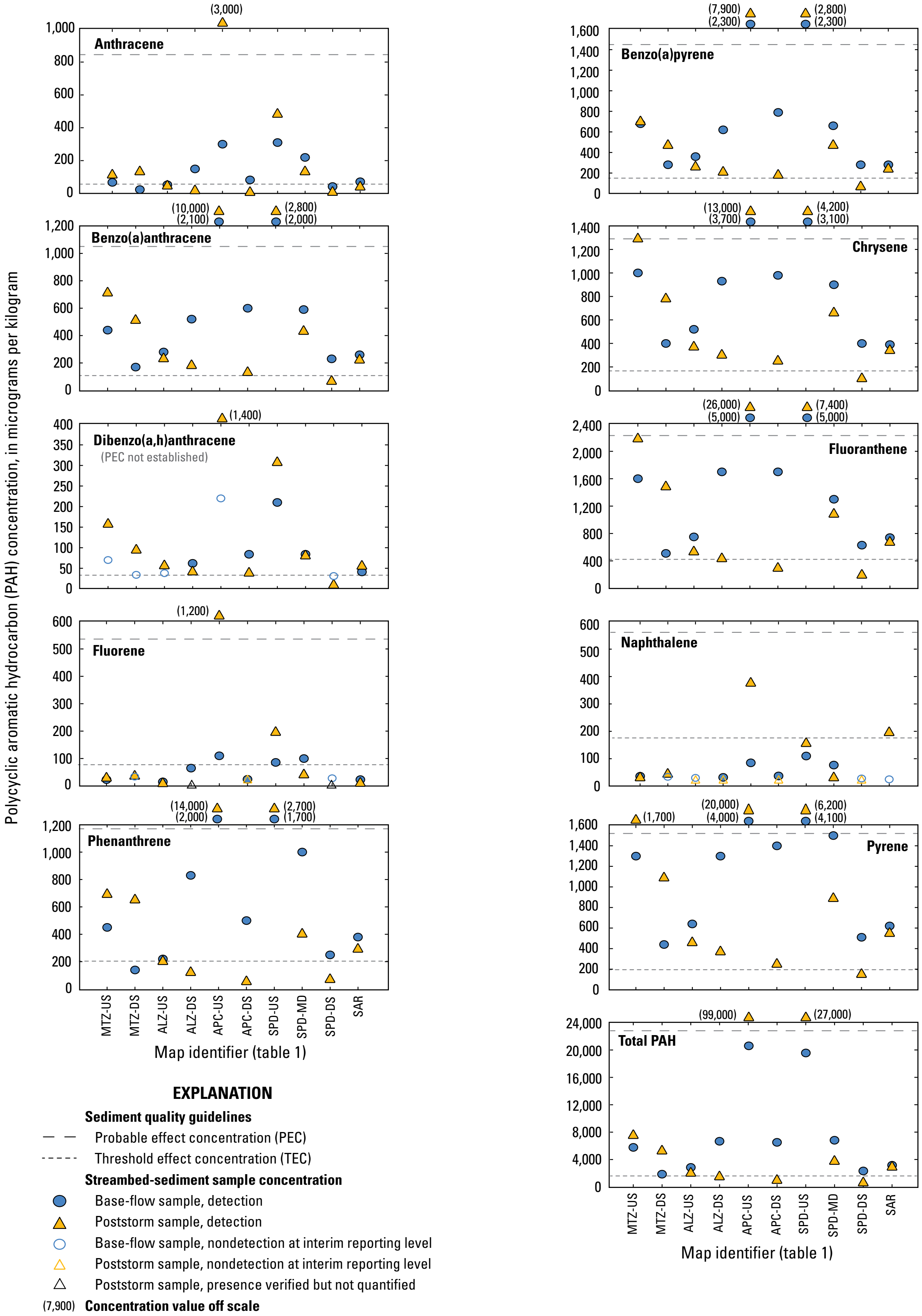


Figure 12. Comparison of consensus-based sediment quality guidelines (MacDonald and others, 2000) with concentrations of polycyclic aromatic hydrocarbons (PAHs) in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

percentage by which a given PAH exceeded its PEC ranged from less than 1 percent for chrysene in the sample collected during poststorm conditions at the upstream Martínez site (chrysene concentration of 1,300 µg/kg; the PEC for chrysene is 1,290 µg/kg) to greater than 1,200 percent for pyrene in the sample collected during poststorm conditions at the upstream Apache Creek site (20,000 µg/kg pyrene concentration; the PEC for pyrene is 1,520 µg/kg). The greatest degree of PEC exceedance (an average of nearly 700 percent from nine analyses) was observed in the sample collected during poststorm conditions at the upstream Apache site.

Van Metre and Mahler (2010, p. 337, table 1) compiled PAH source profiles documented in the literature to compare to bottom sediments deposited post 1990 in lakes across the United States. They normalized the concentrations of 12 selected PAH compounds (phenanthrene, anthracene, fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b) fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(e) pyrene, indenopyrene, and benzo(g,h,i)perylene) to the sum of the 12 compounds to describe the variability of the PAH mixtures. The same 12 PAHs described by Van Metre and Mahler (2010) were normalized by their sum for the streambed-sediment samples collected during base-flow conditions and for those collected during poststorm conditions at the nine sites on the Westside Creeks and the site on the San Antonio River. Average PAH profiles for samples collected during base-flow and stormflow conditions at sites in the study area were computed by averaging each of the 12 normalized compounds in the 10 samples collected during each hydrologic condition. Average PAH profiles computed for base-flow samples and poststorm samples were each compared to seven PAH source profiles compiled by Van Meter and Mahler (2010) (fig. 13). The seven PAH profiles selected for comparison include parking lot coal-tar sealcoat dust, automobile emissions measured in tunnels, emissions from diesel-powered automobiles, emissions from gasoline-powered automobiles, emissions from coal-fired powerplants, used automobile motor oil, and automobile tire particles. These seven PAH profiles were determined by Wilson (2011) to be the most common contributors of PAHs to sediments in Bexar County, Tex., based on results from a chemical mass balance source-receptor model. The PAH profiles of both the average base-flow and poststorm streambed-sediment samples indicated low concentrations of anthracene, benzo(a) anthracene, benzo(k)fluoranthene, indenopyrene, and benzo(g,h,i)perylene and high concentrations of fluoranthene, pyrene, and benzo(b)fluoranthene relative to the overall PAH mixture. The base-flow and poststorm average concentrations of the PAHs were generally the same (within one standard deviation) with the exception of benzo(b)fluoranthene.

The graphical representations of the average base-flow and average poststorm streambed-sediment PAH profiles most closely resemble that of the parking lot coal-tar sealcoat dust PAH source profile (fig. 13), indicating this PAH source could be the largest contributor of PAHs in the averaged samples. Parking lot coal-tar sealcoat is a black, viscous liquid containing coal-tar pitch that is sprayed or painted on asphalt pavement and marketed to improve the appearance and extend the life of asphalt (U.S. Environmental Protection Agency, 2012). The source profile of parking lot coal-tar sealcoat dust is defined as the average of dust swept from coal-tar sealcoated parking lots from six cities in the United States: Minneapolis, Minn., Chicago, Ill., Detroit, Mich., Washington, D.C., New Haven, Conn., and Austin, Tex. (Mahler and others, 2005; Van Metre and others, 2009).

As one of the oldest inhabited areas of San Antonio, the Westside Creeks area has been subjected to urban influences for many years, and the effect of urbanization was evident in the sediment record in the streams. The sediment samples collected at all 10 sites sampled for this characterization contained elevated concentrations of numerous trace elements, pesticides, brominated flame retardants, PCBs, and PAHs; often at concentrations greater than the TECs, and sometimes greater than the PECs established for those constituents. The upstream and middle San Pedro sites were of specific concern because during base-flow and poststorm conditions, elevated concentrations of lead and historical-use pesticides were detected in the sediment samples collected at these sites—concentrations that consistently exceeded applicable PECs. The total PCB concentrations at the upper and middle San Pedro sites, although less than the TEC, were the largest total PCB concentrations measured among all of the sites in the study area. During both base-flow and poststorm conditions, six individual PAHs were greater than their PECs, and total PAHs were greater than the PEC in samples collected during poststorm conditions at the upstream San Pedro site. The sediment collected from the upstream Apache site also contained high concentrations of PAHs. Greater concentrations of the detected PAHs in the poststorm samples compared to the base-flow samples collected at both the upstream San Pedro and upstream Apache sites indicate there are likely active sources of PAHs in the upper reaches of the San Pedro and Apache Creeks.

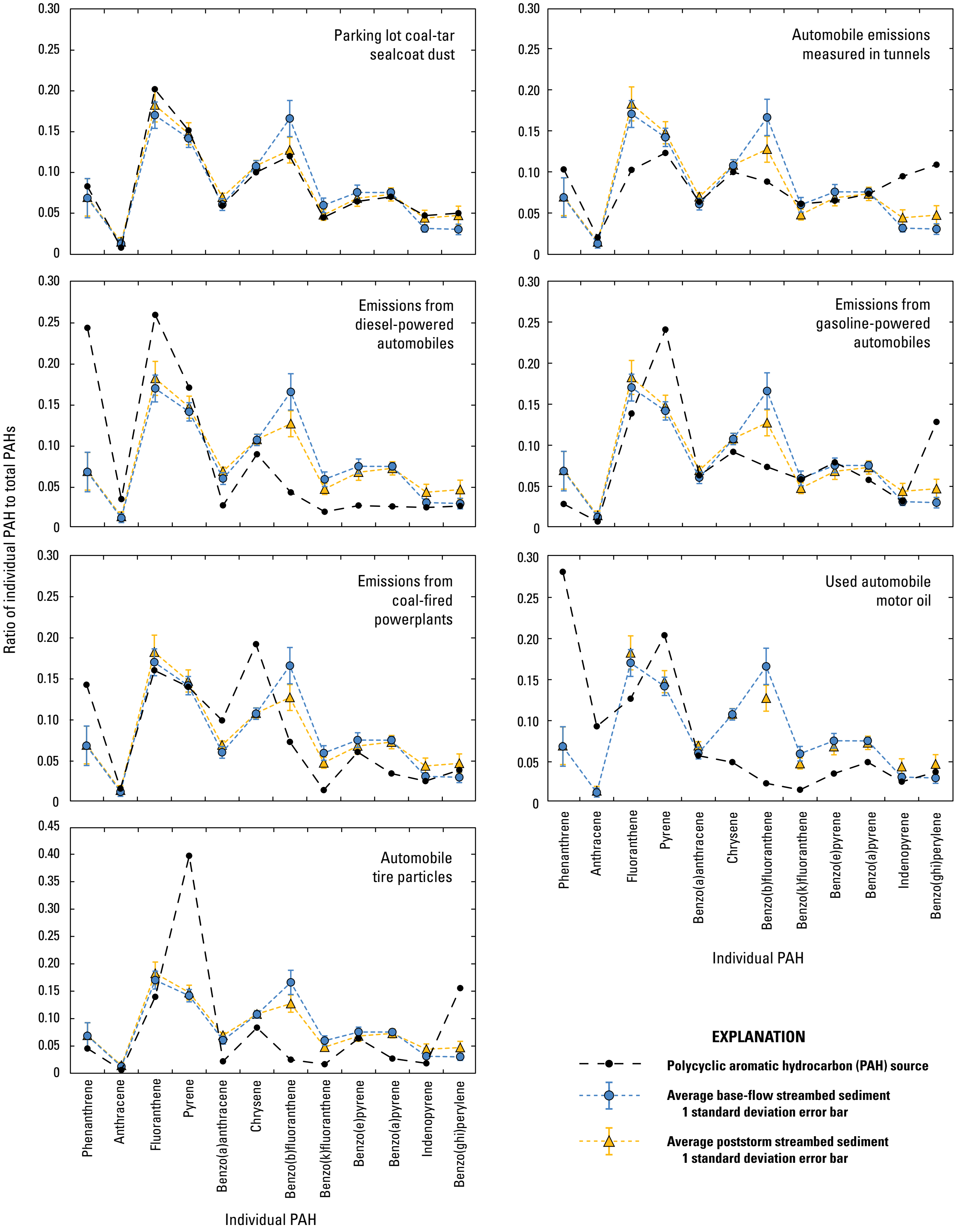


Figure 13. Comparison of polycyclic aromatic hydrocarbon (PAH) profiles for selected PAH sources summarized in Van Metre and Mahler (2010, table 1, p. 337) to PAH profiles for average streambed sediment computed from samples collected during base-flow and poststorm conditions from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

Results of Water-Toxicity Testing

The survival and biomass of fathead minnows were assessed in water collected from each of the 10 sampling sites during base-flow and poststorm conditions and in two types of control water. The control water used for survival testing consisted of diluted and undiluted groundwater (hereinafter referred to as “well water”) from a well at the USGS Columbia Environmental Research Center. The hardness of the undiluted well water was 300 milligrams per liter (mg/L). The undiluted well water was mixed with deionized water to produce diluted well water with a hardness of 100 mg/L.

First, survival of the fathead minnows following exposure to water collected during base-flow conditions was evaluated. Comparisons were made between the survival and biomass of fathead minnows exposed to base-flow environmental water samples or to well water (diluted and undiluted) used in the accompanying control experiments. Control experiments assessing the survival and biomass of fathead minnows in diluted and undiluted well water were run concurrently with the experiments assessing survival and biomass of fathead minnows in water samples collected during base-flow conditions from the nine Westside Creeks sites and from the site on the San Antonio River. The results of the control experiments greatly exceeded the test acceptability criterion of greater than 80 percent survival (U.S. Environmental Protection Agency, 2002) as the survival of fathead minnows was greater than or equal to 95 percent in both the diluted and undiluted well water. Survival and mean biomass did not differ between the control experiments using diluted or undiluted well water.

Six of the ten environmental water samples collected during base-flow conditions resulted in appreciably reduced survival and biomass relative to the control experiments. The water samples collected from the downstream Martínez site, the upstream and downstream Alazán sites, the downstream Apache site, and from the middle and downstream San Pedro sites proved most toxic to the fathead minnows, with survival rates ranging from 35 to 68 percent compared to 95 to 98 percent survival rates in the control experiments. The water sample from the downstream San Pedro site caused the greatest reductions in both survival and mean biomass compared to the control experiments (fig. 14; table 11). The 4-hour pulse exposure to elevated UV in clean control water following initial exposure did not result in any subsequent mortality, either during the pulse or after the 20-hour recovery period.

Second, survival of the fathead minnows following exposure to water collected during poststorm conditions was evaluated. Survival of fathead minnows was 100 percent in both the diluted and undiluted well water control tests that were done in conjunction with the exposure tests using water collected during poststorm conditions. As in the exposure tests using water collected during base flow, the survival exposure experiments using water collected during poststorm conditions were done concurrently with the survival experiments using diluted and undiluted well water collected from the same well used to provide control water in the base-flow exposure tests. Water samples representing poststorm conditions were collected from the same 10 sites that were used in the exposure experiments using water collected during base-flow conditions. The 100-percent survival of fathead minnows in diluted and undiluted well water that was determined in conjunction with the poststorm sample exposure tests greatly exceeded the criterion of greater than 80 percent survival specified for control tests. Survival and biomass did not differ between the two controls. Significant differences between control samples and water collected from the sampling sites were determined by one-way analysis of variance with pairwise comparison using Williams’ test (Williams, 1972). If data were not normally distributed or did not have equal variances, Steel’s many-one rank test (Steel, 1959) or Wilcoxon rank sum test with Bonferroni adjustment was used (U.S. Environmental Protection Agency, 2002). The level of statistical significance was set at $p = 0.05$. Results of the 7-day exposure tests indicated that exposure of the fish to water collected from the sampling sites during poststorm conditions did not significantly reduce survival or biomass relative to exposure of the fish to the diluted or undiluted water used in the control experiments. Survival for fish in all 10 environmental water samples during poststorm conditions was greater than or equal to 97 percent (fig. 14; table 12). The 4-hour pulse exposure to elevated UV in clean water following initial exposure did not result in subsequent mortality, either during the pulse or after the 20-hour recovery period.

Periodically during the toxicity testing, dissolved oxygen concentrations, pH, specific conductance, hardness, alkalinity, and total and unionized ammonia concentrations were measured in the water samples (Crow and others, 2016).The samples were also periodically analyzed for the concentrations of select major ions (calcium, potassium, magnesium, sodium, sulfate, and chloride) during testing (Crow and others, 2016). Both ammonia and major-ions concentrations were considered as potential contributors to fathead minnow toxicity observed during exposure to samples collected during base-flow conditions. Concentrations of ammonia were low (for example, total ammonia less than 0.45 mg/L) relative to published toxicity thresholds for fathead minnows (159.2 mg/L for acute exposure and 9.187 mg/L for chronic exposure) (U.S. Environmental Protection Agency, 2013). The relations between fathead minnow survival and concentrations of major ions (for example, sodium, sulfate, chloride, and specific conductance) in the water samples also were examined, and no appreciable correlations were observed. It is unlikely that the observed toxicity to fathead minnows from the water samples collected during base-flow conditions at the downstream Martínez, upstream Alazán, downstream Alazán, downstream Apache, middle San Pedro Creek, and downstream San Pedro Creek sites was the result of environmental stressors on the organisms caused by differences in water-quality constituents routinely monitored during toxicity testing (major-ion concentrations, dissolved oxygen concentration, pH, specific conductance, hardness, alkalinity, and total and unionized ammonia concentrations).

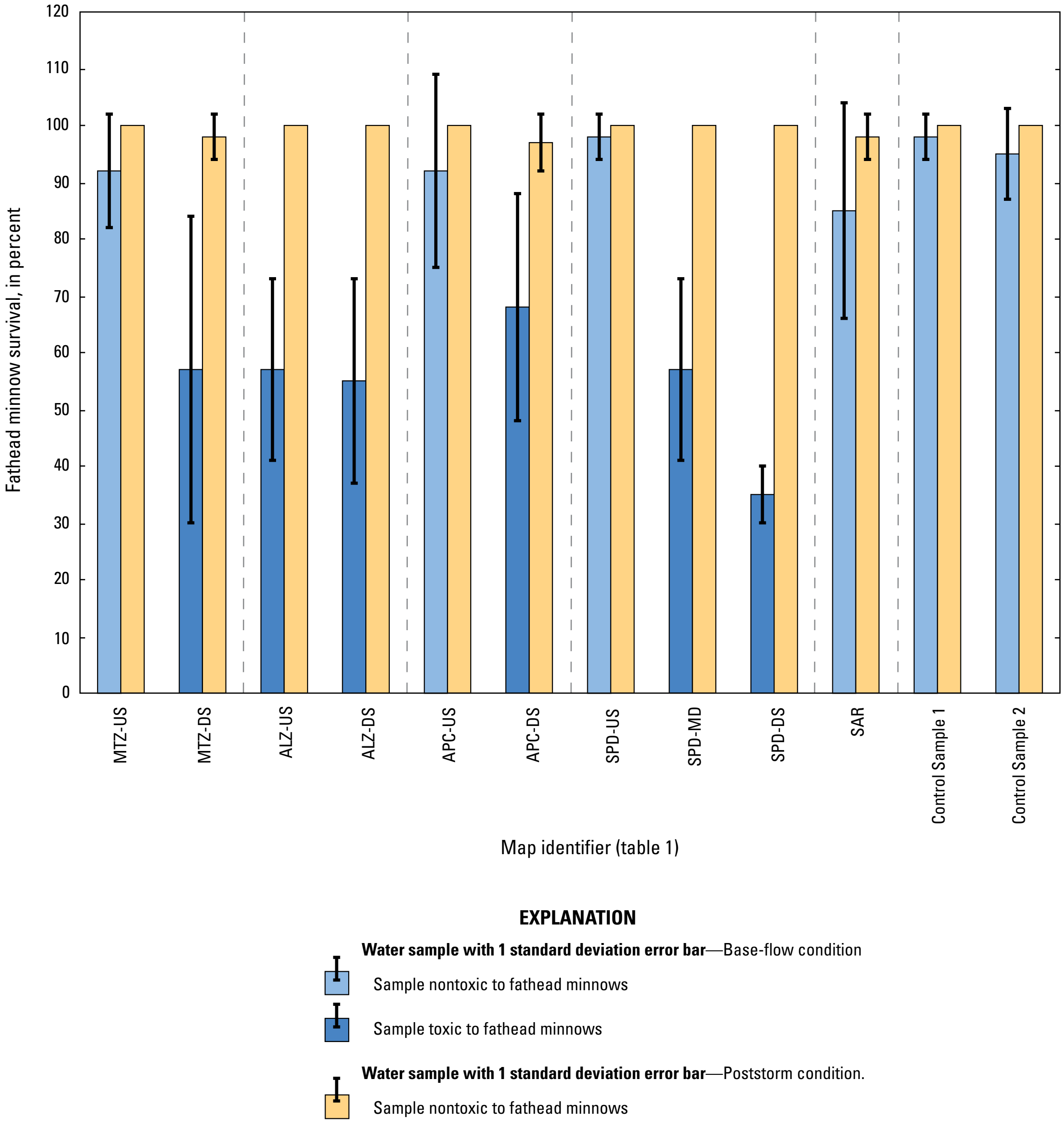


Figure 14. Responses of *Pimephales promelas* (fathead minnow) in 7-day exposure to water samples collected during base-flow and poststorm conditions from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

The relations between fathead minnow survival and concentrations of selected constituents in the streambed-sediment samples collected during base-flow conditions also were examined to determine if any correlations might exist. Fathead minnow survival was compared to concentrations in streambed sediments of lead; the pesticides dieldrin, chlordane, and DDE; the brominated flame retardants PBDE 85, 153, and 154 and Dechlorane Plus, total PCBs; and total PAHs. A sufficient number of detections in the pesticides DDD or DDT were not detected to make a comparison; additionally, the brominated flame retardants PBDE 99 and 100 were not compared because neither compound was detected in the streambed-sediment sample collected in conjunction with the water sample with the smallest survival rate. Linear regression analysis and the coefficient of determination (R^2) are commonly used to assess the relation between two variables of interest; R^2 values range from 0 to 1 and represent the fraction of the variance explained by the linear regression (Helsel and Hirsch, 2002). Linear regression analysis did not indicate a strong relation between fathead minnow survival and any of the examined streambed-sediment constituents. The R^2 values for the relations of survival to the selected streambed-sediment constituents ranged from 0.01 for concentrations of lead, DDE, and total PCBs to 0.44 for concentrations of total PAH.

Table 11. Responses of *Pimephales promelas* (fathead minnow) in 7-day exposure to water samples collected during base-flow conditions from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, January 2014.

[Mean initial weight and standard deviation at the beginning of the test was 0.925 ± 0.126 (sample size = 40); UV, ultraviolet; mg, milligrams; --, not applicable; mg/L, milligrams per liter]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Control sample identifier	Mean survival (percent)	Survival standard deviation (percent)	UV Survival (percent)[1]	Mean biomass (mg)	Biomass standard deviation (mg)
--	--	--	--	--	Control 1 (hardness 100 mg/L)	98	4	100	5.3	0.3
--	--	--	--	--	Control 2 (hardness 300 mg/L)	95	8	100	4.6	0.5
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	--	92	10	100	4.8	0.5
08178375	Martínez Creek at West Poplar Street, San Antonio, Tex.	Downstream Martínez	MTZ-DS	1/27/2014	--	[2]60	27	100	[2]2.9	1.5
08178310	Alazán Creek at West Laurel Street, San Antonio, Tex.	Upstream Alazán	ALZ-US	1/27/2014	--	[2]57	16	100	[2]3.1	0.3
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	1/29/2014	--	[2]55	18	100	[2]3.4	1.4
08178445	Apache Creek at West Commerce Street, San Antonio, Tex.	Upstream Apache	APC-US	1/29/2014	--	92	17	100	5.4	0.6
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	--	[2]70	20	100	[2]3.4	0.8
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	1/29/2014	--	98	4	100	4.3	0.4
08178465	San Pedro Creek at West Cevallos Street, San Antonio, Tex.	Middle San Pedro	SPD-MD	1/31/2014	--	[2]57	16	100	4.5	0.6
08178504	San Pedro Creek at Probandt Street at San Antonio, Tex.	Downstream San Pedro	SPD-DS	1/31/2014	--	[2]35	35	100	[2]1.8	0.7
08178515	San Antonio River at Mission Road, San Antonio, Tex.	San Antonio River	SAR	1/31/2014	--	85	19	100	4.1	0.9

[1] Survival after the 20-hour recovery period under ambient laboratory lighting conditions.

[2] Significant reduction in an endpoint relative to both controls ($p<0.05$).

Table 12. Responses of *Pimephales promelas* (fathead minnow) in 7-day exposure to water samples collected during poststorm conditions from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, May 2014.

[Mean initial weight and standard deviation at the beginning of the test was 1.21 plus or minus 0.21 (sample size = 40); UV, ultraviolet; mg, milligrams; --, not applicable; mg/L, milligrams per liter]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Control sample identifier	Mean survival (percent)	Survival standard deviation (percent)	UV survival (percent)[1]	Mean biomass (mg)	Biomass standard deviation (mg)
--	--	--	--	--	Control 1 (hardness 100 mg/L)	100	--	100	6.1	0.2
--	--	--	--	--	Control 2 (hardness 300 mg/L)	100	--	100	6.1	0.5
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	5/28/2014	--	100	--	100	6.0	0.2
08178375	Martínez Creek at West Poplar Street, San Antonio, Tex.	Downstream Martínez	MTZ-DS	5/28/2014	--	98	4	100	5.5	0.3
08178310	Alazán Creek at West Laurel Street, San Antonio, Tex.	Upstream Alazán	ALZ-US	5/29/2014	--	100	--	100	6.2	0.6
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	--	100	--	100	5.4	0.6
08178445	Apache Creek at West Commerce Street, San Antonio, Tex.	Upstream Apache	APC-US	5/29/2014	--	100	--	100	6.4	0.4
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	5/29/2014	--	97	5	100	5.5	0.5
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	--	100	--	100	5.5	0.5
08178465	San Pedro Creek at West Cevallos Street, San Antonio, Tex.	Middle San Pedro	SPD-MD	5/29/2014	--	100	--	100	5.9	0.6
08178504	San Pedro Creek at Probandt Street at San Antonio, Tex.	Downstream San Pedro	SPD-DS	5/28/2014	--	100	--	100	6.1	0.3
08178515	San Antonio River at Mission Road, San Antonio, Tex.	San Antonio River	SAR	5/28/2014	--	98	4	100	5.8	0.5

[1] Survival after the 20-hour recovery period under ambient laboratory lighting conditions.

Summary

Elevated concentrations of sediment-associated contaminants often are measured in urban areas and in San Antonio, Texas, the seventh most populous city in the United States, sediment-associated contaminants have been detected and documented in previous studies. Sediment-associated contaminants can influence the health of aquatic organisms that ingest particulate matter when bioaccumulation of trace elements and organic compounds occurs. The accumulation of trace elements and organic compounds can cause various physiological issues and can ultimately result in death of aquatic organisms. Subsequent ingestion of aquatic organisms can transfer the accumulated contaminants upward through the food chain resulting in biomagnification.

The Alazán, Apache, Martínez, and San Pedro Creeks in San Antonio, Tex., are part of a network of tributaries to the San Antonio River known locally as the Westside Creeks. The Westside Creeks flow through some of the oldest neighborhoods in San Antonio. In 2008, the San Antonio River Authority (SARA) started a community-based restoration effort working to restore the environmental condition of 14 miles of channelized sections of the Alazán, Apache, Martínez, and San Pedro Creeks, while enhancing or maintaining current flood control components and increasing recreational opportunities. It is anticipated the construction activities on the 14 miles of stream channel could appreciably disturb stream channel sediments.

The U.S. Geological Survey (USGS), in cooperation with SARA, collected sediment samples and samples for water-toxicity testing from sites on Alazán, Apache, Martínez, and San Pedro Creeks, and from a site on the San Antonio River as part of an initial characterization of selected contaminants in the study area. Sediment samples were analyzed for selected constituents, including trace elements and organic contaminants such as pesticides, polychlorinated biphenyls (PCBs), brominated flame retardants, and polycyclic aromatic hydrocarbons (PAHs). The frequencies with which the organic contaminants were detected in the streambed-sediment samples were assessed, and comparisons of concentrations among sites were made to describe the occurrence and distribution of the contaminants. As an indicator of ecological health in relation to mobilized (and thus, possibly bioavailable) contaminants in disturbed streambed sediments, the toxicity of water samples collected from the same locations as sediment samples to the indicator species *Pimephales promelas* (fathead minnow) was evaluated by using standard 7-day water-toxicity testing.

Potential risks of contaminants in streambed-sediment samples were evaluated by comparing concentrations of contaminants in sediment to effects-based sediment quality guidelines (SQGs). The SQGs evaluate the potential toxicity of bed sediments to benthic biota. Two SQG concentration levels were used: (1) a lower level, called the threshold effect concentration (TEC), below which harmful effects to benthic biota are not expected, and (2) a higher level, the probable effect concentration (PEC), above which harmful effects are expected to occur frequently.

The concentrations of the trace elements arsenic, cadmium, mercury, and nickel were less than the TEC in all of the samples. Lead and zinc were most frequently detected at concentrations greater than the TEC. Concentrations of lead in all four samples collected from the upper and middle San Pedro Creek sites were greater than the PEC. Sources of the potentially toxic lead concentrations in the contributing areas of these two sites might include older petroleum storage tanks that in the past could have held leaded fuel or possibly from a variety of automobile components used in the numerous automobile-related businesses in the area.

Some SQGs for organic compounds are for concentrations that are normalized by dividing them by the percentage of organic carbon. Normalizing the concentrations in this manner compensates for differences in concentrations of the organic compounds that could be related to differences in the amount of organic carbon in the samples. The percentages of organic carbon in streambed-sediment samples collected during base flow were greater than the percentages measured in samples collected during poststorm conditions at a majority of the sites. To account for variations in the percentage of organic carbon in the sediment sample, the polybrominated diphenyl ether (PBDE) concentrations were normalized by dividing them by the percentage of organic carbon before comparisons between sites were made.

Of the 19 pesticides investigated in this study, historical-use pesticides that have been banned or are being phased out because of their toxicity and persistence in the environment were more frequently detected in streambed-sediment samples compared to current-use pesticides. Three chlordane compounds (*cis*-chlordane, *trans*-chlordane, and *trans*-nonachlor) were detected in all of the samples collected during both base-flow and poststorm conditions. Pesticides were most frequently detected in concentrations greater than their PECs in samples from the upstream and middle San Pedro sites. During base-flow conditions, concentrations of dichlorodiphenyldichloroethane (DDD), dichlorodiphenyldichloroethylene (DDE), and dichlorodiphenyltrichloroethane (DDT) exceeded their PECs in the sample collected from the middle San Pedro site. During poststorm conditions chlordane, DDD, and DDE concentrations in samples collected at the upstream San Pedro site, and DDD and DDE concentrations at the middle San Pedro site exceeded their PECs.

Brominated flame retardants were found at every site where streambed-sediment samples were collected; available guidelines indicate the measured concentrations were frequently large enough to potentially cause adverse effects on aquatic life. Brominated flame retardants were more frequently detected in samples collected during poststorm conditions than in those collected during base-flow conditions, with the greatest increase in the number of brominated flame retardants detected when comparing samples collected from the San Pedro Creek sites during base-flow and poststorm conditions. PBDEs 85, 153, and 154 were found in all streambed-sediment samples. The organic-carbon normalized concentrations of PBDE 99 and PBDE 100 were compared to Federal Environmental Quality Guidelines (FEQGs) developed by Environment Canada. The organic-carbon normalized concentrations of PBDE 99 exceeded the FEQG developed for this constituent in all 19 streambed-sediment samples in which PBDE 99 was detected. The organic-carbon normalized concentrations of PBDE 100 exceeded the FEQG for PBDE 100 in 13 of the 19 streambed-sediment samples in which PBDE 100 was detected. The organic-carbon normalized concentrations of the three most frequently detected compounds, PBDE 85, PBDE 153, and PBDE 154, were compared among the sample collection sites. The concentration variations of PBDEs 85, 153, and 154 were similar to those of PBDEs 99 and 100. The greatest concentrations of organic-carbon normalized PBDEs 85, 99, 100, 153, and 154 were observed in samples collected during base-flow conditions at the upstream Apache site. Concentrations of these compounds in the samples collected at the same site during poststorm conditions were substantially reduced from the base-flow sample concentrations, possibly indicating a source that is diluted during rainfall events.

Eighteen common PCB congeners were analyzed in the streambed-sediment samples collected from the 10 sites. PCBs 174, 187, and 194 were found in every streambed-sediment sample collected during both base-flow and poststorm conditions. The concentrations of total PCBs, computed as the sum of the 18 reported congeners, did not exceed the TEC in any of the samples. The concentrations of total PCBs in the samples collected during base-flow and poststorm conditions from the upstream and middle sites on San Pedro Creek were greater than the concentrations in the samples collected from the other study sites.

A majority of the 10 individual PAHs and total PAH exceeded their TECs, and the PECs were exceeded in 30 of 220 analyses. In general, TECs were exceeded in a greater number of analyses in samples collected during base-flow conditions than in those collected during poststorm conditions; whereas, PECs were exceeded in a greater number of analyses during poststorm conditions than in those collected during base-flow conditions. At the upstream Apache site, 6 of the individual PAHs measured in the sample collected during base-flow conditions exceeded the 9 established PECs and 8 PECs were exceeded in the sample collected during poststorm conditions. The total PAH concentration in the sample collected during poststorm conditions was 3.3 times greater than the PEC developed for total PAHs, making it the most contaminated site in regards to total PAHs in the study area.

Average PAH profiles for samples collected during base-flow and stormflow conditions at sites in the study area were computed by averaging each of the 12 normalized (to the sum of the 12 compounds) compounds in the 10 samples collected during each hydrologic condition. Average PAH profiles computed for base-flow samples and poststorm samples were compared to seven published PAH source profiles. The graphical representations of the average base-flow and average poststorm streambed-sediment PAH profiles most closely resembled that of the published parking lot coal-tar sealcoat dust PAH source profile, indicating this PAH source, which is a black, viscous liquid containing coal-tar pitch that is sprayed or painted on asphalt pavement to create a protective seal, could be the largest contributor of PAHs in the averaged samples.

Six of the environmental water samples collected during base-flow conditions at the 10 sites were toxic to the fathead minnow relative to both of the controls (reduced survival or biomass). The water samples from five sites caused lowered survival rates ranging from 35 to 68 percent in fathead minnow populations. The 4-hour pulse exposure to elevated ultraviolet radiation (UV) in clean water following initial exposure did not result in subsequent mortality, either during the pulse or after the 20-hour recovery period. The relations between fathead minnow survival and concentrations of major ions measured in the water samples were examined and no appreciable correlations were observed. The relations between fathead minnow survival and concentrations of selected constituents in the streambed-sediment samples collected during base-flow conditions also showed no significant correlations.

Survival for fathead minnow in all 10 environmental water samples collected during poststorm conditions was greater than or equal to 97 percent. The 4-hour pulse exposure to elevated UV in clean water following initial exposure did not result in subsequent mortality, either during the pulse or after the 20-hour recovery period.

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Tables 3 and 5–9

Table 3. Relative percent differences between environmental samples and duplicate samples for trace elements measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

[mg/kg, milligrams per kilogram; ENV, environmental sample; DUP, duplicate sample; RPD, relative percent difference; <, less than; --, no data]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	Thallium (mg/kg)	Antimony (mg/kg)	Arsenic (mg/kg)	Barium (mg/kg)	Beryllium (mg/kg)	Bismuth (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Cobalt (mg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	0.42	1.9	5.2	258	1.2	0.3	0.42	44.5	6.2
					DUP	0.41	1.9	5.2	260	1.2	0.3	0.42	45.1	6.2
					RPD	0.60	0.0	0.0	0.19	0.0	0.0	0.00	0.33	0.0
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	0.39	1.2	6.4	316	1.2	1.22	0.51	40.5	5.5
					DUP	0.40	1.1	6.6	311	1.1	1.08	0.48	39.9	5.3
					RPD	0.63	2.2	0.8	0.40	2.2	3.04	1.52	0.37	0.9
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	0.47	1.3	5.3	374	1.6	0.3	0.31	46.9	7.6
					DUP	0.50	1.3	5.2	399	1.6	0.3	0.32	49.8	7.7
					RPD	1.55	0.0	0.5	1.62	0.0	0.0	0.79	1.50	0.3
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	0.40	1.9	2.9	285	0.92	0.34	0.91	43.0	4.1
					DUP	0.40	2.0	2.8	282	0.94	0.31	0.81	42.9	4.1
					RPD	0.00	1.3	0.9	0.26	0.54	2.31	2.91	0.06	0.0

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	Copper (mg/kg)	Gallium (mg/kg)	Lead (mg/kg)	Lithium (mg/kg)	Manganese (mg/kg)	Molybdenum (mg/kg)	Nickel (mg/kg)	Niobium (mg/kg)	Scandium (mg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	34.9	11.0	78.5	27.6	203	1.5	13.8	8.5	6.3
					DUP	34.9	11.1	76.3	28.7	203	1.6	13.4	8.9	6.5
					RPD	0.00	0.23	0.71	0.98	0.00	1.6	0.74	1.1	0.8
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	38.0	9.90	58.8	24.6	281	1.1	11.8	8.6	5.6
					DUP	35.1	10.2	58.0	24.0	289	1.1	10.6	9.0	5.6
					RPD	1.98	0.75	0.34	0.62	0.70	0.0	2.68	1.1	0.0
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	27.1	13.8	53.1	34.7	325	1.1	16.4	9.3	6.8
					DUP	26.9	14.0	51.9	33.9	330	1.0	16.6	9.7	7.1
					RPD	0.19	0.36	0.57	0.58	0.38	2.4	0.30	1.1	1.1
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	44.7	7.9	238	24.5	198	1.6	7.7	7.0	3.7
					DUP	50.6	7.6	222	21.5	186	1.6	7.8	6.9	3.5
					RPD	3.10	1.0	1.74	3.26	1.56	0.0	0.3	0.4	1.4

Table 3. Relative percent differences between environmental samples and duplicate samples for trace elements measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[mg/kg, milligrams per kilogram; ENV, environmental sample; DUP, duplicate sample; RPD, relative percent difference; <, less than; --, no data]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	Silver (mg/kg)	Strontium (mg/kg)	Tantalum (mg/kg)	Thorium (mg/kg)	Uranium (mg/kg)	Vanadium (mg/kg)	Zinc (mg/kg)	Aluminum (mg/kg)	Calcium (mg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	0.243	239	0.63	8.37	3.00	66.8	208	45,800	125,000
					DUP	0.238	237	0.63	8.85	3.09	68.2	209	46,100	122,000
					RPD	0.52	0.21	0.00	1.39	0.74	0.52	0.12	0.16	0.61
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	0.453	300	0.58	8.83	2.82	60.5	198	41,500	152,000
					DUP	0.460	300	0.60	8.92	2.87	59.0	183	41,700	147,000
					RPD	0.38	0.00	0.85	0.25	0.44	0.63	1.97	0.12	0.84
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	<0.02	266	--	9.45	2.48	82.2	150	56,200	111,000
					DUP	<0.02	268	--	9.61	2.51	87.0	151	55,900	116,000
					RPD	--	0.19	--	0.42	0.30	1.42	0.17	0.13	1.10
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	<0.02	334	--	6.44	2.51	41.9	300	33,900	155,000
					DUP	<0.02	338	--	6.80	2.73	41.8	311	31,500	149,000
					RPD	--	0.30	--	1.36	2.10	0.06	0.90	1.83	0.99

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	Cesium (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Phosphorus (mg/kg)	Potassium (mg/kg)	Rubidium (mg/kg)	Sodium (mg/kg)	Titanium (mg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	5.4	19,200	6,550	789	11,500	66.3	3,260	2,440
					DUP	5.4	19,100	6,590	726	11,500	66.9	3,030	2,550
					RPD	0.0	0.13	0.15	2.08	0.00	0.23	1.83	1.10
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	4.8	17,700	7,370	875	8,410	55.5	2,360	2,040
					DUP	5.1	17,500	7,220	799	8,390	56.6	2,340	2,100
					RPD	1.5	0.28	0.51	2.27	0.06	0.49	0.21	0.72
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	10.0	23,100	8,730	625	11,900	75.1	2,210	2,420
					DUP	14.8	23,400	8,740	635	11,900	76.7	2,910	2,520
					RPD	9.68	0.32	0.03	0.40	0.00	0.53	6.84	1.01
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	8.0	14,400	5,950	884	9,180	50.9	2,410	1,840
					DUP	9.7	14,000	6,100	851	8,800	49.2	2,350	1,840
					RPD	4.8	0.70	0.62	0.95	1.06	0.85	0.63	0.00

Table 5. Results from U.S. Geological Survey National Water Quality Laboratory (NWQL) analysis of National Institute of Standards and Technology (NIST) standard reference materials 8704 and 1941b.

[±, plus or minus; --, no data; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls; <, less than; E, estimated]

Constituent, units	NIST concentration with standard deviation	NWQL concentration	NWQL set spike recovery, percent	NWQL concentration adjusted for set spike recovery
Calcium, milligrams per kilogram	2.641 ± 0.083	2.63	--	--
Magnesium, milligrams per kilogram	1.2 ± 0.018	1.14	--	--
Potassium, milligrams per kilogram	2.001 ± 0.041	1.92	--	--
Sodium, milligrams per kilogram	0.553 ± 0.015	0.57	--	--
Carbon (inorganic plus organic), percent	3.351 ± 0.017	3.33	--	--
Aluminum, milligrams per kilogram	6.1 ± 0.18	5.91	--	--
Barium, milligrams per kilogram	413 ± 13	397	--	--
Cadmium, milligrams per kilogram	2.94 ± 0.29	2.90	--	--
Cesium, milligrams per kilogram	5.83 ± 0.12	6.10	--	--
Chromium, milligrams per kilogram	121.9 ± 3.8	116.0	--	--
Cobalt, milligrams per kilogram	13.57 ± 0.43	13.30	--	--
Iron, milligrams per kilogram	3.97 ± 0.1	3.85	--	--
Lead, milligrams per kilogram	150 ± 17	159	--	--
Manganese, milligrams per kilogram	544 ± 21	551	--	--
Nickel, milligrams per kilogram	42.9 ± 3.7	41.9	--	--
Scandium, milligrams per kilogram	11.26 ± 0.19	11.20	--	--
Titanium, milligrams per kilogram	0.457 ± 0.02	0.31	--	--
Vanadium, milligrams per kilogram	94.6 ± 4	93.4	--	--
Zinc, milligrams per kilogram	408 ± 15	401	--	--
Antimony, milligrams per kilogram	3.07 ± 0.32	2.90	--	--
Arsenic, milligrams per kilogram	17.0	16.6	--	--
cis-Chlordane, micrograms per kilogram	0.85 ± 0.11	0.08	77.5	0.11
cis-Nonachlor, micrograms per kilogram	0.378 ± 0.053	0.071	82.6	0.086
DDD, micrograms per kilogram	4.66 ± 0.46	<2.18	89.1	--
DDE, micrograms per kilogram	3.22 ± 0.28	<1	76	--
DDT, micrograms per kilogram	1.12 ± 0.42	<4	96.9	--
trans-Chlordane, micrograms per kilogram	0.566 ± 0.093	0.059	81.5	0.072
trans-Nonachlor, micrograms per kilogram	0.438 ± 0.073	0.009	83.1	0.011
PCB congener 49, micrograms per kilogram	4.34 ± 0.28	<3.52	75.1	--
PCB congener 52, micrograms per kilogram	5.24 ± 0.28	<1	69.1	--
PCB congener 70, micrograms per kilogram	4.99 ± 0.29	<2	78.8	--
PCB congener 101, micrograms per kilogram	5.11 ± 0.34	0.909	79.2	1.15
PCB congener 110, micrograms per kilogram	4.62 ± 0.36	<1	80.2	--
PCB congener 118, micrograms per kilogram	4.23 ± 0.19	2.03	74.8	2.71
PCB congener 138, micrograms per kilogram	3.6 ± 0.28	<2.02	76.0	--

Table 5. Results from U.S. Geological Survey National Water Quality Laboratory (NWQL) analysis of National Institute of Standards and Technology (NIST) standard reference materials 8704 and 1941b.—Continued

[±, plus or minus; --, no data; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls; <, less than; E, estimated]

Constituent, units	NIST concentration with standard deviation	NWQL concentration	NWQL set spike recovery, percent	NWQL concentration adjusted for set spike recovery
PCB congener 146, micrograms per kilogram	1.22 ± 0.12	<0.524	75.2	--
PCB congener 149, micrograms per kilogram	4.35 ± 0.26	2.06	72.9	2.83
PCB congener 170, micrograms per kilogram	1.35 ± 0.09	0.886	74.3	1.19
PCB congener 174, micrograms per kilogram	1.51 ± 0.39	0.743	72.3	1.03
PCB congener 180, micrograms per kilogram	3.24 ± 0.51	1.69	75.0	2.25
PCB congener 183, micrograms per kilogram	0.979 ± 0.087	0.42	72.0	0.58
PCB congener 187, micrograms per kilogram	2.17 ± 0.22	1.07	71.7	1.49
PCB congener 194, micrograms per kilogram	1.04 ± 0.06	0.471	75.1	0.63
PCB congener 206, micrograms per kilogram	2.42 ± 0.19	1.29	74.4	1.73
1-Methylphenanthrene, micrograms per kilogram	73.2 ± 5.9	<117.25	--	--
1-Methylpyrene, micrograms per kilogram	52.5 ± 2.3	<117.25	--	--
2,6-Dimethlnaphthalene, micrograms per kilogram	75.9 ± 4.5	162	77.8	208
2-Methylanthracene, micrograms per kilogram	36 ± 15	<119	--	--
9H-fluorene, micrograms per kilogram	85 ± 15	89.6	80.4	111
Acenaphthene, micrograms per kilogram	38.4 ± 5.2	31.7	79.6	40
Acenaphthylene, micrograms per kilogram	53.3 ± 6.4	98.5	75.1	131
Anthracene, micrograms per kilogram	184 ± 18	237	85.2	278
Benzo[a]anthracene, micrograms per kilogram	335 ± 25	319	98.7	323
Benzo[a]pyrene, micrograms per kilogram	358 ± 17	264	100	264
Benzo[b]fluoranthene, micrograms per kilogram	453 ± 21	E692	117	E590
Benzo[e]pyrene, micrograms per kilogram	325 ± 25	347	114	304
Benzo[ghi]perylene, micrograms per kilogram	307 ± 45	E135	109	E124
Benzo[k]fluoranthene, micrograms per kilogram	225 ± 18	E250	111	E225
Chrysene, micrograms per kilogram	291 ± 31	450	102	439
Dibenzo[a,h]anthracene, micrograms per kilogram	53 ± 10	<117.25	--	--
Fluoranthene, micrograms per kilogram	651 ± 50	780	95	818
Indenopyrene, micrograms per kilogram	341 ± 57	E131	106	E123
Naphthalene, micrograms per kilogram	848 ± 95	1,020	77.0	1,325
Perylene, micrograms per kilogram	397 ± 45	498	99.2	502
Phenanthrene, micrograms per kilogram	406 ± 44	525	87.5	600
Pyrene, micrograms per kilogram	581 ± 39	629	93.7	671
Thorium, milligrams per kilogram	9.07 ± 0.16	10.9	--	--
Uranium, milligrams per kilogram	3.09 ± 0.13	3.37	--	--

Table 6. Relative percent differences between environmental samples and duplicate samples for halogenated organic compounds measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

[µg/kg, micrograms per kilogram; ENV, environmental sample; <, less than; DUP, duplicate sample; RPD, relative percent difference; --, no data; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls; PBDE, polybrominated diphenyl ether]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	alpha-Endosulfan (µg/kg)	Benfluralin (µg/kg)	beta-Endosulfan (µg/kg)	Chlorpyrifos (µg/kg)	*cis*-Chlordane (µg/kg)	*cis*-Nonachlor (µg/kg)	Cyfluthrin (µg/kg)	DCPA (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	<0.2	<0.2	<0.2	<0.2	4.58	2.86	<9.76	<0.2
					DUP	<0.2	<0.2	<0.2	0.48	4.26	2.37	<7.91	<0.2
					RPD	--	--	--	--	1.81	4.68	--	--
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	<0.2	<0.2	<0.2	<0.2	1.01	0.55	<4.43	<0.2
					DUP	<0.2	<0.2	<0.2	0.28	2.10	0.96	E3.54	0.02
					RPD	--	--	--	--	17.5	13.7	--	--
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	<0.2	<0.2	<0.2	<0.2	1.76	0.49	<0.2	<0.2
					DUP	<0.2	<0.2	<0.2	<0.2	1.60	0.53	<0.2	<0.2
					RPD	--	--	--	--	2.38	1.87	--	--
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	<0.2	<0.2	<0.2	E0.23	9.08	3.71	E1.48	0.01
					DUP	<0.2	<0.2	<0.2	E0.19	6.43	2.74	E1.47	<0.2
					RPD	--	--	--	4.76	8.54	7.52	0.17	--

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	Desulfinyl-fipronil (µg/kg)	Dieldrin (µg/kg)	Endosulfan sulfate (µg/kg)	Fipronil sulfide (µg/kg)	Fipronil (µg/kg)	lambda-Cyhalothrin (µg/kg)	Oxychlordane (µg/kg)	Oxyfluorfen (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	0.317	<0.1	<0.4	0.336	<0.1	1.71	<1	<4
					DUP	<0.288	2.81	<0.4	<0.27	<0.1	1.58	<1	<4
					RPD	--	--	--	--	--	1.98	--	--
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	<0.125	<0.1	<0.4	<0.1	<0.1	1.49	<1	<4
					DUP	<0.1	0.573	<0.4	<0.1	<0.1	1.78	<1	<4
					RPD	--	--	--	--	--	4.43	--	--
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	<0.1	E0.662	<0.4	<0.1	<0.1	<0.2	<1	<4
					DUP	<0.1	E0.608	<0.4	<0.1	<0.1	<0.2	<1	<4
					RPD	--	2.13	--	--	--	--	--	--
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	0.189	E2.72	<0.4	0.261	<0.435	<0.2	<1	<4
					DUP	0.229	E2.78	<0.4	0.352	<0.469	<0.2	<1	<4
					RPD	4.78	0.55	--	7.42	--	--	--	--

Table 6. Relative percent differences between environmental samples and duplicate samples for halogenated organic compounds measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[µg/kg, micrograms per kilogram; ENV, environmental sample; <, less than; DUP, duplicate sample; RPD, relative percent difference; --, no data; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls; PBDE, polybrominated diphenyl ether]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	DDD (µg/kg)	DDE (µg/kg)	DDT (µg/kg)	Pendimethalin (µg/kg)	Tefluthrin (µg/kg)	Tetradifon (µg/kg)	*trans*-Chlordane (µg/kg)	*trans*-Nonachlor (µg/kg)	Trifluralin (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	<2	<1	<4	<1	<0.5	<0.2	4.58	5.24	<0.2
					DUP	<2	<1	<4	<1	<0.5	<0.2	4.39	4.57	<0.2
					RPD	--	--	--	--	--	--	1.06	3.41	--
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	<2	22.1	<4	<1	<0.5	<0.2	1.03	1.28	<0.2
					DUP	<8.18	17.3	E11.7	<1	<0.5	<0.2	1.58	2.20	<0.2
					RPD	--	6.09	--	--	--	--	10.5	13.2	--
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	2.96	6.72	0.829	<1	<0.5	<0.2	1.3	1.54	<0.2
					DUP	<2.12	5.41	0.852	<1	<0.5	<0.2	1.3	1.48	<0.2
					RPD	--	5.40	0.68	--	--	--	0.00	0.99	--
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	E30.3	41.5	<4	<1	<0.5	<0.2	E8.82	5.07	<0.2
					DUP	E22.1	28.2	<4	<1	<0.5	<0.2	E5.74	3.75	<0.2
					RPD	7.82	9.54	--	--	--	--	10.6	7.48	--

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	PCB 49 (µg/kg)	PCB 52 (µg/kg)	PCB 70 (µg/kg)	PCB 101 (µg/kg)	PCB 110 (µg/kg)	PCB 118 (µg/kg)	PCB 138 (µg/kg)	PCB 146 (µg/kg)	PCB 149 (µg/kg)	PCB 151 (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	<2	<1	<2	<1	<1	<0.1	<0.1	<0.176	<1	<0.1
					DUP	<2	<1	<2	<1	<1	<0.1	<0.1	<0.175	<1	<0.1
					RPD	--	--	--	--	--	--	--	--	--	--
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	<2	<1	2.94	<1	<1	<0.1	<0.1	<0.214	<1	<0.1
					DUP	E6.42	<1	<2	<1	<2.63	0.646	<0.1	<0.195	<1	0.197
					RPD	--	--	--	--	--	--	--	--	--	--
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	<2	<1	<2	<1	<1	0.19	0.75	0.135	0.664	0.160
					DUP	<2	<1	<2	<1	0.548	0.19	0.63	0.098	0.643	0.138
					RPD	--	--	--	--	--	0.26	4.28	8.04	0.80	3.69
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	<2	<1	<2	2.93	<10.7	3.20	6.06	1.29	5.72	1.24
					DUP	<2	<1	<2	2.06	<10.3	2.89	5.10	1.08	4.85	0.95
					RPD	--	--	--	8.72	--	2.55	4.30	4.43	4.12	6.52

Table 6. Relative percent differences between environmental samples and duplicate samples for halogenated organic compounds measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[µg/kg, micrograms per kilogram; ENV, environmental sample; <, less than; DUP, duplicate sample; RPD, relative percent difference; --, no data; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls; PBDE, polybrominated diphenyl ether]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	PCB 170 (µg/kg)	PCB 174 (µg/kg)	PCB 177 (µg/kg)	PCB 180 (µg/kg)	PCB 183 (µg/kg)	PCB 187 (µg/kg)	PCB 194 (µg/kg)	PCB 206 (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	0.432	0.416	0.250	0.859	0.126	0.49	0.208	0.256
					DUP	0.478	0.305	0.199	0.682	<0.1	0.37	0.147	0.165
					RPD	2.53	7.70	5.68	5.74	--	6.98	8.59	10.8
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	0.684	0.412	0.28	1.04	0.159	0.562	0.288	0.458
					DUP	0.963	0.429	0.30	1.09	0.244	0.599	0.265	0.653
					RPD	8.47	1.01	1.72	1.17	10.5	1.59	2.08	8.78
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	0.566	0.363	0.242	0.896	0.197	0.412	0.164	0.111
					DUP	0.491	0.299	0.203	0.756	0.170	0.335	0.174	0.124
					RPD	3.55	4.83	4.38	4.24	3.68	5.15	1.48	2.77
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	4.24	2.73	1.89	6.82	1.340	3.42	1.4	0.970
					DUP	3.07	1.96	1.40	4.91	0.944	2.45	1.0	0.649
					RPD	8.00	8.21	7.45	8.14	8.67	8.26	8.3	9.91

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	1,2-bis(2,4,6-tribromophenoxy) ethane (TBE) (µg/kg)	PBDE 47 (µg/kg)	PBDE 66 (µg/kg)	PBDE 71 (µg/kg)	PBDE 85 (µg/kg)	PBDE 99 (µg/kg)	PBDE 100 (µg/kg)	PBDE 138 (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	0.36	14.2	0.474	<0.1	0.856	18.3	4.23	0.204
					DUP	1.43	12.5	0.346	<0.1	0.608	15.2	3.48	<0.1
					RPD	29.9	3.18	7.80	--	8.47	4.63	4.86	--
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	0.502	13.4	0.423	<0.1	0.624	14.3	3.35	<0.1
					DUP	<0.32	10.0	0.275	<0.1	0.546	13.0	2.96	0.156
					RPD	--	7.26	10.6	--	3.33	2.38	3.09	--
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	E0.0865	0.813	0.0462	<0.1	E0.0796	0.976	0.257	<0.1
					DUP	E0.0826	<0.734	0.0438	<0.1	E0.0651	0.924	0.244	<0.1
					RPD	1.15	--	1.33	--	5.01	1.37	1.30	--
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	E0.384	E5.02	E0.231	<0.152	E0.412	E6.09	E1.61	<0.1
					DUP	<0.1	E5.48	E0.218	E0.513	E0.393	E6.66	E1.72	<0.1
					RPD	--	2.19	1.45	--	1.18	2.24	1.65	--

Table 6. Relative percent differences between environmental samples and duplicate samples for halogenated organic compounds measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[µg/kg, micrograms per kilogram; ENV, environmental sample; <, less than; DUP, duplicate sample; RPD, relative percent difference; --, no data; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls; PBDE, polybrominated diphenyl ether]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	PBDE 153 (µg/kg)	PBDE 154 (µg/kg)	PBDE 183 (µg/kg)	Methyl triclosan (µg/kg)	Octa-chloro-styrene (µg/kg)	Penta-bromo-toluene (µg/kg)	De-chlorane plus (µg/kg)	Triclo-san (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	1.96	1.73	<0.1	<6	<1	<1	0.57	<4
					DUP	1.63	1.28	<0.62	<6	<1	<1	1.28	<4
					RPD	4.60	7.48	--	--	--	--	19.3	--
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	2.00	1.29	<0.1	<6	<1	<1	0.79	E28.9
					DUP	1.65	1.33	<0.266	<6	<1	<1	1.03	E4.33
					RPD	4.79	0.76	--	--	--	--	6.50	37.0
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	0.115	0.1100	<0.1	<6	<1	<1	0.09	<4
					DUP	0.121	0.0995	E0.0695	<6	<1	<1	0.12	<4
					RPD	1.27	2.51	--	--	--	--	7.09	--
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	E0.729	0.598	0.226	<6	<1	<1	1.83	E6.42
					DUP	E0.671	0.608	<0.152	<6	<1	<1	0.76	E5.81
					RPD	2.07	0.415	--	--	--	--	20.6	2.49

Table 7. Relative percent differences between environmental samples and duplicate samples for polycyclic aromatic hydrocarbons measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

[µg/kg, micrograms per kilogram; ENV, environmental sample; <, less than; DUP, duplicate sample; RPD, relative percent difference; --, no data; E, estimated]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	2,6-Dimethlnaphthalene (µg/kg)	Anthracene (µg/kg)	9,10-Anthraquinone (µg/kg)	Benzo[a] pyrene (µg/kg)	Bis(2-ethylhexyl) phthalate (µg/kg)	Carbazole (µg/kg)	Diethyl phthalate (µg/kg)	Fluoranthene (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	68.3	68.0	343	678	1,420	150	<31.75	1,650
					DUP	70.6	80.3	347	799	1,650	155	<28	1,690
					RPD	0.83	4.15	0.29	4.10	3.75	0.82	--	0.60
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	83.2	82.7	286	786	1,350	140	<32	1,740
					DUP	54.9	50.7	188	421	726	85.1	<32.5	899
					RPD	10.25	12.0	10.3	15.1	15.0	12.2	--	15.9
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	<25	25.2	E59.6	223	142	24.4	<25	448
					DUP	<25	15.3	E102	187	<90	42.0	<25	543
					RPD	--	12.2	13.1	4.39	--	13.3	--	4.79
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	95.7	494	910	2,790	E779	E648	<25	E7,430
					DUP	81.6	437	864	2,650	E791	E579	<25	E6,980
					RPD	3.98	3.06	1.30	1.29	0.38	2.81	--	1.56

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	Naphthalene (µg/kg)	Phenanthrene (µg/kg)	Pyrene (µg/kg)	Benzo[a] anthracene (µg/kg)	Hexachlorobenzene (µg/kg)	Pentachloronitrobenzene (µg/kg)	1,2,4-Trichlorobenzene (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	35.6	453	1,280	442	<31.75	<31.75	<31.75
					DUP	32.4	474	1,320	486	<28	<28	<28
					RPD	2.35	1.13	0.77	2.37	--	--	--
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	37.0	501	1,390	598	<32	<32	<32
					DUP	<32.5	306	722	288	<32.5	<32.5	<32.5
					RPD	--	12.1	15.8	17.5	--	--	--
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	<25	129	380	186	<25	<25	<25
					DUP	<25	188	448	140	<25	<25	<25
					RPD	--	9.31	4.11	7.06	--	--	--
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	161	2,690	E6,190	2,800	<25	<25	<25
					DUP	215	2,470	E5,840	2,540	<25	<25	<25
					RPD	7.18	2.13	1.45	2.43	--	--	--

Table 7. Relative percent differences between environmental samples and duplicate samples for polycyclic aromatic hydrocarbons measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[µg/kg, micrograms per kilogram; ENV, environmental sample; <, less than; DUP, duplicate sample; RPD, relative percent difference; --, no data; E, estimated]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	1,2-Dimethyl-naphthalene (µg/kg)	1,6-Dimethyl-naph-thalene (µg/kg)	1-Methyl-9H-fluorene (µg/kg)	1-Methyl-phenan-threne (µg/kg)	1-Methyl-pyrene (µg/kg)	2,3,6-Trimethyl-naph-thalene (µg/kg)	2-Ethyl-naph-thalene (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	<31.75	<31.75	<31.75	35.7	44.1	<31.75	<31.75
					DUP	<28	<28	<28	38.7	53.0	<28	<28
					RPD	--	--	--	2.02	4.58	--	--
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	<32	<32	4.92	39.7	54.4	<32	<32
					DUP	<32.5	<32.5	<32.5	25.2	30.6	<32.5	<32.5
					RPD	--	--	--	11.2	14.0	--	--
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	<25	<25	1.42	11.1	21.7	<25	<25
					DUP	<25	<25	<25	10.8	19.3	<25	<25
					RPD	--	--	--	0.68	2.93	--	--
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	21.6	32.5	37.0	208	218	43.0	<25
					DUP	13.8	31.1	26.6	203	210	21.9	18.6
					RPD	11.0	1.10	8.18	0.61	0.93	16.3	--

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	2-Methyl-anthra-cene (µg/kg)	Benzo[def] fluorene (µg/kg)	9H-Fluo-rene (µg/kg)	Ace-naph-thene (µg/kg)	Ace-naph-thylene (µg/kg)	Benzo[b] fluoran-thene (µg/kg)	Benzo[e] pyrene (µg/kg)	Benzo[ghi] perylene (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	<31.75	75.9	23.1	14.4	<31.75	E1,660	768	E255
					DUP	<28	79.9	27.8	16.7	<28	E1,370	890	E238
					RPD	--	1.28	4.62	3.70	--	4.79	3.68	1.72
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	<32	77.0	24.2	17.3	<32	E1,610	726	E364
					DUP	<32.5	43.4	18.1	11.7	11.8	E908	427	E207
					RPD	--	14.0	7.21	9.66	--	13.9	13.0	13.7
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	<25	23.0	6.64	3.78	4.18	368	208	E156
					DUP	<25	15.8	6.29	4.35	6.01	352	188	E129
					RPD	--	9.28	1.34	3.55	9.02	1.11	2.53	4.74
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	110	432	197	178	65.5	E4,680	E2,340	E1,180
					DUP	100	396	165	154	66.0	E4,340	E2,170	E1,130
					RPD	2.43	2.17	4.42	3.61	0.19	1.88	1.88	1.08

Table 7. Relative percent differences between environmental samples and duplicate samples for polycyclic aromatic hydrocarbons measured in streambed-sediment samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[µg/kg, micrograms per kilogram; ENV, environmental sample; <, less than; DUP, duplicate sample; RPD, relative percent difference; --, no data; E, estimated]

U.S. Geological Survey station number	U.S. Geological Survey station name	Short name for sampling site	Map identifier (fig. 1)	Sample date	Sample type	Benzo[k] fluoranthene (µg/kg)	Chrysene (µg/kg)	Dibenzo [a,h] anthracene (µg/kg)	Dibenzothiophene (µg/kg)	Indenopyrene (µg/kg)	Pentachloroanisole (µg/kg)	Perylene (µg/kg)	Phenanthridine (µg/kg)
08178345	Martínez Creek at West Hildebrand Avenue, San Antonio, Tex.	Upstream Martínez	MTZ-US	1/27/2014	ENV	E636	1,010	<70.5	<31.75	E276	<31.75	171	25.4
					DUP	E544	1,100	<69.4	<29	E261	<28	209	25.4
					RPD	3.90	2.13	--	--	1.40	--	5.00	0.00
08178460	Apache Creek at South Brazos Street, San Antonio, Tex.	Downstream Apache	APC-DS	1/29/2014	ENV	E506	983	E84.3	<32	E360	<32	209	22.8
					DUP	E336	604	53.0	<32.5	E202	<32.5	115	<32.5
					RPD	10.1	11.9	11.4	--	14.1	--	14.5	--
08178410	Alazán Creek at Tampico Street, San Antonio, Tex.	Downstream Alazán	ALZ-DS	5/29/2014	ENV	134	308	E44.2	6.32	E142	<25	61.5	<25
					DUP	128	306	E38.4	8.55	E126	<25	47.6	<25
					RPD	1.15	0.16	3.51	7.50	2.99	--	6.37	--
08178100	San Pedro Creek at Santa Rosa Street, San Antonio, Tex.	Upstream San Pedro	SPD-US	5/28/2014	ENV	E1,640	4,180	E313	137	E1,080	<25	E799	100
					DUP	E1,560	3,820	E324	136	E1,050	<25	E763	84.6
					RPD	1.25	2.25	0.86	0.18	0.70	--	1.15	4.17

Table 8. Analytical results for halogenated organic compounds found in laboratory set blank samples, and set spike data associated with samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

[PBDE, polybrominated diphenyl ether; µg/kg, micrograms per kilogram; <, less than; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls]

Set number	Sample identifier, units	1,2-Bis (2,4,6-tribromo-phenoxy) ethane	PBDE 183	PBDE 138	PBDE 85	PBDE 153	PBDE 154	PBDE 99	PBDE 100	PBDE 47	PBDE 71	PBDE 66	Ben-flur-alin	Chlor-pyrifos
201407007	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.30	0.086	0.80	<0.1	<0.1	<0.2	<0.2
	Spike, percent recovery	83	73	78	93	97	96	110	90	150	70	72	63	110
	Spike acceptable range lower limit, percent recovery	49	36	28	36	38	47	27	27	24	37	11	10	19
	Spike acceptable range upper limit, percent recovery	157	162	166	168	158	143	183	159	192	163	137	124	169
201417415	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	0.036	0.26	<0.1	<0.1	<0.2	<0.2
	Spike, percent recovery	140	95	100	110	95	93	110	96	140	93	110	31	83
	Spike acceptable range lower limit, percent recovery	49	36	28	36	38	47	27	27	24	37	11	10	19
	Spike acceptable range upper limit, percent recovery	157	162	166	168	158	143	183	159	192	163	137	124	169
201416702	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.11	0.035	0.22	<0.1	<0.1	<0.2	<0.2
	Spike, percent recovery	140	88	110	99	94	85	120	92	140	87	100	61	88
	Spike acceptable range lower limit, percent recovery	49	36	28	36	38	47	27	27	24	37	11	10	19
	Spike acceptable range upper limit, percent recovery	157	162	166	168	158	143	183	159	192	163	137	124	169
201424008	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.059	<0.1	0.14	<0.1	<0.1	<0.2	<0.2
	Spike, percent recovery	100	100	110	120	110	110	130	120	160	110	120	99	91
	Spike acceptable range lower limit, percent recovery	49	36	28	36	38	47	27	27	24	37	11	10	19
	Spike acceptable range upper limit, percent recovery	157	162	166	168	158	143	183	159	192	163	137	124	169
201408409	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.23	0.055	0.50	<0.1	0.01	<0.2	<0.2
	Spike, percent recovery	80	65	75	91	94	88	150	110	250	78	79	83	85
	Spike acceptable range lower limit, percent recovery	49	36	28	36	38	47	27	27	24	37	11	10	19
	Spike acceptable range upper limit, percent recovery	157	162	166	168	158	143	183	159	192	163	137	124	169
201425501	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.16	0.051	0.25	<0.1	<0.1	<0.2	<0.2
	Spike, percent recovery	110	110	120	130	130	130	160	120	190	120	120	39	110
	Spike acceptable range lower limit, percent recovery	49	36	28	36	38	47	27	27	24	37	11	10	19
	Spike acceptable range upper limit, percent recovery	157	162	166	168	158	143	183	159	192	163	137	124	169

Table 8. Analytical results for halogenated organic compounds found in laboratory set blank samples, and set spike data associated with samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[PBDE, polybrominated diphenyl ether; µg/kg, micrograms per kilogram; <, less than; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls]

Set number	Sample identifier, units	Cyfluthrin	Dacthal	Desulfinyl-fipronil	Dieldrin	Endo-sulfan sulfate	Fipronil	Fipronil sulfide	Hexa-chloro-benzene	Methyl triclo-san	Octa-chloro-styrene
201407007	Blank, µg/kg	<0.2	<0.2	<0.1	<0.1	<0.4	<0.1	<0.1	0.016	<6	<1
	Spike, percent recovery	E86	84	62	110	83	<0.1	48	55	93	63
	Spike acceptable range lower limit, percent recovery	15	52	16	47	21	33	28	20	30	42
	Spike acceptable range upper limit, percent recovery	123	136	148	161	165	123	148	158	156	126
201417415	Blank, µg/kg	<0.2	<0.2	<0.1	<0.1	<0.4	E0.90	<0.1	0.034	<6	<1
	Spike, percent recovery	E130	76	61	82	84	E56	56	68	96	75
	Spike acceptable range lower limit, percent recovery	15	52	16	47	21	33	28	20	30	42
	Spike acceptable range upper limit, percent recovery	123	136	148	161	165	123	148	158	156	126
201416702	Blank, µg/kg	<0.2	<0.2	<0.1	<0.1	<0.4	<0.1	<0.1	0.027	<6	<1
	Spike, percent recovery	E110	93	85	90	97	E62	71	78	99	89
	Spike acceptable range lower limit, percent recovery	15	52	16	47	21	33	28	20	30	42
	Spike acceptable range upper limit, percent recovery	123	136	148	161	165	123	148	158	156	126
201424008	Blank, µg/kg	<0.2	<0.2	<0.1	<0.1	<0.4	E0.42	<0.1	0.021	<6	<1
	Spike, percent recovery	E110	110	91	120	130	E84	86	97	55	94
	Spike acceptable range lower limit, percent recovery	15	52	16	47	21	33	28	20	30	42
	Spike acceptable range upper limit, percent recovery	123	136	148	161	165	123	148	158	156	126
201408409	Blank, µg/kg	<0.2	<0.2	<0.1	<0.1	<0.4	E0.015	<0.1	0.031	<6	<1
	Spike, percent recovery	E99	88	90	91	110	E0.007	65	82	83	73
	Spike acceptable range lower limit, percent recovery	15	52	16	47	21	33	28	20	30	42
	Spike acceptable range upper limit, percent recovery	123	136	148	161	165	123	148	158	156	126
201425501	Blank, µg/kg	<0.2	<0.2	<0.1	<0.1	<0.4	<0.1	<0.1	0.014	<6	<1
	Spike, percent recovery	E120	93	94	130	130	E130	98	80	120	93
	Spike acceptable range lower limit, percent recovery	15	52	16	47	21	33	28	20	30	42
	Spike acceptable range upper limit, percent recovery	123	136	148	161	165	123	148	158	156	126

Table 8. Analytical results for halogenated organic compounds found in laboratory set blank samples, and set spike data associated with samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[PBDE, polybrominated diphenyl ether; µg/kg, micrograms per kilogram; <, less than; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls]

Set number	Sample identifier, units	Oxychlordane	Oxyfluorfen	Pendimethalin	Pentabromotoluene	Pentachloroanisole	Pentachloronitrobenzene	Tefluthrin	Tetradifon	Triclosan	Trifluralin
201407007	Blank, µg/kg	<1	<4	<1	<1	<0.1	<0.1	<0.5	<0.2	<4	<0.2
	Spike, percent recovery	39	74	74	83	60	74	75	95	E5.2	64
	Spike acceptable range lower limit, percent recovery	32	33	50	69	35	48	43	60	14	12
	Spike acceptable range upper limit, percent recovery	164	153	146	141	155	162	127	138	170	138
201417415	Blank, µg/kg	<1	<4	<1	<1	<0.1	<0.1	<0.5	<0.2	E0.51	<0.2
	Spike, percent recovery	65	89	69	82	75	57	93	77	E7.0	27
	Spike acceptable range lower limit, percent recovery	32	33	50	69	35	48	43	60	14	12
	Spike acceptable range upper limit, percent recovery	164	153	146	141	155	162	127	138	170	138
201416702	Blank, µg/kg	<1	<4	<1	<1	<0.1	<0.1	<0.5	<0.2	E0.54	<0.2
	Spike, percent recovery	77	94	78	88	86	74	95	89	E6.3	55
	Spike acceptable range lower limit, percent recovery	32	33	50	69	35	48	43	60	14	12
	Spike acceptable range upper limit, percent recovery	164	153	146	141	155	162	127	138	170	138
201424008	Blank, µg/kg	<1	<4	<1	<1	0.014	<0.1	<0.5	<0.2	E0.62	<0.2
	Spike, percent recovery	100	110	100	110	99	110	97	81	E5.5	94
	Spike acceptable range lower limit, percent recovery	32	33	50	69	35	48	43	60	14	12
	Spike acceptable range upper limit, percent recovery	164	153	146	141	155	162	127	138	170	138
201408409	Blank, µg/kg	<1	<4	<1	<1	<0.1	<0.1	<0.5	<0.2	E0.70	<0.2
	Spike, percent recovery	82	91	91	82	82	81	79	86	E7.6	94
	Spike acceptable range lower limit, percent recovery	32	33	50	69	35	48	43	60	14	12
	Spike acceptable range upper limit, percent recovery	164	153	146	141	155	162	127	138	170	138
201425501	Blank, µg/kg	<1	<4	<1	<1	<0.1	<0.1	<0.5	<0.2	<4	<0.2
	Spike, percent recovery	110	110	87	110	74	71	100	99	E2.8	37
	Spike acceptable range lower limit, percent recovery	32	33	50	69	35	48	43	60	14	12
	Spike acceptable range upper limit, percent recovery	164	153	146	141	155	162	127	138	170	138

Table 8. Analytical results for halogenated organic compounds found in laboratory set blank samples, and set spike data associated with samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[PBDE, polybrominated diphenyl ether; µg/kg, micrograms per kilogram; <, less than; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls]

Set number	Sample identifier, units	alpha-Endosulfan	beta-Endosulfan	bis(Hexachlorocyclopentadieno) cyclooctane [dechlorane plus]	*cis*-Chlordane	*cis*-Nonachlor	lambda-Cyhalothrin	DDD	DDE	DDT
201407007	Blank, µg/kg	<0.2	<0.2	<1	<0.2	<0.1	<0.2	<2	<1	<4
	Spike, percent recovery	83	89	66	92	70	50	63	61	80
	Spike acceptable range lower limit, percent recovery	21	21	44	32	42	8	13	25	22
	Spike acceptable range upper limit, percent recovery	165	165	170	170	156	156	147	151	156
201417415	Blank, µg/kg	<0.2	<0.2	<1	<0.2	<0.1	<0.2	<2	<1	<4
	Spike, percent recovery	82	87	86	79	78	110	94	87	92
	Spike acceptable range lower limit, percent recovery	21	21	44	32	42	8	13	25	22
	Spike acceptable range upper limit, percent recovery	165	165	170	170	156	156	147	151	156
201416702	Blank, µg/kg	<0.2	<0.2	<1	<0.2	<0.1	<0.2	<2	<1	<4
	Spike, percent recovery	83	91	91	82	89	86	95	98	99
	Spike acceptable range lower limit, percent recovery	21	21	44	32	42	8	13	25	22
	Spike acceptable range upper limit, percent recovery	165	165	170	170	156	156	147	151	156
201424008	Blank, µg/kg	<0.2	<0.2	<1	<0.2	<0.1	<0.2	<2	<1	<4
	Spike, percent recovery	110	130	110	100	110	100	120	110	130
	Spike acceptable range lower limit, percent recovery	21	21	44	32	42	8	13	25	22
	Spike acceptable range upper limit, percent recovery	165	165	170	170	156	156	147	151	156
201408409	Blank, µg/kg	<0.2	<0.2	<1	<0.2	<0.1	<0.2	<2	<1	<4
	Spike, percent recovery	84	98	86	77	83	72	89	76	97
	Spike acceptable range lower limit, percent recovery	21	21	44	32	42	8	13	25	22
	Spike acceptable range upper limit, percent recovery	165	165	170	170	156	156	147	151	156
201425501	Blank, µg/kg	<0.2	<0.2	<1	<0.2	<0.1	<0.2	<2	<1	<4
	Spike, percent recovery	110	140	110	110	110	75	120	110	130
	Spike acceptable range lower limit, percent recovery	21	21	44	32	42	8	13	25	22
	Spike acceptable range upper limit, percent recovery	165	165	170	170	156	156	147	151	156

Table 8. Analytical results for halogenated organic compounds found in laboratory set blank samples, and set spike data associated with samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[PBDE, polybrominated diphenyl ether; µg/kg, micrograms per kilogram; <, less than; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls]

Set number	Sample identifier, units	PCB congener 49	PCB congener 52	PCB congener 70	PCB congener 101	PCB congener 110	PCB congener 118	PCB congener 138	PCB congener 146	PCB congener 149	PCB congener 151
201407007	Blank, µg/kg	<2	<1	<2	<1	<1	<0.1	<0.1	<0.1	<1	<0.1
	Spike, percent recovery	E55	E57	59	82	87	74	76	66	79	68
	Spike acceptable range lower limit, percent recovery	9	4	9	10	16	35	27	37	12	21
	Spike acceptable range upper limit, percent recovery	113	112	115	130	130	155	155	145	114	141
201417415	Blank, µg/kg	<2	<1	<2	<1	<1	<0.1	<0.1	<0.1	<1	<0.1
	Spike, percent recovery	E110	E89	95	84	87	84	80	80	81	77
	Spike acceptable range lower limit, percent recovery	9	4	9	10	16	35	27	37	12	21
	Spike acceptable range upper limit, percent recovery	113	112	115	130	130	155	155	145	114	141
201416702	Blank, µg/kg	<2	<1	<2	<1	<1	<0.1	<0.1	<0.1	<1	<0.1
	Spike, percent recovery	E92	E90	96	89	95	93	88	89	85	89
	Spike acceptable range lower limit, percent recovery	9	4	9	10	16	35	27	37	12	21
	Spike acceptable range upper limit, percent recovery	113	112	115	130	130	155	155	145	114	141
201424008	Blank, µg/kg	<2	<1	<2	<1	<1	<0.1	<0.1	<0.1	<1	<0.1
	Spike, percent recovery	E85	E95	110	110	110	100	110	100	98	95
	Spike acceptable range lower limit, percent recovery	9	4	9	10	16	35	27	37	12	21
	Spike acceptable range upper limit, percent recovery	113	112	115	130	130	155	155	145	114	141
201408409	Blank, µg/kg	<2	<1	<2	<1	<1	<0.1	<0.1	<0.1	<1	<0.1
	Spike, percent recovery	E75	E69	79	79	80	75	76	75	73	73
	Spike acceptable range lower limit, percent recovery	9	4	9	10	16	35	27	37	12	21
	Spike acceptable range upper limit, percent recovery	113	112	115	130	130	155	155	145	114	141
201425501	Blank, µg/kg	<2	<1	<2	<1	<1	<0.1	<0.1	<0.1	<1	<0.1
	Spike, percent recovery	E110	E92	110	97	100	100	100	100	100	96
	Spike acceptable range lower limit, percent recovery	9	4	9	10	16	35	27	37	12	21
	Spike acceptable range upper limit, percent recovery	113	112	115	130	130	155	155	145	114	141

Table 8. Analytical results for halogenated organic compounds found in laboratory set blank samples, and set spike data associated with samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[PBDE, polybrominated diphenyl ether; µg/kg, micrograms per kilogram; <, less than; E, estimated; DDD, dichlorodiphenyldichloroethane; DDE, dichlorodiphenyldichloroethylene; DDT, dichlorodiphenyltrichloroethane; PCB, polychlorinated biphenyls]

Set number	Sample identifier, units	PCB congener 170	PCB congener 174	PCB congener 177	PCB congener 180	PCB congener 183	PCB congener 187	PCB congener 194	PCB congener 206	*trans*-Chlordane	*trans*-Nonachlor
201407007	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.013	<0.1	<0.2	<0.1
	Spike, percent recovery	76	70	67	62	62	61	68	68	83	98
	Spike acceptable range lower limit, percent recovery	28	51	38	40	34	33	57	66	39	28
	Spike acceptable range upper limit, percent recovery	154	135	140	142	142	153	135	120	165	160
201417415	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1
	Spike, percent recovery	81	80	79	82	82	81	81	81	81	77
	Spike acceptable range lower limit, percent recovery	28	51	38	40	34	33	57	66	39	28
	Spike acceptable range upper limit, percent recovery	154	135	140	142	142	153	135	120	165	160
201416702	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1
	Spike, percent recovery	90	89	88	93	90	89	89	90	87	85
	Spike acceptable range lower limit, percent recovery	28	51	38	40	34	33	57	66	39	28
	Spike acceptable range upper limit, percent recovery	154	135	140	142	142	153	135	120	165	160
201424008	Blank, µg/kg	0.011	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1
	Spike, percent recovery	99	98	97	99	100	99	99	100	110	110
	Spike acceptable range lower limit, percent recovery	28	51	38	40	34	33	57	66	39	28
	Spike acceptable range upper limit, percent recovery	154	135	140	142	142	153	135	120	165	160
201408409	Blank, µg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1
	Spike, percent recovery	74	72	72	75	72	72	75	74	82	83
	Spike acceptable range lower limit, percent recovery	28	51	38	40	34	33	57	66	39	28
	Spike acceptable range upper limit, percent recovery	154	135	140	142	142	153	135	120	165	160
201425501	Blank, µg/kg	<0.1	<0.1	<0.1	0.009	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1
	Spike, percent recovery	98	98	97	100	98	96	99	97	110	110
	Spike acceptable range lower limit, percent recovery	28	51	38	40	34	33	57	66	39	28
	Spike acceptable range upper limit, percent recovery	154	135	140	142	142	153	135	120	165	160

Table 9. Analytical results for polycyclic aromatic hydrocarbons found in laboratory set blank samples and set spike data associated with samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.

[<, less than; E, estimated; µg/kg, micrograms per kilogram; --, no data]

Set number	Sample identifier, units	1,2,4-Trichlorobenzene	1,2-Dimethylnaphthalene	1,6-Dimethylnaphthalene	1-Methyl-9H-fluorene	1-Methylphenanthrene	1-Methylpyrene	2,3,6-Trimethylnaphthalene	2,6-Dimethylnaphthalene	2-Ethylnaphthalene
201414703	Blank, µg/kg	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Spike, percent recovery	90.2	110	107	113	115	111	106	103	104
	Spike acceptable range lower limit, percent recovery	22.68	25.76	22.01	32.51	14.84	23.71	23.85	20.56	22.74
	Spike acceptable range upper limit, percent recovery	89.25	114.15	113.96	123.22	139.30	133.72	114.99	114.74	111.80
201423004	Blank, µg/kg	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Spike, percent recovery	83.7	109	108	106	131	E138	105	105	105
	Spike acceptable range lower limit, percent recovery	22.68	25.76	22.01	32.51	14.84	23.71	23.85	20.56	22.74
	Spike acceptable range upper limit, percent recovery	89.25	114.15	113.96	123.22	139.30	133.72	114.99	114.74	111.80
201415405	Blank, µg/kg	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Spike, percent recovery	70.1	77.8	77.5	82.7	88.9	97.1	77.8	77.8	76.4
	Spike acceptable range lower limit, percent recovery	22.68	25.76	22.01	32.51	14.84	23.71	23.85	20.56	22.74
	Spike acceptable range upper limit, percent recovery	89.25	114.15	113.96	123.22	139.30	133.72	114.99	114.74	111.80
201424503	Blank, µg/kg	<25	<25	<25	<25	<25	<25	<25	<25	<25
	Spike, percent recovery	--	--	--	--	--	--	--	--	--
	Spike acceptable range lower limit, percent recovery	22.68	25.76	22.01	32.51	14.84	23.71	23.85	20.56	22.74
	Spike acceptable range upper limit, percent recovery	89.25	114.15	113.96	123.22	139.30	133.72	114.99	114.74	111.80

Set number	Sample identifier, units	2-Methylanthracene	4H-Cyclopenta[def]phenanthrene	Acenaphthene	Acenaphthylene	Anthracene	Anthraquinone	Benz[a]anthracene	Benzo[a]pyrene
201414703	Blank, µg/kg	<25	<25	<25	<25	<25	<25	<25	<25
	Spike, percent recovery	106	115	110	101	107	106	106	106
	Spike acceptable range lower limit, percent recovery	29.69	18.79	21.84	30.01	27.77	25.27	25.43	22.34
	Spike acceptable range upper limit, percent recovery	119.93	136.23	120.78	106.12	117.84	131.62	133.51	132.37
201423004	Blank, µg/kg	<25	<25	<25	<25	<25	1.7	4.9	7.0
	Spike, percent recovery	E122	137	106	95.5	122	E112	139	E127
	Spike acceptable range lower limit, percent recovery	29.69	18.79	21.84	30.01	27.77	25.27	25.43	22.34
	Spike acceptable range upper limit, percent recovery	119.93	136.23	120.78	106.12	117.84	131.62	133.51	132.37
201415405	Blank, µg/kg	<25	<25	<25	<25	<25	<25	<25	<25
	Spike, percent recovery	86.4	88.2	79.6	75.1	85.2	97.5	98.7	100
	Spike acceptable range lower limit, percent recovery	29.69	18.79	21.84	30.01	27.77	25.27	25.43	22.34
	Spike acceptable range upper limit, percent recovery	119.93	136.23	120.78	106.12	117.84	131.62	133.51	132.37
201424503	Blank, µg/kg	<25	<25	<25	<25	<25	<25	<25	<25
	Spike, percent recovery	--	--	--	--	--	--	--	--
	Spike acceptable range lower limit, percent recovery	29.69	18.79	21.84	30.01	27.77	25.27	25.43	22.34
	Spike acceptable range upper limit, percent recovery	119.93	136.23	120.78	106.12	117.84	131.62	133.51	132.37

Table 9. Analytical results for polycyclic aromatic hydrocarbons found in laboratory set blank samples and set spike data associated with samples collected from sites on the Westside Creeks (Alazán, Apache, Martínez, and San Pedro Creeks) and San Antonio River, San Antonio, Texas, 2014.—Continued

[<, less than; E, estimated; µg/kg, micrograms per kilogram; --, no data]

Set number	Sample identifier, units	Benzo[b] fluoranthene	Benzo[e] pyrene	Benzo [ghi] perylene	Benzo[k] fluoranthene	Bis(2-ethylhexyl) phthalate	Carbazole	Chrysene	Dibenz [a,h] anthracene	Dibenzothiophene	Diethyl phthalate	Fluoranthene
201414703	Blank, µg/kg	<25	<25	<25	<25	13.8	<25	<25	<25	<25	4.6	<25
	Spike, percent recovery	120	127	113	114	113	117	104	108	108	99.3	114
	Spike acceptable range lower limit, percent recovery	22.66	24.06	20.31	25.76	17.11	31.46	18.98	24.38	30.18	0.00	23.40
	Spike acceptable range upper limit, percent recovery	146.34	147.20	135.58	138.24	143.51	136.25	139.01	134.99	130.56	111.98	141.14
201423004	Blank, µg/kg	9.4	5.1	10.2	5.9	43.2	1.9	6.0	E8.9	<25	5.0	14.1
	Spike, percent recovery	141	145	139	133	150	147	129	133	105	E68.9	E133
	Spike acceptable range lower limit, percent recovery	22.66	24.06	20.31	25.76	17.11	31.46	18.98	24.38	30.18	0.00	23.40
	Spike acceptable range upper limit, percent recovery	146.34	147.20	135.58	138.24	143.51	136.25	139.01	134.99	130.56	111.98	141.14
201415405	Blank, µg/kg	<25	<25	<25	<25	13.8	<25	<25	<25	<25	9.4	1.3
	Spike, percent recovery	117	114	109	111	87.4	103	102	109	82.5	45.4	95.4
	Spike acceptable range lower limit, percent recovery	22.66	24.06	20.31	25.76	17.11	31.46	18.98	24.38	30.18	0.00	23.40
	Spike acceptable range upper limit, percent recovery	146.34	147.20	135.58	138.24	143.51	136.25	139.01	134.99	130.56	111.98	141.14
201424503	Blank, µg/kg	<25	<25	<25	<25	<51.0	<25	1.3	<25	<25	5.6	2.6
	Spike, percent recovery	--	--	--	--	--	--	--	--	--	--	--
	Spike acceptable range lower limit, percent recovery	22.66	24.06	20.31	25.76	17.11	31.46	18.98	24.38	30.18	0.00	23.40
	Spike acceptable range upper limit, percent recovery	146.34	147.20	135.58	138.24	143.51	136.25	139.01	134.99	130.56	111.98	141.14

Set number	Sample identifier, units	Fluorene	Hexachlorobenzene	Indeno [1,2,3-cd] pyrene	Naphthalene	Pentachloroanisole	Pentachloronitrobenzene	Perylene	Phenanthrene	Phenanthridine	Pyrene
201414703	Blank, µg/kg	<25	<25	<25	7.2	<25	<25	<25	2.0	<25	<25
	Spike, percent recovery	111	105	111	105	111	81.7	99.4	113	114	113
	Spike acceptable range lower limit, percent recovery	27.87	24.22	23.10	15.74	24.24	10.94	16.00	19.15	22.34	22.00
	Spike acceptable range upper limit, percent recovery	123.53	119.08	134.54	114.18	123.78	102.39	130.79	137.48	139.66	138.32
201423004	Blank, µg/kg	<25	<25	E10.4	2.4	<25	<25	2.3	6.5	<25	11.2
	Spike, percent recovery	105	96.3	138	98.4	100	69.5	122	131	E119	E131
	Spike acceptable range lower limit, percent recovery	27.87	24.22	23.10	15.74	24.24	10.94	16.00	19.15	22.34	22.00
	Spike acceptable range upper limit, percent recovery	123.53	119.08	134.54	114.18	123.78	102.39	130.79	137.48	139.66	138.32
201415405	Blank, µg/kg	<25	<25	<25	2.0	<25	<25	<25	<25	<25	<25
	Spike, percent recovery	80.4	76.4	106	77.0	79.3	59.0	99.2	87.5	102	93.7
	Spike acceptable range lower limit, percent recovery	27.87	24.22	23.10	15.74	24.24	10.94	16.00	19.15	22.34	22.00
	Spike acceptable range upper limit, percent recovery	123.53	119.08	134.54	114.18	123.78	102.39	130.79	137.48	139.66	138.32
201424503	Blank, µg/kg	<25	<25	<25	6.7	<25	<25	<25	3.2	<25	2.0
	Spike, percent recovery	--	--	--	--	--	--	--	--	--	--
	Spike acceptable range lower limit, percent recovery	27.87	24.22	23.10	15.74	24.24	10.94	16.00	19.15	22.34	22.00
	Spike acceptable range upper limit, percent recovery	123.53	119.08	134.54	114.18	123.78	102.39	130.79	137.48	139.66	138.32

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