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Open-File Report 2019–1106

U.S. Department of the Interior
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DAVID BERNHARDT, Secretary

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James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2019

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Also, thanks to Orlando Romero, previously of the U.S. Geological Survey (USGS), for his vision and scope of the work, as well as his contribution early in the process. Huge thanks to the additional USGS staff who carried out the field work efforts—often in the middle of the night—including Harold Nelson and Erik Storms.

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
yard (yd)	0.9144	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)
	Volume	
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
	Flow rate	
cubic foot per second (ft^3/s)	35.315	cubic meter per second (m^3/s)
	Mass	
pound (lb)	35.315	kilogram (kg)

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

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

Supplemental Information

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or nanograms per liter (ng/L).

Specific conductance is given in microsiemens per centimeter (µS/cm).

Concentrations of chemical constituents in soil are given in nanograms per kilogram dry weight (ng/kg dw).

Load masses for runoff events are given in milligrams (mg).

Abbreviations

AHYMO	Arid Lands Hydrologic Model
AISWS	Albuquerque International Sunport Weather Station
AMAFCA	Albuquerque Metropolitan Arroyo Flood Control Authority
ATSDR	Agency for Toxic Substances and Disease Registry
DEM	digital elevation model
DPM	Development Process Manual
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
GOES	Geostationary Operational Environmental Satellite
MS4	municipal separate storm sewer systems
NMED	New Mexico Environment Department
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NWIS	National Water Information System
PCB	polychlorinated biphenyl
R^2	coefficient of determination
RPD	relative percent difference
SSC	suspended sediment concentration
SSCAFCA	Southern Sandoval County Flood Control Authority
SWMP	stormwater management plan
TOC	total organic carbon
TSS	total suspended solids
USGS	U.S. Geological Survey

Characterization and Load Estimation of Polychlorinated Biphenyls (PCBs) From Selected Rio Grande Tributary Stormwater Channels in the Albuquerque Urbanized Area, New Mexico, 2017–18

By Zachary M. Shephard, Kathleen E. Conn, Kimberly R. Beisner, Alanna D. Jornigan, and Christina F. Bryant

Abstract

In cooperation with the New Mexico County of Bernalillo, the U.S. Geological Survey characterized potential polychlorinated biphenyl (PCB) concentration and estimated loading into the Rio Grande from watersheds that are under the county's jurisdiction. Water and sediment samples were collected in 2017–18 from six sites within four stormwater drainage basins in the Albuquerque, New Mexico, urbanized area for the analysis of PCB congeners and other water-quality constituents during dry and wet seasons. Also, the rainfall-runoff model Arid Lands Hydrologic Model (AHYMO) was used to estimate stormwater discharge at the two sample collection sites not affected by pump station operation. Along with the PCB analysis, the discharge data were used to estimate total PCB stormflow event loads for eight events in these urban Rio Grande tributaries. PCBs were detected in 34 of 36 water samples at concentrations as high as 65.8 nanograms per liter and in 12 of 13 sediment samples at concentrations as high as 163,000 nanograms per kilogram dry weight. Six of the 36 water samples exceeded the New Mexico surface-water quality standard for protection of wildlife habitat and aquatic life of 14 nanograms per liter for PCBs. None of the water samples exceeded the U.S. Environmental Protection Agency's National Pollutant Discharge Elimination System permit level limit of 200 nanograms per liter for PCBs in stormwater systems discharging into the Rio Grande. PCB concentrations in water samples in this study were not linearly related to antecedent precipitation or measured water-quality parameters, but PCB concentrations had a statistically significant positive Kendall's tau correlation with total suspended solids for water samples and with total organic carbon for sediment samples. The PCB congener profiles indicate that sources to stormwater drainage basins in Bernalillo County originate both from legacy sources, such as Aroclors (for example, in landfills and old building materials), and from current-use sources, such as yellow pigments (for example, in printed materials and packaging in urban litter or refuse). Total PCB stormflow event loads were calculated with average potential minimum and maximum event loads of 0.73 and 4.32 milligrams per storm event, respectively, at the Adobe Acres pump station site and 56.78 and 315.13 milligrams per storm event at the Sanchez Farms inflow at Albuquerque, N. Mex., site.

Introduction

The U.S. Environmental Protection Agency's (EPA) National Pollutant Discharge Elimination System (NPDES) permit program was introduced in 1972 and authorized by the Clean Water Act (EPA, 2019a). The NPDES permit program works to control water pollution by regulating point sources that discharge into waters of the United States. Urbanized areas that subsequently discharge stormwater into large water bodies through municipal separate storm sewer systems (MS4s), like many of the urbanized areas of New Mexico, are considered point sources by NPDES standards and are therefore subject to regulation (EPA, 2019b). By 1999 the EPA had completed a two-phase NPDES permitting process for MS4s, which requires implementation of a stormwater management plan (SWMP). The SWMP describes the stormwater control practices that will be implemented consistent with permit requirements to minimize the discharge of pollutants from the sewer system (EPA, 2019c).

Bernalillo County, which encompasses the city boundary of Albuquerque, New Mexico, and the designated Albuquerque urbanized area (fig. 1) is subject to regulation under the EPA NPDES permitting process for stormwater runoff. Accurate hydrologic and water-quality data are critical to the implementation of the Bernalillo County SWMP. To meet this data need, the U.S. Geological Survey (USGS), in cooperation with the New Mexico County of Bernalillo, began collecting water samples to assess water quality from four stormwater drainage basins in Albuquerque's urbanized area (fig. 1) in 2004. The sample collection continued uninterrupted through the end of the county's fiscal year 2014 (June 30, 2014). To fulfill EPA monitoring requirements

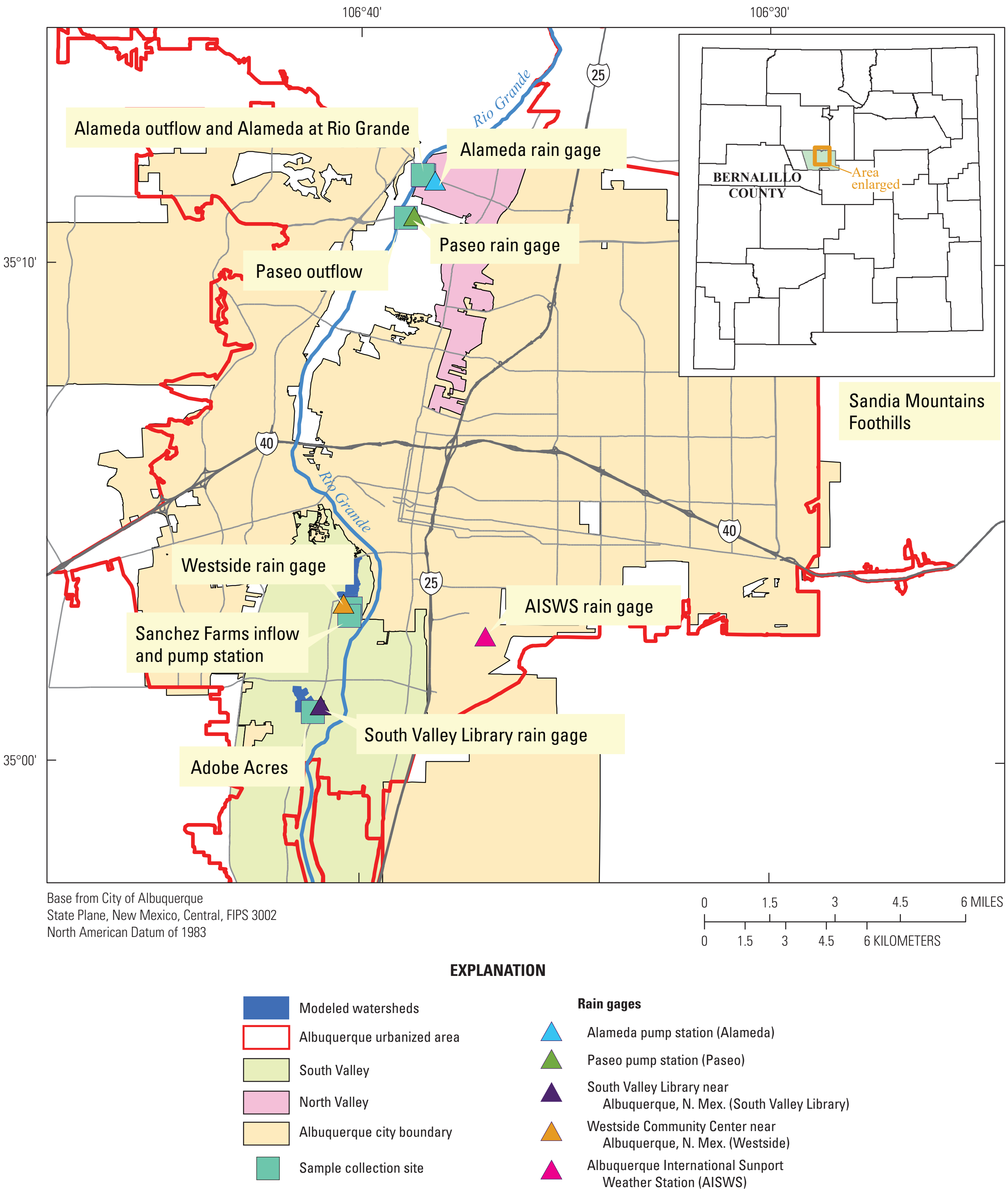


Figure 1. City of Albuquerque, New Mexico, including the urbanized area, and location of water and sediment sample collection sites and rain gages.

outlined in the NPDES permit, these samples were analyzed for trace metals, nutrients, chemical oxygen demand, biological oxygen demand, *Escherichia coli* (*E. coli*) bacteria, total organic carbon (TOC), and the field properties of specific conductance, pH, and water temperature. Results of these analyses are publicly available through the USGS National Water Information System (NWIS) (USGS, 2019a).

Independent of Bernalillo County's normal compliance monitoring and sampling, the NPDES permit also requires the county to complete a study of potential polychlorinated biphenyl (PCB) concentrations and loading into the Rio Grande from watersheds that are under its jurisdiction. Therefore, in 2017 the USGS in cooperation with Bernalillo County initiated a preliminary investigation of PCB concentrations in water and sediment, and of corresponding PCB loads, in the Albuquerque urbanized area to help determine potential contributions of PCBs into the Rio Grande from the county's four primary stormwater pumping outflows.

History and Chemistry of PCBs

PCBs are a class of chemical compounds that contain between 1 and 10 chlorine atoms attached to a biphenyl molecule (fig. 2). The different combinations of the number and location of the chlorine atoms result in 209 individual compounds, known as congeners. The congeners can be categorized by the number of chlorine atoms into groups called homologs, from monochlorobiphenyls, which have 1 chlorine atom, to decachlorobiphenyls, which have 10 chlorine atoms.

This family of human-made chemicals was produced in the United States from 1929 to 1977, primarily by Monsanto Chemical Company (ATSDR 2000), before Congress banned the manufacturing, processing, distribution in commerce, and use of PCBs under the Toxic Substances Control Act and the Resource Conservation and Recovery Act in 1976. PCBs were manufactured as different mixtures of individual congeners under the trade name of Aroclors, and were used as coolants and lubricants in transformers, capacitors, and other electrical equipment because of their insulating properties and very high boiling point. They were also used as plasticizers in rubbers, resins, and carbonless paper and were used in sealants, caulking compounds, paints, pigments, dyes, and inks. More than 1.5 billion pounds of PCBs were manufactured in the United States between 1929 and 1977 (Agency for Toxic Substances and Disease Registry [ATSDR], 2000). Some production is still allowed through exemptions, and there is inadvertent generation of PCBs as manufacturing byproducts. In 1982, the EPA identified 70 manufacturing processes likely to inadvertently generate PCBs and estimated an annual production of 100,090 pounds per year (Panero and others, 2005). PCB congener 11, or PCB-11, and the nonachloro- and decachloro-congeners (containing 9 and 10 chlorine atoms, respectively, including PCB-206, -207, -208, and -209) have been detected in current-use pigments and dyes (Stone, 2016). Sources of current-use PCBs to the environment may include effluents from ink and dye manufacturing and from pulp mills repulping postconsumer paper, as well as leaching from printed magazines, newspapers, fabrics, and packaging materials in landfills, and collection systems where litter can accumulate (Hu and Hornbuckle, 2010; Rodenburg and others, 2010; Guo and others, 2014). The relative contributions of PCBs to the environment from additional unpermitted nonpoint releases, such as from paints, agricultural chemicals, plastic materials, and detergents, are unknown and need further investigation. The stormwater systems targeted for sampling in this study are in the Albuquerque urbanized area; therefore, potential sources of PCBs to the basins include precipitation-derived transport of legacy Aroclor PCBs, for example, from landfills or illicit dump sites, as well as leaching of current-use PCBs, for example, from urban litter or refuse that accumulates within the basins.

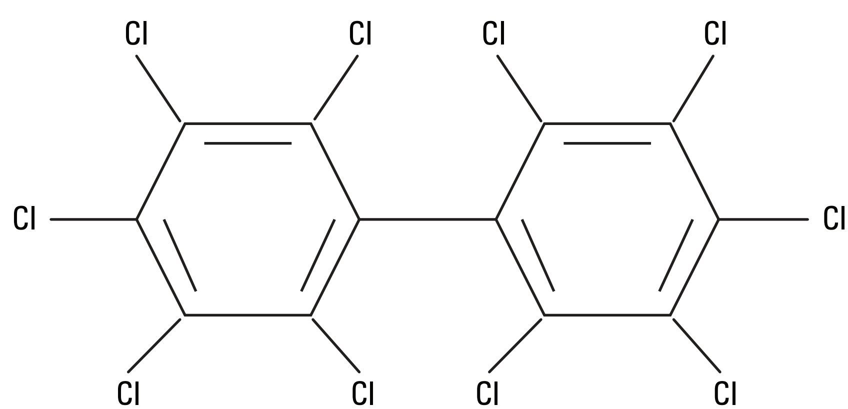


Figure 2. Chemical structure of a polychlorinated biphenyl containing 10 chlorine atoms (decachlorobiphenyl). There are 209 possible structures, called congeners, each containing between 1 and 10 chlorine atoms attached at different locations on the central biphenyl molecule.

Despite the ban on production of PCBs in the 1970s, legacy PCBs can still be released to the environment from hazardous waste sites, illegal or improper disposal of industrial wastes and consumer products, leaks from old transformers and other products, leaching from caulking materials, and burning of some wastes in incinerators (ATSDR, 2000). The stable chemical properties of PCBs that were useful in industrial applications make them some of the most persistent chemicals in the environment. Over time, PCBs move from one environmental compartment to another. For example, PCBs volatilize and can be deposited on land surfaces through wet and dry deposition (Nelson and others, 1998), stormwater runoff can carry land surface chemicals into rivers and oceans (Andersson and others, 2015), PCBs partition from water to sediment and settle in river and bed sediments (Andersson and others, 2015), and ingestion of resuspended contaminated sediments by aquatic organisms can result in bioaccumulation in organisms and biomagnification up the food chain (Ruus and others, 2012; Desforges and others, 2018).

Humans can be exposed to PCBs by ingesting contaminated drinking water and food, especially fish from contaminated waters, and by inhaling contaminated air. Additional exposure routes near known hazardous waste sites include interaction with contaminated sediment, for example, through recreation. A wide range of adverse health effects have been associated with exposure to PCBs in humans and animals, including liver, thyroid, dermal, and ocular changes; immunological alterations; neurodevelopmental changes; reduced birth weight; reproductive toxicity; and cancer (ATSDR, 2000).

Purpose and Scope

This report presents a preliminary assessment of PCB concentrations and loading in stormwater runoff events from four selected Rio Grande tributary watersheds that are under Bernalillo County's jurisdiction in the Albuquerque urbanized area, New Mexico. PCB concentrations were determined in water and sediment samples collected from four stormwater drainage basins from summer 2017 to fall 2018. Also, estimates of stormwater discharge hydrographs at the sampled basin outflow points for two sampling locations were made using a rainfall-runoff computer simulation model. The total PCB concentrations and discharge estimates were used to estimate PCB loads from the two stormwater drainage basin outlet points. The results described in this report provide insights into PCB concentrations and loadings in the Rio Grande, as well as the health of the Rio Grande as a whole, and can be used to assist in fulfilling the county's NPDES permit requirements for the EPA.

Study Site Descriptions

The study area is in the City of Albuquerque urbanized area, located in north-central New Mexico (fig. 1). The eastern part of the city is built upon the alluvial fans of the Sandia Mountains foothills, and the western part lies along the Rio Grande river terrace and flood plain. Elevation in the city ranges from about 5,000 to 7,000 feet (Veenhuis, 2003). The land area of the City of Albuquerque is approximately 188 square miles, and the U.S. Census Bureau estimated the population to be 560,218 people in 2018 (U.S. Census Bureau, 2018). There were an estimated 243,402 housing units in the City of Albuquerque as of 2017 (U.S. Census Bureau, 2017). The Albuquerque urbanized area has a stormwater infrastructure system of natural and concrete-lined arroyo channels, as well as underground storm drainage pipes, that help direct stormwater runoff through the city and into the Rio Grande. These channels are ephemeral and typically only have measurable discharge following intense rainstorm events or from rapid snowmelt. Water-quality and sediment samples were collected at six different locations near the outfalls of four small urban drainage channels: Alameda, Paseo, Sanchez Farms, and Adobe Acres. Aerial imagery of each sample collection site is shown in figure 3.

The Albuquerque urbanized area has a semiarid climate; average annual precipitation is about 8 inches in the lower elevations near the Rio Grande and increases to about 12 inches at the foothills of the Sandia Mountains (NOAA, 2019). According to the National Weather Service's Albuquerque International Sunport Weather Station (AISWS), more than one-half of the annual precipitation in the Albuquerque urbanized area occurs as rainstorms from July through October (NOAA, 2019). These monsoon rainstorms are typically small convective cells that move rapidly through the area, are often intense, and can result in flash flooding. On rare occasion, large frontal storms that originate from remnant hurricanes in the Gulf of Mexico move into the area (Veenhuis, 2003).

Water-Quality and Sediment Sample Collection Site Descriptions

Water-quality and sediment samples were collected at six sites within four stormwater drainage basins. The Alameda and Sanchez Farms watersheds each had two sites and the Adobe Acres and Paseo watersheds had one site each (fig. 3).

Alameda Watershed Water-Quality and Sediment Sample Collection Sites

There were two water-quality sample collection sites near the outlet of the Alameda stormwater drainage basin (fig. 3*C*). The Alameda pump station outflow (USGS site identification number 351146106382801) water-quality and sediment sample collection site (hereafter Alameda outflow) is a small concrete-lined basin (fig. 4*A*) approximately 70 yards east of the Rio Grande. Water is pumped into the concrete basin from a stormwater pump station located just to the east of the site. With sufficient pumping volume, the water flows from the concrete-lined collection basin down a straight unlined canal towards the Rio Grande. Standing water remains in the basin when water is not being pumped into it. Some fine-grained substrate has settled into the concrete basin.

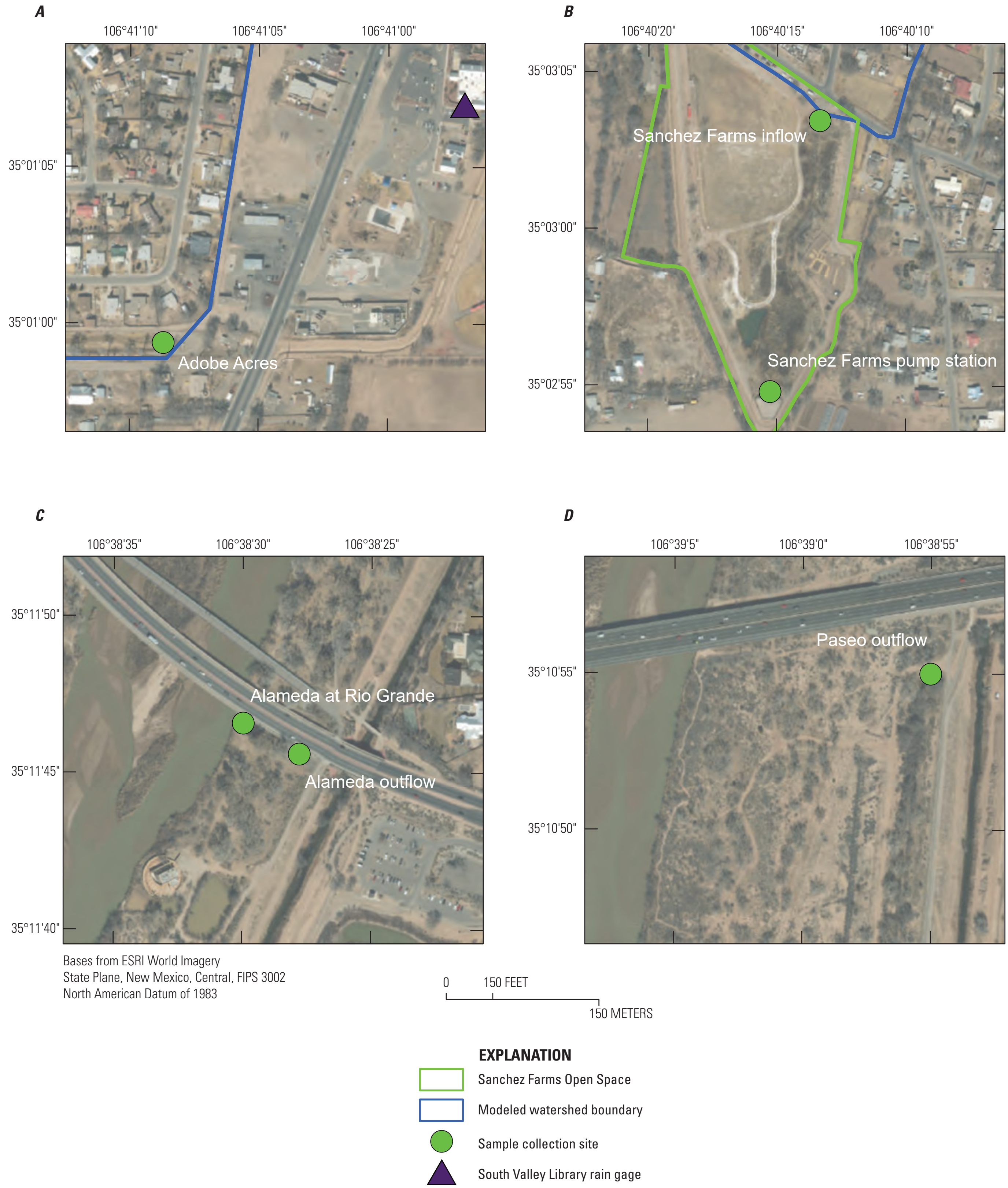


Figure 3. Aerial views of the sample collection sites in the Albuquerque urbanized area, Bernalillo County, New Mexico. *A*, Adobe Acres pump station (Adobe Acres); *B*, Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow) and pump station (Sanchez Farms pump station); *C*, Alameda pump station outflow (Alameda outflow) and Alameda pump at Rio Grande Inlet (Alameda at Rio Grande); and *D*, Paseo pump station outflow (Paseo outflow).

Figure 4. Ground views of water-quality and sediment sample collection sites, Alameda stormwater drainage basin, Albuquerque urbanized area, Bernalillo County, New Mexico. *A*, Alameda pump station outflow (Alameda outflow), looking west (concrete-lined basin in foreground). *B*, Alameda pump at Rio Grande Inlet (Alameda at Rio Grande), looking west (also seen in the background of *A*).

Figure 4. Ground views of water-quality and sediment sample collection sites, Alameda stormwater drainage basin, Albuquerque urbanized area, Bernalillo County, New Mexico. *A*, Alameda pump station outflow (Alameda outflow), looking west (concrete-lined basin in foreground). *B*, Alameda pump at Rio Grande Inlet (Alameda at Rio Grande), looking west (also seen in the background of *A*).

The Alameda pump at Rio Grande Inlet (USGS site identification number 351147106383001) water-quality and sediment sample collection site (hereafter Alameda at Rio Grande) (fig. 4*B*) is located within the unlined outflow channel from the Alameda outflow concrete basin. Samples were collected near a small footbridge that crosses the canal. The site is typically dry except during runoff events when stormwater is pumped through the concrete basin and down the unlined channel. Given a sufficient pump volume, water flows through the channel and directly into the Rio Grande. Small volumes of standing water have been observed in the channel on days following storm events. The substrate in the collection basin is muddy with branches and sticks.

Paseo Watershed Water-Quality and Sediment Sample Collection Site

The Paseo pump station outflow (USGS site identification number 351055106385501) water-quality and sediment sample collection site (hereafter Paseo outflow) is located approximately 250 yards east of the Rio Grande (fig. 3*D*). This site is below an outflow pipe that discharges water from a stormwater pump located to the east of the site (fig. 5). The water then flows from the collection site down an unlined canal in a sinuous path through a section of the Rio Grande flood plain. During this study, stormwater was always observed to infiltrate the ground surface before reaching the Rio Grande. The bed material at the site is muddy, and there are some cattails (*Typha latifolia*) and other aquatic vegetation growing along the canal near the collection site.

Sanchez Farms Watershed Water-Quality and Sediment Sample Collection Sites

There are two water-quality and sediment sample collection sites in the Sanchez Farms Open Space recreation area (fig. 3*B*). The Sanchez Farms inflow at Albuquerque, N. Mex. (USGS site identification number 350304106401310) (hereafter Sanchez Farms inflow), water-quality and sediment sample collection site is located on the northern end of the Sanchez Farms Open Space recreation area (fig. 6*A*). This site is at the entrance where stormwater flows into a concrete basin through subsurface stormwater drainage pipes. This concrete basin has small openings near the top of the retaining walls that allow water to spill out if a sufficient volume of water enters the basin (fig. 6*A*). Water that flows out of the basin openings then flows to the south through a constructed wetland towards the Sanchez Farms pump station water-quality and sediment sample collection site (described in the next section). Collecting samples at the Sanchez Farms inflow and pump station, which are upgradient and downgradient, respectively, of the wetland, may indicate potential mitigating effects of the wetland on water quality. Urban litter or refuse, a potential PCB source, including clothing, fast food containers, and other packaging waste, has been observed to frequently accumulate in the concrete basin.

The Sanchez Farms pump station (USGS identification number 350255106401510) water-quality and sediment sample collection site is located on the southern end of the Sanchez Farms Open Space recreation area (fig. 6*B*). Between stormflow events, there is a shallow pool of standing water at this site. Water-quality and sediment samples were collected in the pool, just upgradient from a stormwater pump that is located behind a large metal grate. Cattails are abundant along the banks at this site, and the substrate is primarily decaying cattails with some fine sediment. Water from this site must first be mobilized by the pump station through an underground pipe before reaching the Rio Grande, which is approximately 0.40 mile east of the pump station, though travel distance through underground pipes from the site to the Rio Grande may be longer.

Adobe Acres Watershed Water-Quality and Sediment Sample Collection Site

The Adobe Acres pump station (USGS identification number 350059106410810) (hereafter Adobe Acres) water-quality and sediment sample collection site (fig. 3*A*) is located at the eastern end of an unlined drainage canal that flows into a stormwater pump station (fig. 7). Before water reaches the pump station, it flows through a metal grate and enters a small concrete basin, where the samples were collected. Cattails and other emergent aquatic vegetation are abundant on the surface of the water in the unlined channel just before the concrete basin. When sediment is disturbed in the area, there is a strong hydrogen sulfide odor, likely from decaying vegetation. Water that leaves this site is then mobilized by the pump station through an underground pipe before reaching the Rio Grande, which is approximately 0.75 mile east of the pump station, though travel distance through underground pipes from the site to the Rio Grande may be longer.

Rain Gage Site Descriptions

Four rain gages were used for precipitation event summary and characterization in this study, as well as for rainfall-runoff model input data. The four rain gages were located near the sample collection sites and are assumed to be representative of the precipitation conditions within each watershed. The rain gage locations are shown in figure 1.

Alameda Pump Station Rain Gage

The Alameda pump station rain gage (USGS identification number 351140106381230) (fig. 1) (hereafter Alameda rain gage) is located within the Bernalillo County Alameda pump station outflow lockup, on an adobe wall circling the pump station catwalk. The rain gage is mounted on a heavy brick foundation, which is securely mounted on a Bernalillo County electrical box that is approximately 9 feet above land surface.

Figure 5. Ground view of water-quality and sediment sample collection site, Paseo pump station outflow (Paseo outflow), Albuquerque urbanized area, New Mexico, looking northeast.

Figure 6. Ground views of water-quality and sediment sample collection sites, Sanchez Farms, Albuquerque urbanized area, New Mexico. *A*, Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow), looking south. *B*, Sanchez Farms pump station downgradient from constructed wetlands at Sanchez Farms, looking west.

Figure 6. Ground views of water-quality and sediment sample collection sites, Sanchez Farms, Albuquerque urbanized area, New Mexico. *A*, Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow), looking south. *B*, Sanchez Farms pump station downgradient from constructed wetlands at Sanchez Farms, looking west.—Continued

Figure 7. Ground view of water-quality and sediment sample collection site, Adobe Acres pump station (Adobe Acres), Albuquerque urbanized area, New Mexico, looking west.

Paseo Pump Station Rain Gage

The Paseo pump station rain gage (USGS identification number 351057106384330) (fig. 1) (hereafter Paseo rain gage) is located within the Bernalillo County Paseo pump station lockup on the roof of a maintenance shed. The rain gage is mounted on a stainless-steel pipe structure and sits approximately 20 feet above land surface. This gage reports data in real time (USGS, 2019b).

Westside Community Center Near Albuquerque, N. Mex., Rain Gage

The Westside Community Center near Albuquerque, N. Mex., rain gage (350310106402430) (figs. 1 and 8) (hereafter Westside rain gage) is located on the roof of the Westside Community Center in Albuquerque. The rain gage is mounted on a stainless-steel pipe structure and sits approximately 25 feet above land surface. This gage reports data in real time (USGS, 2019b).

South Valley Library Near Albuquerque, N. Mex., Rain Gage

The South Valley Library near Albuquerque, N. Mex., rain gage (USGS identification number 350107106405730) (figs. 1, 3, and 9) (hereafter South Valley Library rain gage) is located on the roof of the South Valley Library in Albuquerque. The rain gage is mounted on a stainless-steel pipe structure and sits approximately 35 feet above land surface. This gage reports data in real-time (USGS, 2019b).

Methods

The four primary Bernalillo County outflows to the Rio Grande where water and sediment samples were collected were the Alameda pump station and Paseo pump station in the North Valley and Sanchez Farms pump station and Adobe Acres pump station in the South Valley (fig. 1). In the absence of observed discharge data, the rainfall-runoff model AHYMO (City of Albuquerque, 2018), which has been developed for use in the Albuquerque area (City of Albuquerque, 1997), was used to estimate stormwater discharge at two of the sampled outflow sites: just before the Sanchez Farms inflow and Adobe Acres. Discharges at the Paseo outflow and Alameda outflow sites are dependent upon the operation of the pump stations, whereas discharges at the Sanchez Farms inflow and Adobe Acres are from direct urban runoff. Therefore, in this study, discharges were simulated only at the Sanchez Farms inflow and Adobe Acres sampling sites. These estimated discharge values, along with the PCB concentrations measured in the stormwater samples, were used to estimate total PCB stormflow event loads in the two corresponding Rio Grande tributary watersheds.

Since 2008, precipitation data have also been collected by the USGS at the four previously discussed gage locations (fig. 1), one near each of the four sampled watersheds. Precipitation data are a component of the stormwater monitoring data collection activities required by the NPDES permit for Bernalillo County. These data have been collected in accordance with standard USGS protocols for the collection of precipitation data (USGS, 2009) and have been stored in the NWIS database (USGS, 2019b). Additionally, water-quality and sediment samples were collected following USGS protocols (USGS, variously dated), and analytical results were stored in the NWIS database (USGS, 2019a).

Water and Sediment Sample Collection Methods

Wet season water and sediment samples that coincided with the monsoon season in New Mexico were collected from July through October 2017 and 2018 in response to recorded precipitation events of 0.25 inch or greater at any of the three real-time USGS rain gages (Paseo, Westside, and South Valley Library) located near sampling sites. Dry season samples were defined as being collected in December 2017 and November 2018.

Water

Field properties (temperature, pH, and specific conductance) were measured in the water body prior to sample collection. Water samples were collected as dip samples using a glass compositing container. Wet season samples were collected as a composite of five samples over time for a total duration of 25 minutes to 2 hours, depending on the duration of the storm event.

TOC samples were preserved with sulfuric acid. Samples were kept on ice until returning to the laboratory and then were stored in a refrigerator and shipped overnight on ice to the analyzing laboratory.

Sediment

Sediment samples were collected from bed sediment by using a US BMH-53 hand-held piston-type bed-material sampler. A composite of three to six sediment core plugs were combined in a stainless-steel bowl and homogenized with a stainless-steel spatula; after homogenization a subsample was transferred to the sediment sampling container. Samples were stored on ice in a refrigerator and shipped overnight on ice to the analyzing laboratory.

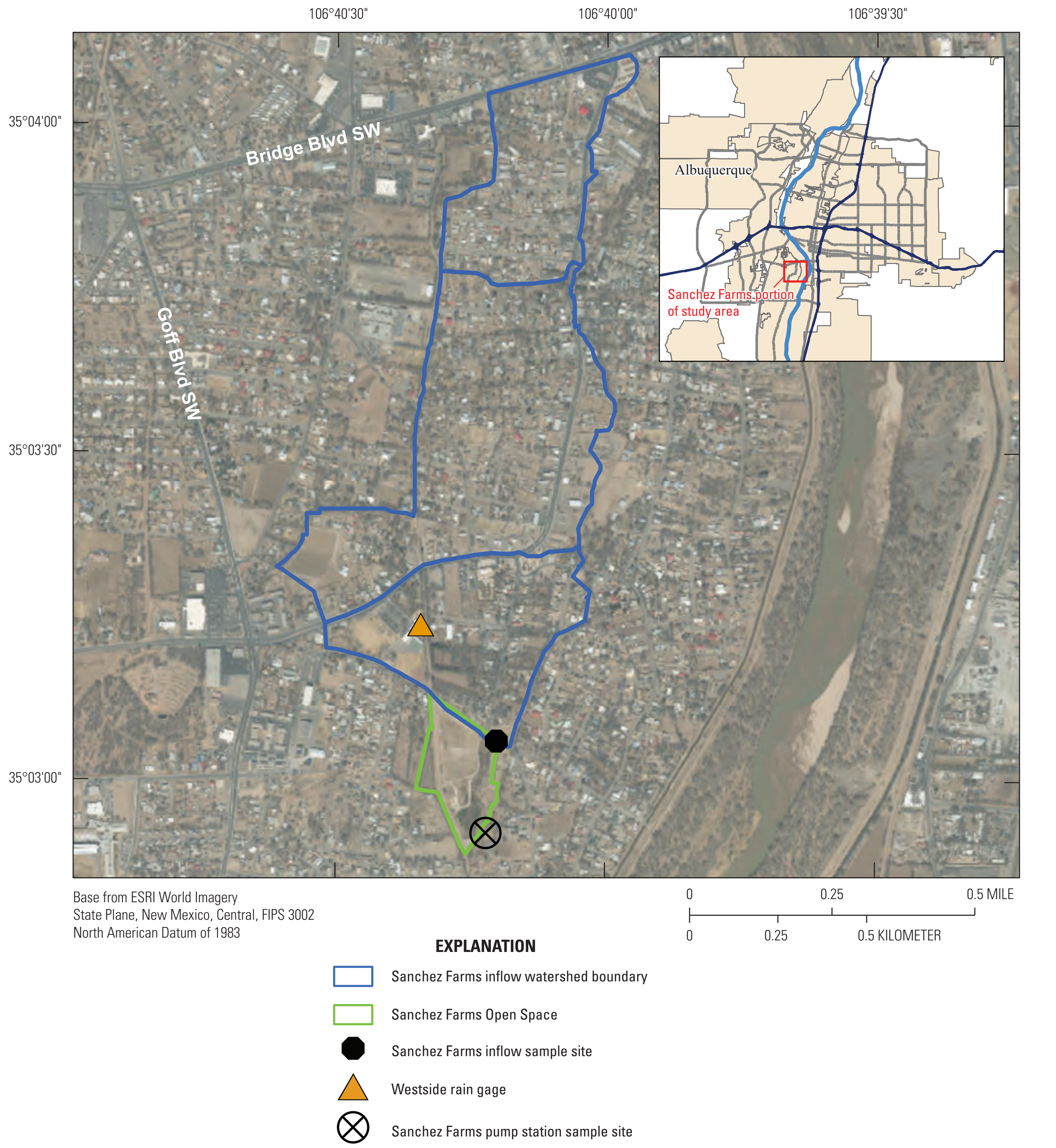


Figure 8. Delineated Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow), watershed boundary and Westside Community Center near Albuquerque, N. Mex., rain gage (Westside rain gage), Albuquerque, New Mexico.

Figure 9. Delineated Adobe Acres pump station (Adobe Acres) watershed boundary and South Valley Library near Albuquerque, N. Mex., rain gage (South Valley Library rain gage) Albuquerque, New Mexico.

Analytical Methods for Water and Sediment Samples

Water samples were analyzed for suspended sediment concentration (SSC), total suspended solids (TSS), TOC, and PCB congeners. SSC and percent fine sediment with a particle-size diameter smaller than 0.0625 mm (analyzed on a subset of eight samples) were analyzed at the USGS New Mexico Sediment Laboratory located in Albuquerque, New Mexico. RTI Laboratories, located in Livonia, Michigan, analyzed TSS by using SM-2540D (American Public Health Association, American Water Works Association, and Water Environment Federation, 2018a) and TOC by using SM-5310B (American Public Health Association, American Water Works Association, and Water Environment Federation, 2018b). Two hundred and nine PCB congeners were analyzed in water samples by Cape Fear Analytical, a subcontract laboratory for RTI Laboratories located in Wilmington, North Carolina, by using EPA method 1668 (EPA, 2008).

Sediment samples were analyzed for percent moisture, organic carbon, and PCB congeners. In the sediment samples, Cape Fear Analytical analyzed the 209 PCB congeners by using EPA method 1668 (EPA, 2008) and RTI Laboratories analyzed percent moisture by using ASTM D2216 (ASTM International, 2019) and organic carbon by using SW9060A (EPA, 2015).

Quality Assurance

In addition to the environmental samples collected in the field, as quality assurance for water samples, one equipment blank and two field blank samples were collected using certified organic free blank water from the USGS National Field Supply Service. Five samples were collected as replicate water samples. The replicate samples were sequential (collected after the main environmental sample) to assess field and laboratory variability. Not every replicate and blank have results for all analytes, but every analyte has results in at least one sample, with the exception of the field blank, which did not measure for SSC or specific conductance.

As quality assurance for sediment samples, one field blank was collected using certified clean silica sand that was in contact with the sediment coring device and stainless-steel bowl. Three replicate samples were collected for the sediment samples as a separate subsample from the homogenized sediment in the stainless-steel bowl. Not every replicate has results for all analytes, but every analyte has results in at least one replicate sample. The sediment field blank was not analyzed for organic carbon but was analyzed for all other analytes.

Data Analysis

Field notes and laboratory analytical reports were compared with the data in the NWIS database for completeness and accuracy (USGS, 2019b). Analytical chemistry results reported from the laboratory were checked to assess whether laboratory quality assurance and quality control were within the acceptable criteria outlined for USGS contract laboratory reporting. Data were analyzed and approved after confirming that the quality assurance and quality control were acceptable and the laboratory and database results agreed. Environmental sample data are publicly available in NWIS (USGS, 2019b).

PCBs are summarized in the report as total PCBs, the sum of all detected congener concentrations in a sample. Total PCB concentrations in water samples were compared against the New Mexico Environment Department (NMED) surface-water quality standards of 14 nanograms per liter (ng/L) for the protection of wildlife habitat and aquatic life (NMED, 2018) and against the minimum qualification level of 200 ng/L in the NPDES permit (NMED, 2018). The minimum qualification level is defined as "… the minimum quantification level for a constituent determined by official published documents of the United States Environmental Protection Agency" (NMED, 2018). Total PCB concentrations in sediment samples were compared against a threshold effect concentration of 40,000 nanograms per kilogram dry weight (ng/kg dw) and a midrange effect threshold of 400,000 ng/kg dw, derived from a compilation of literature studies of benthic toxicity testing (MacDonald and others, 2000).

Simple linear regressions were calculated in Microsoft Excel between TSS and SSC and between total PCBs in water and other water-quality and hydrologic parameters to identify surrogate parameters for predicting water PCB concentrations that are easier and less costly to collect than PCBs. Nonparametric statistical method analysis to calculate Kendall's tau was performed in the statistical programing language R by using the cor.test function (R Core Team, 2018). A p-value of less than (<) 0.05 (95-percent confidence level) was used to indicate statistical significance.

Collection of Precipitation Data

Precipitation data were collected using unheated Onset Corporation dual tipping bucket gages with 6.125-inch-diameter funnel rain gages, with the exception of the Alameda rain gage, which had a 6.5-inch-diameter funnel. The tipping buckets tip one time per 0.01 inch of water. Data collected by the Alameda rain gage were stored in 5-minute intervals on a ruggedized HOBO Event data recorder. The Paseo, Westside, and South Valley Library rain gages are real-time gages, which transmit data to USGS offices typically every 1 to 4 hours. Real-time data are available on NWIS as they are collected (USGS, 2019b). All collected data were reviewed and approved according to USGS guidelines. Data are stored at 5-minute intervals on a Satlink2 data collection platform, which allows transmission to NWIS by way of a Geostationary Operational Environmental Satellite (GOES) top-hat antenna. Data collection equipment (including the Satlink2 and its battery) is housed in a 1- by 1- by 1.5-foot metal shelter mounted on a stainless-steel pipe structure. Precipitation data were collected following protocols outlined in USGS (2009).

Rainfall-Runoff Modeling

Simulated discharge from an urban rainfall-runoff model was used for the PCB load calculations in this report. A total of eight events were modeled at two outfall locations, Adobe Acres and Sanchez Farms inflow.

AHYMO Rainfall-Runoff Model

Rainfall-runoff modeling in this study was conducted using the Arid Lands Hydrologic Model (AHYMO) (City of Albuquerque, 2018) software program. AHYMO was adapted from the United States Department of Agriculture Agricultural Research Service Hydrologic Model (HYMO) (Williams and Hann, 1973) in an effort by the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) to better represent New Mexico hydrologic conditions. AHYMO has undergone several iterations of development since its inception; however, the most recent version of AHYMO, AHYMO-S4-R2, was released in 2018 after the consulting firm C.E. Anderson transferred ownership of the program to the City of Albuquerque (City of Albuquerque, 2018). The model was originally verified for physical and hydrologic conditions characteristic of the greater Albuquerque area and has been considered a useful tool by local engineers and hydrologists for the past two decades (Schoener, 2010). Guidance for setting up model simulations has been developed by local hydrology and engineering professionals and is documented in chapter 22 of the Albuquerque "Development Process Manual" (DPM) (City of Albuquerque, 1997).

AHYMO Equations and Procedures

AHYMO generates continuous discharge data given an input rainfall distribution and selected basin characteristics. Following the guidance of the DPM, simulated discharge values are calculated using a split-hydrograph approach, as documented in Anderson and Heggen (1991). In this approach, runoff volume is calculated for hydrographs for both pervious and impervious areas by using separate initial abstraction (precipitation depth that must be exceeded before direct runoff begins) and uniform infiltration rates (constant rainfall infiltration loss rate after the initial abstraction). Initial abstraction values and uniform infiltration rates are determined by "land treatment" types, which are described in tables A-4, A-5, A-6, and A-7 in chapter 22 section 2 of the DPM (City of Albuquerque, 1997). Areal watershed percentages of land treatment types are dependent on land use and land parcel size and were populated in the model by following the guidance of table D-3 in section 2 of the Southern Sandoval County Flood Control Authority (SSCAFCA) DPM (SSCAFCA, 2009). Time of concentration, lag time, and time to peak for transforming the runoff volume to the basin outlet are computed by AHYMO with the Soil Conservation Service Upland Method, first identified by the City of Albuquerque DPM (City of Albuquerque, 1997). This approach utilizes different equations based on the subbasin reach length.

Model Preparation

Prior to assessing the basin characteristics that determine the input parameters for AHYMO, the urban watershed boundaries were delineated using a methodology similar to Parece and Campbell (2015). This approach followed the general workflow of first determining the topographic-based watershed boundary and then modifying this boundary by incorporating the effects of urban stormwater infrastructure such as storm pipes, artificial channels, and road gutters that can divert stormflow either into or out of the topographically determined watershed. This was done by using automated geographic information system tools, with some additional manual delineation based on aerial photography and knowledge of the landscape. The initial topographic watershed was created by using the tools available in the Hydrology toolbox in Esri software ArcMap version 10.6.1, with a digital elevation model (DEM) as the initial input. The DEM was created from a 2-foot contour shapefile available from the City of Albuquerque (https://www.cabq.gov/gis/geographic-information-systems-data), with a final cell size of 50 by 50 feet. A final manual adjustment of the watershed boundary was made to account for irregularities and resolution issues with the input DEM, though some uncertainty remained in the final delineated watershed boundary because of potentially missing spatial storm drainage data and because of a lack of field verification. Additional geospatial analysis was conducted in ArcMap version 10.6.1 to derive the additional AHYMO data input requirements of basin channel length, basin centroid distance, and slope.

Precipitation data from the Westside rain gage were used as input data for the Sanchez Farms inflow rainfall-runoff model, and precipitation data from the South Valley Library rain gage were used for the Adobe Acres rainfall-runoff model. Precipitation data were reformatted to incremental inches starting from the beginning of each simulated rainfall response event. The watershed boundaries and their spatial relations to the Westside and South Valley Library rain gages are shown in figures 8 and 9, respectively.

Discharge values were simulated through rainfall-runoff modeling at the Sanchez Farms inflow and the Adobe Acres sites. Discharge at Alameda outflow, Alameda at Rio Grande, and Paseo outflow is dependent on operation of the stormflow pumps and therefore cannot be accurately simulated. The Sanchez Farms pump station site is located in a wetland, and discharge at that point is highly uncertain because of the large groundwater contribution and the unknown contribution to flow from the Sanchez Farms inflow concrete overflow basin. Therefore, load calculations, which are dependent on discharge, were determined for only the Sanchez Farms inflow and the Adobe Acres sites.

Rainfall-runoff modeling in this report was conducted without altering the initial abstraction values and constant infiltration rates suggested by the Albuquerque DPM because there were no measured discharge data with which to calibrate the model simulation data. The suggested model parameter values were empirically determined for the Albuquerque area but have not been calibrated for the specific subwatersheds in this study. The model results in this study have therefore not been verified. Also, AHYMO is an event-based stormflow model and does not account for base-flow input. During dry periods, however, stream discharge has been observed in the field at the Adobe Acres site, which can likely be attributed to groundwater-fed base flow. This base-flow discharge at the Adobe Acres site may be strongly affected by anthropogenic factors. The discharge results for Adobe Acres therefore represent the inflow volume from direct stormwater runoff but likely do not reflect the actual combined event and base-flow discharge.

Load Calculation Methods

Methods for calculating PCB loads are described in this section. In addition, the methods for addressing uncertainty associated with calculating loads is described.

Concentration Discharge Calculation

Total PCB loads were calculated using a simple *concentration x discharge* approach with the following equation (Meals and others, 2013),

$$load = \sum_{i=1}^{n} c_i q_i \Delta t$$

where over a set of n products, c is concentration, q is discharge, and Δt is the time interval over which the concentration and discharge measurements apply. In this study, concentration was in units of nanograms per liter, discharge was calculated in cubic feet per second (ft^3/s) and converted to liters per second, and the time step for the model simulations was 300 seconds, or 5 minutes. Loads were calculated for each individual stormflow event during which water samples were collected.

Load Calculation Uncertainty

Because of the flashiness of stormwater runoff in the Albuquerque urbanized area, only one composite sample was collected during each stormflow event over the course of 25 minutes to 2 hours; a higher sampling frequency during an event would increase the accuracy of the load calculation. Most samples were collected during the falling limb of the stormflow hydrograph (as determined by AHYMO), and it is possible that concentrations in the rising limb or peak of the hydrograph may exhibit different concentrations. Because of the low sampling frequency, the concentration at the time of sampling was assumed to be constant for the duration of the stormflow event. Assuming a constant concentration is a source of uncertainty in the load calculation because contaminant concentrations can be dependent on the magnitude of discharge, and discharge rates do not remain constant for the duration of an event.

To address the combined concentration and discharge uncertainty, total PCB event load estimates were constrained on the basis of the potential minimum and maximum loads for each event at each site. The potential minimum event loads for each event were estimated by applying the lowest measured concentration of total PCBs among all samples collected at a respective site to each stormflow event load calculation at that respective site. Likewise, the potential maximum loads were estimated by applying the highest measured total PCB concentration among all samples collected at a respective site to each stormflow event load calculation at that respective site. Each event therefore is reported with three separate load calculations: an estimated event load based on the concentration collected during the event, a potential minimum event load based on the lowest total PCB concentration collected at the site, and a potential maximum event load based on the maximum total PCB concentration measured at the site.

Precipitation in Albuquerque Near the Rio Grande

This section characterizes precipitation in Albuquerque, and details specific storm events during the study. In addition, this section highlights the importance of having multiple rain gages in the study area, due to the spatial heterogeneity of precipitation in Albuquerque.

Annual and Monsoon Season Precipitation 2008–18

The NOAA AISWS gage is the primary source of weather information for the Albuquerque metropolitan area. During the period from 2008 through 2018 at the AISWS gage (NOAA, 2019), an average of 64 percent of the annual precipitation total occurred between July and October, and 6 years had higher than average (7.90 inches) annual precipitation totals and higher than average (5.06 inches) monsoon precipitation totals (2008, 2010, 2013, 2014, 2015, and 2018). However, a higher than average percentage of total precipitation as monsoon rainfall did not always occur in years when monsoon precipitation itself was higher than average; 2009 and 2011 had lower than average monsoon and annual precipitation totals, but 70 and 68 percent of their annual precipitation occurred between the months of July and October, respectively. Conversely, just 50 percent of precipitation in 2015 occurred during the monsoon months (fig. 10).

Data from the AISWS are often used to characterize precipitation in the Albuquerque area, but precipitation that falls as a result of convective thunderstorms is often highly localized (Gupta and others, 2002). Additionally, the AISWS is in the southwest quadrant of the city; thus, the Bernalillo County rain gages operated by the USGS offer a more widespread survey of precipitation within the City of Albuquerque that better characterize the spatial heterogeneity of rainfall. Precipitation measured from July through October for 2008–18 for each of the four Bernalillo County rain gages (fig. 11) shows generally similar precipitation values for the pair of sites in the north (Alameda rain gage and Paseo rain gage) and the south (Westside rain gage and South Valley Library rain gage).

The funnel of the Alameda rain gage was partially clogged from July 26, 2017, through September 28, 2017, during which time 2.45 inches of precipitation were recorded. Because of quality-assurance standards, the data collected while the gage was clogged were removed from the NWIS database. Prior analysis of data from other rain gages in the Albuquerque urbanized area with partially clogged funnels indicates that, while precipitation intensity data are strongly affected by the clogged funnel, cumulative precipitation data remain similar to the estimated inverse-distance weighted total. The inverse-distance weighted total precipitation is an estimated value of precipitation calculated by taking the average precipitation value of surrounding gages and weighting them by applying the inverse of the distance to each known point. Because the clogged gage data remained similar to the estimated data, the 2.45 inches of precipitation that were omitted from the approved data in NWIS have been added to annual and monsoon totals recorded at that gage for the purposes of this report. These annual and monsoon precipitation values are considered estimates in this study, despite their corroboration by raw data collected at the site during this period (fig. 11).

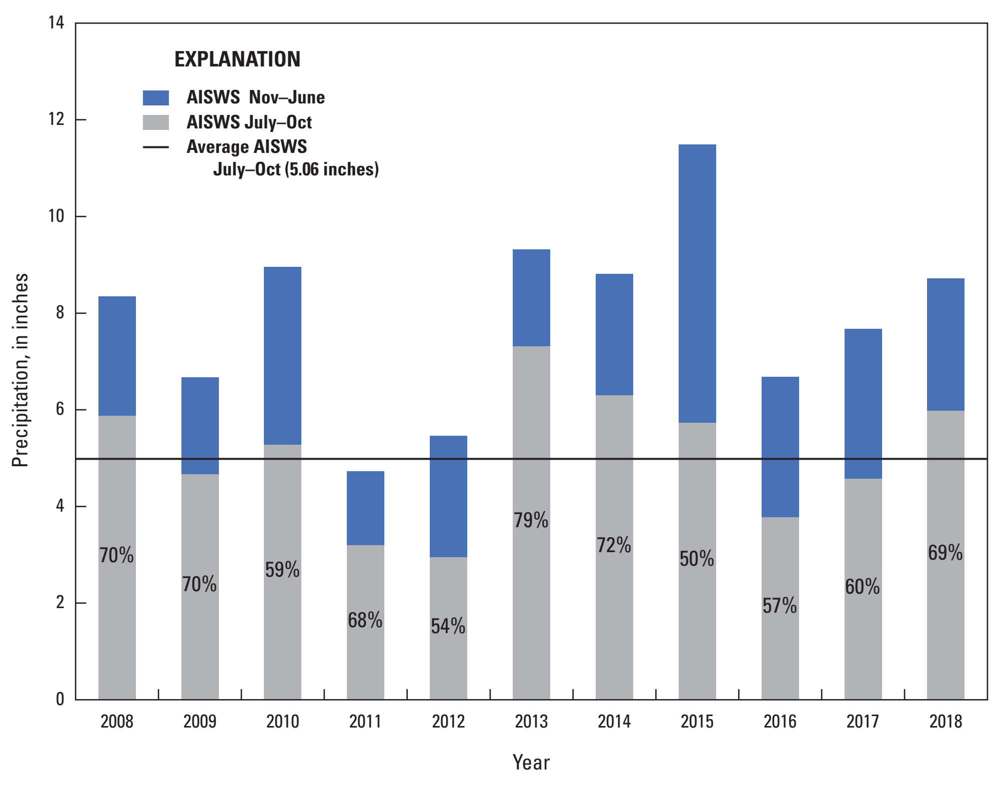


Figure 10. Annual precipitation at the National Weather Service Albuquerque International Sunport Weather Station (AISWS), 2008–18. Gray bars represent inches of precipitation from July through October; number is percent of total precipitation that fell during these months. [Data from NOAA, 2019].

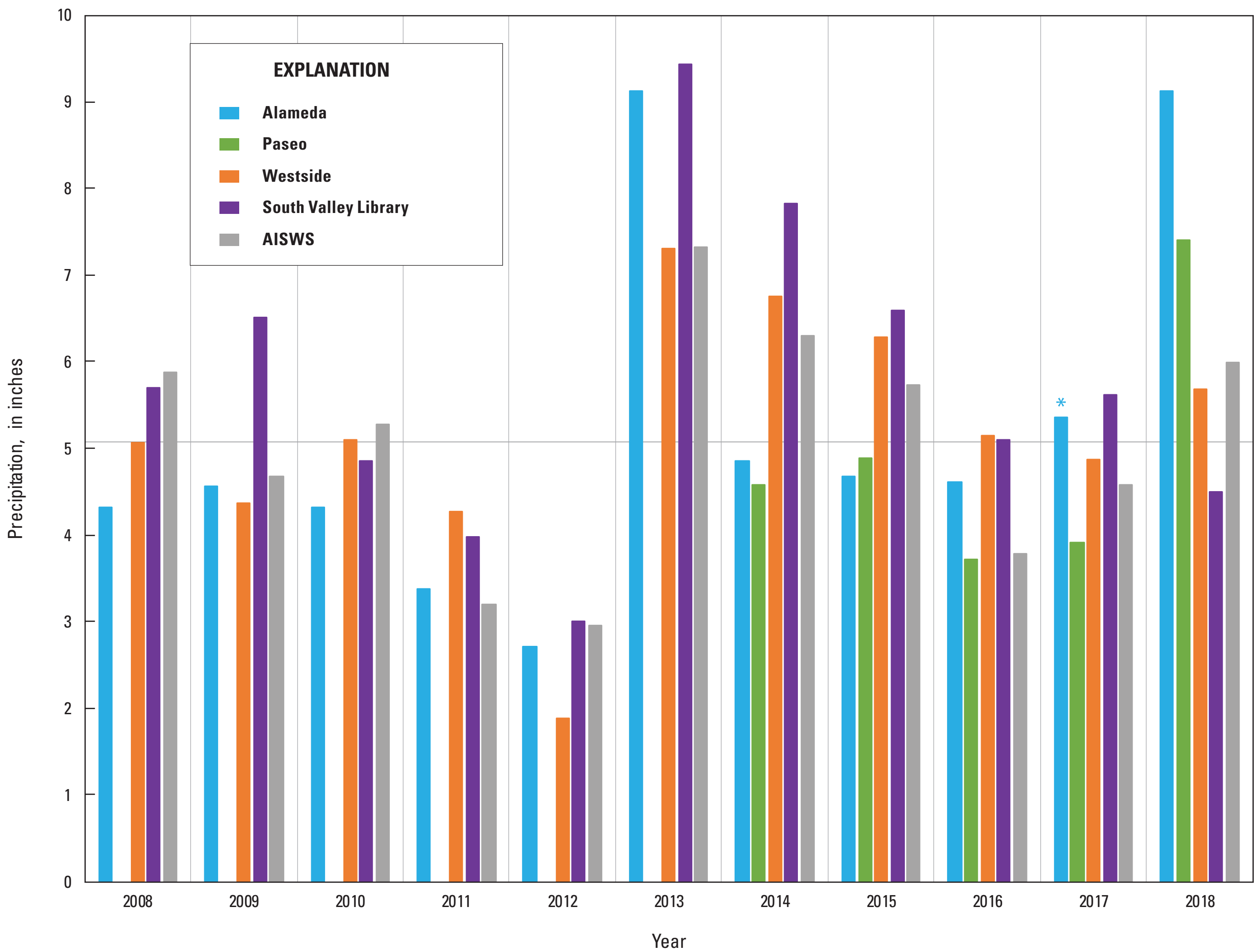


Figure 11. Precipitation measured at Alameda pump station (Alameda), Paseo pump station (Paseo), Westside Community Center near Albuquerque, N. Mex. (Westside), and South Valley Library near Albuquerque, N. Mex. (South Valley Library), rain gages and National Weather Service Albuquerque International Sunport Weather Station (AISWS) for July through October 2008–18. Solid black line represents the average July through October precipitation at AISWS. Asterisk (*) for Alameda rain gage in 2017 represents 2.45 inches of precipitation that was added as an estimate because the gage funnel was clogged at this time.

Precipitation Events 2017–18

Precipitation occurrence was considered as an isolated event if a substantial amount of precipitation over a continuous period was observed with more than 24 hours between precipitation measurements.

The largest 2017 precipitation event occurred on September 27, 2017 (fig. 12*A*, table 1). At the Paseo rain gage, this event occurred from 11:10 through 22:30; 0.98 inch of precipitation was recorded, although almost all of that precipitation fell during the 5.5-hour period from 17:00 through 22:30. The event at the Westside rain gage occurred over a 5.75-hour period from 16:35 through 22:20; 1.07 inches of precipitation were recorded. The event at the South Valley Library rain gage occurred from 12:45 to 22:15; 1.25 inches of precipitation was recorded, although almost all of that precipitation fell during the 5.5-hour period from 16:45 to 22:15.

In 2018, the largest event at all four rain gages occurred on October 23, 2018, to October 24, 2018 (fig. 12*B*, table 1). The Alameda rain gage recorded 1.65 inches of precipitation from 06:25 on October 23, 2018, through 11:45 on October 24, 2018; approximately 84 percent of that precipitation fell from 14:40 on October 23, 2018, to 11:45 on October 24, 2018. The Paseo rain gage recorded 1.61 inches of precipitation from 06:25 on October 23, 2018, through 11:20 on October 24, 2018; approximately 83 percent of that precipitation fell from 14:55 on October 23, 2018, to 11:20 on October 24, 2018. The Westside rain gage recorded 1.45 inches of precipitation from 06:15 on October 23, 2018, through 11:25 on October 24, 2018; approximately 83 percent of that precipitation fell from 14:25 on October 23, 2018, to 11:25 on October 24, 2018. The South Valley Library rain gage recorded 1.54 inches of precipitation from 06:10 on October 23, 2018, through 11:35 on October 24, 2018; about 78 percent of that precipitation fell from 15:10 on October 23, 2018, to 11:35 on October 24, 2018.

The maximum 5-minute intensity for the period of record did not necessarily coincide with the maximum precipitation event at each gage. The maximum 5-minute precipitation intensity at the Alameda rain gage and the Paseo rain gage both occurred on July 26, 2018; the Alameda rain gage recorded 0.33 inch per 5 minutes of precipitation at 19:35, and the Paseo rain gage recorded 0.50 inch per 5 minutes of precipitation at 19:50. The maximum 5-minute precipitation intensity at both the Westside rain gage and the South Valley Library rain gage was 0.38 inch per 5 minutes at 23:45 on September 28, 2017.

Chemical Concentrations

This section characterizes PCB concentrations in stormwater and sediment samples collected in the study area and discusses potential sources of PCBs on the basis of congener profiles. In addition, PCB concentration relations to additional water-quality properties or constituents are discussed.

Quality-Control Samples

No constituents were detected in the water equipment blank sample or the two water field blank samples. This included TOC (less than 2 milligrams per liter [mg/L]), TSS (less than 2 mg/L), SSC (less than 0.5 mg/L), and PCB congeners. Detection levels for individual PCB congeners ranged from 0.020 to 0.120 ng/L in the equipment blank sample, from 0.021 to 0.130 ng/L in one field blank sample, and from 0.100 to 0.610 ng/L in the other field blank sample. PCB-4 was detected in a laboratory blank sample at 0.107 ng/L (reporting level of 0.100 ng/L). PCB-4 detections in five environmental samples associated with that laboratory blank were censored as nondetects because they were detected at concentrations within two times the laboratory blank concentration (0.110 to 0.180 ng/L). The relative percent difference (RPD) between water field replicate samples was 1.2 and 2.1 percent for specific conductance for two sets of replicates, 5.3 to 40 percent for TOC for five sets of replicates, 8.3 to 103 percent for TSS for five sets of replicates, and 4 to 126 percent for SSC for four sets of replicates. Most of the PCB congeners were below detection in the five sets of water field replicate samples. A few were detected at concentrations near the reporting level in one of the paired samples and below the reporting level in the other paired sample. The RPDs for congeners detected in both samples of a pair were 0 to 25 percent (PCB-11), 43 percent (PCB-110/115), and 50 percent (PCB-118).

PCB congeners were not detected in the sediment field blank sample. Detection levels for individual congeners ranged from 1.7 to 10 ng/kg dw. The RPD between sediment field replicate samples was 0, 5.2, and 12.5 percent for organic carbon for three sets of replicates; 2.9 percent for PCB-11 (detected in both samples of one of two replicate pairs); and 6.1 and 14.9 percent for PCB-118 (detected in both samples of two of two replicate pairs). Two congeners were detected in one sample and not the paired replicate (220 and less than 230 ng/kg dw for PCB-153/168 and 570 and less than 600 ng/kg dw for PCB-187). The remaining congeners were not detected in the sediment field replicate samples. Other than the five censored PCB-4 detections for water samples, the results of the field and laboratory quality-control samples were satisfactory and indicated that the data could be used as reported.

PCBs in Water and Sediment Samples

PCBs in water and sediment samples collected for this study are presented in this section of the report. Concentrations for the PCB congeners are available in NWIS (USGS, 2019b).

A

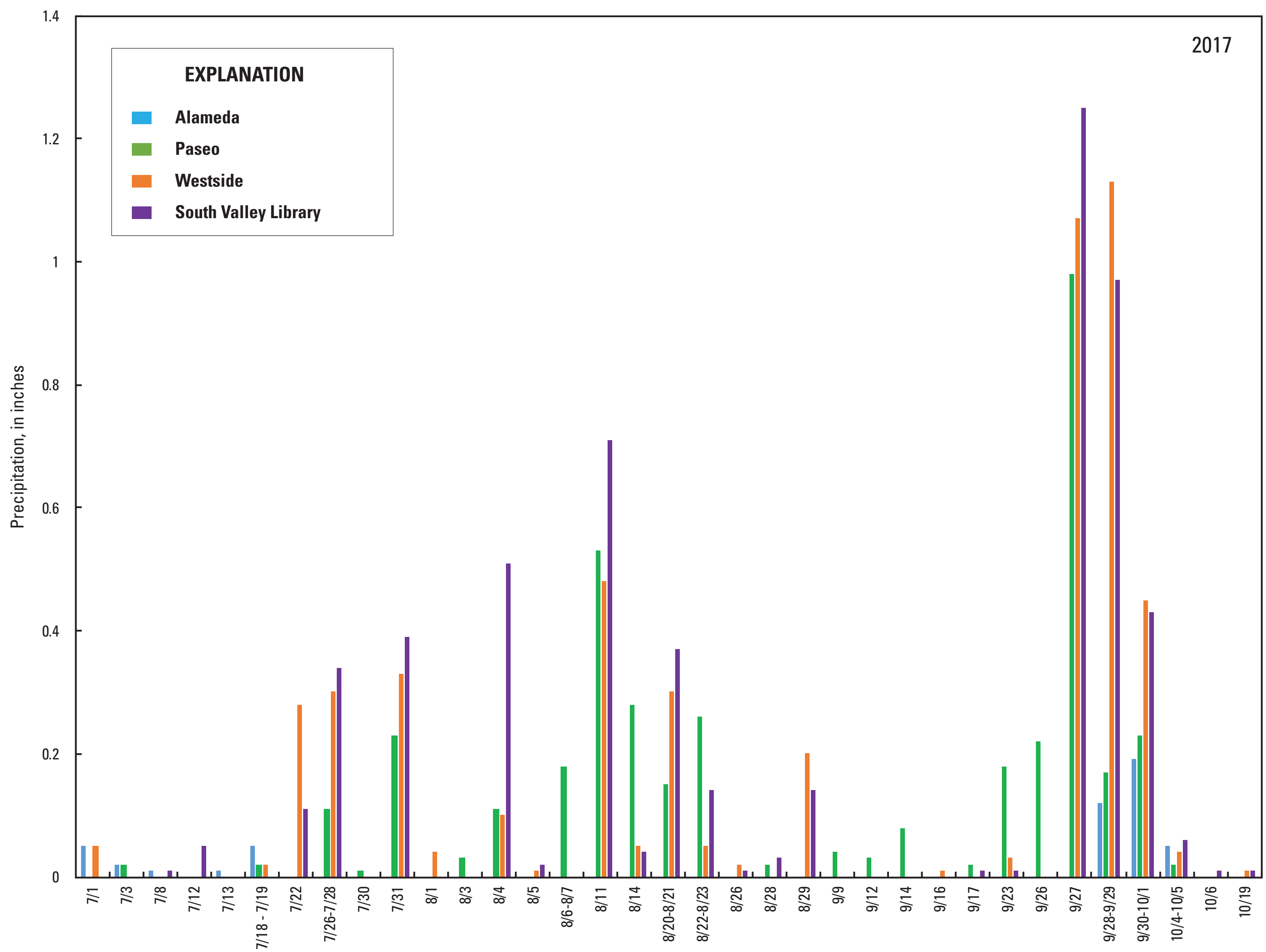


Figure 12. Total precipitation by event at the Alameda pump station (Alameda), Paseo pump station (Paseo), Westside Community Center near Albuquerque, N. Mex. (Westside), and South Valley Library near Albuquerque, N. Mex. (South Valley Library), rain gages, July through October. *A*, 2017. *B*, 2018.

B

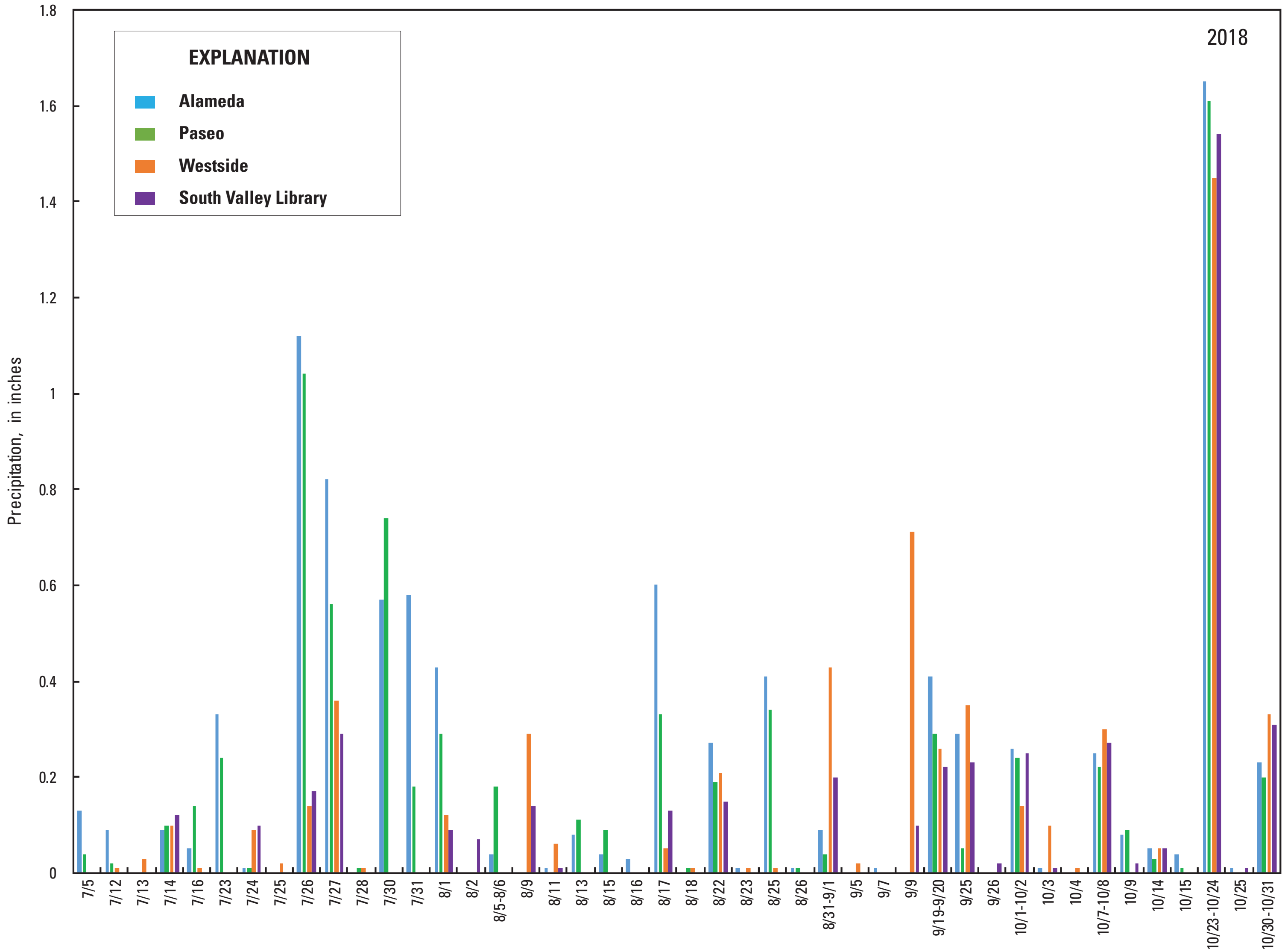


Figure 12. Total precipitation by event at the Alameda pump station (Alameda), Paseo pump station (Paseo), Westside Community Center near Albuquerque, N. Mex. (Westside), and South Valley Library near Albuquerque, N. Mex. (South Valley Library), rain gages, July through October. *A*, 2017. *B*, 2018.

Table 1. Precipitation event and intensity maximum values, Bernalillo County, New Mexico, 2017–18.

[Values represent precipitation measured between July 1 and October 31. in., inch; h:m, hour:minute; NA, not available; Alameda funnel clogged 7/26/2017 to 9/28/2017]

Site (rain gage) name and number	2017–18		2017			2018		
	Maximum 5-minute intensity (in.)	Date	Maximum precipitation event (in.)	Date	Duration (h:m)	Maximum precipitation event (in.)	Date	Duration (h:m)
Alameda (351140106381230)	0.33	7/26/2018	NA	NA	NA	1.65	10/23–10/24/2018	29:20
Paseo (351057106384330)	0.50	7/26/2018	0.98	9/27/2017	11:20	1.61	10/23–10/24/2018	28:55
Westside (350310106402430)	0.38	9/28/2017	1.07	9/27/2017	5:45	1.45	10/23–10/24/2018	29:10
South Valley Library (350107106405730)	0.38	9/28/2017	1.25	9/27/2017	9:30	1.54	10/23–10/24/2018	29:25

Water Samples

PCBs were detected in 34 of 36 water samples (table 2); PCB-11 was the only congener detected in 12 of those samples (USGS, 2019b). Concentrations of total PCBs in the 34 water samples with PCB detections were binned into three groups: (1) high concentrations, which exceeded the New Mexico surface-water quality standard for protection of wildlife habitat and aquatic life of 14 ng/L (NMED, 2018), (2) medium concentrations, from 0.700 to 14 ng/L, and (3) low concentrations, with concentrations less than 0.700 ng/L. The 0.700-ng/L value was chosen as the threshold between low and medium concentrations because this was the highest total PCB concentration in samples with PCB-11 as the only detected congener. Six water samples had high total PCB concentrations exceeding the 14 ng/L criteria (20.3–65.8 ng/L), whereas the remaining 30 samples were below the criteria. Two of these 30 samples had PCB concentrations below detection (<0.096 and <0.650 ng/L). Twelve of these samples had low total PCB concentrations (0.110–0.690 ng/L), and the remaining 16 had medium concentrations (0.800–7.62 ng/L) (table 2). None of the 36 water samples exceeded the NPDES permit level of 200 ng/L (NMED, 2018).

There were multiple orders of magnitude of variation in PCB concentrations, both between sites and at the same site over time, indicative of short-duration, high-concentration inputs of PCBs characteristic of urban stormwater runoff. For example, at Alameda at Rio Grande, total PCB concentrations increased from 0.260 ng/L on July 24, 2018, to 46.8 ng/L on July 26, 2018, and returned to 0.480 ng/L on July 27, 2018 (table 2). The timing of the high PCB concentration pulse corresponded to a large precipitation event (24-hour antecedent precipitation on July 26 was 1.12 inches at the Alameda rain gage), which suspended fine particulate matter in the water column (SSC increased from 47 to 299 mg/L, and percent fine material increased from 72 to 99 percent). During this same precipitation event, PCB concentrations also were high at Sanchez Farms pump station (20.3 ng/L on July 28, 2018), medium at Sanchez Farms inflow (6.09 ng/L on July 28, 2018) and low at Paseo outflow (0.350 and 0.580 ng/L on July 27, 2018), indicating high variability in the timing and magnitude of PCB concentrations between stormwater drainage basins across the watershed (table 2).

The highest total PCB concentration was measured at the Sanchez Farms pump station on September 25, 2018 (65.8 ng/L) (table 2). The two Sanchez sites had four of the six high PCB concentrations in water, and all samples from these two sites had either medium or high PCB concentrations, except for one sample without PCB detections at Sanchez Farms pump station. The two other high concentrations occurred at Alameda at Rio Grande on July 26, 2018 (46.8 ng/L), and Adobe Acres on July 12, 2017 (21.3 ng/L) (table 2). The other five water samples at Alameda at Rio Grande and nine samples at Adobe Acres had medium or low PCB concentrations. All of the water samples from the Alameda outflow and Paseo outflow had medium or low PCB concentrations or no PCB detections.

On 3 days, paired water samples were collected first at Sanchez Farms inflow and then, 1 to 10 hours later, at Sanchez Farms pump station (table 2, July 28, 2018, October 23, 2018, and November 2, 2018). Water travels from the Sanchez Farms inflow basin through a constructed wetland to the Sanchez Farms pump station. The traveltime between the two stations is unknown. Comparison of water quality at these two stations provides a first qualitative understanding of processes occurring in the wetland. Water temperatures were 1.8 to 11.9 degrees Celsius warmer in the inflow sample as compared to the pump station sample. On 2 of the 3 days (July 28, 2018, and October 23, 2018), TOC, SSC, and TSS were higher in the pump station sample than in the inflow sample, whereas on the third day (November 2, 2018) the reverse was true for TOC and TSS (no SSC data were available for November 2, 2018, for the pump station sample). Most notably, specific conductance on these three days was 278 to 644 microsiemens per centimeter (µS/cm) at the pump station, which was 1.4 to 5.1 times higher than in the paired inflow station sample. Concentrations of PCBs were in the medium (0.700–14 ng/L) or high (greater than 14 ng/L) categories in all six samples,

Table 2. Concentrations of polychlorinated biphenyls and other measurements of water quality in stormwater drainage basin water samples, Bernalillo County, New Mexico, 2017–18.

[h:m, hour:minute. Total PCBs, sum of detected concentrations of 209 polychlorinated biphenyl congeners, in nanograms per liter, rounded to three significant figures. Total PCB concentration bin: L, low concentrations less than 0.700 nanograms per liter; M, medium concentrations from 0.700 to 14.0 nanograms per liter; H, high concentrations greater than 14.0 nanograms per liter. PCBs, polychlorinated biphenyls; ng/L, nanogram per liter; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; mm, millimeter; in., inch; -, not analyzed for; NC, noncomposite sample; <, less than; ND, not detected]

Sampling date	Sample start time (h:m)	Sample end time (h:m)	Total PCBs (ng/L)	Total PCB concentration bin	Water temperature (degrees Celsius)	pH	Specific conductance (µS/cm)	Total organic carbon (mg/L)	Total suspended solids (mg/L)	Suspended sediment concentration (mg/L)	Suspended sediment, sieve diameter (percent smaller than 0.0625 mm)	24-hour antecedent rainfall at associated rain gage (in.)	72-hour antecedent rainfall at associated rain gage (in.)
Alameda Pump at Rio Grande inlet (351147106383001)													
9/27/2017	21:45	23:15	1.59	M	16.4	8.4	75	24	230	376	-	0.98	1.23
7/24/2018	1:00	2:50	0.260	L	24.8	7.1	204	59	48	47	72	0.33	0.33
7/26/2018	22:00	22:40	46.8	H	23.5	8.2	111	14	93	299	99	1.12	1.13
7/27/2018	23:20	23:55	0.480	L	22.8	8.1	77	13	72	78	97	0.81	1.93
8/17/2018	20:00	20:30	0.690	L	26.5	7.8	138	33	100	86	95	0.54	0.61
10/23/2018	10:22	11:02	0.600	L	16.2	8.6	183	44	75	74	-	0.27	0.27
Alameda pump station outflow (351146106382801)													
7/12/2017	8:30	NC	5.08	M	23.1	7.8	509	62	570	330	-	0	0
12/12/2017	11:00	NC	0.140	L	6.7	7.8	635	54	24	-	-	0	0
11/2/2018	10:45	NC	0.110	L	10.4	7.6	156	13	10	16	-	0	0.2
11/7/2018	15:00	NC	0.120	L	15.4	7.9	190	11	12	13	-	0	0
Paseo pump station outflow (351055106385501)													
12/12/2017	14:00	NC	<0.096	ND	7.8	8.3	712	2.9	7	-	-	0	0
7/27/2018	13:30	14:10	0.350	L	21.6	7.9	111	15	120	457	100	1.04	1.05
7/27/2018	14:30	NC	0.580	L	22.2	8.1	162	14	590	476	88	1.04	1.05
Sanchez Farms inflow (350304106401310)													
8/4/2017	18:15	19:30	23.4	H	24.5	7.9	216	70	220	317	-	0.08	0.08
7/28/2018	1:00	1:40	6.09	M	24.6	7.6	90	12	46	63	-	0.36	0.52
10/23/2018	17:25	18:00	33.8	H	17.2	8.5	85	11	55	75	-	0.29	0.54
11/2/2018	11:45	NC	4.32	M	17.7	7.0	457	82	73	94	-	0	0.33

Table 2. Concentrations of polychlorinated biphenyls and other measurements of water quality in stormwater drainage basin water samples, Bernalillo County, New Mexico, 2017–18.—Continued

[h:m, hour:minute. Total PCBs, sum of detected concentrations of 209 polychlorinated biphenyl congeners, in nanograms per liter, rounded to three significant figures. Total PCB concentration bin: L, low concentrations less than 0.700 nanograms per liter; M, medium concentrations from 0.700 to 14.0 nanograms per liter; H, high concentrations greater than 14.0 nanograms per liter. PCBs, polychlorinated biphenyls; ng/L, nanogram per liter; µS/cm, microsiemens per centimeter; mg/L, milligram per liter; mm, millimeter; in., inch; -, not analyzed for; NC, noncomposite sample; <, less than; ND, not detected]

Sampling date	Sample start time (h:m)	Sample end time (h:m)	Total PCBs (ng/L)	Total PCB concentration bin	Water temperature (degrees Celsius)	pH	Specific conductance (µS/cm)	Total organic carbon (mg/L)	Total suspended solids (mg/L)	Suspended sediment concentration (mg/L)	Suspended sediment, sieve diameter (percent smaller than 0.0625 mm)	24-hour antecedent rainfall at associated rain gage (in.)	72-hour antecedent rainfall at associated rain gage (in.)
Sanchez Farms pump station (350255106401510)													
7/28/2017	11:00	13:00	1.67	M	24.2	7.5	941	36	93	701	79	0.23	0.29
12/14/2017	10:30	NC	3.44	M	0.6	8.1	2,000	5.9	8	-	-	0	0
7/28/2018	1:00	1:45	20.3	H	21.9	7.4	458	29	110	106	-	0.36	0.52
9/1/2018	9:55	10:35	6.31	M	18.4	7.8	1,410	21	210	110	71	0.42	0.42
9/9/2018	23:25	23:50	7.41	M	19.1	7.8	351	18	58	86	-	0.71	0.71
9/25/2018	20:50	21:30	65.8	H	18.0	8.3	828	15	130	-	-	0.35	0.35
10/23/2018	18:15	18:55	7.62	M	15.4	8.0	278	19	94	93	-	0.29	0.54
11/2/2018	12:15	NC	2.39	M	5.8	7.6	644	14	34	-	-	0	0.33
11/7/2018	13:20	NC	<0.650	ND	6.4	7.5	1,530	12	12	220	-	0	0.33
Adobe Acres pump station (350059106410810)													
7/12/2017	11:30	NC	21.3	H	26.0	7.5	922	18	12,000	45,100	-	0	0
7/28/2017	9:00	11:00	1.02	M	26.0	7.4	339	22	180	537	-	0.27	0.34
8/21/2017	5:45	7:15	0.80	M	19.2	7.5	187	14	92	-	-	0.37	0.37
9/27/2017	21:15	NC	1.62	M	17.9	7.8	82	8.0	57	68	-	1.07	1.07
12/14/2017	9:10	NC	5.76	M	2.4	8.1	1,060	14	2,800	-	-	0	0
8/9/2018	23:20	0:00	1.76	M	24.4	7.6	356	30	78	82	-	0.14	0.14
9/20/2018	10:45	11:25	0.320	L	21.6	7.1	347	19	37	50	-	0.22	0.22
10/8/2018	9:55	10:35	0.340	L	13.8	7.9	265	12	19	17	-	0.27	0.27
11/2/2018	12:45	NC	0.230	L	13.1	7.3	747	4.6	16	19	-	0	0.31
11/7/2018	12:10	NC	1.07	M	13.5	7.1	968	11	340	496	-	0	0

with no upstream to downstream pattern: on October 23, 2018, PCB concentrations were in the high category in the inflow and in the medium category at the pump station; on July 28, 2018, the reverse was true; and on November 2, 2018, both samples had concentrations in the medium category.

Sediment Samples

Total PCBs (sum of 209 congeners) were detected in 12 of 13 sediment samples, ranging over multiple orders of magnitude from 340 to 163,000 ng/kg dw (table 3). Concentrations of total PCBs in the 13 sediment samples were binned into three categories: (1) high concentrations equal to or greater than 40,000 ng/kg dw, a threshold effect concentration below which adverse toxic effects on sediment-dwelling organisms are not expected to occur (MacDonald and others, 2000); (2) low concentrations less than 4,000 ng/kg dw, a 10-fold safety factor lower than the threshold effect concentration; and (3) medium concentrations from 4,000 to less than 40,000 ng/kg dw. There was one high concentration sample, collected at Sanchez Farms inflow on July 28, 2018, containing total PCBs of 163,000 ng/kg dw. The remaining 12 samples were below this threshold value. There were four medium-concentration samples (concentration ranges of 9,370–27,700 ng/kg dw) collected from Alameda at Rio Grande and Sanchez Farms pump station. The remaining samples had low concentrations (concentration ranges of 340–2,410 ng/kg dw). No samples exceeded an additional threshold of 400,000 ng/kg dw of PCBs, above which adverse toxic effects on sediment-dwelling organisms are expected to occur frequently. Organic carbon in the sediment samples ranged from 6,100 to 250,000 milligrams per kilogram (mg/kg) dw, or 0.61 to 25 percent of total sediment by dry weight (table 3).

Table 3. Concentrations of polychlorinated biphenyls and organic carbon in stormwater drainage basin sediment samples, Bernalillo County, New Mexico, 2017–18.

[h:m, hour:minute; PCB, polychlorinated biphenyl; ng/kg dw, nanogram per kilogram dry weight; concentration bin: L, low PCB concentrations less than 4,000 nanograms per kilogram dry weight; M, medium PCB concentrations from 4,000 to less than 40,000 nanograms per kilogram dry weight; H, high PCB concentrations 40,000 nanograms per kilogram dry weight and higher; ng/kg OC, nanogram per kilogram organic carbon; log K_D, sediment-water partition coefficient, where K_D (L/kg) = total PCBs concentration in bed sediment (ng/kg dw) / total PCBs concentration in unfiltered water (ng/L); log K_{OC}, organic carbon-water partition coefficient, where K_{OC} (L/kg organic carbon) = total PCBs concentration in organic carbon-normalized bed sediment (ng/kg organic carbon) / total PCBs concentration in unfiltered water (ng/L); -, no water sample collected on this day; <, less than]

Sampling date	Sample time (h:m)	Total PCBs (ng/kg dw)	Concentration bin	Organic carbon (mg/kg dw)	Organic carbon (percent)	Total PCBs (ng/kg OC)	log K_D	log K_{OC}
Alameda pump at Rio Grande Inlet (351147106383001)								
7/24/2018	3:00	13,200	M	78,000	7.8	169,000	4.71	5.81
7/26/2018	23:00	9,370	M	46,000	4.6	204,000	2.30	3.64
Alameda pump station outflow (351146106382801)								
12/12/2017	11:00	940	L	77,000	7.7	12,200	3.83	4.94
Paseo pump station outflow (351055106385501)								
7/12/2017	9:45	1,420	L	14,000	1.4	101,000	-	-
12/12/2017	14:00	<2,600	L	15,000	1.5	<173,000	-	-
7/27/2018	14:20	1,110	L	24,000	2.4	46,300	3.28	4.90
Sanchez Farms inflow at Albuquerque, N. Mex. (350304106401310)								
7/28/2018	1:45	163,000	H	250,000	25	653,000	4.43	5.03
Sanchez Farms pump station (350255106401510)								
7/28/2017	11:00	2,410	L	29,000	2.9	83,100	3.16	4.70
12/14/2017	10:30	27,700	M	160,000	16	173,000	3.91	4.70
7/28/2018	2:00	25,100	M	110,000	11	228,000	3.09	4.05
Adobe Acres pump station (350059106410810)								
7/28/2017	9:00	1,770	L	7,400	0.74	239,000	3.24	5.37
12/14/2017	9:10	1,700	L	91,000	9.1	18,700	2.47	3.51
8/10/2018	0:10	340	L	6,100	0.61	55,700	2.29	4.50

The three sediment samples with greater than 10 percent organic carbon content were from the two Sanchez Farms sites. Organic carbon-normalized PCB concentrations—that is, total PCBs (ng/kg OC)—ranged from 12,200 to 653,000 ng/kg organic carbon (table 3).

One paired set of sediment samples was collected on the same day (July 28, 2018) from the Sanchez Farms inflow and the Sanchez Farms pump station. Concentrations of PCBs and organic carbon were greatly reduced between the inflow and the pump station, from 163,000 to 25,100 ng/kg dw of PCBs and from 25 to 11 percent organic carbon. Though further controlled study that accounts for traveltime between the two sampling locations is needed, the intervening wetland may help to attenuate high pulses of sediment-bound PCBs from the inflow to the pump station. In contrast, the paired water samples collected on the same day (July 28, 2018), in which the pump station PCB concentration was more than three times higher than the inflow PCB concentration and the pump station organic carbon concentration was more than two times higher than the inflow organic carbon concentration. Further study is needed to determine if there are additional sources of PCBs and organic carbon to the pump station, for example, from groundwater, that may explain the elevated concentrations in water at the pump station as compared to the inlet station.

PCB concentrations were compared in 11 pairs of simultaneously collected water and sediment samples to determine an instantaneous sediment-water partition coefficient (K_D) and organic carbon-water partition coefficient (K_{OC}) at the time of sample collection, where

K_D liters per kilogram = Total PCB concentration in bed sediment nanograms per kilogram dry weight/total PCB concentration in unfiltered water nanograms per liter; and

K_{OC} liters per kilogram organic carbon = Total PCB concentration in organic carbon-normalized bed sediment nanograms per kilogram organic carbon /total PCB concentration in unfiltered water nanograms per liter.

Sediment-water partition coefficients ranged from log K_D = 2.29 to 4.71 (table 3), with a median of 3.26. Organic carbon-water partition coefficients ranged from log K_{OC} = 3.51 to 5.81 (table 3). These values are on the low end but within the range of literature values and calculated values based on PCB partition theory, which generally range from log K_{OC} = 4 to 6 (Schwarzenbach and others, 2003). Strongly hydrophobic compounds such as PCBs preferentially partition to solids rather than remain dissolved in water. The PCB concentrations in water samples from these stormwater drainage basins likely fluctuate rapidly, especially during the short-duration, high-intensity stormwater runoff events captured in this study. One of the lowest log K_D values (2.30) was determined during the large precipitation storm on July 26, 2018, when very high PCB concentrations were measured in the water. Two days earlier, on July 24, 2018, at the same site, the PCB concentrations in the water sample were near the detection level, resulting in the highest log K_D of 4.71.

Relation of PCB Concentrations to Other Water-Quality Properties or Constituents

Water temperature ranged from 0.6 to 26.5 degrees Celsius at the time of sample collection for the 36 water samples (table 2). Values of pH ranged from 7.0 to 8.6, and specific conductance ranged from 75 to 2,000 µS/cm. TOC in water samples ranged from 2.9 to 82 mg/L. TSS ranged from 7 to 12,000 mg/L. SSC (for which 29 of the 36 water samples were analyzed) ranged from 13 to 45,100 mg/L. The percent fine material in the eight available suspended sediment samples ranged from 71 to 100 percent. There was a strong linear relation between TSS and SSC for concentrations as high as approximately 100 mg/L (fig. 13, coefficient of determination (R^2) = 0.881), and then the relation devolved above approximately 100 mg/L. TSS and SSC also were significantly positively correlated using the nonparametric Kendall's tau test (Kendall's tau = 0.8; p-value = 3.8E−6). The sample with extremely high TSS (12,000 mg/L) and SSC (45,100 mg/L) was removed from figure 13 for visualization purposes but remained in the dataset (table 2). The day when this high-concentration suspended sediment sample was collected at Adobe Acres (July 12, 2017) also was the day when the only high PCB concentration in water was determined at Adobe Acres (21.3 ng/L, table 2). The authors hypothesize that the PCBs measured in the water sample were sorbed to the high amount of suspended sediment. This was the first sampling event of the study, with no antecedent precipitation. The source or cause of the high SSC is unknown and may have been a sampling artifact, such as the bed sediment being disturbed by the individual collecting the water sample.

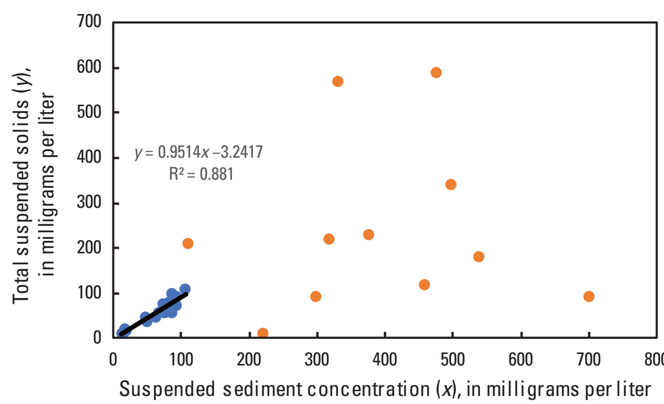


Figure 13. Relation between suspended sediment concentration and total suspended solids in water samples collected from stormwater drainage basins, Bernalillo County, New Mexico, 2017–18. One high value greater than 10,000 milligrams per liter was excluded for visualization.

Simple linear regressions were developed between total PCBs in water and other water-quality and hydrologic parameters to identify surrogate parameters for predicting water PCB concentrations that are easier and less costly to collect than PCBs. There was no linear relation between PCB concentrations in water and SSC (fig. 14*A*, R^2 = 0.0002), TSS (fig. 14*B*, R^2 = 0.00008), TOC (fig. 14*C*, R^2 = 0.0008), specific conductance (fig. 14*D*, R^2 = 0.00001), 24-hour antecedent precipitation (fig. 14*E*, R^2 = 0.0229), or 72-hour antecedent precipitation (fig. 14*F*, R^2 = 0.0242). The water samples with high PCB concentrations (greater than 14 ng/L) had SSC values greater than or equal to 75 mg/L (75 to 45,000 mg/L), when available (one sample with high PCBs had no corresponding SSC value, table 2). However, there were many samples with SSC values greater than 200 mg/L and low or medium PCB concentrations. The samples with high PCB concentrations had TSS values less than 250 mg/L, with the exception of one very high TSS value of 12,000 mg/L. Other samples with the highest TSS values (500–3,000 mg/L) had low or medium PCB concentrations. The water samples with high PCB concentrations had TOC values from 11 to 70 mg/L, and there were many water samples with TOC values greater than 20 mg/L that had low or medium PCB concentrations. The samples with the six highest PCB concentrations had specific conductance values less than 1,000 µS/cm.

Sampling events during the wet season targeted stormwater runoff immediately following a precipitation event, so the 24-hour antecedent precipitation often contributed most of the 72-hour antecedent precipitation total, resulting in similar graphs for these two precipitation periods (fig. 14*E* and *F*). The six highest PCB concentrations in water samples were not linearly related to antecedent precipitation and occurred over a range of precipitation from 0 to greater than 1 inch.

There were no strong, simple linear relations between PCB concentration in water and explanatory variables including SSC, TSS, TOC, specific conductance, or 24-hour or 72-hour antecedent precipitation total. High SSC or high percent fine sediment did not indicate high PCB concentrations. However, based on the physicochemical properties of PCBs, if two samples are collected at the same location and time, theoretically the one with higher SSC, higher percent fine sediment, and (or) higher TOC will have the higher PCB concentration. This is because PCBs are hydrophobic and preferentially sorb to particulates, rather than remain dissolved in water, and preferentially sorb to organic matter on fine sediment such as silts and clays, which have large surface areas as compared to sandy material (Karickhoff and others, 1979; Schwarzenbach and Westall, 1981).

Nonparametric analysis identified one significant water correlation: total PCBs and TSS were significantly positively correlated (Kendall's tau = 0.4, p-value = 0.0007). When only the SSC values less than 100 mg/L were considered, there was also a significant positive correlation between total PCBs and SSC less than 100 mg/L (Kendall's tau = 0.3; p-value = 0.019). In sediment, total PCBs were significantly positively correlated with organic carbon content (Kendall's tau = 0.62, p-value = 0.003). The results indicate that none of the explanatory variables in this study—SSC, TSS, TOC, specific conductance, or antecedent precipitation—are a singular simple, linear proxy of water PCB concentration in these stormwater systems. However, the SSC in the water sample likely is one important variable. PCB concentrations in water likely are a function of a complex mix of variables, including timing of sample collection on the hydrograph or pump cycle. Particulates and associated contaminants often have the highest concentration at the beginning of a precipitation event as they are first washed off the land surface, with decreasing concentrations throughout the remainder of the event (Gilbreath and McKee, 2015). The small area of the watersheds in this study likely minimizes the difference in traveltimes between areas of the watershed that may have different PCB contributions from different particle sources. Watershed characteristics also may affect PCB concentrations. For example, the prevalence of urban litter or refuse such as food containers and magazines with PCB-containing inks (Stone, 2016) may leach PCBs into the water and sediment in the storm drain system.

PCB Congener Profiles and Source Implications

Approximately 11 congeners (or coeluting congers) were detected frequently and consistently contributed the highest proportions to the total PCB concentration in water and sediment samples (table 4; USGS, 2019b). PCB-11 was the most frequently detected congener in water samples—in all 34 samples with detected PCBs—and often was the only detected congener in a sample, with detected concentrations ranging from 0.110 to 2.20 ng/L. PCB-11 was detected less frequently in sediment samples—7 of 12 samples with detected PCBs. Other than PCB-11, the remaining frequently detected congeners in water samples (detected in more than 55 percent of samples, or 20 or more samples) were all pentachloro (containing five chlorines) congeners such as PCB-110/115 and PCB-118 or hexachloro (containing six chlorines) congeners such as PCB-129/138/163, PCB-147/149, and PCB-153/168. These pentachloro and hexachloro congeners also were the most frequently detected congeners in sediment samples (table 4). PCB-118 was detected in all 12 sediment samples with detected PCBs. In addition, PCB-90/101/113 and PCB-99 were detected frequently in sediment samples (but less frequently in water samples). The congeners with the highest concentrations in water and sediment samples were PCB-110/115, PCB-118, and PCB-129/138/163.

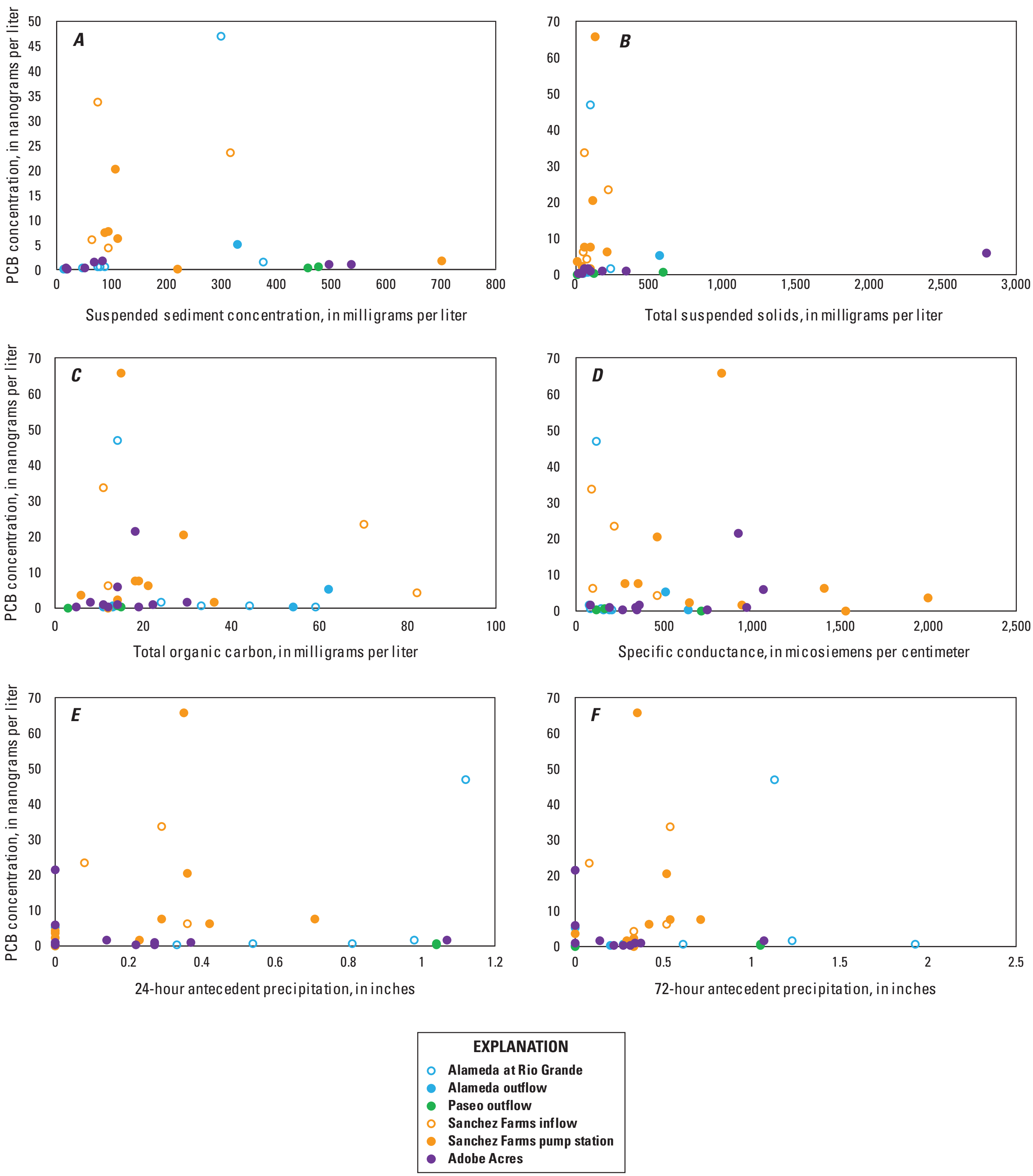


Figure 14. Relations between polychlorinated biphenyl concentration in water samples collected from stormwater drainage basins, Bernalillo County, New Mexico, 2017–18, and *A*, suspended sediment concentration; *B*, total suspended solids; *C*, total organic carbon; *D*, specific conductance; *E*, 24-hour antecedent precipitation; and *F*, 72-hour antecedent precipitation.

Table 4. Polychlorinated biphenyl congeners detected in more than 55 percent of stormwater drainage basin water or sediment samples, Bernalillo County, New Mexico, 2017–18.

[More than 55 percent is 20 or more water samples and 8 or more sediment samples. Less frequently detected congeners are reported in the table when they were detected frequently in the other matrix type. ng/L, nanogram per liter; ng/kg dw, nanogram per kilogram dry weight; PCB, polychlorinated biphenyl]

Congener(s)	Homolog group	Water		Sediment	
		Number of detections (out of 36 samples)	Maximum concentration (ng/L)	Number of detections (out of 13 samples)	Maximum concentration (ng/kg dw)
PCB-11	Di	34	2.20	7	2,300
PCB-90/101/113	Penta	17	3.70	8	10,000
PCB-95	Penta	20	1.90	8	5,500
PCB-99	Penta	16	1.40	8	4,300
PCB-105	Penta	19	2.70	8	7,900
PCB-110/115	Penta	21	6.40	9	17,000
PCB-118	Penta	22	5.90	12	18,000
PCB-129/138/163	Hexa	20	8.20	8	18,000
PCB-132	Hexa	20	2.50	8	5,600
PCB-147/149	Hexa	20	4.10	8	7,500
PCB-153/168	Hexa	20	4.90	8	10,000

There were three distinct PCB congener profiles in the water and sediment samples across the six sites and over time. The first profile contained only PCB-11; it was the only congener detected in the 12 water samples with low PCB concentrations (table 2). For example, the two Paseo outflow water samples with PCB concentrations above the reporting level and three of the four Alameda outflow water samples had this profile (example profiles shown in fig. 15*A* and *B*, respectively). The four water samples with low PCB concentrations at Alameda at Rio Grande and the three water samples with low PCB concentrations at Adobe Acres also had this PCB-11 profile.

The second profile in the water and sediment samples was dominated by pentachloro and hexachloro congeners, in addition to PCB-11. The pentachloro congeners included PCB-110/115 and PCB-118 and hexachloro congeners such as PCB-129/138/163, PCB-147/149, and PCB-153/168. This profile was common in the water and sediment samples with high PCB concentrations (tables 2 and 3). For example, all of the Sanchez Farms inflow and Sanchez Farms pump station water and sediment samples with PCB detections had this profile (examples shown in fig. 15*C* and *D*, respectively). The Adobe Acres sediment samples and medium- and high-concentration water samples also had this profile (fig. 15*E*). PCB-11 contributed a higher percentage to the total PCB concentration at the Adobe Acres site as compared to the Sanchez Farms sites.

Three water samples and two sediment samples were collected during a large precipitation event on July 24, 2018, through July 28, 2018, at Alameda at Rio Grande. One water sample and one sediment sample were collected on July 24, 2018, as the storm was beginning (0.33 inch of rain had fallen in the previous 24 hours). One water sample and one sediment sample were collected 2 days later, on July 26, 2018, after 1.12 inches of rain had fallen in the previous 24 hours. A water sample was collected the next day, on July 27, 2018, as the storm was ending (0.81 inch of rain in the previous 24 hours). The early-storm and late-storm water samples (collected on July 24, 2018, and July 27, 2018, respectively) had the first PCB congener profile, with PCB-11 as the only detected congener. The PCB congener profiles of the sediment samples resembled the second profile. The July 26, 2018, water sample had a unique congener profile (fig. 15*F*). This third distinct congener profile had lower proportions of low-chlorine congeners such as PCB-110 and PCB-118 and higher proportions of high-chlorine congeners such as PCB-147/149, PCB-153/168, PCB-170, PCB-174, and PCB-180/193 as compared to the second profile.

When water and sediment samples at a site had detections of congeners besides PCB-11, the PCB congener profile was similar in water and sediment, for all sites (for example, fig. 15*C*–*E*), with the one exception described earlier (water sample collected on July 26, 2018, at Alameda at Rio Grande, fig. 15*F*). The profiles indicate that the source of PCBs to each stormwater drainage basin is similar and that there is not preferential partition of individual congeners between water and sediment. The different signature of the water sample at Alameda at Rio Grande indicates that there was a distinct PCB source in water to that site during the July 26, 2018, precipitation event that was not reflected in the sediment samples collected on July 24, 2018, or July 26, 2018. Subsequent water samples had low PCB concentrations, and no sediment samples were collected after that July 2018 event to help identify the unique signature in settling sediment.

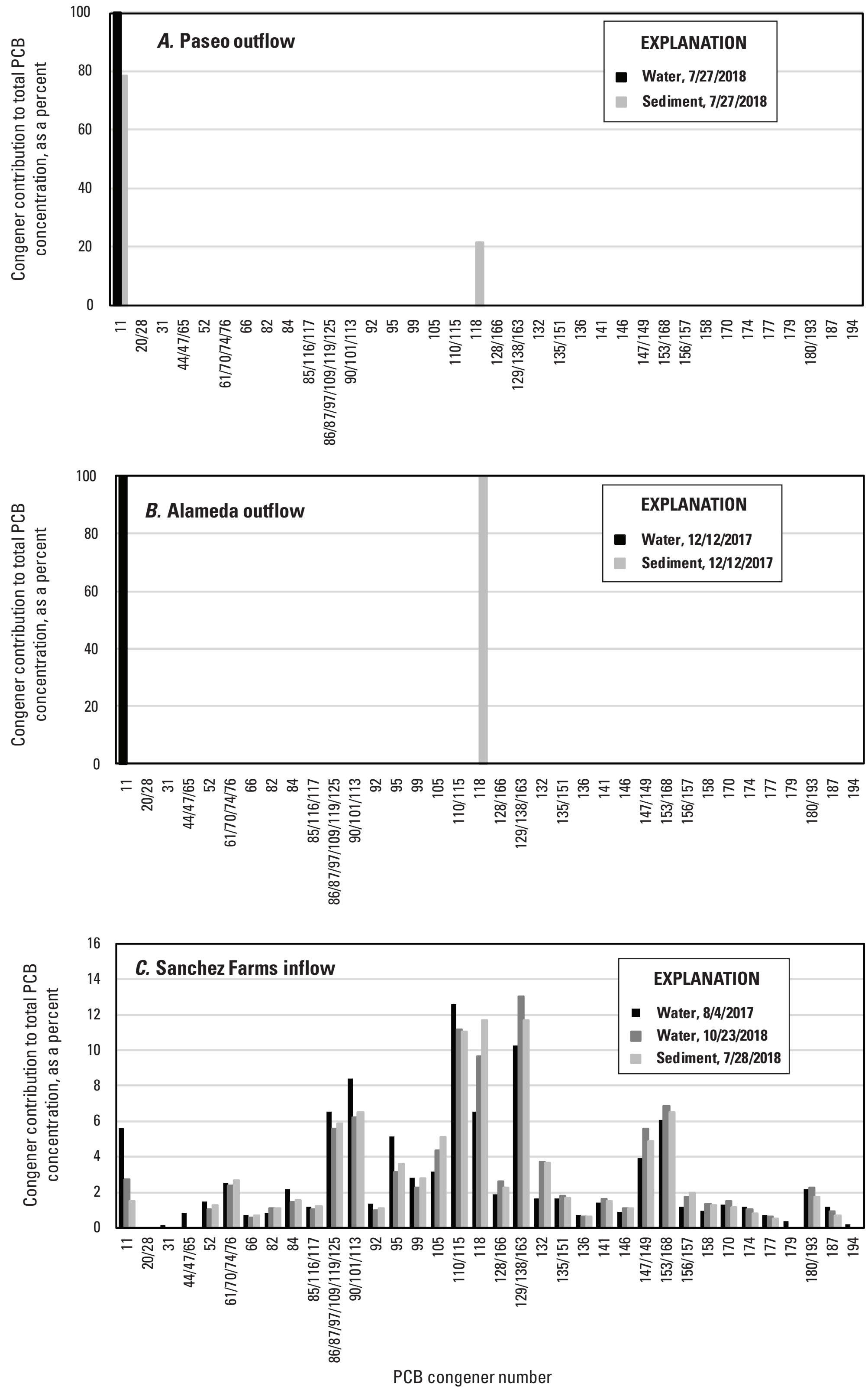


Figure 15. Example polychlorinated biphenyl congener profiles in water and sediment samples at *A*, Paseo pump station outflow (Paseo outflow); *B*, Alameda pump station outflow (Alameda outflow); *C*, Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow); *D*, Sanchez Farms pump station; *E*, Adobe Acres pump station (Adobe Acres); and *F*, Alameda pump at Rio Grande Inlet (Alameda at Rio Grande), Bernalillo County, New Mexico, 2017–18 (if a congener contributed more than 1 percent of the total PCB concentration in any sample, it was included in all plots).

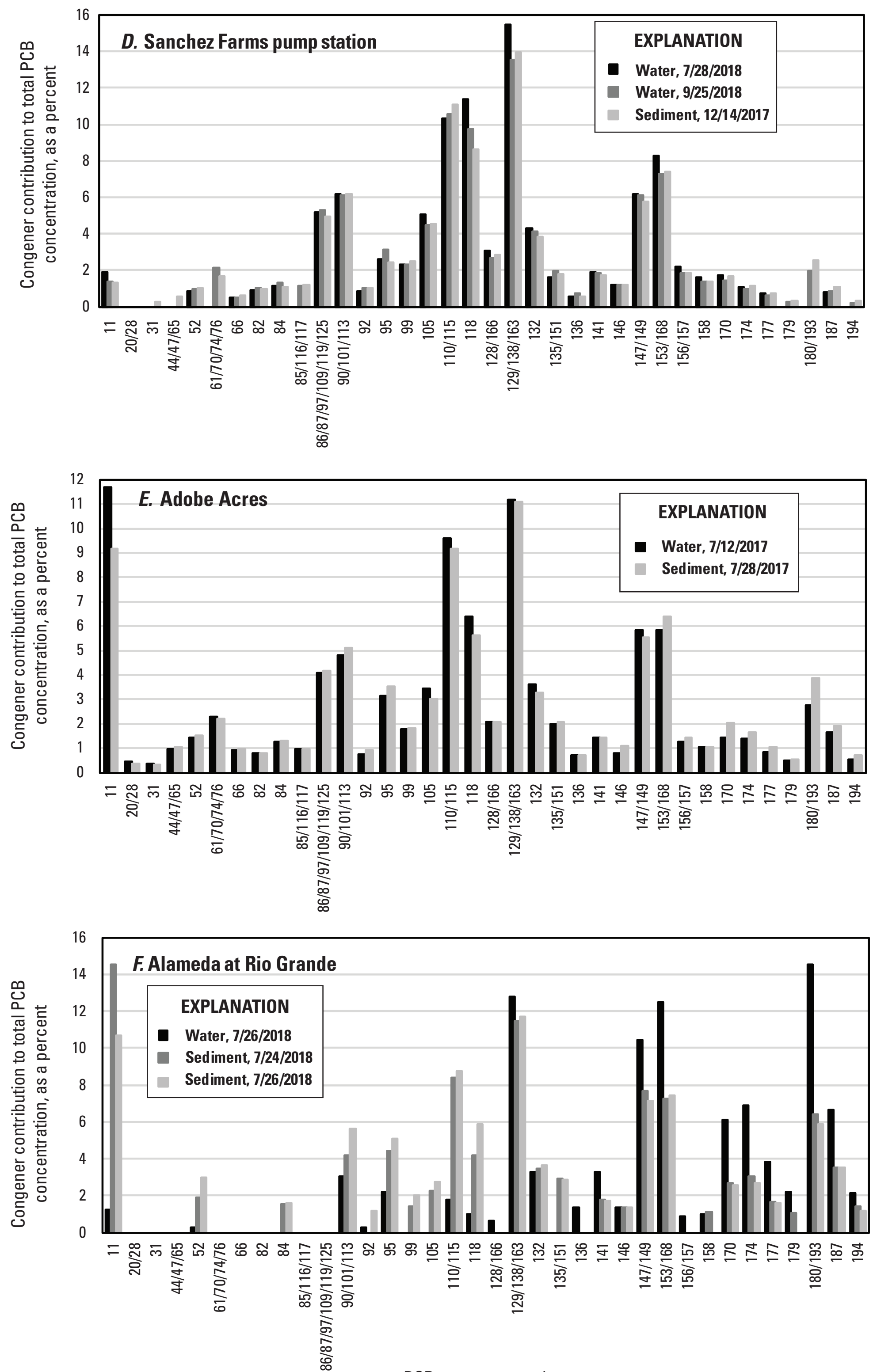


Figure 15. Example polychlorinated biphenyl congener profiles in water and sediment samples at *A*, Paseo pump station outflow (Paseo outflow); *B*, Alameda pump station outflow (Alameda outflow); *C*, Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow); *D*, Sanchez Farms pump station; *E*, Adobe Acres pump station (Adobe Acres); and *F*, Alameda pump at Rio Grande Inlet (Alameda at Rio Grande), Bernalillo County, New Mexico, 2017–18 (if a congener contributed more than 1 percent of the total PCB concentration in any sample, it was included in all plots).—Continued

The first congener profile discussed previously for water and sediment samples was predominantly PCB-11. PCB-11 is a common laboratory contaminant regularly detected in quality-control samples at PCB analytical laboratories. In this study, PCB-11 was not detected in the equipment blank, field blank, or laboratory blank samples by the analytical laboratory (see “Quality-Control Samples” section). PCB-11 was not a major component of historical Aroclor formulations and has been identified in modern sources of PCBs, for example, as a component of diarylide yellow pigments used in food packaging, color newspapers, and magazines (Hu and Hornbuckle, 2010; Rodenburg and others, 2010; Guo and others, 2014). Therefore, it is an indicator of current-use PCBs rather than historical Aroclor-sourced PCBs. Reported concentrations of PCB-11 in source materials such as printed paper and fabric materials, pigments, inks, and paints have ranged from part-per-billion or lower levels to a few reports of concentrations exceeding the 50 part-per-million total PCB EPA standard by more than 20 times (Shang and others, 2014). PCB-11 is the predominant congener in yellow pigment samples, sometimes accounting for more than 99 percent of the total PCB concentration (Shang and others, 2014). Congeners found to co-occur with PCB-11 in source materials, typically contributing less than 10 percent of the total PCB concentration, include PCB-28, PCB-52, and PCB-77 (Shang and others, 2014). In this study, PCB-20/28 was detected in two water samples with PCB-11 concentrations greater than 1 ng/L. PCB-52 was detected in 17 water samples, and PCB-77 was detected in 5 water samples, including 4 samples with total PCBs greater than 14 ng/L. These three congeners contributed less than 1 percent of the total PCB concentration in Aroclor mixtures, supporting the hypothesis that some of the PCBs present in the storm drain system samples in this study were from current-use sources rather than legacy Aroclor sources. Stormwater runoff washes contaminants from impervious surfaces in urban areas like parking lots. Urban litter collects in the sampled stormwater drainage basins, and leaching of inked materials such as food containers, color newspapers, and magazines is a possible source.

The second profile discussed previously contains PCB-11 and many other congeners used in Aroclor mixtures. PCB-118 is the predominant congener in Aroclor 1254; Aroclor 1254 also has large contributions from PCB-61/70/74/76, PCB-110/115, PCB-86/87/97/109/119/125, PCB-105, and PCB-129/138/163 (fig. 16*A*). PCB-129/138/163 also makes a large contribution to Aroclor 1260 (fig. 16*B*), along with PCB-147/149, PCB-153/168, and PCB-180/193. The second profile discussed for water and sediment samples resembles a mixture of Aroclor 1254 and Aroclor 1260. For example, a representative profile—the water sample collected on July 12, 2017, at Adobe Acres—resembles a theoretical mixture of 50 percent Aroclor 1254 and 50 percent Aroclor 1260 in addition to containing PCB-11 (fig. 16*C*). The third profile discussed previously, which occurred in only one water sample collected on July 26, 2018, at Alameda at Rio Grande, resembled pure Aroclor 1260 (fig. 16*B*).

The six water samples with the highest PCB concentrations were collected in July through October, during the wet season. It is likely that contaminants such as PCBs accumulate on the land surface and on airborne particulates during the dry spring and early summer seasons and are washed into the storm drain systems during the wet season. Water samples collected after the wet season in November and December had low or medium PCB concentrations. The samples were collected after no precipitation had occurred, and likely there had been time for processes that can reduce PCB concentrations in water to occur, such as settling of suspended particulates in the bottom sediment of the basins, photolysis, and volatilization.

PCB sources to stormwater drainage basins in the Albuquerque urbanized area appear to originate both from legacy sources (Aroclor mixtures) and from current-use sources (for example, pigments). Alameda at Rio Grande had a distinctly Aroclor 1260-dominant signature in the one high-concentration water sample collected after more than 1 inch of precipitation had fallen in the previous 24 hours (July 26, 2018). The two sediment samples collected during the same precipitation event at that site had a mixed Aroclor 1260/1254 congener signature that was prevalent in all other medium- and high-concentration water and sediment samples collected from the other stormwater drainage basins in the study. Aroclor 1260 was approximately 11 percent of the total U.S. production of PCBs (Brown, 1994) and was produced predominantly for four uses: in transformers, in hydraulic fluids, as a plasticizer in synthetic resins, and in dedusting agents (Nisbet and Sarofim, 1972; Erickson, 1997). The similarity of the PCB profile in the July 26, 2018, water sample at Alameda at Rio Grande to Aroclor 1260 (fig. 16*B*) indicates a point source, such as a contaminated site or spill source, of relatively unweathered Aroclor 1260 that can be transported by rainfall runoff to Alameda at Rio Grande. Single, point sources of Aroclor 1260 contamination have been identified in the Delaware River Basin (Du and others, 2008) and New York/New Jersey harbor (Panero and others, 2005).

PCB-11 often was the only congener detected in water samples and was detected at concentrations as high as 2.2 ng/L (table 4). It was not detected in quality-control samples including laboratory blanks and equipment blanks. It is the primary PCB congener in many yellow pigments, inks, and paints (Shang and others, 2014), and a growing body of literature indicates that yellow pigment manufacturing is the primary source of PCB-11 to the environment (Litten and others, 2002; Hu and Hornbuckle, 2010). This indicates that current-use products containing yellow pigments, such as color magazines, printed paper and fabrics, and printed food containers, are one source of PCBs to these stormwater drainage basins.

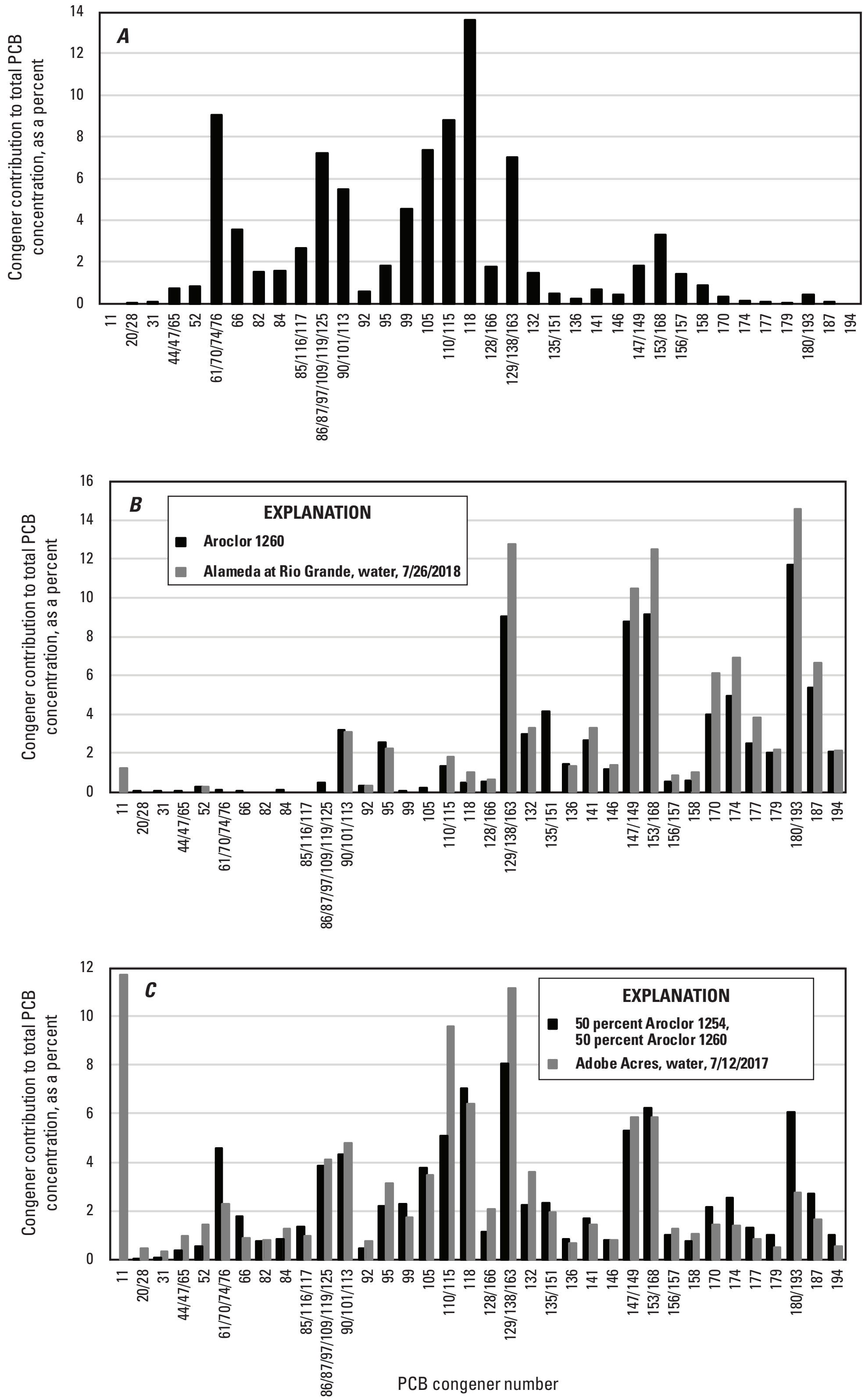


Figure 16. Polychlorinated biphenyl congener profiles of *A*, Aroclor 1254; *B*, Aroclor 1260 compared to the profile of the water sample collected on 7/26/2018 at Alameda Pump at Rio Grande Inlet (Alameda at Rio Grande); and *C*, a theoretical mixture of 50 percent Aroclor 1254 and 50 percent Aroclor 1260 compared to the profile of the water sample collected on 7/12/2017 at Adobe Acres pump station (Adobe Acres) (Aroclor profiles from Frame and others, 1996; if a congener contributed more than 1 percent of the total PCB concentration in any sample, it was included in all plots).

Nonachloro (PCB-206, -207, -208) and decachloro (PCB-209) congeners also have been suggested as indicators of current-use PCBs, as they were not part of legacy Aroclor mixtures and have been measured in phthalocyanine green pigments (Anezaki and Nakano, 2014) and as byproducts from the manufacture of titanium dioxide (Du and others, 2008). Nonachloro and decachloro PCB congeners were rarely detected and, when detected, were present at low concentrations in the water samples from the stormwater drainage basins in this study. Nonachloro and decachloro PCB congeners were detected in four sediment samples, though at very low concentrations (less than 3 percent of the total PCB concentration), indicating that products containing these high-molecular-weight PCB congeners were not a major source of PCBs to the stormwater drainage basins during the sampling events.

Environmental weathering processes alter the source PCB composition. Each individual congener has unique physiochemical properties, such as solubility, volatility, and microbial dechlorination, that affect the extent of weathering processes. The weathering typically results in a PCB profile in environmental water and sediment samples that does not match any single source profile but rather represents the source plus weathering plus mixing with other weathered sources.

PCB Concentration Site Comparison and Context With Previous Studies

The results of this study quantitatively confirm that there are measurable concentrations of PCBs in water and sediment in the four stormwater systems sampled in the study area. High concentrations exceeding the New Mexico surface-water quality standard for protection of wildlife habitat and aquatic life of 14 ng/L (NMED, 2018) were detected multiple times in water at the Sanchez Farms sites, and most of the remaining samples at those sites had medium concentrations (0.700–14 ng/L) (table 2). The one sediment sample in the study that exceeded the threshold effect concentration of 40,000 ng/kg dw was from Sanchez Farms inflow (163,000 ng/kg dw) (table 3). Alameda at Rio Grande had a single high-concentration water sample and two medium-concentration sediment samples during a large precipitation event in July 2018. Alameda outflow had one medium-concentration water sample; the remaining water samples and sediment samples had low concentrations of PCBs. Paseo outflow had low or nondetectable PCB concentrations in water and sediment throughout the study. Adobe Acres had a single high-concentration water sample in July 2017, which may have been related to the very high SSC (45,100 mg/L) (table 2). About one-half of the remaining water samples at Adobe Acres had medium-concentration levels of PCBs. The remaining Adobe Acres water samples and the three sediment samples at that site had low concentrations of PCBs.

Water and sediment samples from the Sanchez Farms sites had the highest PCB concentrations of any site. At the Sanchez Farms sampling sites, water flows through a constructed wetland from Sanchez Farms inflow to Sanchez Farms pump station. The wetland appears to reduce sediment-bound PCB concentrations and sediment organic content; this reduction may be caused by strong sorption of PCBs to soil organic matter and clay rather than by uptake of PCBs in plants through the roots (Mackova and others, 2009). No upstream-to-downstream pattern was apparent for PCB concentrations in water. Specific conductance increased between the inflow station and the pump station. Additional sampling at a higher spatial and temporal resolution within the Sanchez Farms Open Space recreation area may elucidate sources of water and contaminants contributing to the wetland system, including groundwater and an upgradient pond; traveltimes; and chemical processes including settling of particulates, volatilization, and plant uptake within the wetlands.

The PCB concentrations in urban stormwater in the Albuquerque urbanized area, measured in this study (<0.096–65.8 ng/L) were similar to the range of PCB concentrations measured in the Upper Rio Grande watershed including urban runoff in Los Alamos (0.1–144 ng/L), northern New Mexico tributaries of the Rio Grande (0.28–29.5 ng/L), and Rio Grande and Rio Chama river water samples collected during baseline and storm events (not detected–51.4 ng/L) (Los Alamos National Laboratory, 2012). The PCB concentrations measured in this study also were within the range of stormwater-affected river samples collected over eight wet seasons from the Guadalupe River, California, between 2003 and 2014 (sum of 40 PCB congeners ranged from 0.69 to 167 ng/L; McKee and others, 2017). Sources of PCBs in the Guadalupe River were found to predominantly reflect Aroclors 1254 and 1260 (McKee and others, 2017), similar to the results of this study.

Concentrations of PCBs in sediment from urban stormwater drainage basins in the Albuquerque urbanized area measured in this study (340–163,000 ng/kg dw) were within the range of reported values in urban river sediments in the Rhone River, France, of 3,500–300,000 ng/kg dw (Desmet and others, 2012) and similar to values at Leon Creek, San Antonio, Texas, of 200–8,700 ng/kg dw at the low end but could be much higher (Wilson, 2016). PCBs were cited as most likely to be the congener mixture of Aroclor 1260 in Leon Creek (Wilson, 2016).

AHYMO Rainfall-Runoff Modeling Results

Six stormflow events were simulated at Adobe Acres, and two events were simulated at the Sanchez Farms inflow, for a total of eight simulated events. A summary of the simulated stormflow event data and their associated estimated PCB event loads can be found in table 5. The delineated area of the Adobe Acres watershed was 0.22 square mile, which had only one subwatershed for AHYMO modeling purposes (figs. 1, 3*A*, and 9). The Sanchez Farms watershed was divided into three subwatersheds, which totaled in area of 1.03 square miles.

Adobe Acres Pump Station Stormflow Events

The average total estimated runoff volume for all Adobe Acres stormflow events was 1.86 acre-feet, with an average peak discharge rate of 11.99 ft^3/s (table 5). The cumulative event precipitation depth total for these events averaged 0.43 inch. Although several of the events spanned 2 calendar days, each stormflow event occurred in a relatively short time span, all lasting less than 14 hours. In addition to being short duration, the stormflow events were also relatively flashy. From the time the model determined as the start of discharge (discharge = 0.1 ft^3/s) to the time of the peak discharge rate, the average time was 2 hours and 32 minutes. However, some of the events had multiple local peaks in discharge (fig. 17). In the case of the stormflow event that occurred between September 19, 2018, and September 20, 2018 (fig. 17*C*), peak discharge was not reached on the first local peak, so the time to peak discharge was 8 hours and 10 minutes (table 5). With the exception of this event, the remaining stormflow events reached peak discharge in less than 3 hours, and peak discharge for two events occurred in less than 1 hour. The shortest time to peak discharge was just 30 minutes during the stormflow event between October 7, 2018, and October 8, 2018.

Sanchez Farms Inflow Stormflow Events

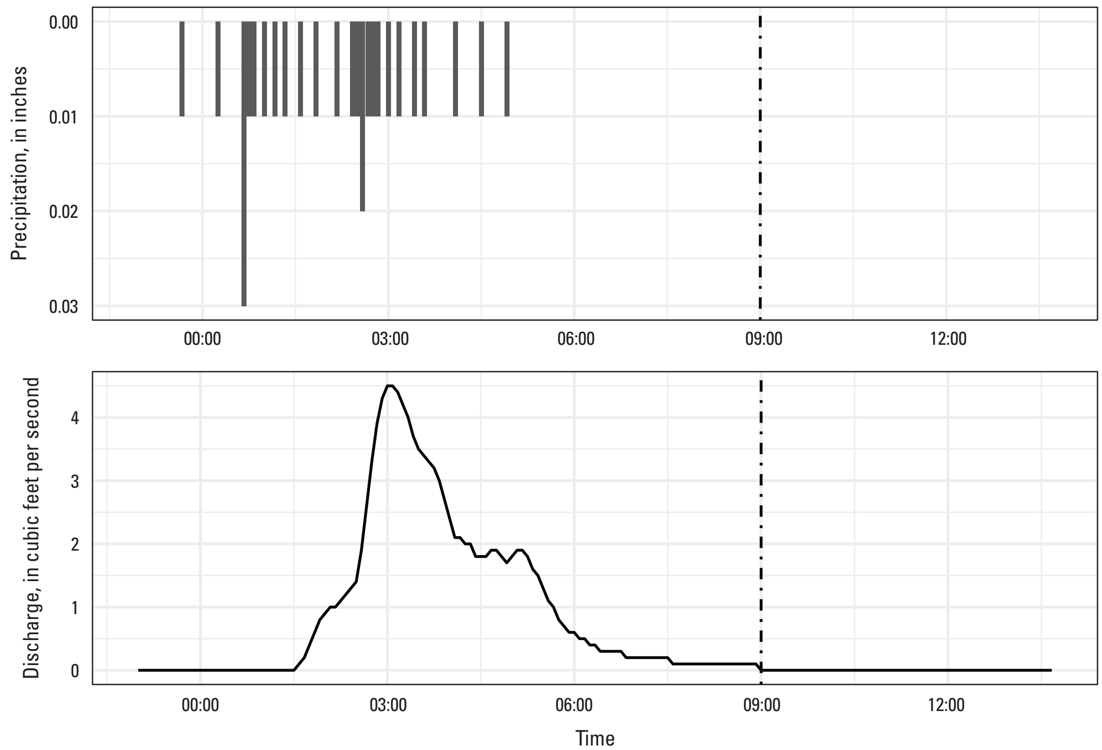
The two simulated events at the Sanchez Farms inflow varied significantly in terms of total cumulative precipitation and total runoff volume. The event between July 27, 2018, and July 28, 2018, had a cumulative precipitation of 0.36 inch and runoff volume of 2.23 acre-feet, and the event between October 23, 2018, and October 24, 2018, had a cumulative precipitation of 1.45 inches and runoff volume of 12.90 acre-feet (table 5). The later event was relatively long and was the only simulated event to exceed the duration of 24 hours. This event was associated with multiple spikes in precipitation and multiple local peaks in discharge, so it had the highest total runoff volume of any stormflow event at either of the outflow sites included in simulations (fig. 18). The event between July 27, 2018, and July 28, 2018, had a lower total runoff volume but a slightly higher peak discharge of 17.74 ft^3/s, compared to 16.63 ft^3/s for the October 23, 2018, to October 24, 2018, stormflow event. The runoff total volume and peak discharge rates of either stormflow event at this site exceeded the average total volume and peak discharge rate values of the stormflow events at the Adobe Acres site.

Table 5. Summary of load calculations and model simulation results for Adobe Acres pump station (Adobe Acres) and Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow), sites, Albuquerque, New Mexico, 2017–18.

[h:m, hour:minute; mg, milligram; in., inch; ft^3/s, cubic foot per second]

Discharge event date(s)	Discharge event start time (h:m)	Discharge event end time (h:m)	Estimated event load (mg)	Potential minimum event load (mg)	Potential maximum event load (mg)	Cumulative event precipitation total (in.)	Total runoff volume (acre-feet)	Peak discharge (ft^3/s)	Time to peak (h:m)
Adobe Acres pump station (350059106410810)									
7/28/2017	1:35	8:55	1.01	0.32	1.75	0.27	0.81	4.49	1:25
8/9–8/10/2018	20:55	1:10	0.34	0.06	0.34	0.14	0.16	1.31	1:30
8/21/2017	1:05	9:20	1.47	0.59	3.24	0.37	1.50	16.84	2:45
9/19–9/20/2018	22:30	10:50	0.26	0.26	3.24	0.22	0.67	1.97	8:10
9/27–9/28/2017	16:55	6:10	14.26	2.82	15.50	1.28	7.14	41.45	0:55
10/7–10/8/2018	20:55	7:50	0.36	0.34	1.88	0.27	0.87	5.86	0:30
Averages			2.95	0.73	4.32	0.43	1.86	11.99	2:32
Sanchez Farms inlet (350304106401310)									
7/27–7/28/2018	22:25	7:05	16.71	16.71	92.74	0.36	2.23	17.74	1:05
10/23–10/24/2018	6:35	17:50	537.51	96.85	537.51	1.45	12.90	16.63	26:15
Averages			277.11	56.78	315.13	0.91	7.56	17.19	13:40

A



B

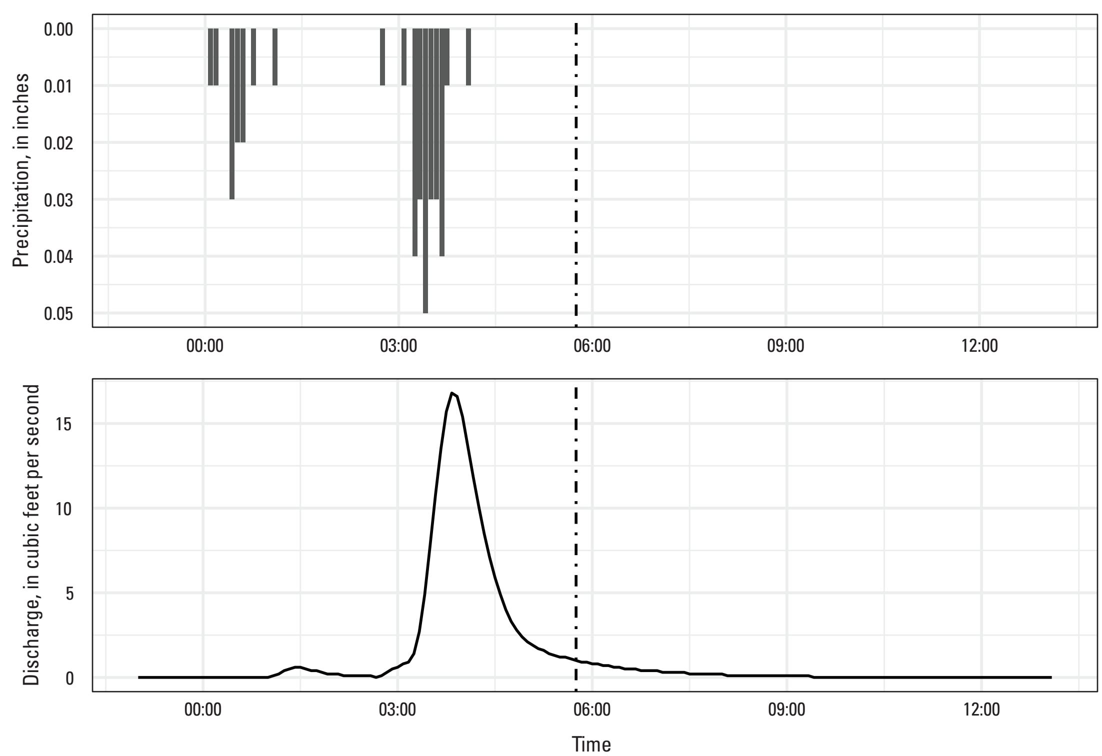
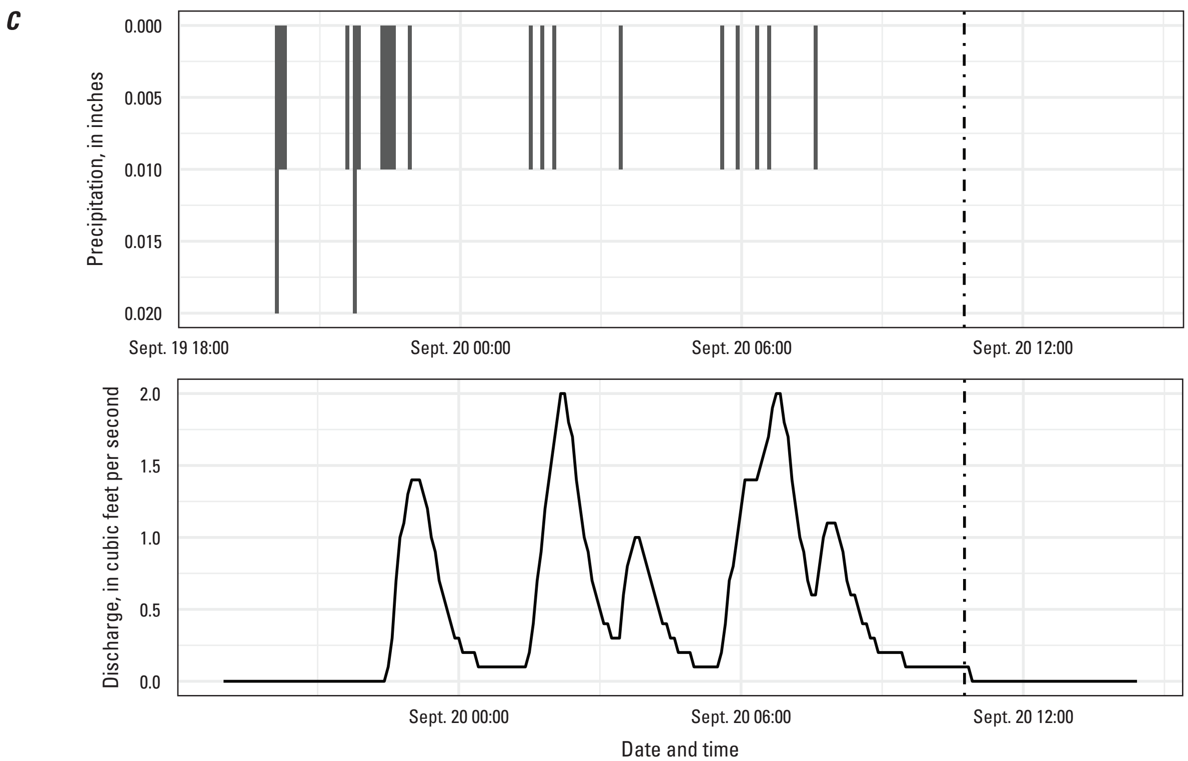


Figure 17. Precipitation and discharge results at the Adobe Acres pump station (Adobe Acres) site for *A*, 7/28/17; *B*, 8/21/17; *C*, 9/19–9/20/18; *D*, 9/27–9/28/17; *E*, 10/7–10/8/18; and *F*, 8/9–8/10/18. The dashed line on each graph represents the time at which a water-quality sample was collected.



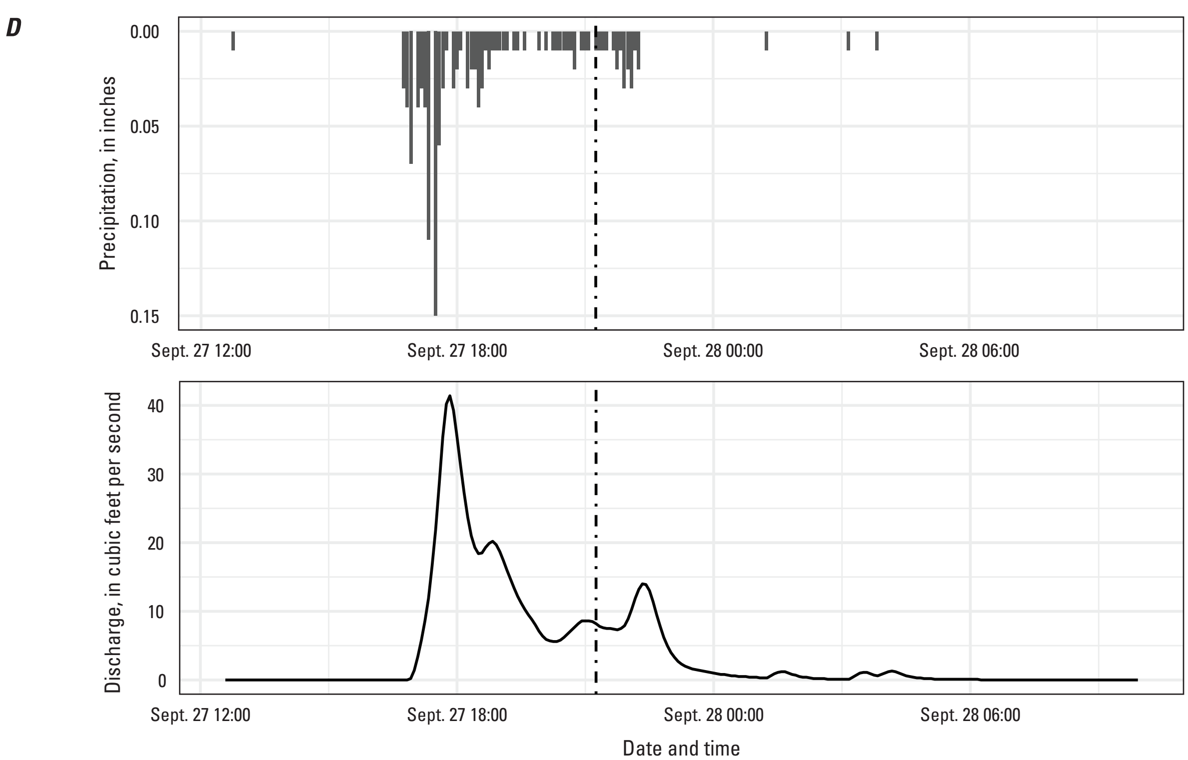
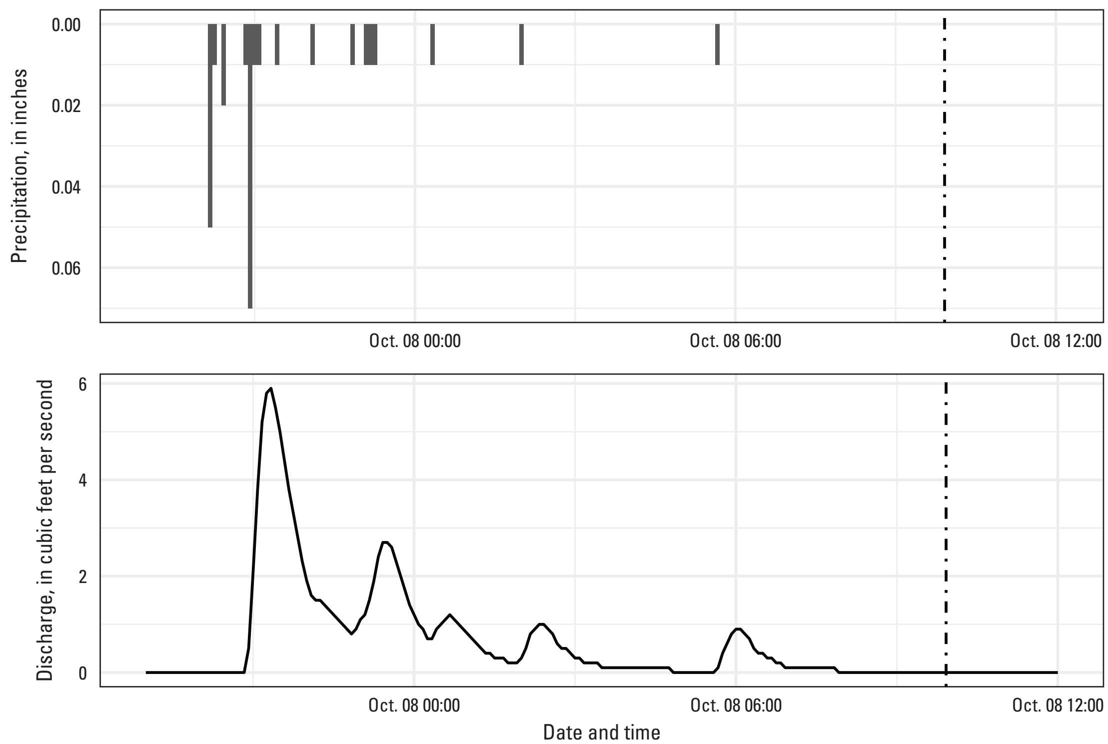


Figure 17. Precipitation and discharge results at the Adobe Acres pump station (Adobe Acres) site for *A*, 7/28/17; *B*, 8/21/17; *C*, 9/19-9/20/18; *D*, 9/27-9/28/17; *E*, 10/7-10/8/18; and *F*, 8/9-8/10/18. The dashed line on each graph represents the time at which a water-quality sample was collected.—Continued

E



F

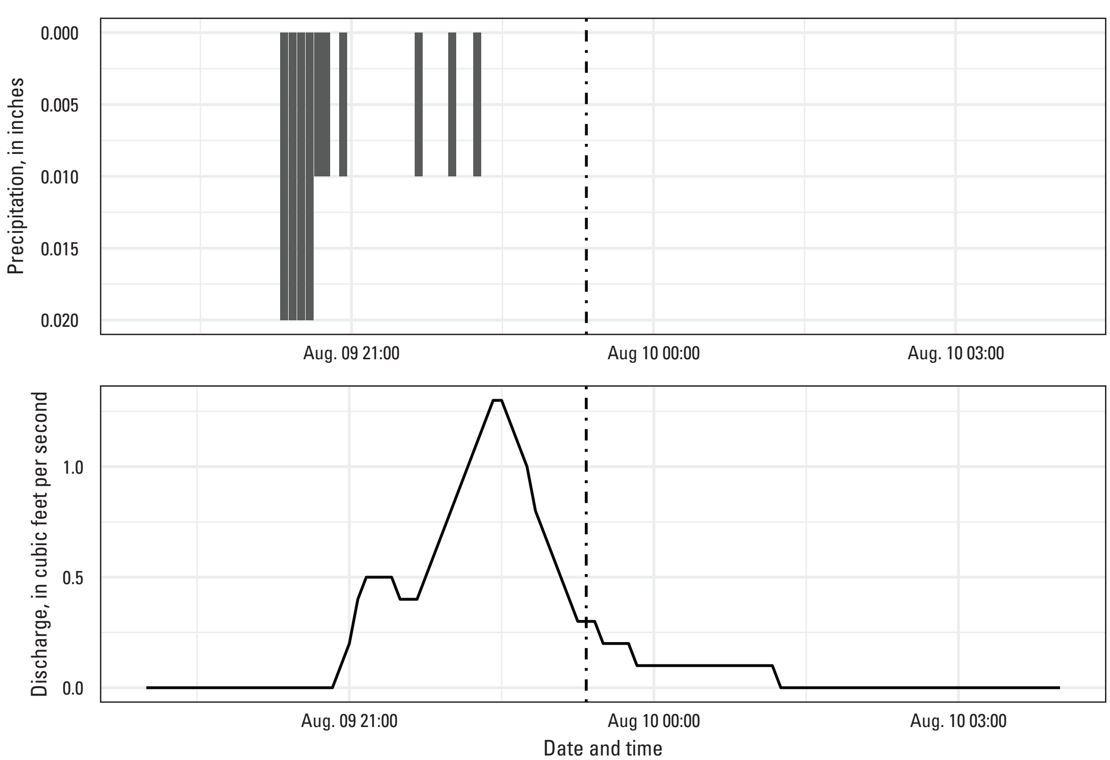
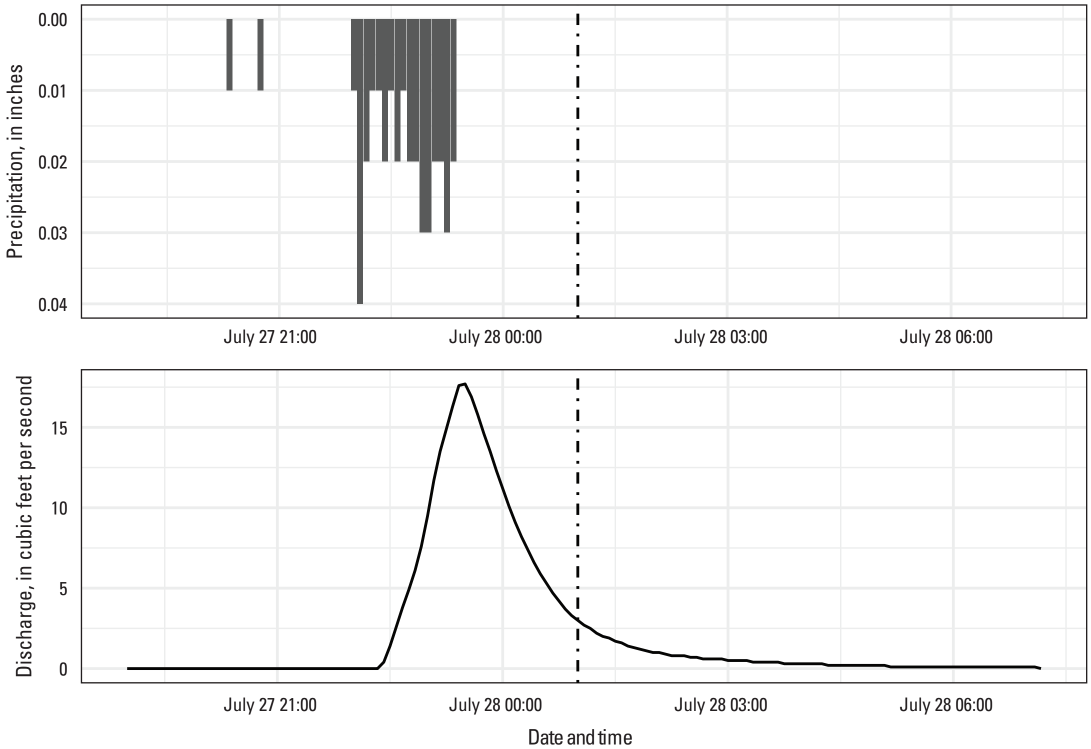


Figure 17. Precipitation and discharge results at the Adobe Acres pump station (Adobe Acres) site for *A*, 7/28/17; *B*, 8/21/17; *C*, 9/19-9/20/18; *D*, 9/27-9/28/17; *E*, 10/7-10/8/18; and *F*, 8/9-8/10/18. The dashed line on each graph represents the time at which a water-quality sample was collected.—Continued

A



B

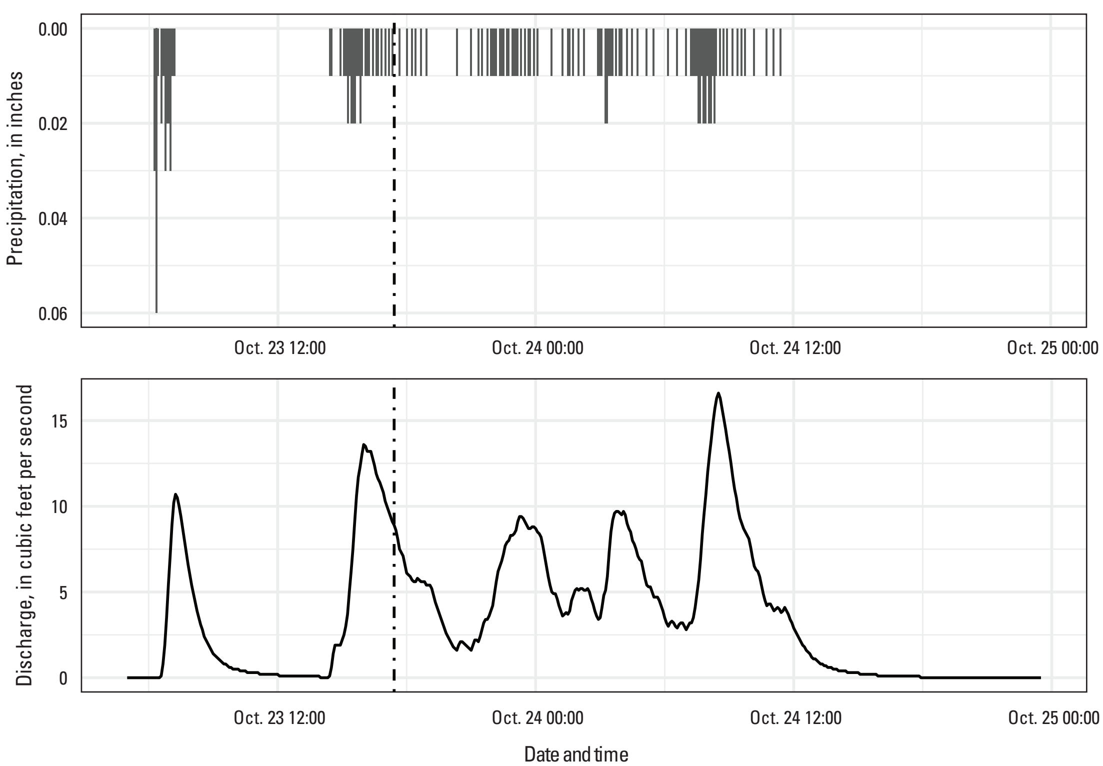


Figure 18. Precipitation and discharge results at the Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow), site for *A*, 7/27-7/28/18; and *B*, 10/23-10/24/18. The dashed line on each graph represents the time at which a water-quality sample was collected.

PCB Load Estimates

Because of the short duration and time to peak of the stormflow events, as well as the related difficult sampling efforts, only one water-quality sample was collected per stormflow event. A disadvantage of collecting only one sample per event is that the analysis is limited by the lack of understanding of the relation between discharge and total PCB concentrations, as it relates to the variability of discharge magnitude over the course of a single event and long-term trends across subsequent events. Additionally, most samples were collected during the falling limb of the stormflow hydrograph (as determined by AHYMO), and it is possible that concentrations in the rising limb or peak of the hydrograph may exhibit different concentrations. However, in this study, the discrete total PCB concentration is assumed to be consistent for the duration of each stormflow event. Additionally, because of a lack of observed discharge data at the study sites, the model results have not been verified. The total PCB event load results presented in this study have a high degree of uncertainty and should be considered as relative values, with the potential minimum and maximum PCB load estimates being approximate constraints on the uncertainty. Future studies could increase the accuracy of event load estimates by increasing the sampling frequency during stormflow events, as well as by collecting field discharge measurements either to help calibrate and validate the model results or to be used directly in load calculations.

Adobe Acres Pump Station PCB Load Estimates

At the Adobe Acres site, the average estimated PCB event load during the period of study (runoff volume ranging from 0.16 to 7.14 acre-feet) was 2.95 milligrams (mg), with average potential minimum and maximum event loads of 0.73 and 4.32 mg, respectively (fig. 19, table 5). The stormflow event with the largest total PCB loads occurred between September 27, 2017, and September 28, 2017, with an estimated total PCB load of 14.26 mg, based on the PCB concentration of the sample collected during the event, with potential minimum and maximum event loads of 2.82 and 15.50 mg, respectively. The stormflow event with the smallest estimated event load occurred between September 19, 2018, and September 20, 2018, with an estimated total PCB load of 0.26 mg, with potential minimum and maximum event loads of 0.26 and 3.24 mg, respectively. The potential minimum and maximum event loads occurred at the same time of year (late September), but 1 year apart, indicating that the total volume of runoff may be a more important factor than the time of year the event occurs in terms of effect on PCB loads.

The largest total PCB load (14.26 mg) at the Adobe Acres site, which was calculated for the event between September 27, 2017, and September 28, 2017, was in response to the largest magnitude stormflow event sampled, which was a result of a cumulative precipitation total of

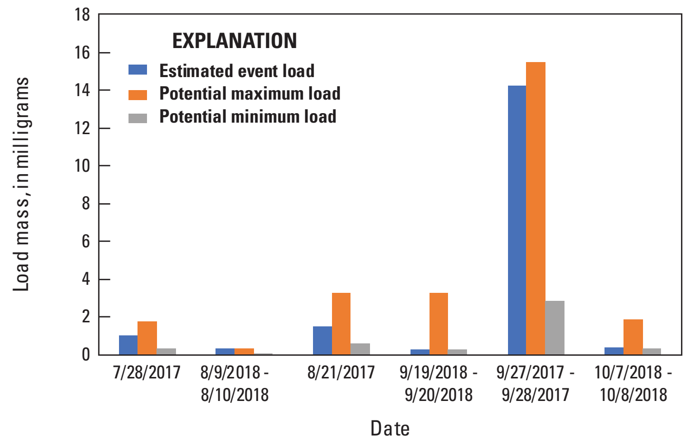


Figure 19. Estimated event load, as well as the potential maximum and minimum event loads, for each sampled stormflow event at the Adobe Acres pump station (Adobe Acres) site, Albuquerque, New Mexico, 2017–18.

1.28 inches (approximately three times higher than the average cumulative precipitation of 0.43 inch for all events modeled at Adobe Acres) and produced 7.14 acre-feet of stormflow runoff (table 5). The total PCB concentration measured on this date (1.62 ng/L) (table 2) was higher than the average concentrations during the simulated events at this site of 0.98 ng/L. The lowest estimated PCB event load was associated with a relatively small magnitude stormflow event between September 19, 2018, and September 20, 2018, which had a runoff volume of 0.67 acre-feet and peak discharge of 1.97 ft^3/s. This second smallest event recorded at Adobe Acres had a lower than average total PCB concentration of 0.320 ng/L (table 2). The event with the lowest minimum constraint on PCB event loads of 0.06 mg occurred between August 9, 2018, and August 10, 2018, and was associated with the lowest magnitude stormflow event with a total runoff volume of 0.16 acre-feet and peak discharge of 1.31 ft^3/s (table 5).

Sanchez Farms Inflow PCB Load Estimates

At the Sanchez Farms inflow site, of the two events for which discharge was simulated (runoff volume ranging from 2.23 to 12.90 acre-feet), the average estimated PCB event load was 277.11 mg, with minimum and maximum average event loads of 56.78 and 315.13 mg, respectively (fig. 20, table 5). For the stormflow event between July 27, 2018, and July 28, 2018, the estimated PCB event load was 16.71 mg, with a potential minimum estimated event load of 16.71 mg and a potential maximum estimated event load of 92.74 mg. For the stormflow event between October 23, 2018, and October 24, 2018, the estimated event load was 537.51 mg, with a potential minimum event load of 96.85 mg, and a potential maximum event load of 537.51 mg. The magnitude of this

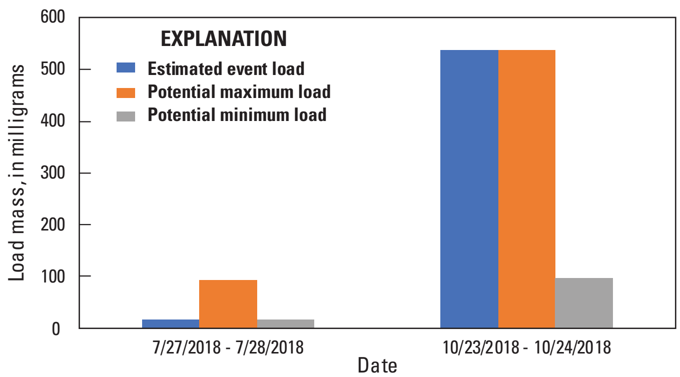


Figure 20. Estimated event load, as well as the maximum and minimum potential event loads, for each sampled stormflow event at the Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow) site, Albuquerque, New Mexico, 2017–18.

load, which was the largest calculated load at either of the two sites, was associated with a large total runoff volume of 12.90 acre-feet, which was the largest volume out of the eight sampled stormflow events between Adobe Acres and Sanchez Farms inflow. The event between July 27, 2018, and July 28, 2018, had the second largest event load out of the eight sampled stormflow events between the two sites, which was associated with the third largest total runoff volume between the two sites. The large runoff volumes of the stormflow events at the Sanchez Farms inflow site relative to the Adobe Acres site are a key determinant in the higher estimated event loads.

Implications for PCB Stormwater Concentrations and Loads Into the Rio Grande

The six water samples with the highest PCB concentrations (20.3–65.8 ng/L) exceeded the New Mexico surface-water quality standard for protection of wildlife habitat and aquatic life of 14 ng/L (NMED, 2018) (table 2). These exceedances occurred in July, August, September, and October. The remaining 30 samples had PCB concentrations below the standard (<0.096–7.62 ng/L) and were collected from July through December (table 2). None of the 36 water samples exceeded the NPDES permit level of 200 ng/L. One sediment sample, collected at Sanchez Farms inflow on July 28, 2018, containing a total PCB concentration of 163,000 ng/kg dw (table 3), exceeded a literature threshold effect concentration of 40,000 ng/kg dw of PCBs, below which adverse toxic effects on sediment-dwelling organisms are not expected to occur (MacDonald and others, 2000). The remaining 12 sediment samples (table 3) had total PCB concentrations below this threshold value. These water and sediment PCB concentration threshold values are based on laboratory toxicity tests and do not address nontoxic adverse effects, such as chronic, accumulative effects on systems such as the endocrine system. They also do not address effects on organisms exposed to a mixture of chemicals with additive or synergistic effects, as is usually present in urban stormwater runoff and receiving waters, such as mixtures of PCBs, metals, polycyclic aromatic hydrocarbons, and pharmaceutically active compounds.

Discharges simulated at the Sanchez Farms inflow and Adobe Acres sites, as well as the associated loads, do not flow directly into the Rio Grande. It is unknown how much of this stormwater reaches the Rio Grande, as it first flows into the pump stations before being pumped and routed to the river. The outflow from the stormwater collection basin at Paseo outflow is routed into a channel in the flood plain of the Rio Grande. Following large magnitude precipitation events during July through October in 2017 and 2018, the Paseo outflow channel was visited to assess the downstream migration of the pump station outflow water. On field visits, the water from the outflow channel reached a berm. Ponded water was not observed to have moved past the berm at the end of the flood-plain channel, nor was there visual evidence of flow moving past the berm towards the Rio Grande in 2017 and 2018.

Summary

In cooperation with the New Mexico County of Bernalillo, the U.S. Geological Survey (USGS) characterized potential polychlorinated biphenyl (PCB) concentrations and loading into the Rio Grande from watersheds that are under the county's jurisdiction. This report represents the results of a preliminary assessment of PCB concentrations and loading from stormwater runoff events from four Rio Grande tributary watersheds in the Albuquerque urbanized area, Bernalillo County, New Mexico. These results provide insights into PCB concentrations and loadings in the Rio Grande, as well as the health of the Rio Grande as a whole, and can be used to assist in fulfilling Bernalillo County's National Pollutant Discharge Elimination System (NPDES) permit requirements for the U.S. Environmental Protection Agency (EPA).

Precipitation data in this study were collected at four sites: Alameda pump station (Alameda) rain gage, Paseo pump station (Paseo) rain gage, Westside Community Center near Albuquerque, N. Mex. (Westside) rain gage, and South Valley Library near Albuquerque, N. Mex. (South Valley Library) rain gage. These four Bernalillo County rain gages operated by the USGS offer a widespread precipitation dataset that helps characterize the heterogeneity of precipitation events in the Albuquerque urbanized area. Generally, the sites in the north (Alameda and Paseo rain gages) have similar precipitation values to each other, as do the sites in the south (Westside and South Valley Library rain gages). The largest 2017 precipitation event between July and October occurred on September 27, 2017. During this event, the Paseo rain gage recorded 0.98 inch of rain, the Westside rain gage recorded 1.07 inches of rain, and the South Valley Library rain gage recorded 1.25 inches of rain. In 2018, the largest precipitation event between July and October at all four rain gages occurred on October 23, 2018, to October 24, 2018. The Alameda rain gage recorded 1.65 inches of rain, the Paseo rain gage recorded 1.61 inches of rain, the Westside rain gage recorded 1.45 inches of rain, and the South Valley Library rain gage recorded 1.54 inches of rain. The maximum 5-minute intensity for the period of record did not necessarily coincide with the maximum precipitation event at each gage. The maximum 5-minute precipitation intensity at the Alameda rain gage and the Paseo rain gage both occurred on July 26, 2018; the Alameda rain gage recorded 0.33 inch per 5 minutes of precipitation, and the Paseo rain gage recorded 0.50 inch per 5 minutes of precipitation. The maximum 5-minute precipitation intensity at both the Westside rain gage and the South Valley Library rain gage was 0.38 inch per 5 minutes on September 28, 2017.

PCBs were analyzed for in water and sediment samples collected from the stormwater drainage basins at the following sample collection sites: Alameda pump station outflow (Alameda outflow), Alameda pump at Rio Grande Inlet (Alameda at Rio Grande), Paseo pump station outflow (Paseo outflow), Sanchez Farms inflow at Albuquerque, N. Mex. (Sanchez Farms inflow), Sanchez Farms pump station, and Adobe Acres pump station (Adobe Acres). PCBs were detected in 34 of 36 water samples, and PCB-11 was the only congener detected in 12 of those samples. There were multiple orders of magnitude variation in PCB concentrations, both between sites and at the same site over time, indicative of short-duration, high-concentration inputs of PCBs characteristic of urban stormwater runoff likely affected by multiple variables including antecedent precipitation amount and intensity, pump operations, and point during the hydrograph when the sample was collected. Total PCB concentrations in six of 36 water samples exceeded the New Mexico surface-water quality standard for protection of wildlife habitat and aquatic life of 14 nanograms per liter (ng/L). None of the water samples had a total PCB concentration exceeding the NPDES permit level of 200 ng/L. There were no linear relations with variables such as suspended sediment concentration, total suspended solids, specific conductance, total organic carbon, or 24- or 72-hour antecedent precipitation. Nonparametric analysis determined that, for water samples, PCB and TSS were significantly positively correlated using the Kendall's tau test.

Approximately one third of the water samples contained only PCB-11, which is present in yellow pigments and indicates a current-use source of PCBs to the stormwater drainage basins such as urban litter. When additional congeners were detected, the profiles resembled a mixture of Aroclor 1254 and Aroclor 1260. A congener profile for one PCB water sample, collected on July 26, 2018, at Alameda at Rio Grande, resembled pure Aroclor 1260. This indicates that there is a point source, such as a contaminated site or spill source, of relatively unweathered Aroclor 1260 that can be transported by rainfall runoff to Alameda at Rio Grande. Additional study may be warranted to better understand the PCB dynamics within the Sanchez Farms wetland system, which contained the highest concentrations of PCBs measured in water and sediment samples in this study.

The rainfall-runoff model Arid Lands Hydrologic Model (AHYMO) was used to simulate discharge at the Sanchez Farms inflow site and the Adobe Acres site. Discharge at the remaining sites was dependent on stormflow pump operation and could not be determined. The simulated discharge and the total PCB concentrations measured at the Sanchez Farms inflow site and the Adobe Acres site were used to estimate total PCB event loads. A low sample frequency during the course of the stormflow events contributes to uncertainty with these load calculations. In addition, although AHYMO was developed to work specifically in the Albuquerque area, the rainfall-runoff models were not calibrated or verified with observed discharge data in the simulated subwatersheds. Because of this uncertainty, estimates on the potential minimum and maximum total PCB loads for each event at either site were made by applying minimum and maximum total PCB concentrations collected at each respective site to each event load calculation at that site. The estimated event loads were highly dependent on the total event runoff volume, rather than on total PCB concentration. The average estimated event loads at the Adobe Acres site for six events was 2.95 milligrams (mg), with average potential minimum and maximum loads of 0.73 and 4.32 mg, respectively. The highest estimated potential maximum event load was 15.50 mg, and the lowest estimated potential minimum event load was 0.26 mg. At the Sanchez Farms inflow site, the average estimated event loads for two measurable events was 277.11 mg, with average potential minimum and maximum loads of 56.78 and 315.13 mg, respectively. The highest estimated potential maximum event load was 537.51 mg, and the lowest estimated potential minimum event load was 16.71 mg.

During field visits, water pumped from the Paseo pump station was not observed to move past the flood plain channel into the Rio Grande in 2017 or 2018. The discharge simulated by AHYMO at Adobe Acres and Sanchez Farms inflow, and the associated PCB loads, first must be pumped to the Rio Grande. Because of the absence of pump station discharge data, and the observation that the pumped water must travel a short distance through the flood plain before directly entering the Rio Grande, the exact volume of this runoff that reaches the river is unknown.

The results of this study quantitatively confirm that there are measurable concentrations of PCBs in water and sediment in the four stormwater systems sampled in the Albuquerque urbanized area, Bernalillo County, New Mexico. Through a comprehensive PCB congener analysis and total PCB load estimates, this report provides preliminary estimates of the amounts of PCBs that could be contributing to the Rio Grande and describes the potential sources of PCBs in the Albuquerque urbanized area.

References Cited

Agency for Toxic Substances and Disease Registry (ATSDR), 2000, Toxicological profile for polychlorinated biphenyls (PCBs): Atlanta, Ga., U.S. Department of Health and Human Services, Public Health Service, accessed on February 15, 2019, at https://www.atsdr.cdc.gov/ToxProfiles/TP.asp?id=142&tid=26.

American Public Health Association, American Water Works Association, and Water Environment Federation, 2018a, 2540 solids (2017): Standard methods for the examination of water and wastewater, part 2000: Accessed April 20, 2019, at https://www.standardmethods.org/doi/full/10.2105/SMWW.2882.030.

American Public Health Association, American Water Works Association, and Water Environment Federation, 2018b, 5310 total organic carbon (TOC) (2017): Standard methods for the examination of water and wastewater, part 5000: Accessed April 20, 2019, at https://www.standardmethods.org/doi/full/10.2105/SMWW.2882.104.

Anderson, C.E., and Heggen, R.J., 1991, A comparison of a gaged urban watershed and computer modeling using HYMO, *in* Association of State Floodplain Managers, eds., Inspiration: Come to the Headwaters, Proceedings of the Fifteenth Annual Conference of the Association of State Floodplain Managers: Denver, Colo., p. 107–112.

Andersson, M., Bogen, J., Ottesen, R.T., and Bonsnes, T.E., 2015, Polychlorinated biphenyls in urban lake sediments and migration potential from urban stormwater in Bergen, Norway: Journal of Environmental Engineering, v. 141, no. 11, 04015028 [also available at https://doi.org/10.1061/(ASCE)EE.1943-7870.0000957.]

Anezaki, K., and Nakano, T., 2014, Concentration levels and congener profiles of polychlorinated biphenyls, pentachlorobenzene, and hexachlorobenzene in commercial pigments: Environmental Science and Pollution Research, v. 21, p. 998–1009.

ASTM International, 2019, D2216-19 standard test methods for laboratory determination of water (moisture) content of soil and rock by mass: West Conshohocken, Pa., ASTM International, doi: 10.1520/D2216-19, accessed April 20, 2019, at https://www.astm.org/Standards/D2216.htm.

Brown, J.F., Jr., 1994, Determination of PCB metabolic, excretion, and accumulation rates for use as indicators of biological response and relative risk: Environmental Science and Technology, v. 28, no. 13, p. 2295–2305.

City of Albuquerque, 1997, Section 22.2, Hydrology of the Development Process Manual: City of Albuquerque, accessed September 3, 2019 at http://library.amlegal.com/nxt/gateway.dll/New%20Mexico/albuqwin/cityofalbuquerquenewmexicocodeofordinanc?f=templates$fn=default.htm$3.0$vid=amlegal:albuquerque_nm_mc.

City of Albuquerque, 2018, AHYMO computer program—User's manual: City of Albuquerque, accessed September 3, 2019, at http://documents.cabq.gov/planning/DevelopmentReviewServices/Hydro-AHYMO-S4%20R2%20User%20Manual-10-24-18.pdf.

Desforges, J.-P., Hall, A., McConnell, B., Rosing-Asvid, A., Barber, J.L., Brownlow, A., De Guise, S., Eulaers, I., Jepson, P.D., Letcher, R.J., Levin, M., Ross, P.S., Samarra, F., Vikingson, G., Sonne, C., and Dietz, R., 2018, Predicting global killer whale population collapse from PCB pollution: Science, v. 361, p. 1373–1376.

Desmet, M., Mourier, B., Mahler, B.J., Van Metre, P.C., Roux, G., Persat, H., Lefevre, I., Peretti, A., Chapron, E., Simonneau, A., Miege, C., and Babut, M., 2012, Spatial and temporal trends in PCBs in sediment along the lower Rhone River, France: Science of the Total Environment, v. 433, p. 189–197, doi:10.1016/j.scitotenv.2012.06.044.

Du, S., Belton, T.J., and Rodenburg, L.A., 2008, Source apportionment of polychlorinated biphenyls in the tidal Delaware River: Environmental Science and Technology, v. 42, no. 11, p. 4044–4051.

Erickson, M.D., 1997, Analytical chemistry of PCBs (2d ed.): CRC Press, Boca Raton, Florida 688 p.

Frame, G.M., Cochran, J.W., and Bowadt, S.S., 1996, Complete PCB congener distributions for 17 Aroclor mixtures determined by 3 HRGC systems optimized for comprehensive, quantitative, congener-specific analysis: Journal of High Resolution Chromatography, v. 19, p. 657–668.

Gilbreath, A.N., and McKee, L.J., 2015, Concentrations and loads of PCBs, dioxins, PAHs, PBDEs, OC pesticides and pyrethroids during storm and low flow conditions in a small urban semi-arid watershed: Science of the Total Environment, v. 526, p. 251–261.

Guo, J., Capozzi, S.L., Kraeutler, T.M., and Rodenburg, L.A., 2014, Global distribution and local impacts of inadvertently generated polychlorinated biphenyls in pigments: Environmental Science and Technology, v. 48, p. 8573–8580.

Gupta, H., Sorooshian, S., Gao, X., Imam, B., Hsu, K., Batidas, L., Li, J., and Mahani, S., 2002, The challenge of predicting flash floods from thunderstorm rainfall: Philosophical Transactions of the Royal Society A—Mathematical, Physical and Engineering Sciences, v. 360, no. 1796, p. 1363–1371, accessed April 20, 2019, at https://www.ncbi.nlm.nih.gov/pubmed/12804254.

Hu, Dingfei, and Hornbuckle, K.C., 2010, Inadvertent polychlorinated biphenyls in commercial paint pigments: Environmental Science and Technology, no. 44, p. 2822–2827.

Karickhoff, S.W., Brown, D.S., and Scott, T.A., 1979, Sorption of hydrophobic pollutants on natural sediments: Water Research, v. 13, p. 241–248.

Litten, S., Fowler, B.I., and Luszniak, D., 2002, Identification of a novel PCB source through analysis of 209 PCB congeners by US EPA modified method 1668: Chemosphere, v. 46, p. 1457–1459.

Los Alamos National Laboratory, 2012, Polychlorinated biphenyls in precipitation and stormwater with the Upper Rio Grande watershed: Los Alamos National Laboratory, ERID-219767, 130 p., accessed February 7, 2019, at https://www.env.nm.gov/DOE_Oversight/documents/11-PolychlorinatedBiphenylsinPrecipandStormwater.pdf.

MacDonald, D.D., Dipinto, L.M., Field, J., Ingersoll, C.G., Long, E.R., and Swartz, R.C., 2000, Development and evaluation of consensus-based sediment effect concentrations for polychlorinated biphenyls: Environmental Toxicology and Chemistry, v. 19, p. 1403–1413.

Mackova, M., Prouzova, P., Stursa, P., Ryslava, E., Uhlik, O., Beranova, K., Rezek, J., Kurzawova, V., Demnerova, K., and Macek, T., 2009, Phyto/rhizoremediation studies using long-term PCB-contaminated soil: Environmental Science and Pollution Research, v. 16, p. 817–829.

McKee, L.J., Bonnema, A., David, N., Davis, J.A., Franz, A., Grace, R., Greenfield, B.K., Gilbreath, A.N., Grosso, C., Heim, W.A., Hunt, J.A., Leatherbarrow, J.E., Lowe, S., Pearce, S.A., Ross, J.R.M., and Yee, D., 2017, Long-term variation in concentrations and mass loads in a semi-arid watershed influenced by historic mercury mining and urban pollutant sources: Science of the Total Environment, v. 605–606, p. 482–497.

Meals, D.W., Richards, R.P., and Dressing, S.A., 2013, Pollutant load estimation for water quality monitoring projects. Tech Notes 8, April 2013: Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, Va., 21 p., accessed September 3, 2019, at https://www.epa.gov/sites/production/files/2016-05/documents/tech_notes_8_dec_2013_load.pdf.

National Oceanic and Atmospheric Administration [NOAA], 2019, Daily Summaries Station Details Albuquerque International Airport, NM, US: National Oceanic and Atmospheric Administration, accessed April 5, 2019, at https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USW00023050/detail.

Nelson, E.D., McConnell, L.L., and Baker, J.E., 1998, Diffusive exchange of gaseous polycyclic aromatic hydrocarbons and polychlorinated biphenyls across the air-water interface of the Chesapeake Bay: Environmental Science and Technology, v. 32, p. 912–919.

New Mexico Environment Department [NMED] Surface Water Quality Bureau, 2018, Standards for interstate and intrastate surface waters: NMAC title 20, chap. 6, part 4, accessed September 3, 2019, at https://www.env.nm.gov/wp-content/uploads/2017/06/20.6.4-NMAC-Section-804-Integrated-Rule-20180228.pdf.

Nisbet, I.C.T., and Sarofim, A.F., 1972, Rates and routes of transport of PCBs in the environment: Environmental Health Perspectives, v. 1, p. 21–38.

Panero, M., Boehme, S., and Muñoz, G., 2005, Pollution prevention and management strategies for polychlorinated biphenyls in the New York/New Jersey harbor: New York Academy of Sciences, 110 p., accessed September 3, 2019, at https://nj.gov/drbc/library/documents/PMP_Resources/NYAS_PCBs_NY-NJHarbor.pdf.

Parece, T.E., and Campbell, J.B., 2015, Identifying urban watershed boundaries and area, Fairfax County, Virginia: Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 365–372, doi: 10.14358/PERS.81.5.365.

R Core Team, 2018, R: A language and environment for statistical computing: Vienna, R Foundation for Statistical Computing, v. 3.6.0.

Rodenburg, L.A., Guo, Jia, Du, Songyan, and Cavallo, G.J., 2010, Evidence for unique and ubiquitous environmental sources of 3,3'-dichlorbiphenyl (PCB 11): Environmental Science and Technology, v. 44, p. 2813–2821.

Ruus, A., Daae, I.A., and Hylland, K., 2012, Accumulation of polychlorinated biphenyls from contaminated sediment by Atlantic cod (*Gadus morhua*): Direct accumulation from resuspended sediment and dietary accumulation via the polychaete *Nereis virens*: Environmental Toxicology and Chemistry, v. 31, p. 2472–2481.

Schoener, G., 2010, Comparison of AHYMO and HEC-HMS for runoff modeling in New Mexico urban watersheds: Albuquerque, University of New Mexico, M.S. thesis, 42 p.

Schwarzenbach, R.P., Gschwend, P.M., Imboden, D.M., 2003, Appendix C: Physicochemical Properties of Organic Compounds, in Environmental Organic Chemistry, second edition, p. 1197–1208.

Schwarzenbach, R.P., and Westall, J., 1981, Transport of nonpolar organic compounds from surface water to groundwater—Lab sorption studies: Environmental Science and Technology, v. 15, p. 1360–1367.

Shang, H., Li, Y., Wang, T., Wang, P., Zhang, H., Zhang, Q., and Jiang, G., 2014, The presence of polychlorinated biphenyls in yellow pigment products in China with emphasis on 3,3′-dichlorobiphenyl (PCB 11): Chemosphere, v. 98, p. 44–50, [Also available at http://dx.doi.org/10.1016/j.chemosphere.2013.09.075.]

Southern Sandoval County Arroyo Flood Control Authority [SSCFACA], 2009, Section 22.2, Hydrology of the Development Process Manual: SSCFACA, accessed September 3, 2019, at https://www.sscafca.org/development/documents/DPM/DPM_4_2010/DPM_Section2_Hydrology.pdf.

Stone, A., 2016, Polychlorinated biphenyls in consumer products: State of Washington Department of Ecology, publication no. 16-04-014, 61 p., accessed September 13, 2019, at https://fortress.wa.gov/ecy/publications/SummaryPages/1604014.html.

U.S. Census Bureau, 2017, 2013–2017 American community survey 5-year estimates: U.S. Census Bureau, accessed April 26, 2019, at https://www.census.gov/programs-surveys/acs/?intcmp=serp.

U.S. Census Bureau, 2018, QuickFacts—Albuquerque city, New Mexico: U.S. Census Bureau, accessed August, 22, 2019, at https://www.census.gov/quickfacts/albuquerquecitynewmexico.

U.S. Environmental Protection Agency [EPA], 2008, Method 1668, revision B chlorinated biphenyl congeners in water, soil, sediment, biosolids, and tissue by HRGC/HRMS: U.S. Environmental Protection Agency, accessed April 25, 2019, at https://nepis.epa.gov/Exe/ZyNET.exe/P1005EUE.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2006+Thru+2010&Docs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C06thru10%5CTxt%5C00000011%5CP1005EUE.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL.

U.S. Environmental Protection Agency [EPA], 2015, Method 9060A total organic carbon: U.S. Environmental Protection Agency, accessed April 20, 2019, at https://www.epa.gov/sites/production/files/2015-12/documents/9060a.pdf.

U.S. Environmental Protection Agency [EPA], 2019a, Laws and regulations, history of the Clean Water Act: U.S. Environmental Protection Agency web page, accessed April 20, 2019, at https://www.epa.gov/laws-regulations/history-clean-water-act.

U.S. Environmental Protection Agency [EPA], 2019b, National Pollutant Discharge Elimination System (NPDES): U.S. Environmental Protection Agency web page, accessed April 20, 2019, at https://www.epa.gov/npdes.

U.S. Environmental Protection Agency [EPA], 2019c, National Pollutant Discharge Elimination System (NPDES), stormwater discharges from municipal sources: U.S. Environmental Protection Agency web page, accessed April 20, 2019, at https://www.epa.gov/npdes/stormwater-discharges-municipal-sources.

U.S. Geological Survey [USGS], 2009, Collection, quality assurance, and presentation of precipitation data: U.S. Geological Survey, Office of Surface Water Technical Memorandum No. 2006.01, 29 p., accessed September 12, 2019, at https://water.usgs.gov/admin/memo/SW/OSW_2006-01_Revised_02122010.pdf.

U.S. Geological Survey [USGS], 2019a, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed April 3, 2019, at https://doi.org/10.5066/F7P55KJN.

U.S. Geological Survey [USGS], 2019b, USGS water data for New Mexico, *in* USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed August, 13, 2019, at https://doi.org/10.5066/F7P55KJN. [Information directly accessible at https://waterdata.usgs.gov/nm/nwis/nwis.]

U.S. Geological Survey [USGS], variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1–A10, accessed April 25, 2019, at http://pubs.water.usgs.gov/twri9A.

Veenhuis, J.E., 2003, Municipal stormwater sampling program, metropolitan area, Albuquerque, New Mexico—Summary of sampling, 1992–2002: U.S. Geological Survey Fact Sheet 005–03, accessed January 2019 at http://pubs.usgs.gov/fs/2003/0005/report.pdf.

Williams, J.R., and Hann, R.W., 1973, HYMO: Problem-oriented computer language for hydrologic modeling. User's manual: U.S. Department of Agriculture, Agricultural Research Service, vol. 8 NO. 1 ARS-S-9, 8 p.

Wilson, J.T., 2016, Occurrence and concentrations of selected trace elements and halogenated organic compounds in stream sediments and potential sources of polychlorinated biphenyls, Leon Creek, San Antonio, Texas, 2012–14: U.S. Geological Survey Scientific Investigations Report 2016–5039, 99 p. [Also available at http://dx.doi.org/10.3133/sir20165039.]

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