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Distribution of Mining-Related Trace Elements in Streambed and Flood-Plain Sediment along the Middle Big River and Tributaries in the Southeast Missouri Barite District, 2012–15

Scientific Investigations Report 2018–5103

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

Front cover. U.S. Geological Survey hydrologic technicians operating the geoprobe used in flood-plain sampling. Coring rod used during flood-plain sampling (circular photograph). Flood plain of the Fourche Renault Creek (background photograph).

Back cover. Upstream view of Mineral Fork Creek near its mouth at the Big River.

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2018

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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)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
gallon (gal)	3.785	cubic decimeter (dm^3)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
	Mass	
ounce, avoirdupois (oz)	28,350	milligrams (mg)
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
ton, short (2,000 lb)	0.9072	megagram (Mg)
ton, long (2,240 lb)	1.016	megagram (Mg)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square hectometer (hm^2)	2.471	acre
square kilometer (km^2)	247.1	acre
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic decimeter (dm^3)	0.2642	gallon (gal)
cubic meter (m3)	1.308	cubic yard (yd^3)
	Mass	
milligram (mg)	35.27	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)
megagram (Mg)	1.102	ton, short (2,000 lb)
megagram (Mg)	0.9842	ton, long (2,240 lb)
	Flow rate	
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as

$$°F=(1.8×°C)+32.$$

Horizontal coordinate information is referenced to the Universal Transverse Mercator projection, Zone 15.

Abbreviations

<	less than
>	greater than
CMERSC	Central Mineral and Environmental Resources Science Center
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
HWM	high water mark
ICP–AES	inductively coupled plasma-atomic emission spectrometry
ICP–MS	inductively coupled plasma-mass spectrometry
MOWSC	Missouri Water Science Center
MPV	most probable value
MSL	Missouri Sediment Laboratory
NIST	National Institute of Standards and Technology
PEC	probable effects concentration
RCRA	Resource Conservation and Recovery Act
RPD	relative percent difference
RSD	relative standard deviation
USGS	U.S. Geological Survey
XRF	x-ray fluorescence

Distribution of Mining-Related Trace Elements in Streambed and Flood-Plain Sediment along the Middle Big River and Tributaries in the Southeast Missouri Barite District, 2012–15

By David C. Smith and John G. Schumacher

Abstract

Lead mining first began in the Big River watershed during the 1700s. Lead was the primary metal mined throughout most of the 1700s and early 1800s and it continued to be mined until the mid-1900s. Barite mining began in the middle part of the watershed in the mid- to late 1800s. Although considerable attention has been given to concentrations of mining-related trace elements (mostly cadmium, lead, and zinc) in the Big River and its tributaries draining the Old Lead Belt, there is less information regarding concentrations of mining-related trace elements in tributaries draining the Barite District in southeast Missouri, which is downstream from the Old Lead Belt, and the contribution of sediment transported from this district to trace elements in lower reaches of the Big River. The purpose of this report is to present results of an investigation of the distribution of mining-related trace elements in sediments in the middle reach of the Big River downstream from the Old Lead Belt and the Big River tributaries that drain a large part of the Barite District.

In general, concentrations of cadmium and lead in streambed sediment were largest in samples from the Big River and smallest in Barite District tributary samples. Concentrations of zinc were somewhat similar in the Big River and Barite District tributaries; however, higher concentrations were present in upstream Big River site samples, as well as in samples from one site on Maddin Creek and at another site on Old Mines Creek that drains the Barite District. Barium concentrations were considerably larger in samples from Barite District tributaries compared to samples collected on the Big River. Samples collected downstream from the Barite District on the Big River had considerably larger barium concentrations than samples collected upstream from the Barite District.

Flood-plain core samples were collected from 26 cores at 5 transect locations along tributaries in the Barite District. Of the individual 693 bulk (unsieved) samples from these cores analyzed by x-ray fluorescence, the probable effects concentration (PEC) values were exceeded for cadmium (PEC of 4.98 milligrams per kilogram [mg/kg], 218 samples), lead (PEC of 128 mg/kg, 91 samples), nickel (PEC of 48.6 mg/kg, 45 samples), and zinc (PEC of 459 mg/kg, 77 samples). Of the 693 samples, 21 exceeded the U.S. Environmental Protection Agency residential yard cleanup level of 400 mg/kg for lead; 19 of these were samples from a single transect near the mouth of Mineral Fork Creek where its flood plain joins the Big River flood plain.

Shortly after the December 2015 flood on the Big River (the third largest flood along the river since the 1950s), 23 samples of fine sediment deposited from the flood were collected from the Big River flood plain upstream and downstream from the Barite District and several tributaries. Overall, the general pattern of barium, lead, and zinc concentrations in the 2015 flood sediment samples was similar to that observed in the streambed-sediment samples.

Overall concentrations of barium were larger at Big River sites downstream from the Barite District, and cadmium, lead, and zinc concentrations were generally similar or smaller at sites downstream from the Barite District when compared to sites upstream from the Barite District. These data indicate a substantial influx of barium from the Barite District into the Big River but only a minimal influx of cadmium, lead, and zinc.

Introduction

Missouri has been a leading producer of lead in the world for more than 100 years (Missouri Department of Natural Resources, 2014). Ore minerals of lead (mostly galena and lead sulfide), zinc (sphalerite and zinc sulfide), and barium (barite and barium sulfate) are present across southeast Missouri with some of the most abundant deposits within the Big River watershed in parts of Washington, Jefferson, and St. Francois Counties, Missouri (fig. 1).

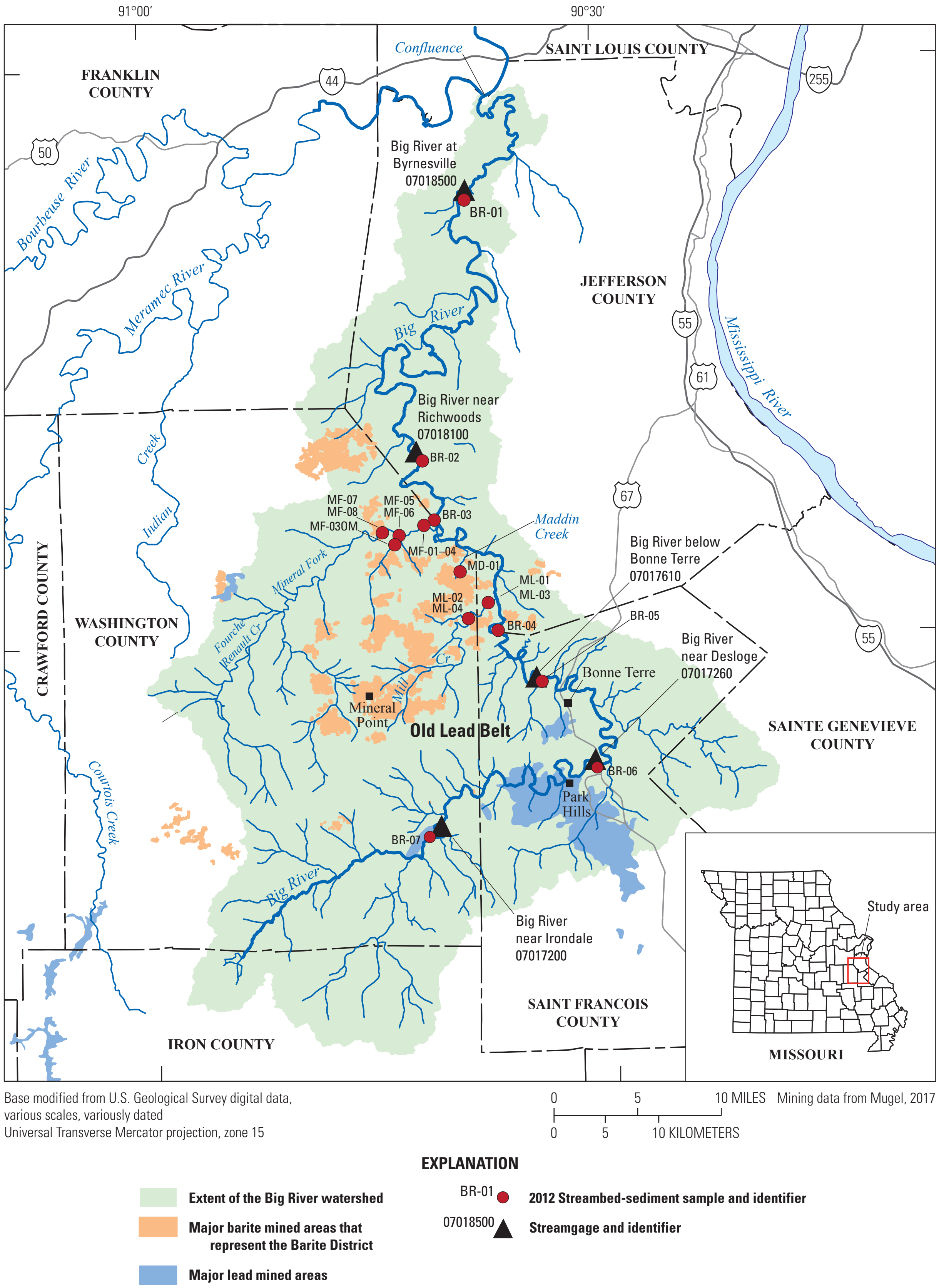


Figure 1. Approximate extent of mined areas in the Big River watershed and locations of U.S. Geological Survey streamgage stations and streambed-sediment sample locations along the Big River, Missouri, 2012.

Mining History

Lead mining first began in the Big River watershed during the 1700s with shallow diggings in surficial materials. In the early 1800s, the mining evolved into development of shallow shafts (less than [<] about 50 feet [ft] deep). In the 1860s, lead ore was discovered several hundred feet beneath the surface near Bonne Terre and Park Hills, Mo., in what is now referred to as the Old Lead Belt. Lead was the primary metal mined in the watershed throughout most of the 1700s and early 1800s and it was mined through the mid-1900s. More than 8.5 million tons of lead was produced from the Old Lead Belt part of the Big River watershed before the last mine was closed in 1972 (Mugel, 2017). Zinc became an important metal commodity in the mid-1800s and barium in the early 1900s. Mining for barite began in the watershed in the mid- to late 1800s initially by handpicking barite "chunks" from small hand-dug pits in the clay-rich soils. Large mechanized strip-mining operations with centralized mills for washing and grinding of barite replaced the hand methods in the 1940s. Barite mining was centered in the eastern part of Washington County and southwest part of Jefferson County, Mo., mostly within the watersheds of three tributaries (Mineral Fork Creek, Maddin Creek, and Mill Creek) that enter the Big River about 20 miles (mi) downstream from the Old Lead Belt (Mugel, 2017). This area had previously been mined for lead and zinc and there was some limited lead recovery during the barite mining (Weigel, 1977). Barite mining peaked in the early 1970s and the last mine closed in the 1990s. Wharton (1972) estimated 11.8 million tons of barite was produced from the Barite District.

Lead ore (primarily galena) was the first commodity mined in the 1700s by early Europeans in the watershed; however, some zinc was recovered starting in the early to mid-1800s. The earliest lead mines in the late 1700s and early 1800s were referred to as "diggings" (also called "pits" or "shafts") in the residual soil and were about 15–20 ft deep (Schoolcraft, 1819). These hand-dug features were round holes about 4 ft in diameter normally dug to the top of the bedrock where lead ore was often concentrated. Some of the deeper shafts used horse whim or later a steam-powered windlass to hoist the ore to the surface (Ball, 1916). Small horizontal drifts were dug short distances under the residuum until they became unstable and then the shaft was abandoned and the process was repeated a short distance away until the landscape was covered with pits in areas rich in lead ore (Ball, 1916). Early ore processing methods were crude and began with simple hand cleaning using hammers to remove non-ore material (waste) from the galena that was smelted in small furnaces. The waste containing other lead minerals (cerrusite and anglesite), zinc ore, and barite ("tiff") was placed in nearby "dumps" until the 1800s when these minerals started being recovered. By the mid-1800s, mining operations were active in some shafts as deep as 170 ft and drifted several hundred feet long. In the 1860s, most of the lead and zinc mining in the Barite District shifted to the vast underground deposits discovered in the Old Lead Belt near the towns of Parks Hills and Bonne Terre in the 1860s (Ball, 1916; fig. 1).

Mining of barite in the region began in the mid-1800s as commercial uses were determined for the "tiff" formally discarded during earlier lead and zinc mining—mostly as paint pigment. By the 1870s, small-scale hand mining of barite was taking place across a wide area estimated by Tarr (1919) to be about 250 square miles (mi^2) in mostly locally owned individual prospects. Beginning in the late 1920s, larger scale mechanized barite strip mining was driven by barium, becoming an important additive in drilling mud used in drilling oil wells (Burford, 1978). Hand mining, however, continued to be important until the 1940s when mechanized strip mining became the dominant practice. At the peak of mechanized strip mining in the 1950s and 1960s, there were nearly 30 wash plants (where barite extracted from the overburden was washed to remove clay and impurities) in the region and 4 grinding plants in the vicinity of Mineral Point, northeast of Potosi, Mo. Mechanical strip mining eventually occurred over about a 75-mi^2 area, with at least 25 mi^2 of actual strip mines (Mugel, 2017). By 1972, an estimated 11.8 million tons of barite had been produced from the Barite District (Wharton, 1972, 1975). Some barite was mined in tributaries to the upper reaches of Big River upstream from the Big River near Irondale streamgage (U.S. Geological Survey [USGS] station 07017200; fig. 1) but no barite mineralization occurred within the rich lead and zinc deposits of the Old Lead Belt. The last barite mine closed in the 1990s.

Previous Studies

More than 200 years of lead and zinc mining and 100 years of barite mining has left a legacy of mine waste contamination in the Big River watershed. The most obvious signs are large mine waste piles (hundreds of acres in size and often more than 100 ft tall), metal-rich sediments that discharge from the piles to local streams in the Old Lead Belt, and large tracts of disturbed and partially vegetated land and mill ponds in the Barite District about 20 mi northwest of the Old Lead Belt. There have been at least 16 major documented releases of mine wastes in the Big River or its tributaries (Meneau, 2016). One of these releases occurred in 1975 when a barite mill pond failed along Mill Creek and another release occurred in 1977 when about 50,000 cubic yards (yd^3) of lead-zinc mine waste from a tailings impoundment in the Old Lead Belt near Park Hills, Mo., was released into the adjacent Big River. The barite mill dam failure resulted in a fish kill along about a 12-mi reach from Mill Creek and extending into the Big River. Red, turbid water downstream was noticeable in the final 73 mi of the Big River and benthic invertebrate populations were impaired (Duchrow, 1976). Many studies regarding the Big River have documented elevated levels of lead, zinc, and cadmium in algae, plants, crayfish, mussels, fish, and stream sediments (for example, Schmitt and Finger, 1982; Kramer, 1976; Smith and Schumacher; 1991; Pavlowsky and others, 2010). Lead concentrations in fish have resulted in fish consumption advisories for the 93-mi reach of the Big River from the Old Lead Belt to its mouth at the Meramec River (Missouri Department of Health and Senior Services, 2018). The U.S. Environmental Protection Agency (EPA) is in the process of remediating lead-contaminated soils identified at thousands of properties in the watershed (EPA, 2011, 2016). Although considerable attention has been given to concentrations of mining-related trace elements (mostly cadmium, lead, and zinc) in the Big River and its tributaries draining the Old Lead Belt, there is less information regarding concentrations of mining-related trace elements in tributaries draining the Barite District and the contributions of Barite District sediments to metal concentrations in lower reaches of the Big River.

Description of Study Area

The Big River has a watershed of about 912 mi^2 in southeastern Missouri (fig. 1). The study area is about 45 mi southwest of St. Louis, Mo.; is centered on the Barite District of southeast Missouri draining into the Big River; and includes about 90 mi^2 of the middle part of the Big River watershed in eastern Washington County and western Jefferson County, Mo. Barite mining occurred throughout much of the western part of the Big River watershed but was concentrated to about a 200-mi^2 region that included watersheds of the Big River tributaries Mineral Fork Creek (190 mi^2); Mill Creek (51 mi^2); and Maddin Creek (4.5 mi^2), which is part of about a 25-mi long reach of the Big River between the Big River below Bonne Terre streamgage (USGS station 07017610; fig. 1) and the Big River near Richwoods streamgage (USGS station 07018100; fig. 1).

Purpose and Scope

The purpose of this report is to present results of an investigation of the distribution of mining-related trace elements in sediments in the middle reach of the Big River and its tributaries that drain a large part of the Barite District. A focus of the study was to contrast mining-related trace-element concentrations in tributaries draining mined areas in the Barite District with trace-element concentrations in the middle reach of the Big River that drains the Old Lead Belt Subdistrict of the Southeast Missouri Lead District, which is about 35 mi upstream from the Barite District. Three general geomorphological features were the focus of sediment collection. Streambed-sediment samples were collected during 2012 at 10 locations along 3 tributaries draining the Barite District and at 5 locations on the Big River. Core samples of flood-plain deposits were collected in 2013 from 26 cores along two tributaries draining the Barite District (Mineral Fork Creek and Mill Creek) and along a tributary of Mineral Fork Creek upstream from the Barite District (Fourche Renault Creek). Fine sediments deposited by the December 2015 flood event were collected from locations along the Big River upstream and downstream from the Barite District and along Barite District tributaries.

Methods

All samples were collected by USGS personnel and transported to the USGS Missouri Sediment Laboratory (MSL) in Rolla, Mo., for initial particle-size distribution processing, which included drying, disaggregating, splitting, and sieving of samples. After processing, samples were sent to the USGS Central Mineral and Environmental Resources Science Center (CMERSC) laboratory in Denver, Co., for elemental analyses, using either inductively coupled plasma-atomic emission spectrometry (ICP–AES) and inductively coupled plasma-mass spectrometry (ICP–MS) methods or the x-ray fluorescence (XRF) method. All data generated or analyzed during this study are included in the main text of this publication.

To assess the effects of select trace elements on aquatic life in freshwater systems, MacDonald and others (2000) developed consensus-based probable effects concentrations (PECs). If the PEC is exceeded, there is an increased chance that the overabundance of trace elements in freshwater habitats can result in toxicity to aquatic life. The PEC is commonly used by regulatory agencies to assess damage to ecosystems. The reported PECs for cadmium (4.98 milligrams per kilogram [mg/kg]), lead (128 mg/kg), and zinc (459 mg/kg) are used in this report as a general guideline for evaluating the concentrations of mining-related trace elements and the probable danger posed to aquatic life in streams.

Streambed Sediment

During August 2012, streambed-sediment samples were collected at 10 locations along 3 tributaries draining the Barite District (Mineral Fork Creek, Maddin Creek, and Mill Creek) and at 5 locations on the Big River—2 upstream and 3 downstream from the Barite District (table 1 and fig. 1). Data generated during this study are available from ScienceBase (Smith and Wilson, 2018). Composite samples of streambed sediments were collected at each location along a stream reach equal to three channel widths. Within the sampled reach, 20–30 subsamples targeting depositional areas of fine-grained sediments were collected. Depositional areas for fine-grained sediment are commonly located where the current velocity decreases, typically because of a decrease in streambed slope, or downstream from channel obstructions such as large rocks or woody debris. All subsamples were collected from the upper 2–3 inches (in.) of the sediment bed using a 2-in. diameter polyvinylchloride cup. Subsamples were placed directly into large (1 gallon) plastic bags for transport to the MSL.

Streambed-sediment samples were dried and then split and sieved for grain-size and chemical analyses. Samples were initially air dried for several days to remove excessive water from the bags and then transferred to nonmetallic trays and

Table 1. Location of streambed-sediment samples, flood-plain sediment samples, and sediment deposited on the flood plain during the December 2015 flood and underlying soils, and flood-plain cores collected from the middle Big River and its tributaries and tributaries draining the Barite District, Missouri, 2012–16.

[Latitude and longitude are in decimal degrees. USGS, U.S. Geological Survey; --, not applicable; (N), pre-2015 deposit soil from 6 to 8 inches below original grade]

Site identifier	Site name	Date of sample	USGS station identifier	Latitude	Longitude
		Streambed sediment			
		Big River			
BR-01	Big River at Byrnesville	August 2012	07018500	38.39172220	−90.63780560
BR-02	Big River near Richwoods	August 2012	07018100	38.15961110	−90.70605560
BR-03	Big River at Mammoth Conservation Access	August 2012	380722090403501	38.12277778	−90.67638889
BR-04	Big River above Mill Creek confluence	August 2012	380024090372501	38.00666667	−90.62361111
BR-05	Big River below Bonne Terre	August 2012	07017610	37.96552778	−90.57441670
		Maddin Creek			
MD-01	Maddin Creek at Baryties		380343090393201	38.06194444	−90.65888889
		Mineral Fork			
MF-01	Mineral Fork near Big River confluence	August 2012	380604090405501	38.10111111	−90.68194444
MF-02	Mineral Fork near Washington County State Park	August 2012	380542090410901	38.09500000	−90.68583333
MF-03	Mineral Fork at Kingston conservation access	August 2012	380545090424001	38.09583333	−90.71111111
MF-04	Mineral Fork near Bliss, at Highway 47 bridge	August 2012	380545090445001	38.09583333	−90.74722222
		Old Mines Creek			
MF-03OM	Old Mines Creek at Cruise Mill		380459090440001	38.08305556	−90.73333333
		Mill Creek			
ML-01	Mill Creek near Big River confluence	August 2012	380159090372801	38.03305556	−90.62444444
ML-02	Mill Creek at Dark Hollow near Blackwell, Missouri	August 2012	380153090374601	38.03138889	−90.62944444
ML-03	Mill Creek below Tiff, Missouri	August 2012	380123090390201	38.02305556	−90.65055556
ML-04	Mill Creek at Tiff, Missouri	August 2012	380056090390601	38.01555556	−90.65166667
		Flood-plain cores			
		Mill Creek			
MLC-03-02	Mill Creek above Blackwell, Missouri	August 2014	--	38.03121001	−90.62926426
MLC-A-03	Mill Creek above Blackwell, Missouri	August 2014	--	38.03109200	−90.62906208
MLC-A-04	Mill Creek above Blackwell, Missouri	August 2014	--	38.03096669	−90.62888967
MLC-A-5	Mill Creek above Blackwell, Missouri	August 2014	--	38.03087147	−90.62870560
MLC-A-01	Mill Creek above Blackwell, Missouri	August 2014	--	38.03159298	−90.62954966
MLC-B-01	Mill Creek below Tiff, Missouri	August 2014	--	38.01307811	−90.65283819
MLC-B-04	Mill Creek below Tiff, Missouri	August 2014	--	38.01353996	−90.65318327
MLC-B-03	Mill Creek below Tiff, Missouri	August 2014	--	38.01334617	−90.65300114
MLC-B-02	Mill Creek below Tiff, Missouri	August 2014	--	38.01324030	−90.65289770
MLC-B-05	Mill Creek below Tiff, Missouri	August 2014	--	38.01362243	−90.65175709

Table 1. Location of streambed-sediment samples, flood-plain sediment samples, and sediment deposited on the flood plain during the December 2015 flood and underlying soils, and flood-plain cores collected from the middle Big River and its tributaries and tributaries draining the Barite District, Missouri, 2012–16.—Continued

[Latitude and longitude are in decimal degrees. USGS, U.S. Geological Survey; --, not applicable; (N), pre-2015 deposit soil from 6 to 8 inches below original grade]

Site identifier	Site name	Date of sample	USGS station identifier	Latitude	Longitude
Mineral Fork					
MFC-B-05	Mineral Fork, near Kingston conservation access	August 2014	--	38.09811621	−90.71098798
MFC-B-04	Mineral Fork, near Kingston conservation access	August 2014	--	38.09782770	−90.71091120
MFC-B-03	Mineral Fork, near Kingston conservation access	August 2014	--	38.09754012	−90.71086510
MFC-B-02	Mineral Fork, near Kingston conservation access	August 2014	--	38.09711390	−90.71075848
MFC-B-00	Mineral Fork, at Kingston conservation access	August 2014	--	38.09464233	−90.71110809
MFC-B-01	Mineral Fork, near Kingston conservation access	August 2014	--	38.09642893	−90.71061121
MFC-A-01	Mineral Fork, near Washington County State Park	August 2014	--	38.09500099	−90.68499411
MFC-A-02	Mineral Fork, near Washington County State Park	August 2014	--	38.09488188	−90.68469252
MFC-A-03	Mineral Fork, near Washington County State Park	August 2014	--	38.09459388	−90.68429011
FR-02	Fourche Renault near Missouri Route 185	August 2014	--	38.01621680	−90.87406293
FR-01	Fourche Renault near Missouri Route 185	August 2014	--	38.01614916	−90.87387032
FR-03	Fourche Renault near Missouri Route 185	August 2014	--	38.01632568	−90.87435974
FR-04	Fourche Renault near Missouri Route 185	August 2014	--	38.01643163	−90.87467599
FR-05	Fourche Renault near Missouri Route 185	August 2014	--	38.01654889	−90.87494002
BR-FP	Big River at Mineral Fork Creek	August 2014	--	38.09513938	−90.68090717
Flood-plain sediment samples from December 2015 flood deposits					
Big River, upstream from Washington County Barite District					
BR-26	Newberry Riffle	January 2016	--	37.89461736	−90.50110910
BR-27	Newberry Riffle	January 2016	--	37.89496385	−90.50068569
BR-21	St. Francois State Park picnic area	January 2016	--	37.95650904	−90.54102482
BR-22	St. Francois State Park picnic area	January 2016	--	37.95882783	−90.54092220
BR-23	St. Francois State Park picnic area	January 2016	--	37.95768760	−90.54083677
BR-25	St. Francois State Park at mouth of Coonville Creek	January 2016	--	37.96753634	−90.53397886
BR-24	St. Francois State Park at mouth of Coonville Creek	January 2016	--	37.96737277	−90.53400326
Big River, downstream from Washington County Barite District					
BR-19	Washington State Park Highway 21 access	January 2016	--	38.08624733	−90.66251416
BR-18	Washington State Park Highway 21 access	January 2016	--	38.08631355	−90.66282357
BR-18-SL (N)	Washington State Park Highway 21 access	January 2016	--	38.08638745	−90.66267720

Table 1. Location of streambed-sediment samples, flood-plain sediment samples, and sediment deposited on the flood plain during the December 2015 flood and underlying soils, and flood-plain cores collected from the middle Big River and its tributaries and tributaries draining the Barite District, Missouri, 2012–16.—Continued

[Latitude and longitude are in decimal degrees. USGS, U.S. Geological Survey; --, not applicable; (N), pre-2015 deposit soil from 6 to 8 inches below original grade]

Site identifier	Site name	Date of sample	USGS station identifier	Latitude	Longitude
BR-16	Washington State Park-picnic ground	January 2016	--	38.08550212	−90.68408542
Big River, downstream from Washington County Barite District—Continued					
BR-17	Washington State Park-picnic ground	January 2016	--	38.08696335	−90.68146159
BR-20	Mamouth access	January 2016	--	38.12123807	−90.67663483
BR-20-SL (N)	Mamouth access	January 2016	--	38.12119913	−90.67659720
BR-15	Highway H Conservation access	January 2016	--	38.16321236	−90.70905813
BR-15-SL (N)	Highway H Conservation access	January 2016	--	38.16314652	−90.70902381
BR-14	Brown’s Ford	January 2016	--	38.21327342	−90.70629705
BR-14-SL (N)	Brown’s Ford	January 2016	--	38.21332693	−90.70622008
BR-13	Brown’s Ford	January 2016	--	38.21334513	−90.70644096
Dry Creek, Jefferson County tributary to the Big River					
DC-01	Dry Creek at Butcher Branch Road	January 2016	--	38.21995843	−90.65556413
DC-01-SL (N)	Dry Creek at Butcher Branch Road	January 2016	--	38.21978792	−90.65616556
Mineral Fork Creek and tributary, Washington County Barite District Big River tributary					
MF-01	Mineral Fork at US Highway 47 (in channel)	January 2016	--	38.09535685	−90.74731573
MF-01-SL (N)	Mineral Fork at US Highway 47 (flood plain)	January 2016	--	38.09541208	−90.74730107
OMC-01	Old Mines Creek at Highway 47	January 2016	--	38.07563792	−90.73939475
MF-02	Mineral Fork Kingsington access	January 2016	--	38.09568013	−90.71118600
MF-03	Mineral Fork Kingsington access	January 2016	--	38.09305497	−90.71163005
Mill Creek and tributaries, Washington County Barite District Big River tributary					
FBT-01	Fountain Farm Brook of Mill Creek at Highway E	January 2016	--	37.97596575	−90.72775964
UK-01	Unknown tributary to Sibboleth Brook at Highway E	January 2016	--	38.02561166	−90.69180239
ML-01	Mill Creek at Tiff Road	January 2016	--	38.01573115	−90.65096492

dried at 60 degrees Celsius (°C) in laboratory ovens. After drying, the entire sample was sieved through two stacked stainless-steel sieves with mesh sizes of 25 and 2 millimeters (mm; fig. 2). The total weight of material retained on the sieves and the weight of the material passing through the 2-mm sieve were recorded. Material that passed through the 2-mm sieve was split into two subsamples—split A and split B—using a stainless-steel splitter with a 2-mm opening, and the weights of both subsamples were recorded (fig. 3). A representative fraction of split A (ideally approximately 2 grams, but a minimum of 0.5 gram) was removed for the chemical analysis of the <2-mm fraction (fig. 3). The remaining fraction of split A was sieved through a 0.250-mm sieve and a representative fraction of material that passed through the 0.250-mm sieve (pan material) was removed for the chemical analysis of the less than 0.250-mm fraction (ideally approximately 2 grams but a minimum of 0.5 gram) after the weights of material retained on the sieve and in the pan were recorded. Split B was further separated into two additional splits—split B1 and split B2—using the stainless-steel splitter. Split B1 was sieved through stacked sieves with openings of 0.250 mm and 0.063 mm using the sieve shaker. Weights of each fraction remaining on the sieves and the pan were recorded before a fraction from the pan (<0.063 mm) was collected for chemical analyses. Split B2 was archived.

Subsamples from three size fractions (<2 mm, <0.250 mm, and <0.063 mm) of each of the 15 streambed-sediment samples were placed in sealed plastic bags and sent to the USGS CMERSC laboratory for determinations of 42 major and trace elements. Major and trace elements were analyzed by the CMERSC contract laboratory using ICP–AES and ICP–MS. The samples were decomposed using a mixture of hydrochloric, nitric, perchloric, and hydrofluoric acids at low temperature. An aliquot of the digested sample was aspirated into the ICP–AES and ICP–MS to determine concentrations of major and trace elements. Calibration on the ICP–AES is completed by standardizing with digested rock reference materials and a series of multiple element solution standards. The ICP–MS was calibrated with aqueous standards, and internal standards were used to compensate for matrix effects and internal drifts (Taggart, 2002).

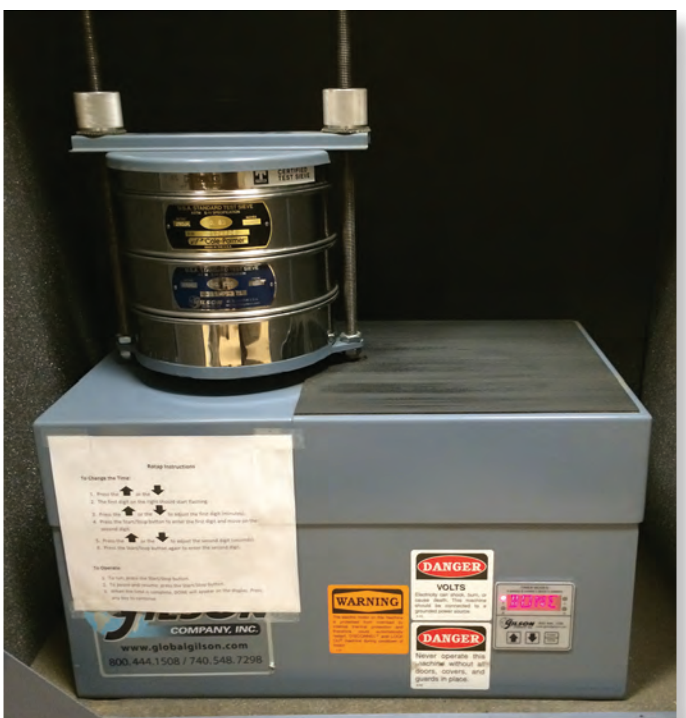


Figure 2. Photograph showing stacked sieves in preparation of mechanical sieving process (photograph by David C. Smith, U.S. Geological Survey).

Flood-Plain Sediment

Flood-plain sediment samples were collected from cores at six sites along tributaries draining the Barite District (table 1; fig. 4). Flood-plain core transects were co-located with previously collected 2012 streambed-sediment sample locations, except for FR in the upper part of the Mineral Fork Creek along Fourche Renault Creek and a single location on the Big River flood plain just upstream from Mineral Fork Creek (BR-FP). Fourche Renault Creek ends where Mineral Fork Creek begins. At each site, an attempt was made to drill a transect of cores across the flood plain. Five to six cores were generally spaced evenly across the flood plain from the outer edge where the ground elevation increased to near each creek with a few exceptions. Two sites were hand-cored sites with only 3 (MFC-A) and 1 (BR-FP) sampling locations due to no vehicle access. Two cores (MFC-B-00 and MLC-B-05) were offset from the original flood-plain transect due to difficult access. Cores were drilled to refusal using a truck or tractor-mounted Geoprobe™ direct-push soil-sampling unit. To provide higher resolution for soil near the surface, a small trench was hand dug adjacent to each core and soil samples were collected at 1-in. intervals from 0 to 6 in. deep and then at intervals from 6 to 9 in. and 9 to 12 in. deep. Continuous core samples were collected from each core using a 4-ft long, 2.25-in. outside diameter core barrel to collect a 1.125-in. diameter core. The core barrel had a clear acetate liner that prevented contact with the metal core barrel. The core barrel was pushed into the subsurface in approximately 4-ft runs until refusal. The core barrel was then mechanically removed after each run and opened to remove the acetate liner containing the core sample. The length of core inside the liner was measured to determine the percent recovery, which is the length of recovered core divided by the length of the run. Plastic caps were placed on both ends of the plastic liner and secured with electrical tape. The plastic liner was labeled with the date, time, depth, orientation, and core identification. A tape measurement was made in the open hole to verify the depth between pushes and ensure that the hole did not collapse. Ensuring the hole has not collapsed allows the core barrel to be pushed through the hole directly to the next undisturbed section without extra

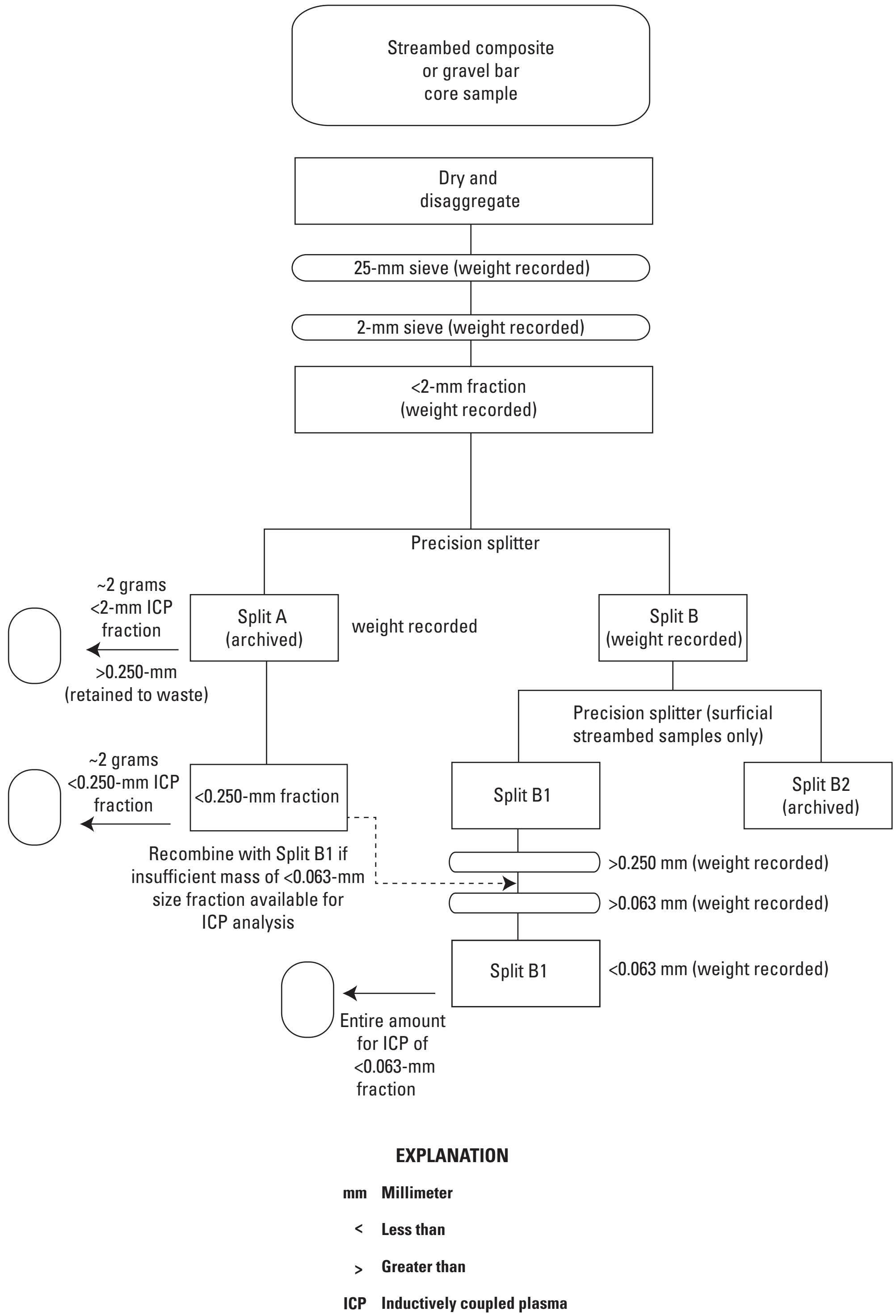
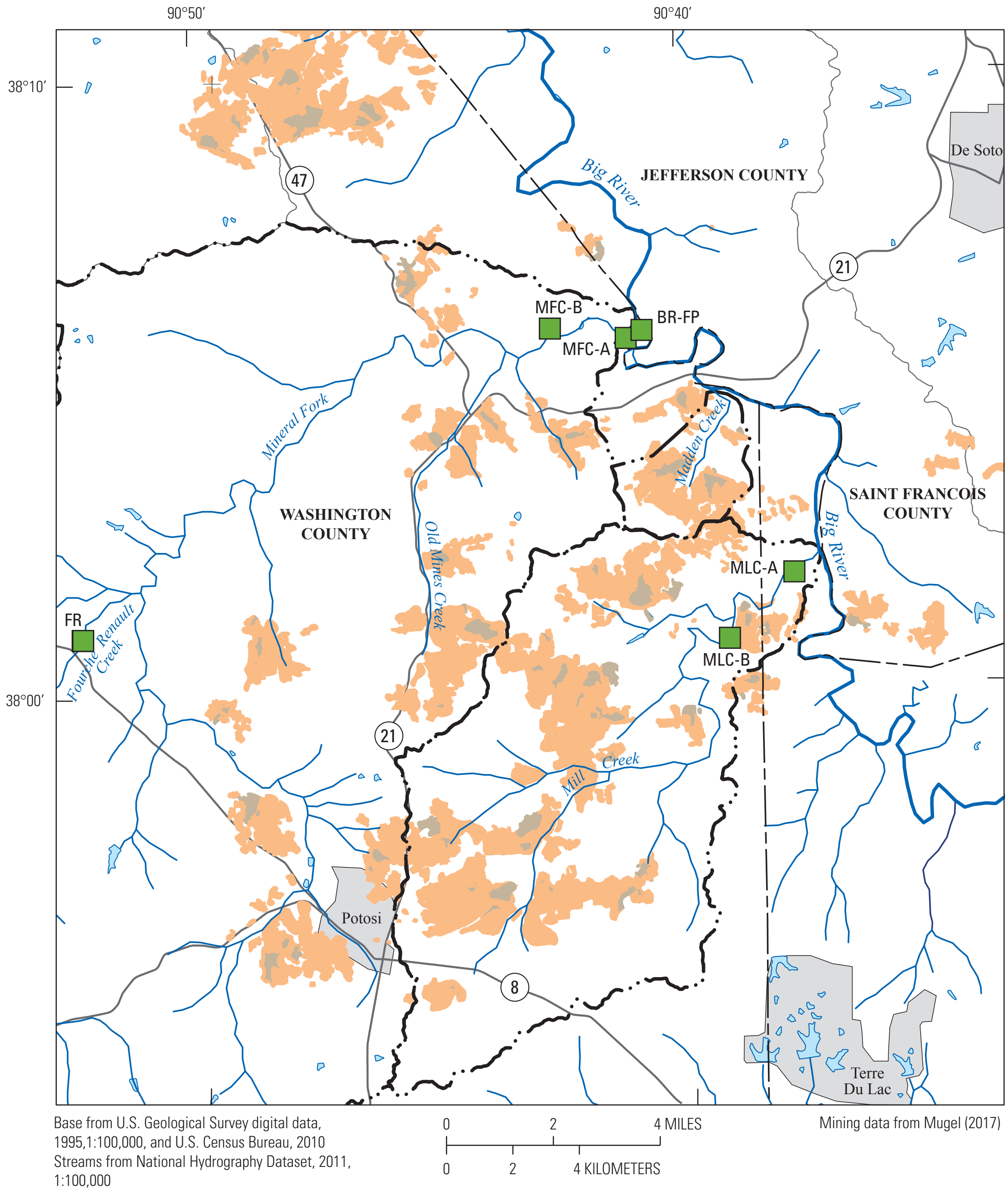


Figure 3. Process for splitting and sieving streambed-sediment and flood-plain sediment samples.



Base from U.S. Geological Survey digital data, 1995,1:100,000, and U.S. Census Bureau, 2010
Streams from National Hydrography Dataset, 2011, 1:100,000
Roads from National Highway Planning Network, 2017
Universal Transverse Mercator projection, zone 15

Mining data from Mugel (2017)

EXPLANATION

Barite mined areas

Major barite mined areas

Barite waste pond

Watershed boundary

MFC-B **Flood-plain transect and identifier**

Figure 4. Location of flood-plain core transects along tributaries draining the Barite District and nearby Big River, Missouri, 2014.

material falling in over the undisturbed sample. The core barrel may pick up soil from shallower depths than the target depth if the hole collapses. Measuring the depth of the hole ensured that the sample was representative of the target depth. This process was done after each run until the sampler met refusal.

The core samples inside the acetate liners were transported to the USGS office in Rolla, Mo. The acetate tubes containing flood-plain cores were cut lengthwise with a special core cutting knife to expose an area of the core about 1 in. wide. The outside of the core is typically disturbed during the coring process as it slides against the steel cutting head and into the core barrel. A knife was then used to shave off the outer ¼ in. of the core to expose undisturbed material that had not been in contact with the acetate liner, creating a flat, usable surface for the XRF, and then the core was cut into 2-ft lengths, placed in core boxes, and allowed to dry before analyses using the XRF. The XRF measurements were made using a 60-second scan at three equally spaced intervals within each 1-ft interval of the core and the average of these three readings assigned to the mid-point of the 1-ft interval. For example, the average of measurements at 2.25, 2.5, and 2.75 ft would represent the metal concentrations in the 2–3-ft depth interval and assigned the average depth of 2.5 ft.

To determine if variable grain size had a measurable effect on metal concentrations determined by the XRF on the "bulk" core (unsieved intact core), core material from one core from each location was selected for re-analyses using the XRF in various grain-size fractions. The selected core was split longitudinally in approximate equal halves and subsamples were collected from one-half of the core at selected depth intervals (1-ft intervals) for sieving and XRF analysis of trace elements in the size fractions. The sieving procedure used for the streambed-sediment samples was modified because of the small volume of material in the core samples and sieves were stacked, resulting in the following size fractions analyzed by the XRF: greater than (>) 2 mm, 2 to 0.250 mm, 0.250 to 0.063 mm, and <0.063 mm. The XRF results of the sieved fractions from each interval were then compared to the average of the bulk core scan for that same interval.

December 2015 Flood Deposits

Between December 23 and 28, 2015, more than 6 in. of rainfall was recorded at the Big River near Desloge streamgage (USGS station 07017260, fig. 1). This amount was much greater than typical rainfall at this time of year across the Big River watershed and most of southern Missouri, resulting in substantial flooding along the Big River. Around 10:00 p.m. on December 29, 2015, the instantaneous discharge at the Big River near Richwoods streamgage (USGS station 07018100; fig. 1) exceeded 50,000 cubic feet per second at a stage of more than 29.5 ft. This was the third largest discharge recorded at this streamgage in more than 70 years of record (U.S. Geological Survey, 2015). Because of the small number of streambed-sediment samples available and the unique opportunity presented by the near historic flood along the Big River, and fine sediments deposited by the December 2015 flood event were collected from more than 90 locations along the Big River including Barite District tributaries. Data from samples collected from 12 locations along the middle reach of the Big River and its tributaries are presented in this report (table 1; fig. 5). A small plastic putty knife was used to carefully remove fine sediments from surfaces such as concrete boat ramps, sidewalks, and flat rocks (fig. 6). At six locations, a sample of native soil also was collected from 3 to 6 in. of depth beneath the original land surface. Native soil in this instance refers to soil 3 to 6 in. below the ground surface (below what is referred to as the "O horizon," which is where the root material resides). This deeper soil was selected to best reflect the preflood soil. In most locations, the recent flood sediments were fine-grained silts that ranged from 0.1-in. thick to more than 2-in. thick. Care was taken to minimize collection of sediment directly in contact with the underlying surface. At several locations, recent flood deposits were of sufficient thickness that they could be collected from grassy areas on the flood plain. The samples were placed in sealed plastic bags and transported to the MSL where they were air dried for 3 to 4 days. Samples were lightly disaggregated each day in the plastic bags by simple hand manipulation. After samples had completely dried, the bulk samples were analyzed using the XRF at the USGS CMERSC. Samples were placed in a test stand and analyzed three times, with the sample bag mixed between each of the three analyses. Concentrations of trace elements reported in the samples were the average of the three individual analyses. After XRF analyses of the bulk samples were completed, each sample was sieved using a 0.063-mm sieve and the <0.063-mm size fraction of each sample was analyzed by the XRF.

Quality Assurance and Quality Control

Project quality assurance and quality control was maintained using replicate and split samples, check standards, blank samples, and laboratory confirmation samples. The results of the chemical analysis were compared using data quality objectives (DQOs) to ensure quality assurance and quality control.

Replicate and Split Replicate Samples

To ensure sieving techniques could be replicated and performed of equal quality for all samples in the study, original replicate and split replicate samples were created. Split replicates were created by using an aluminum splitter with a 2-in. diameter opening. The entire sample contents were poured through the hopper and equal amounts of sample were portioned into two pans below the hopper. Each separate portion was sieved to the three size fractions used for all sample analyses (<2 mm, 0.250 mm, and 0.063 mm). Two samples

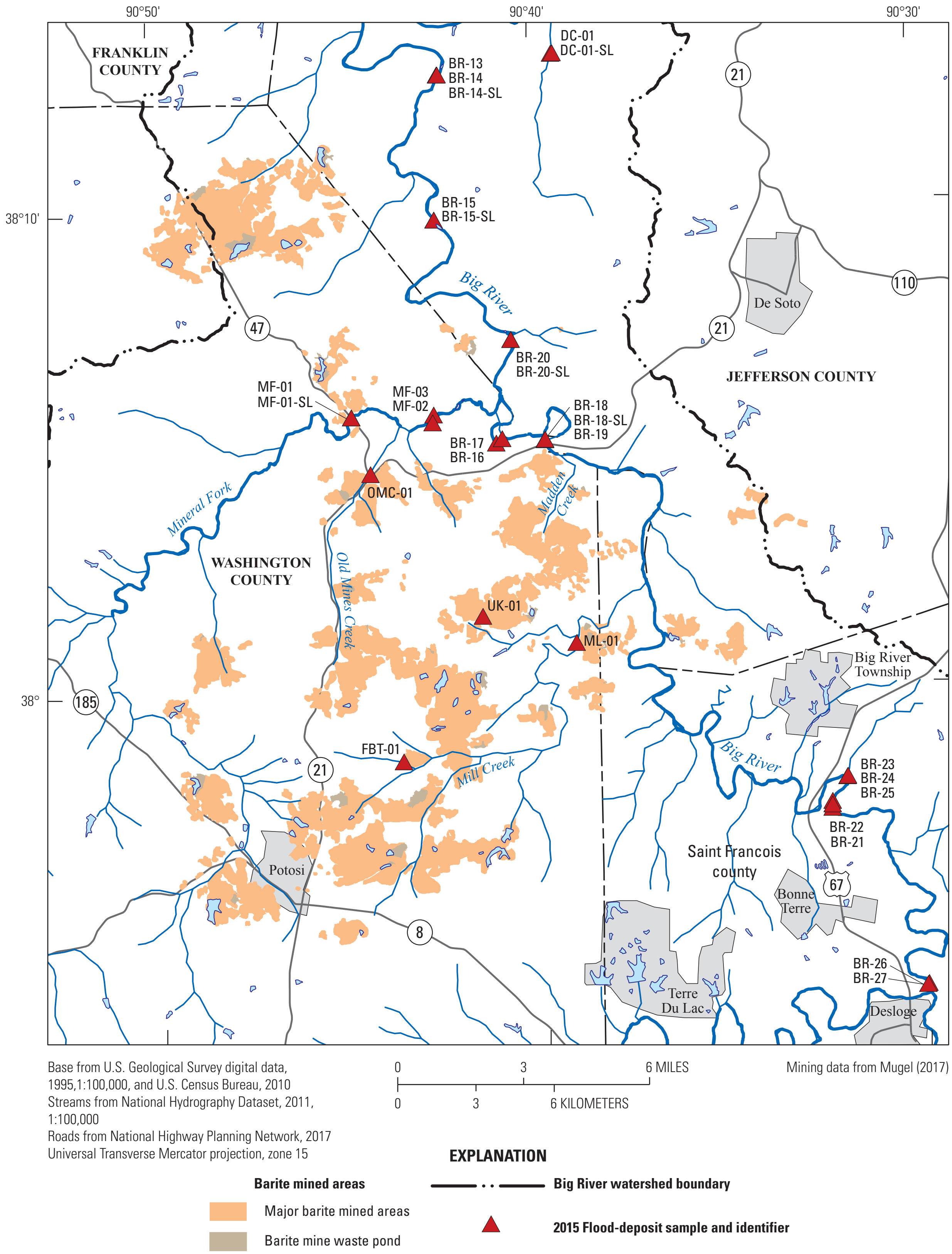


Figure 5. Location of samples collected from the middle and lower Big River watershed of sediment deposited by the December 2015 flood, Missouri, 2016.

Figure 6. Examples of fine-grained sediments deposited by the December 2015 flood in the Big River watershed. (photographs by David C. Smith, U.S. Geological Survey).

(BR-02 and BR-04) were split and the chemical analysis results of split samples were compared using a DQO of 30 percent for the relative percent difference (RPD).

The RPD between analytical results for the split samples are listed in table 2. The RPD was calculated as the absolute value of the difference between the concentrations in the original and split replicate samples divided by the average concentration in the original and split replicate samples multiplied by 100. The average RPD values in the three size fractions for the four trace elements of interest were 19 percent for barium (6 to 37 percent), 38 percent for cadmium (2 to 94 percent), 8 percent for lead (2 to 18 percent), and 33 percent for zinc (1 to 83 percent). Overall, there were 11 exceedances of a DQO of 30 percent for 13 average RPD values for the three size fractions. There was a strong relation between RPD value and size fraction analyzed. The smallest RPD values were measured in the <0.063-mm size fraction and largest RPD values were measured in the <2-mm fraction (table 2).

Check Standards

A handheld XRF instrument was used to determine concentrations of trace elements in core samples from flood-plain cores and samples of flood deposits from the December 2015 flood. Quality control on analytical results from the XRF instrument included daily check standards and blanks and analyses of split samples. Check standards of known concentrations were used to ensure the instrument was within daily calibration requirements and assess the general accuracy and precision of the XRF measurements. Check standards and silica sand blanks were analyzed by the XRF at the beginning and end of each day and periodically throughout the day. All flood-plain core samples were analyzed using an XRF and standards supplied by the EPA Region 7. CAN Till-4 (supplied by the instrument manufacturer; Lynch, 1996) and EPA Resource Conservation and Recovery Act (RCRA; EPA, 2007) standards were used to validate EPA XRF measurements during sample analyses. The December 2015 flood-deposit

Table 2. Relative percent difference between original and split replicate streambed-sediment samples analyzed by the laboratory.

[Gray shaded cells indicate mining-related trace elements of concern for this study. Gray shaded cells with bold font indicate RPDs that exceeded the data qualiity objective of 30. <, less than; mm, millimeter; RPD, relative percent difference; w%, percent by weight; --, not determined; mg/kg, milligram per kilogram]

Constituent	Unit	Elemental concentrations in sample BR-02						Elemental concentrations in sample BR-04						Average RPD			
		<2-mm fraction		<0.250-mm fraction		<0.063-mm fraction		<2-mm fraction		<0.250-mm fraction		<0.063-mm fraction					
		Original sample	Split sample	Original sample	Split sample	Original sample	Split sample	Original sample	Split sample	Original sample	Split sample	Original sample	Split sample	<2-mm fraction	<0.250-mm fraction	<0.063-mm fraction	Overall average all fractions
Aluminum	w%	0.48	0.47	1.71	1.49	3.10	3.07	0.76	0.79	1.94	1.39	3.27	3.22	3	23	1	9.21
Calcium	w%	0.25	0.21	2.25	2.12	3.24	3.50	5.98	6.10	6.37	6.12	5.65	5.74	10	5	5	6
Iron	w%	1.21	1.12	1.14	1.08	1.56	1.62	1.91	1.89	1.73	1.86	1.74	1.96	4	6	8	6
Potassium	w%	0.26	0.26	1.17	1.10	1.68	1.60	0.75	0.82	1.64	1.36	1.51	1.87	4	12	13	10
Magnesium	w%	0.09	0.09	0.96	0.94	1.27	1.41	2.97	3.00	2.97	2.92	1.87	1.98	1	2	8	3
Sodium	w%	0.02	0.02	0.15	0.11	0.40	0.38	0.04	0.05	0.11	0.08	0.35	0.33	11	**31**	6	16
Sulfur	w%	0.01	0.01	0.02	0.02	0.03	0.03	<0.01	<0.01	<0.01	<0.01	0.05	0.05	--	--	0	0
Titanium	w%	0.02	0.02	0.10	0.08	0.22	0.21	0.03	0.03	0.09	0.07	0.21	0.21	0	24	2	9
Silver	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	--	--	--	--
Arsenic	mg/kg	6	6.0	3.0	3.0	5.0	5.0	7.0	7.0	4.0	4.0	5.0	5.0	0	0	0	0
Barium	mg/kg	338	549	1,800	1,820	2,090	2,310	155	202	379	290	804	814	**37**	14	6	19
Beryllium	mg/kg	0.3	0.4	0.6	0.6	1.0	1.1	0.9	0.9	1.1	1.0	1.2	1.2	14	5	5	8
Bismuth	mg/kg	0.05	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	9	13	4	9
Cadmium	mg/kg	0.9	11.3	3.8	3.1	6.8	6.9	3.2	3.8	10.0	8.3	14.7	14.4	**94**	19	2	**38**
Cerium	mg/kg	9.64	10.2	29.9	24.9	57.5	54.1	18.0	19.2	34.2	24.9	51.9	51.8	6	25	3	11
Cobalt	mg/kg	6.6	6.1	13.5	11.8	22.2	21.7	13.0	12.6	21.2	17.4	31.9	32.5	5	17	2	8
Chromium	mg/kg	11	9.0	20.0	19.0	44.0	44.0	12.0	10.0	16.0	21.0	34.0	41.0	19	16	9	15
Cesium	mg/kg	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	--	--	--	--
Copper	mg/kg	9.2	14.9	19.5	17.1	41.5	35.6	16.8	11.4	34.6	27.3	69.6	62.7	**43**	18	13	25
Gallium	mg/kg	1.95	1.7	4.1	3.5	7.1	6.9	2.1	2.2	4.1	3.3	6.8	7.0	7	18	3	10
Indium	mg/kg	<0.02	<0.02	0.08	0.07	0.12	0.13	0.20	0.22	0.23	0.23	0.20	0.20	--	7	4	5
Lanthanum	mg/kg	5.2	5.3	14.2	11.9	27.4	25.9	7.4	8.1	15.7	10.9	23.3	23.4	5	27	3	12
Lithium	mg/kg	4	4.0	8.0	7.0	13.0	12.0	4.0	4.0	8.0	7.0	13.0	13.0	0	13	4	6
Manganese	mg/kg	330	328	2,090	1,800	3,740	3,890	2,410	2,480	3,300	2,960	4,180	4,190	2	13	2	6
Molybdenum	mg/kg	0.6	0.5	0.5	0.6	0.7	0.8	0.8	0.7	0.7	0.7	0.8	0.8	9	3	8	7
Niobium	mg/kg	1	0.9	3.7	3.0	7.7	7.8	1.5	1.5	3.7	2.4	7.5	7.8	5	**32**	3	13
Nickel	mg/kg	7.9	8.1	14.9	13.1	27.4	25.6	15.6	15.0	25.4	21.2	41.5	40.5	3	15	5	8

Table 2. Relative percent difference between original and split replicate streambed-sediment samples analyzed by the laboratory.—Continued

[Gray shaded cells indicate mining-related trace elements of concern for this study. Gray shaded cells with bold font indicate RPDs that exceeded the data quality objective of 30. <, less than; mm, millimeter; RPD, relative percent difference; w%, percent by weight; --, not determined; mg/kg, milligram per kilogram]

Constituent	Unit	Elemental concentrations in sample BR-02						Elemental concentrations in sample BR-04						Average RPD			
		<2-mm fraction		<0.250-mm fraction		<0.063-mm fraction		<2-mm fraction		<0.250-mm fraction		<0.063-mm fraction					
		Original sample	Split sample	Original sample	Split sample	Original sample	Split sample	Original sample	Split sample	Original sample	Split sample	Original sample	Split sample	<2-mm fraction	<0.250-mm fraction	<0.063-mm fraction	Overall average all fractions
Phosphorus	mg/kg	140	130	230	220	350	330	240	290	430	350	600	580	13	12	5	10
Lead	mg/kg	263	265	910	792	1,620	1,590	586	634	1,140	917	1,960	1,930	4	18	2	8
Rubidium	mg/kg	8.2	7.7	29.1	26.5	45.5	42.6	17.2	18.9	39.9	31.0	36.0	43.9	8	17	13	13
Antinomy	mg/kg	0.22	0.2	0.3	0.2	0.5	0.5	0.3	0.3	0.3	0.2	0.5	0.5	2	27	3	11
Scandium	mg/kg	0.8	0.6	2.3	1.9	4.2	4.2	1.3	1.2	2.5	1.9	4.1	4.2	18	23	1	14
Tin	mg/kg	0.3	0.3	0.7	0.7	1.3	1.2	16.3	0.4	1.3	2.1	1.6	1.4	**95**	24	11	**43**
Strontium	mg/kg	13.6	13.5	52.1	47.2	85.9	87.4	27.5	30.7	48.1	40.5	82.6	80.3	6	14	2	7
Tellurium	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	--	--	--	--
Thorium	mg/kg	1.6	1.8	4.1	3.6	8.0	7.5	2.0	2.2	5.2	3.2	7.2	7.1	11	**30**	4	15
Thallium	mg/kg	<0.1	<0.1	0.2	0.2	0.4	0.3	<0.1	<0.1	0.2	0.1	0.4	0.4	--	**33**	14	24
Uranium	mg/kg	1	1.1	1.3	1.2	2.3	2.2	1.1	1.2	1.5	1.2	2.3	2.3	9	15	2	9
Vanadium	mg/kg	19	18.0	20.0	18.0	34.0	33.0	16.0	16.0	20.0	17.0	34.0	34.0	3	13	1	6
Tungsten	mg/kg	0.2	0.1	0.4	0.3	0.8	0.7	0.5	0.2	0.4	0.3	0.7	0.9	**76**	29	19	**41**
Yttrium	mg/kg	4.1	4.1	9.1	8.2	16.5	16.4	8.1	8.4	16.8	10.0	17.5	17.6	2	**31**	1	11
Zinc	mg/kg	256	2,420	357	307	502	494	276	289	534	463	799	789	**83**	15	1	**33**

samples were analyzed by the USGS XRF unit. Check standards were run during the analyses of these samples using the National Institute of Standards and Technology (NIST) medium standard (2177A) and NIST high standard (2710A; Reed, 2009) in addition to a silica sand blank.

The overall mean concentration, mean standard deviation, 95th and 5th percentile (upper confidence level [UCL] and lower confidence level [LCL], respectively), and mean percent difference were calculated for selected trace elements in each check standard and compared to the standard's most probable value (MPV). Each standard has an MPV for each of the elements in its suite provided by the supplier and is defined as the resultant value with the highest probability for an observation. This would be the most probable concentration of an element for environmental soil samples. A percent difference of within 30 percent for target elements (barium, cadmium, lead, and zinc) for the XRF results and standard MPV was the DQO for this project. The precision of the XRF measurements for the four mining-related trace elements of interest (barium, cadmium, lead, and zinc) was assessed by calculating the relative standard deviation (RSD) for the check standards. The RSD was calculated for target elements in each check standard by dividing the absolute value of difference between the XRF result and the MPV by the average of the XRF result and the MPV then multiplying by 100. The average RSD for each metal of interest in each check standard was then calculated. The XRF precision DQO for the project was an average RSD of within 20 percent for the trace elements of interest in the XRF check standards.

The results of the EPA XRF instrument analysis of the two check standards (RCRA and CAN Till 4) were within the DQO of 30 percent for barium, cadmium, lead, and zinc (table 3). Concentrations of barium, cadmium, lead, and zinc were within 10 percent of the check standard MPVs except for a mean lead concentration of 37 mg/kg in CAN Till 4 check standard that was −25.6 percent lower than the MPV of 50 mg/kg. The mean lead concentration in 54 RCRA check standards of 462 mg/kg was only −7.5 percent lower than the MPV of 500 mg/kg. Except for cadmium where the XRF reported a mean concentration of 517 mg/kg in the RCRA standard (MPV of 500 mg/kg), mean concentrations of barium, lead, and zinc in check standards reported by the XRF tended to be slightly smaller than the standard MPV values but well within the project DQO. The larger percent difference between the XRF result and MPV for lead in the Can Till 4 standard of 50 mg/kg (−25.6 percent) compared to the RCRA standard (−7.5 percent) may indicate a decrease in accuracy at lower concentrations of lead.

The December 2015 flood deposits were analyzed using the USGS XRF. A review of 10 check standards analyzed by the USGS XRF (NIST 2710A and NIST 2711A) indicates concentrations of barium, cadmium, lead, and zinc were within the project goal of 30 percent (table 4). Except for a mean zinc concentration of 364 mg/kg reported by the XRF in NIST 2711A that was −12.1 percent lower than the MPV of 414 mg/kg, concentrations of mining-related trace elements of interest for this study were within 10 percent of the check standards. None of the nine silica blank samples contained detectable concentrations of constituents of interest analyzed by the XRF (table 4). The reporting limits for nickel and zinc for the USGS XRF are likely smaller than the project XRF reporting levels of 65 and 25 mg/kg but have not been rigorously determined, but all of the silica blank samples had nickel and zinc <3 mg/kg.

Blanks

To determine possible sources of bias in chemical results, seven blank samples were processed between analyses of the streambed-sediment samples. Blank samples included a source material blank, a splitter blank, and five blanks processed through various sieves. Blank samples were prepared using a source-material mixture of environmental-grade pure silica sand and silt-sized silica flour. Concentrations of cadmium were less than the minimum detection level in all blank samples (table 5). The source blank had detectable barium (40 mg/kg), lead (4.8 mg/kg), and zinc (5 mg/kg), but all blank sample concentrations except one were less than one-fifth the minimum concentrations detected in the streambed-sediment samples. Barium, lead, and zinc, as well as iron and manganese, concentrations were largest for material retained on the 0.063-mm sieve from split B (sample QA-B063R; table 5). It is possible these elevated concentrations are a result of insufficient cleaning of sieves between environmental samples. Because concentrations of nickel and chromium (common alloys in stainless steel) were not elevated in the split B results, the source of these trace elements is most likely residual from environmental samples from the Big River study area.

Laboratory Confirmation Samples

A total of 30 confirmation samples were submitted to the CMERSC laboratory to verify accuracy of the handheld XRF results and to evaluate laboratory comparability. The samples were selected from flood-plain core depth intervals that had been sieved and represented split samples of various size fractions from 18 different cores at nearly all locations, representing a range of concentrations of barium, lead, and zinc (table 6, at the back of this report). The 30 samples consist of split samples: 2 samples of the >2-mm fraction; 8 samples from <2- to 0.250-mm fraction; 8 samples from the <0.250- to 0.063-mm fraction; and 12 samples from the <0.063-mm fraction (table 6).

Overall, handheld XRF results for the target elements lead and zinc compared favorably to laboratory XRF results with logarithmic linear regression (Helsel and Hirsch, 2002) coefficients of 0.923 for lead and 0.941 for zinc (fig. 7). The handheld XRF results of the original sample were less favorable for the target element barium, which had a logarithmic linear regression coefficient of 0.757, when compared to the

Table 3. Results of analyses of standard reference materials by the U.S. Environmental Protection Agency x-ray fluorescence unit.

[Gray shaded cells indicate mining-related trace elements of concern for this study. MPV, most probable value; mg/kg, milligram per kilogram; *n*, sample size; XRF, x-ray fluoroscence; LCL, lower confidence level; UCL, upper confidence level; RCRA, Resource Conservation and Recovery Act; --, not determined; CAN Till 4, Canadian standard reference material collected near Scission's Brook, New Brunswick, Canada; <, less than]

Constituent	Standard MPV, in mg/kg	*n*	XRF reporting level, in mg/kg	Number of left censored values	XRF mean, in mg/kg	XRF relative standard deviation, in mg/kg	95-percentiles LCL, in mg/kg	95-percentiles UCL, in mg/kg	Percent difference between XRF mean and standard MPV
RCRA Standard									
Arsenic	500	54	11	0	377	24	370	383	−24.6
Barium	--	54	100	0	517	48	504	530	--
Cadmium	500	54	12	0	517	44	506	529	3.5
Cobalt	--	54	260	50	273	47	260	285	--
Copper	--	54	35	27	51	17	46	55	--
Iron	--	54	100	0	43,282	1,529	42,874	43,690	--
Manganese	--	54	85	0	753	99	727	780	--
Nickel	--	54	65	49	70	15	66	74	--
Lead	500	54	13	0	462	27	455	470	−7.5
Selenium	500	54	20	0	471	21	465	476	−5.8
Strontium	--	54	11	0	182	8	180	184	--
Zinc	--	54	25	0	71	10	69	74	--
CAN Till 4									
Arsenic	111	54	11	0	96	9	94	98	−13.4
Barium	395	54	12	1	378	53	364	392	−4.4
Cadmium	--	54	100	53	15	19	10	20	--
Cobalt	8	54	260	51	<267	27	--	--	--
Copper	237	54	35	0	214	27	207	221	−9.9
Iron	39,700	54	100	0	31,245	1,628	30,811	31,679	−21.3
Manganese	490	54	85	0	353	64	336	371	−27.9
Nickel	17	54	65	54	65	0	--	--	--
Lead	50	54	13	2	37	11	34	40	−25.6
Selenium	--	54	20	53	20	1	20	20	--
Strontium	109	54	11	0	115	8	113	117	5.6
Zinc	70	54	25	0	67	16	63	71	−4.4
Silica (SiO_2) blank									
Arsenic	--	29	11	29	11	0	--	--	--
Barium	--	29	12	25	101	3	100	102	--
Cadmium	--	29	100	28	12	1	12	12	--
Cobalt	--	29	260	29	260	0	--	--	--
Copper	--	29	35	29	35	0	--	--	--
Iron	--	29	100	29	100	0	--	--	--
Manganese	--	29	85	29	85	0	--	--	--
Nickel	--	29	65	29	65	0	--	--	--
Lead	--	29	13	29	13	0	--	--	--
Selenium	--	29	20	20	20	0	--	--	--
Strontium	--	29	11	29	11	0	--	--	--
Zinc	--	29	25	28	25	1	25	26	--

Table 4. Results of analyses of standard reference materials by the x-ray fluorescence unit.

[Gray shaded cells indicate mining-related trace elements of concern for this study. MPV, most probable value; *n*, sample size; XRF, x-ray fluoroscence; LCL, lower confidence level; UCL, upper confidence level; NIST, National Institute of Standards and Technology; --, not determined; <, less than]

Constituent	Standard MPV, in mg/kg	*n*	XRF reporting level, in mg/kg	Number of left censored values	XRF mean, in mg/kg	XRF standard deviation, in mg/kg	95-percent LCL, in mg/kg	95-percent UCL, in mg/kg	Percent difference between XRF mean and standard MPV
NIST Standard 2710A									
Arsenic	1,540	10	11	0	1,479	14.0	1,470	1,487	−4.0
Barium	792	10	100	0	720	13.6	712	729	−9.0
Cadmium	12.3	10	12	7	12.3	0.6	11	12	−5.7
Cobalt[1]	5.99	10	260	10	260	0.0	--	--	--
Copper	3,420	10	35	0	3,314	26	3,298	3,330	−3.1
Iron	43,200	10	100	0	46,520	462	46,234	46,807	7.7
Manganese	2,140	10	85	0	2,044	16	2,034	2,054	−4.5
Nickel[1]	8	10	65	10	<65	--	--	--	--
Lead	5,520	10	13	0	5,421	33.1	5,401	5,442	−1.8
Selenium[1]	1	10	20	10	<20	--	--	--	--
Strontium	255	10	11	0	318.6	12.3	311	326	24.9
Zinc	4,180	10	25	0	4,090	38.3	4,067	4,114	−2.1
NIST Standard 2711A									
Arsenic	107	10	11	0	49.3	5.0	46	52	−54.0
Barium	730	10	100	0	663	14.3	654	672	−9.2
Cadmium	54.1	10	12	0	53.5	1.3	53	54	−1.0
Cobalt[1]	9.89	10	260	10	<260	14.0	−115	−98	−1,173.5
Copper	140	10	35	0	112	1.9	111	114	−19.7
Iron	28,200	10	100	0	23,787	98.3	23,726	23,848	−15.6
Manganese	675	10	85	0	514	8.6	508	519	−23.9
Nickel[1]	21.7	10	65	10	29.3	2.4	28	31	34.9
Lead	1,400	10	13	0	1,396	9.8	1,389	1,402	−0.3
Selenium[1]	2	10	20	10	<20	--	--	--	--
Strontium	242	10	11	0	234	2.5	232	235	−3.3
Zinc	414	10	25	0	364	5.7	360	368	−12.1
Silica (SiO_2) blank									
Arsenic	0	9	11	9	<11	--	--	--	--
Barium	0	9	100	9	<100	--	--	--	--
Cadmium	0	9	12	9	<12	--	--	--	--
Cobalt	0	9	260	9	<260	--	--	--	--
Copper	0	9	35	9	<35	--	--	--	--
Iron	0	9	100	9	<100	--	--	--	--
Manganese	0	9	85	9	<85	--	--	--	--
Nickel	0	9	65	9	<65 (<3)	--	--	--	--
Lead	0	9	13	9	<13	--	--	--	--
Selenium	0	9	20	9	<20	--	--	--	--
Strontium	0	9	11	9	<11	--	--	--	--
Zinc	0	9	25	9	<25 (<3)	--	--	--	--

[1]All concentrations were below the XRF reporting limit.

Table 5. Concentrations of major and trace elements in quality assurance blank samples processed through sample splitting and sieve equipment.

[Samples collected on August 22, 2016. All blank samples were analyzed by the contract laboratory using inductively coupled plasma-atomic emission spectrometry and inductively coupled plasma-mass spectrometry methods. Gray shaded cells indicate mining-related trace elements of concern for this study. mm, millimeter; QA, quality assurance sample; SM, source material; SB, splitter blank; R, retained on sieve; P, passed through sieve; w%, percent by weight; <, less than; mg/kg, milligram per kilogram]

				Split A		Split B		
Constituent	Unit	Source material blank	Splitter blank	Material passed through splitter and retained on 0.250-mm sieve	Material passed through splitter and 0.250-mm sieve	Material passed through splitter and 0.250-mm sieve	Material passed through splitter and retained on 0.063-mm sieve	Material passed through splitter and 0.063-mm sieve
		QA-SM	QA-SB	QA-A250R	QA-A250P	QA-B250P	QA-B063R	QA-B063P
Aluminum	w%	0.09	0.1	0.12	0.07	0.06	0.14	0.09
Calcium	w%	0.02	0.02	0.01	0.02	<0.01	0.05	0.02
Iron	w%	0.03	0.02	0.02	0.02	<0.01	0.05	0.02
Potassium	w%	0.01	0.01	<0.01	0.02	<0.01	0.04	0.02
Magnesium	w%	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Sodium	w%	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulfur	w%	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Titanium	w%	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Antimony	mg/kg	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Arsenic	mg/kg	<1	<1	<1	<1	<1	<1	<1
Barium	mg/kg	40	25	16	13	13	74	10
Beryllium	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Bismuth	mg/kg	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04
Cadmium	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cerium	mg/kg	6.13	2.31	2.91	2.76	2.78	2.07	2.4
Cesium	mg/kg	<5	<5	<5	<5	<5	<5	<5
Chromium	mg/kg	<1	2	2	3	1	2	2
Cobalt	mg/kg	0.2	0.2	0.1	0.1	<0.1	0.4	0.1
Copper	mg/kg	2.1	3.7	2.6	1	2	4.6	1
Gallium	mg/kg	0.31	0.28	0.31	0.15	0.18	0.35	0.21
Indium	mg/kg	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Lanthanum	mg/kg	3.4	1.5	1.8	1.8	1.7	1.4	1.6
Lead	mg/kg	4.8	5.1	3.6	3.8	2.5	21.1	3.8
Lithium	mg/kg	2	2	2	3	1	3	3
Manganese	mg/kg	8	11	7	6	<5	34	6
Molybdenum	mg/kg	0.2	0.24	0.19	0.27	0.18	0.3	0.27
Nickel	mg/kg	1.2	2.3	2.	2.3	1.5	3.	2.4
Niobium	mg/kg	0.2	0.2	0.2	0.2	0.1	0.2	0.3
Phosphorus	mg/kg	<50	<50	<50	<50	<50	<50	<50
Rubidium	mg/kg	0.6	0.5	0.3	0.7	<0.2	1.2	0.6
Scandium	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Silver	mg/kg	<1	<1	<1	<1	<1	<1	<1
Strontium	mg/kg	3	3	1.2	6.6	0.8	6.9	6.4
Tellurium	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Thallium	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Thorium	mg/kg	1.1	0.4	0.6	0.5	0.7	0.4	0.5
Tin	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Tungsten	mg/kg	<0.1	0.8	<0.1	<0.1	<0.1	<0.1	<0.1
Uranium	mg/kg	0.3	0.2	0.3	0.2	0.4	0.2	0.2
Vanadium	mg/kg	<1	<1	<1	<1	<1	<1	<1
Yttrium	mg/kg	1.4	1.2	0.6	2.1	0.5	1.8	2.1
Zinc	mg/kg	5	5	3	4	2	10	4

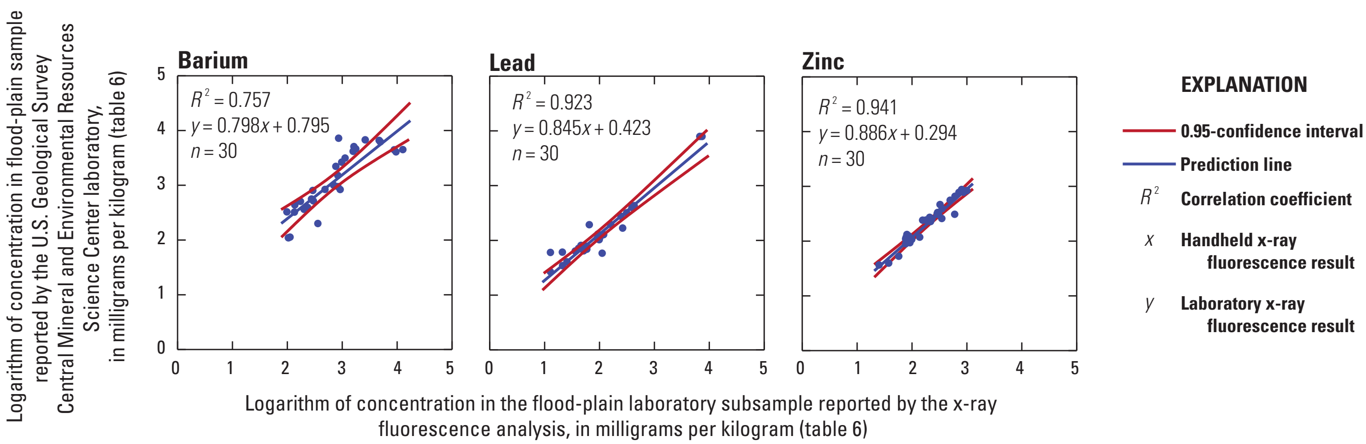


Figure 7. Comparison of concentrations of barium, lead, and zinc in laboratory subsamples and concentrations reported by the x-ray fluorescence analysis in original samples.

laboratory results, which are similar to results by Smith (2016) using similar methods and equipment.

The overall average percent difference of the XRF results for lead compared to the laboratory results of −19 percent was within project DQO although 2 samples had a percent difference <−30 percent and 9 samples had percent difference >30 percent. Lead concentrations determined by the handheld XRF tended to be lower than the concentrations determined by the laboratory based on negative overall average percent difference (table 6) and a y-intercept of <1 (0.423) in the regression equation comparing the two methods (fig. 7). The XRF results of samples with smaller grain-size fractions (<0.250 and 0.063 mm) tended to compare more favorably to laboratory results than larger grain-size fraction (>2 mm and <2 mm) sample results. The average percent difference for the XRF results compared to the laboratory results was −16 (*n*=12) for the <0.063-mm fraction and −9 (*n*=8) for the 0.063–0.250-mm fraction. The percent differences for the larger grain-size fractions tended to be much higher although there were only two samples compared for the >2-mm fraction. The average percent difference for the 0.250–2-mm fraction was −36 (*n*=6) and for the >2-mm grain-size fraction was −34 (*n*=2) (table 6).

The overall average percent difference of the XRF results compared to the laboratory results for zinc was −7 percent, which was within the DQO. The average percent differences did not seem to have the variability among samples with different grain sizes that was evident in the samples analyzed for the other trace elements. All average RPDs tended to be relatively low, ranging from −12 percent for the <0.063-mm fraction to 5 percent for the 0.063–0.250-mm fraction. Zinc concentrations determined by the handheld XRF also tended to trend lower than the concentrations determined by the laboratory based on negative overall average percent difference (table 6) and a positive y-intercept (0.294) of the regression equation comparing the two methods (fig. 7).

The overall average percent difference between the XRF results and the laboratory results for barium was −43, which exceeded the project DQO goal limit of plus or minus 30. The RPD results (table 6) and a y-intercept of <1 (0.795) in the regression equation comparing the two methods (fig. 7) both indicate that barium concentrations determined by the handheld XRF tended to be lower than concentrations determined by the laboratory. The average percent differences for barium were −34 for the <0.063-mm fraction, −59 for the 0.063–0.250-mm fraction, −51 for the 0.250–2-mm fraction, and 2 for the >2-mm fraction.

Distribution of Mining-Related Trace Elements in Streambed and Flood-Plain Sediment

This section presents the concentrations of chemical constituents in streambed sediments, flood-plain core samples, and December 2015 flood deposits. Spatial differences among the sites are described.

Streambed Sediments

In general, streambed-sediment concentrations of cadmium and lead were largest in samples from the Big River (average of 5.4 mg/kg for cadmium and 1,011 mg/kg for lead) and smallest in samples from the Barite District tributaries (average of 1.1 mg/kg for cadmium and 223 mg/kg for lead; fig. 8). Of the individual 45 streambed-sediment samples sent to the laboratory for analysis, the PEC values were exceeded for cadmium (6 samples), lead (35 samples), and zinc (17 samples). Of the 45 samples, 14 exceeded the EPA residential yard cleanup level of 400 mg/kg for lead. Concentrations of zinc were somewhat similar in the Big River (average of 371 mg/kg) and Barite District tributaries (average of 400 mg/kg) but tended to be larger in upstream Big River sites and at single

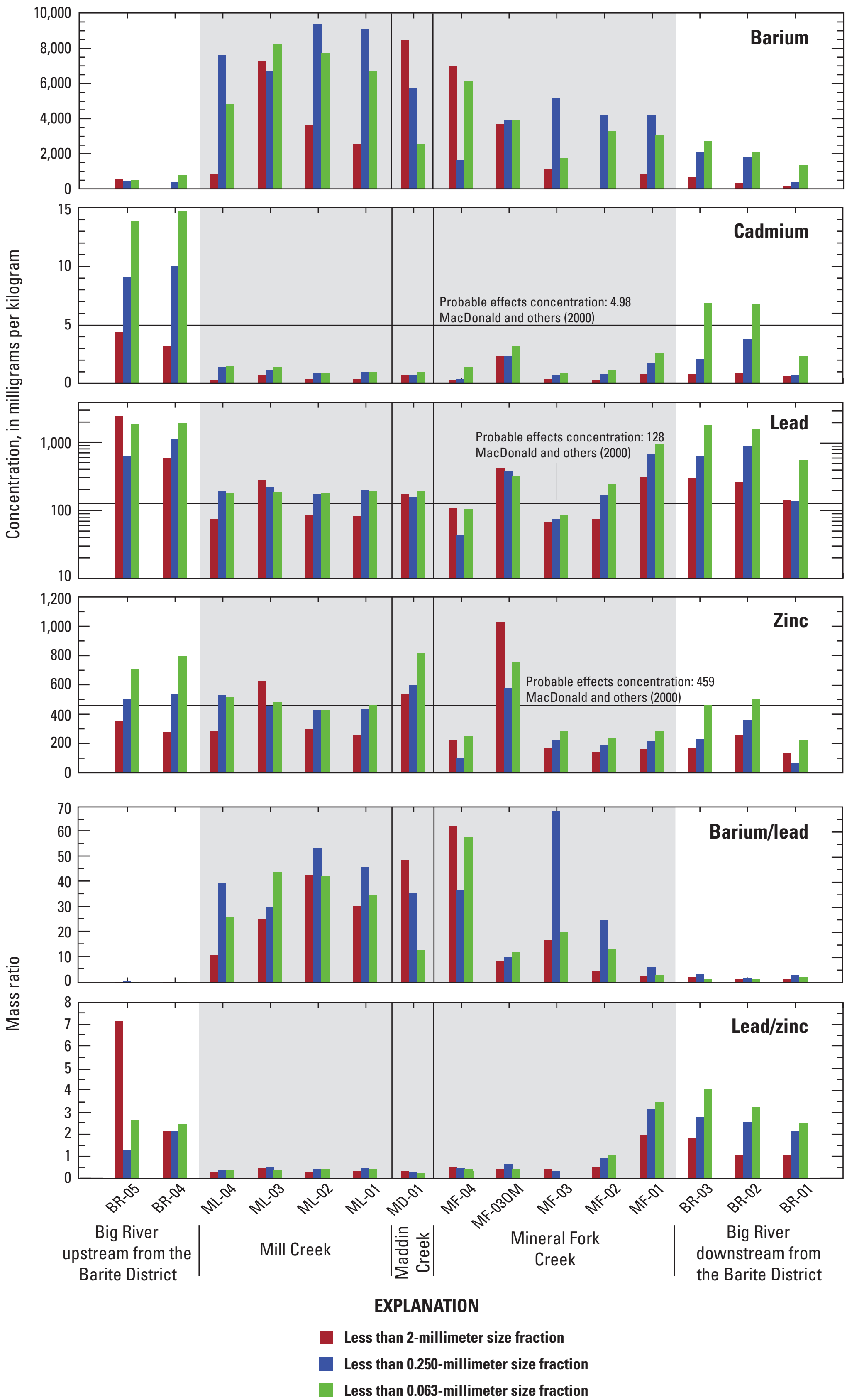


Figure 8. Average concentrations of selected metals in streambed-sediment samples from the middle reach of the Big River and tributaries draining the Barite District.

sites on Old Mines Creek and Mineral Fork Creek. Barium concentrations were considerably larger in samples from Barite District tributaries (average of 4,725 mg/kg) compared to Big River samples (average of 965 mg/kg).

Cadmium, lead, and zinc concentrations from Big River sampling sites decreased downstream from the Old Lead Belt and were largest in the <0.063-mm fraction except for lead in the <2-mm fraction at site BR-05. Concentrations of lead exceeded the PEC in all three grain-size fractions in the five samples from the Big River (table 7, at the back of this report; fig. 8). Concentrations of cadmium and zinc exceeded their respective PEC values in one or more size fractions from all Big River sites except for the farthest downstream site BR-01. The largest cadmium concentrations were in the <0.063-mm fraction at sites BR-04 and BR-05 (14.7 and 13.9 mg/kg), as well as the largest zinc concentrations (799 and 709 mg/kg).

Barium concentrations, unlike cadmium, lead, and zinc, were larger at Barite District tributary sites compared to Big River sites and were larger in Big River sites downstream from the tributaries compared to the upstream sites (table 7; fig. 8). Barium concentrations ranged from 365 (<2-mm fraction at site MF-02) to 9,370 mg/kg (<0.250-mm fraction at site ML-02) in the various size fractions in samples from Barite District tributaries—about 20 times the average concentration of 473 mg/kg in samples from the Big River upstream from the Barite District tributaries at sites BR-04 and BR-05. The largest barium concentrations were in samples from Mill Creek and were similar at all sites along this creek (fig. 8), which drains the more heavily mined areas of the Barite District (fig. 1). In contrast, barium concentrations in Mineral Fork Creek tended to decrease downstream. Overall, barium concentrations tend to be largest in the <0.250-mm fraction in Barite District tributary samples and largest in the <0.063-mm fraction in Big River samples, indicating that barium in the larger grain-size material is less likely to be transported in the smaller tributaries. Along the Big River, barium concentrations ranged from 155 to 804 mg/kg at sites upstream from the Barite District. Downstream from the Barite District tributaries, barium concentrations increased, ranging from 338 to 2,700 mg/kg at sites BR-03 and BR-02. Barium concentrations decreased farther downstream at site BR-01 but were larger than concentrations at both sites upstream from the Barite District.

The pattern and concentrations of barium, cadmium, lead, and zinc in the 2012 streambed-sediment samples from the Big River are similar to those observed by Smith and Schumacher (1991) in samples collected during 1988–89 and Schmitt and Finger (1982), indicating persistent effects on cadmium, lead, and zinc concentrations in the Big River from mine waste releases from the Old Lead Belt and Barite District (fig. 9). Concentrations of calcium, cadmium, lead, and zinc in the 2012 samples (table 7) fell within the range of those reported by Smith and Schumacher (1991) but were slightly smaller than the 1988–89 averages. In the fine-grained (<0.063-mm size fraction) samples at site BR-02, barium, cadmium, lead, and zinc concentrations in the 2012 sample were 7, 30, 13, and 19 percent smaller, respectively, than the average concentrations reported by Smith and Schumacher (1991) but within one standard deviation of the 1988–89 samples. Concentrations of calcium and magnesium were 24 and 35 percent smaller in the 2012 sample, respectively; however, strontium was about 50 percent larger than the 1988–89 samples. Although concentrations in the 2012 sample were smaller than the averages of the 1988–89 samples at site BR-02, they were within the range of the 1988–89 samples and it could not be concluded that there had been a measurable decrease based on only one result. Additional samples from each site, such as the seven collected quarterly by Smith and Schumacher (1991), are needed to determine if there has actually been a measurable decrease in metal concentrations over time. Smith and Schumacher (1991, 1993) indicated that sediment from the Big River near Irondale (site BR-07; fig. 1) represented background concentrations of trace elements in the Big River upstream from most mining activity. Average concentrations in the coarse (<2 mm) and fine (<0.063 mm) size fractions were barium (363 and 627 mg/kg), cadmium (<2 mg/kg), lead (53 and 69 mg/kg), and zinc (102 and 80 mg/kg). Most streambed-sediment samples collected during this current study exceeded the concentrations at Irondale reported by Smith and Schumacher (1991, 1993), including those from the Barite District tributaries, indicating probable mining effects on metal concentrations in Barite District tributary streambed sediments.

All of the 10 streambed-sediment samples from the Barite District tributaries contained cadmium concentrations well below the PEC (4.98 mg/kg); however, several samples contained lead or zinc above their respective PEC (128 mg/kg) values (table 7; fig. 8). Concentrations of lead exceeded the PEC in one or more size fractions from 8 of the 10 samples from Barite District tributaries, but concentrations were an order of magnitude less than those in Big River sites ranging from 45 mg/kg in the <0.250-mm fraction from sample MF-04 to 972 mg/kg in the <0.063-mm fraction from sample MF-01. Sample MF-01 was collected near the mouth of Mineral Fork Creek (fig. 1) and it is probable that this sample also may include sediment from the Big River deposited during higher flow events. Excluding sample MF-01, the largest lead concentrations in any sample from Barite District tributaries was 428 mg/kg in the <2-mm fraction of sample MF-03OM from Old Mines Creek, a tributary to Mineral Fork Creek (fig. 8). Sample MF-03OM also contained the largest zinc concentrations in all size fractions of samples from Barite District tributaries (1,030 mg/kg for the <2-mm fraction, 581 mg/kg for the <0.250-mm fraction, 756 mg/kg for the <0.063-mm fraction; table 7). Sample MF-03OM also contained the largest calcium concentrations of Barite District tributary samples (1.72 percent in the <2-mm size fraction to 23.5 percent in the <0.063-mm fraction). These large concentrations in this sample may be a result of its relation to historic mining areas in the Mineral Fork Creek watershed. There are several mining areas, including about six barite mine waste ponds, upstream from where sample MF-03OM was collected (figs. 1, 4).

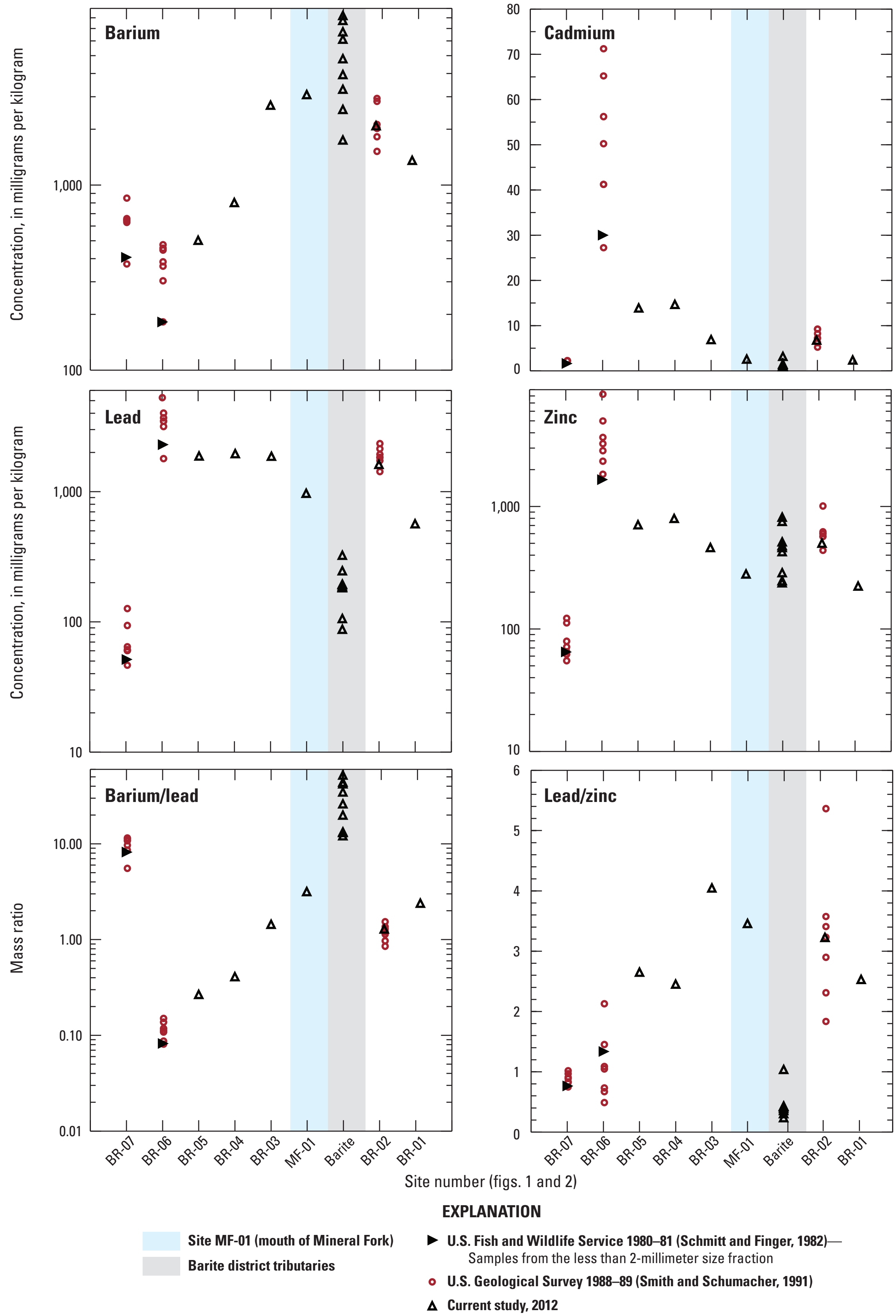


Figure 9. Concentrations and mass ratios of selected constituents in the less than 0.063-millimeter size fraction of streambed-sediment samples collected by the U.S. Geological Survey during 1988–2012 and the U.S. Fish and Wildlife Service during 1980–81 in the Big River watershed. Concentrations determined by complete digestion and laboratory analysis.

Smith and Schumacher (1991) indicated that the large quantity of mine waste not only changed the concentration of trace elements in the Big River streambed sediments, but it also altered mineralogy of the streambeds. Calcite and dolomite, signatures of mine waste, were now dominant minerals in the streambed, whereas a more natural streambed sediment mainly consists of quartz with little calcite or dolomite.

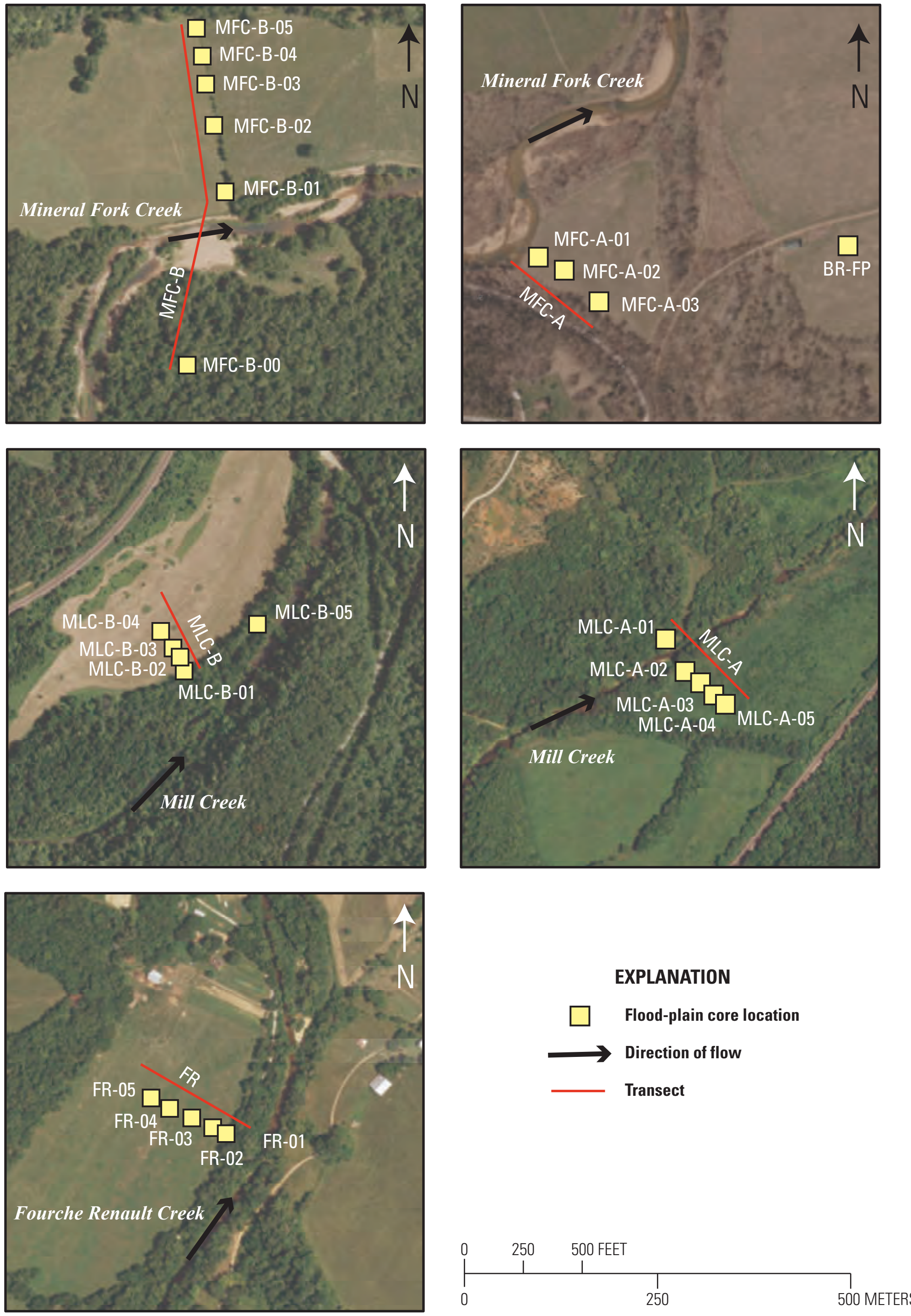
Similar to lead, concentrations of calcium decreased in all size fractions of Big River streambed sediment with increasing distance downstream from nearly 8 percent in the <2-mm fraction at site BR-05 to <0.2 percent in the <2-mm fraction at site BR-01 (table 7). Calcium is strongly positively correlated with lead (correlation coefficient [R^2]=0.70), cadmium (R^2=0.72), and zinc (R^2=0.69) in all size fractions because calcite and dolomite presence may indicate mining influence. There is little correlation between calcium and barium (R^2=-0.17).

Mass ratios of barium to lead and lead to zinc vary in streambed-sediment samples and indicate influxes of metal contamination from various barite, lead, and zinc mining areas. Most noticeable are the large barium to lead ratios in Barite District tributaries compared to the Big River (fig. 8). The average barium to lead ratio (31.8) in all size fractions from Barite District tributaries (excluding site MF-01 that is near the Big River) is nearly 100 times larger than Big River sediments upstream from the Barite District (average of 0.36 at sites BR-04 and BR-05; average of 1 in 1988–89 samples from background site BR-07 at Irondale; Smith and Schumacher, 1991, 1993) and nearly 15 times larger than the Big River sites downstream from the Barite District (average of 2.01 at sites BR-01, BR-02, and BR-03). Two Barite District sites (MF-01 and MF-03OM) have unusually low barium to lead ratios driven mostly by their larger lead concentrations. Site MF-01 is at the mouth of Mineral Fork Creek and is likely affected by sediments being transported by the Big River during flood conditions. Site MF-03OM is along Old Mines Creek where Burford (1978) indicated the earliest lead mining (about 1720) in Washington County was reported. Dake (1930) referred to the Old Mines area as covering several square miles and by 1725 about 1,500 pounds (lb) of lead had been smelted in this area. Consistent with the historic, rich lead ore mined in the Old Mines areas, the sample from site MF-03OM has among the largest lead to zinc ratio, and as mentioned previously, the largest calcium concentrations (possibly indicating waste rock from bedrock mining) of any of the Barite District tributary sites. In a compilation of production figures from various sources, Mugel (2017) indicated that about 180,000 tons of lead and 60,000 tons of zinc were produced (lead to zinc ratio of about 3:1) from the Barite District (includes zinc production from Valley Mines zinc-rich deposits just east of the Barite District and east of the Big River watershed). In contrast, about 7.6 million tons of lead and 800,000 tons of zinc were produced from the Old Lead Belt (about 10:1 lead to zinc ratio). Consistent with general historical production figures, lead to zinc ratios in all size fractions of streambed sediments tend to be smallest in Barite District tributaries (<1.0) and in the Big River background site BR-07 at Irondale (ratio of 1; data from Smith and Schumacher, 1991, 1993), and largest in the Big River downstream from BR-07 at Irondale—decreasing from site BR-05 (ratios of 1.3 to 7.2) to downstream site BR-01 (ratios of 1 to 2.5).

Flood-Plain Sediments

Flood-plain core samples were collected from 26 cores along 5 transects and a single location along streams draining the Barite District—two transects along the lower reach of Mineral Fork Creek (MFC-A and MFC-B), two transects along the lower reach of Mill Creek (MLC-A and MLC-B), a single location on the Big River flood plain, and one transect along Fourche Renault Creek (FR) in the upper part of the Mineral Fork Creek watershed and upstream from most of the previously mined areas in the Barite District (figs. 4, 10). Of the individual 693 bulk samples from these cores analyzed by the XRF, the PEC values were exceeded for cadmium (218 samples), lead (91 samples), nickel (45 samples), and zinc (77 samples). Of the 693 samples, 21 exceeded the EPA residential yard cleanup level of 400 mg/kg for lead; 19 of these were samples from transect MFC-A. This site is near the mouth of Mineral Fork Creek where its flood plain joins the Big River flood plain and so its sample composition may include Mineral Fork Creek and Big River sediment. Because the XRF reporting level of 12 mg/kg for cadmium is larger than the PEC (4.98 mg/kg), the frequency of cadmium exceeding the PEC is likely underreported; therefore, the following discussion focuses primarily on concentrations of barium, lead, and zinc.

Scanning the bulk core provided a rapid determination of metal profiles with depth; however, this can introduce error caused by trace elements being irregularly distributed in various grain-size fractions of the sediment and singular large grains dominating the XRF beam. To determine the usability of the XRF data from the bulk core scans, and to determine if grain size had a measureable effect on reported metal concentrations, 47 samples from five cores (FR-03, MFC-B-02, MLC-B-05, MLC-A-02, and MLC-A-05; fig. 10) were split into four fractions (<0.063 mm, 0.063 to 0.250 mm, 0.250 to 2 mm, and >2 mm) that were analyzed by the XRF and compared to the average bulk core XRF scans of these same intervals (table 8, at the back of this report; fig. 11). Metal concentrations tended to be larger in the smaller size fractions. Concentrations of trace elements in the bulk core also do not provide information on metal concentrations for different size fractions, which is important because finer material may dissolve more easily in stomachs of animals, making the metal have greater bioavailability to animals (Luoma, 1989). Comparison of the <0.063-mm fractions in the 47 sieved samples to the average of the bulk core scans using a paired t-test (Helsel and Hirsch, 2002) indicates no significant difference at an alpha level of 0.05 between barium concentrations (p-value of 0.81 and averages of 1,716 and 1,674 mg/kg) but significant differences were detected between the <0.063-mm fraction sample and bulk sample for lead (p-value of 0.00 and averages



Base from U.S. Department of Agriculture, 2013
National Agriculture Imagery Program
Geographic coordinate system, North American Datum 1983

Figure 10. Flood-plain core location along streams draining the Barite District, Missouri, 2014.

of 105 and 76 mg/kg) and zinc (*p*-value of 0.003 and averages of 262 and 207 mg/kg) concentrations. Profiles of barium, lead, and zinc in the various size fractions (>2-mm fraction not plotted) from five cores indicate that XRF-reported concentrations in the various fractions exhibit similar patterns, but the bulk core scans miss several inflections that are seen in the sieved fraction results, particularly for lead and zinc in the lower part of core MLC-B-05 and lead in the middle part of core FR-03 (fig. 11). The significant difference in lead and zinc concentrations between the <0.063-mm fraction and bulk core, in addition to the missed inflections in the core profiles, preclude the use of bulk core scans beyond evaluating general patterns of trace elements with depth or general comparisons between metal concentrations at various locations.

With few exceptions, the general pattern of metal concentrations in the bulk XRF scans of flood-plain core from all locations was that barium concentrations were greater than zinc concentrations and zinc concentrations were greater than lead concentrations. Samples from transect FR along Fourche Renault Creek upstream from the most intense mining areas contained the smallest concentrations (number in parentheses are averages) of barium (621 mg/kg), lead (29.9 mg/kg), and zinc (58.4 mg/kg). The depth of cores at transect FR ranged from approximately 5 to 18.5 ft (15.8 ft for core FR-03 in fig. 12) and concentrations of trace elements in the five cores from this location were similar and had similar vertical profiles (fig. 12). Barium concentrations in transect FR tended be smaller in the 0–1-ft deep interval then remain steady or increase slightly with increasing depth, whereas concentrations of lead and zinc tended to decrease at depths below about 2 to 4 ft deep, and many lead values were less than the XRF reporting level of 13 mg/kg (fig. 12; table 9, at the back of this report). An expedition in 1719–20 lead by Philippe Francois Renault discovered lead ore and started development of some of the earliest lead mines in southeast Missouri at what was called Mine Renault or Fourche Renault Mine in the headwaters of Mineral Fork Creek that is thought to be along Fourche Renault Creek (Ekberg and others, 1981; Park, 2006; Mugel, 2017). Park (2006) indicated the Mine a Straddle lead mine was located about 1,000 ft upstream from transect FR. The higher lead and zinc concentrations in the upper part of cores along transect FR may be the result of early mining activities in this area because lead and zinc mineralization occurred together but uses for zinc ore were not determined until the mid- to late 1800s.

Downstream from transect FR, profiles of cores at transect MFC-B along the lower part of Mineral Fork Creek tended to have similar vertical profiles as transect FR but the concentrations were generally larger (fig. 12; table 9). Barium concentrations in cores MFC-B-01 through MFC-B-05 (fig. 12) tend to be smallest within the upper 0–1-ft depth and then tend to be similar at deeper depths. The vertical profiles of lead and zinc concentrations were similar with each slightly larger concentration with a depth of 0 to 2 ft in some cores, but the concentrations changed little with depth.

Cores MFC-B-01 through MFC-B-05 (fig. 10) are north of Mineral Fork Creek where the flood plain is about 10 to 12 ft higher than the base-flow water surface of the creek. High water marks (HWMs) from the historic December 2015 flood indicate a water depth of only 1 to 2 ft on parts of the flood plain north of the creek, indicating that this area is rarely flooded. In contrast, core MFC-B-00 (fig. 10), which was a hand sample collected south of Mineral Fork Creek along a footpath between the creek and the Missouri Department of Conservation Kingston Access gravel parking lot, was in an area that is frequently flooded. The HWMs from the December 2015 flood indicate more than 5 ft of inundation at this location.

Samples from transect MFC-A at the junction of the Mineral Fork Creek and Big River flood plains contained the largest lead (average of 1,720 mg/kg; maximum of 7,340 mg/kg; table 9) and among the largest zinc concentrations (450 mg/kg; maximum of 967 mg/kg) detected in any streambed, flood-plain, or flood samples analyzed in this study. Flood-plain samples were collected from two locations along a transect extending about 300 ft southeast of Mineral Fork Creek (cores MFC-A-01 and MFC-A-03; no samples from location MFC-A-02 were used for the analysis due to time constraints) and one additional location about 900 ft east near the Big River (BR-FP). Hand sample methods, which limit sample depth, were used because the location could not be accessed by the drill rig (fig. 10). Core MFC-A-01 was about 20 ft south of an 8–10-ft high cut bank on the outside of a meander bend of Mineral Fork Creek (fig. 10). Lead and zinc concentrations increased steadily from 814 and 372 mg/kg, respectively, in the surface sample (0–1 in. deep) to 7,340 and 967 mg/kg respectively in the 2–3-ft deep sample at the bottom of the core (fig. 12; table 9). Lead and zinc concentrations in the 0–1-ft deep samples at location MFC-A-03 about 250 ft to the south were similar to those in the 0–1-ft deep intervals at core MFC-A-01. Core MFC-A-01 and MFC-A-02 are within a shallow draw that extends about 900 ft southeast to a meander of the Big River (fig. 10). At the time of sampling, this area was an overflow channel and likely an area of sediment deposition for the Big River during high river stages. Examination of aerial photographs and elevation data from Google Earth™ suggests that this feature could be an old abandoned channel of the Big River because it is visually observable for about another 0.5 mile upstream, which includes a crossing of a meander in the Big River. The flood plain 900 ft east of this feature at core BR-FP was about 8 ft higher in elevation and consequently less frequently flooded. Core sample concentrations of lead (<250 mg/kg) and zinc (≤150 mg/kg) in the 0–1-ft interval at core BR-FP were considerably smaller than those at locations MFC-A-01 or MFC-A-03.

Samples from the most downstream transect along Mill Creek (MLC-A) contained the largest barium concentrations (average of 2,931 and maximum of 13,100 mg/kg in bulk core samples) detected in flood plain or stream sediment samples (table 9). Except for cores MLC-A-04 and MLC-A-05 that were farthest from the creek, barium concentrations were

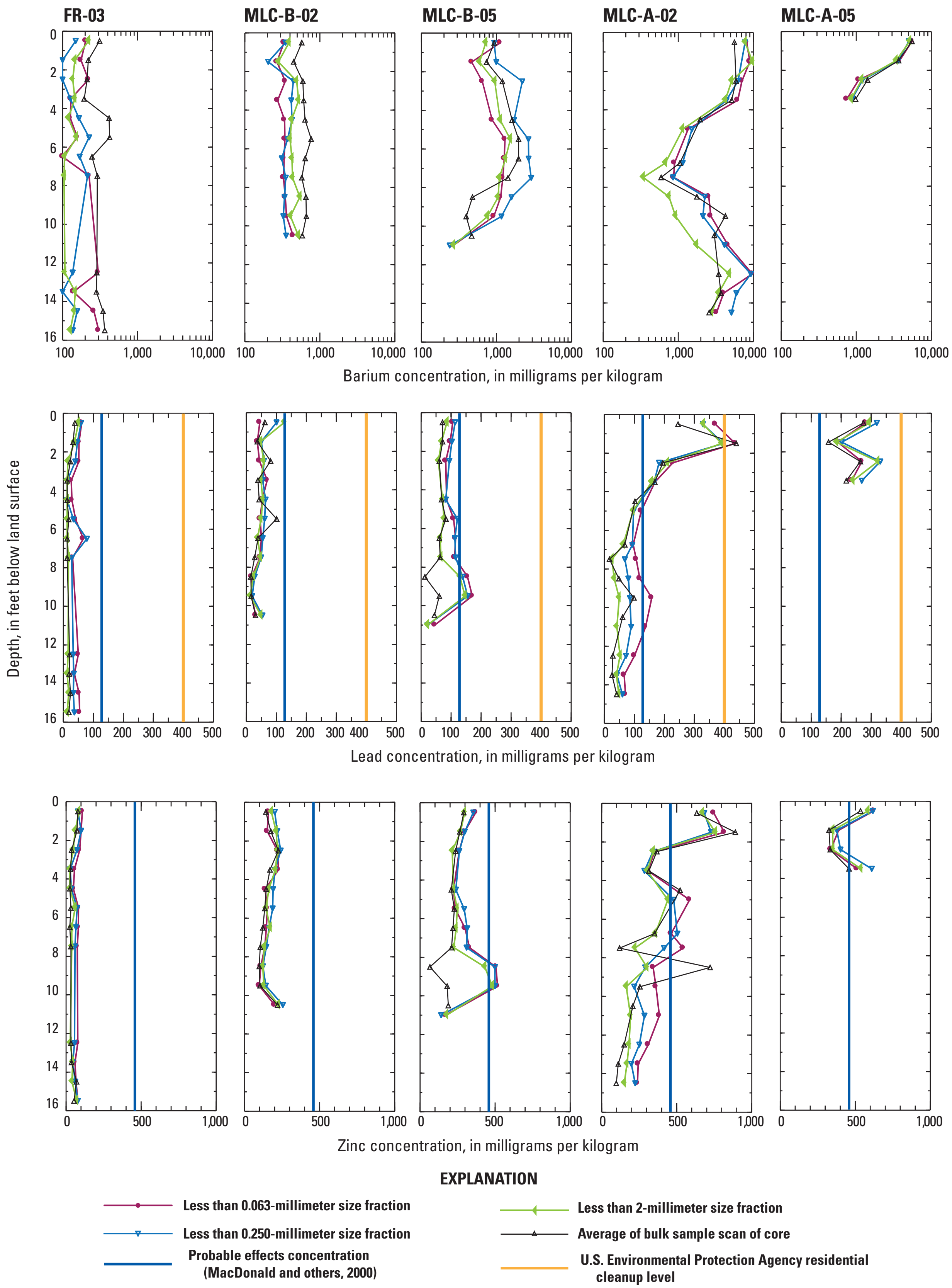


Figure 11. Concentrations of barium, lead, and zinc determined by x-ray fluorescence from selected flood-plain bulk core and selected size-fraction samples, Missouri, 2014.

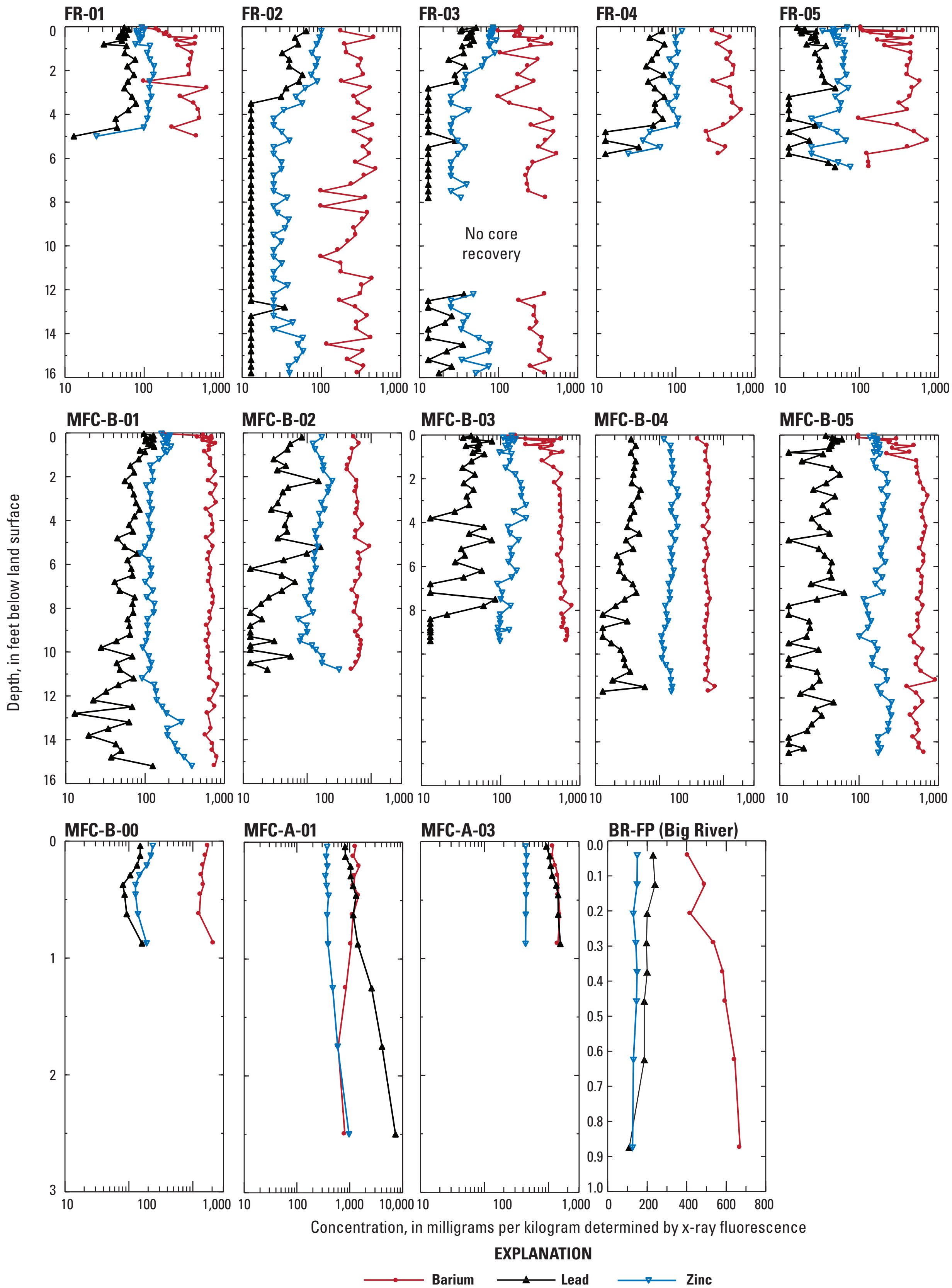


Figure 12. Concentrations of barium, lead, and zinc determined by x-ray fluorescence in bulk cores collected from two locations on the Mineral Fork Creek flood plain and one shallow (less than 1 foot deep) core on the Big River flood plain near transect MFC-A, Barite District, Missouri, 2014.

largest in the upper 2–4-ft intervals at all cores on this transect (fig. 13; table 9). The large barium concentrations at transect MLC-A are consistent with past activities in the near vicinity. Although this is not within the barite strip mined areas shown (fig. 4), the transect is located immediately south of a former barite mill pond and strip mine area. The residuum on hillside north of transect MLC-A contained abundant weathered barite crystals up to golf-ball size and drusy quartz (drusy quartz is indicative of the Potosi Formation). Lead and zinc concentrations generally were <150 and 300 mg/kg. In the vertical profile results for core MLC-A-01, there was an unusual pattern of dramatically increasing barium and decreasing lead and zinc concentrations in samples from the upper 1-ft depth (fig. 13). Core MLC-A-01 is the only core north of Mill Creek. It was closest to the mine waste area and near a steep road leading from the mined area to the creek. Runoff from this area may have contributed to barium, lead, and zinc concentrations. It is possible that the erratic metal concentrations are related to the presence of barite grains in the bulk core sample that are depleted in lead and zinc. Visual inspection of core from MLC-A-01 indicated angular sandy gravel with small diameter (1 to 3 mm) milky-clear, bladed crystals—possibly barite and calcite—in the upper 1 ft of the core, which changed rapidly to a sandy silt below.

Metal concentrations in bulk XRF scans of samples from the upstream transect along Mill Creek (MLC-B) were smaller than concentrations at downstream transect MLC-A (fig. 13). Unlike most cores at other transects, concentrations of barium and zinc tended to be similar (100–500 mg/kg) in the deeper intervals of most cores.

December 2015 Flood Deposits

Twenty-three flood-deposit sediment samples were collected after the December 2015 flood—15 from the Big River flood plain (7 samples upstream and 8 samples downstream from the Barite District), 7 samples along the flood plains of Barite District tributaries (Mill Creek and Mineral Fork Creek), and 1 sample from the Dry Creek flood plain that represents a Big River tributary in Jefferson County with little known mining within its watershed (fig. 14). Metal concentrations reported by XRF in the 2015 flood-deposit sediments indicated samples collected along the Big River had the largest lead and zinc concentrations, whereas samples collected from Barite District tributaries had the largest barium concentrations. The mean lead concentration in flood samples collected along the Big River was 1,746 mg/kg upstream from the Barite District and 1,858 mg/kg downstream from the Barite District, and the mean lead concentration in flood samples collected in the Barite District tributaries was 235 mg/kg (table 10,). The mean zinc concentration in flood samples collected along the Big River was 731 mg/kg upstream from the Barite District and 474 mg/kg downstream from the Barite District, and the mean zinc concentration in flood samples collected in the Barite District tributaries was 423 mg/kg. Barium concentrations in flood sediment samples collected along the Big River downstream from the Barite District were larger overall than those in samples collected along the Big River upstream from the Barite District. The mean barium concentration in flood samples collected along the Big River was 438 mg/kg upstream from the Barite District and 1,471 mg/kg downstream from the Barite District, and the mean barium concentration in flood samples collected in the Barite District tributaries was 6,504 mg/kg. The sample from Dry Creek contained the smallest concentrations of barium (<700 mg/kg), lead (<60 mg/kg), and zinc (<140 mg/kg) in the bulk or fine fraction, which was consistent with the minimal mining in its watershed.

Lead concentrations in flood deposit samples collected upstream from the Barite District were similar to those in samples downstream from the Barite District on the Big River. In bulk samples, lead concentrations determined by XRF analysis ranged from 886 to 2,043 mg/kg (average of 1,495 mg/kg) in the 7 samples collected along the Big River upstream from the Barite District, and were about 20 percent lower than samples collected downstream (1,249 to 2,232; average of 1,859 mg/kg) from the Barite District which does not include pre-2015 deposit soil (sample identifier-SL). Lead concentrations in bulk flood sediment samples collected upstream from the Barite District were not significantly different from concentrations in samples collected downstream from the Barite District at an alpha level of 0.05 (Mann-Whitney Test [Helsel and Hirsch, 2002]; *p*-value of 0.18). Lead concentrations in the <0.063-mm size fraction of these same sample groups were similar in the upstream samples (average of 1,990 mg/kg) and downstream samples (average of 2,067 mg/kg) and about 10 to 30 percent larger than average concentrations in the bulk samples. There was no significant difference between samples collected upstream from those collected downstream for the <0.063-mm fraction (Mann-Whitney Test; *p*-value of 1.00). Lead concentrations in flood-deposit samples collected along the Big River exceeded the 128-mg/kg PEC and the EPA residential cleanup level of 400 mg/kg in the bulk and <0.063-mm fraction (table 10).

Concentrations of barium (ranging from 272 to 3,697 mg/kg) in flood sediment samples collected on the Big River were largest in samples collected downstream from the Barite District. Barium concentrations in samples upstream from the Barite District ranged from 300 to 546 mg/kg. The upstream concentrations were similar to concentrations found in samples (DC-01 and DC-01-SL) from Dry Creek (table 10; fig. 14), which lies east of the Barite District where very little mining has occurred. This similarity may indicate that barium concentrations upstream from the Barite district on the Big River may be closer to background conditions.

Lead concentrations were much larger (2–3 orders of magnitude) in sieved and bulk samples along the Big River upstream from the Barite District than samples collected from tributaries in the Barite District. Concentrations of zinc were somewhat similar in the Big River and Barite District tributaries but tended to be larger in upstream Big River sites (fig. 14).

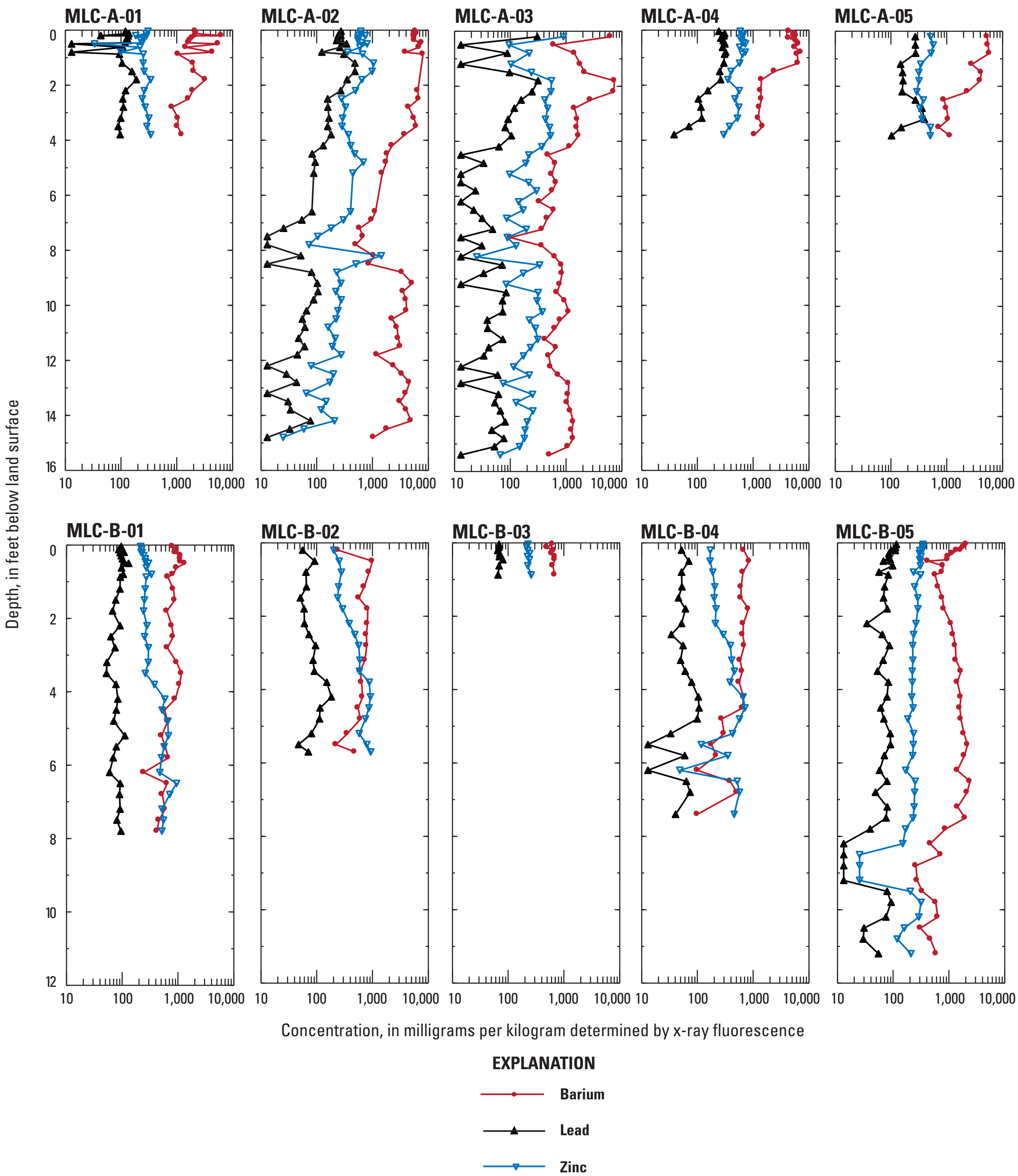


Figure 13. Concentrations of barium, lead, and zinc determined by x-ray fluorescence in bulk cores collected from two locations on the Mill Creek flood plain.

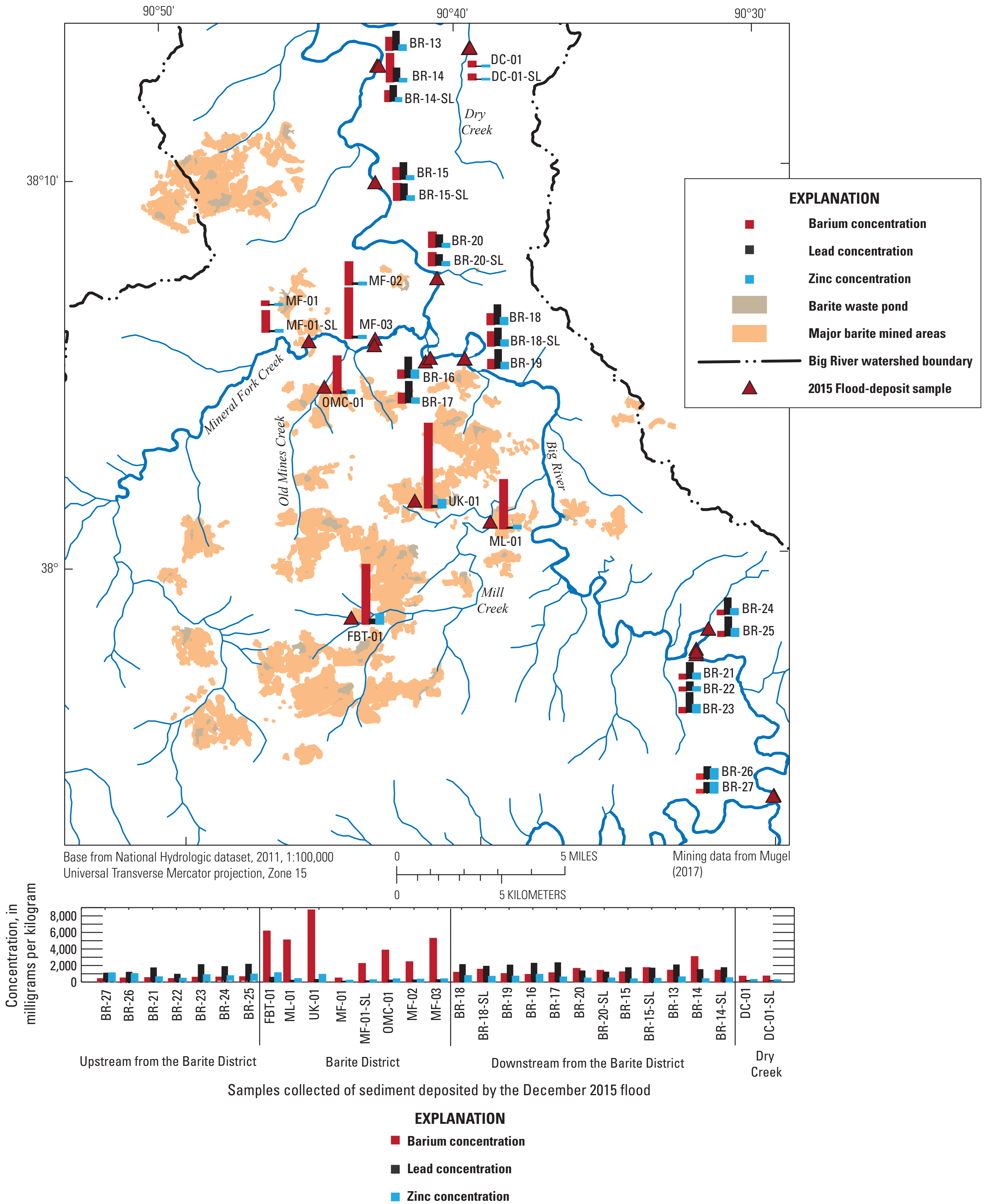


Figure 14. Concentration of barium, lead, and zinc and location of bulk samples collected from sediment deposited by the December 2015 flood in the middle and lower Big River watershed, Missouri, 2016.

Table 10. Concentrations of select trace elements determined by x-ray fluorescence in sediment deposited on the flood plain from the December 2015 flood and in underlying soils, Missouri, 2016.

[mg/kg, milligram per kilogram; Ba, barium; Pb, lead; Zn, zinc; Bulk, unsieved sample; SF, surface sample consisting of only newly deposited fines from recent flood; <, less than; SL, pre-2015 deposit soil from 6 to 8 inches below original grade; --, not determined]

Sample identifier	Grain size	Sample type	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg	Mass ratio		
											Ba/Pb, in mg/kg	Pb/Zn, in mg/kg	Ba/Zn, in mg/kg
Upstream from Washington County Barite District													
Big River													
BR-26	Bulk	SF	<11	426	23	<35	1,180	1,377	<65	953	0.36	1.24	0.45
BR-26	<0.063	SF	<11	546	22	<35	1,529	1,392	<65	1,058	0.36	1.44	0.52
BR-27	Bulk	SF	<11	272	23	<35	1,000	1,265	<65	969	0.27	1.03	0.28
BR-27	<0.063	SF	<11	518	26	<35	2,045	1,213	<65	1,293	0.25	1.58	0.40
BR-21	Bulk	SF	<11	405	<12	45	1,650	1,355	<65	515	0.25	3.20	0.79
BR-21	<0.063	SF	<11	486	<12	57	2,025	1,322	<65	530	0.24	3.82	0.92
BR-22	Bulk	SF	<11	300	<12	35	886	1,386	<65	339	0.34	2.62	0.88
BR-22	<0.063	SF	<11	520	<12	46	1,579	1,429	<65	426	0.33	3.70	1.22
BR-23	<0.063	SF	<11	453	13	55	1,972	1,363	<65	671	0.23	2.94	0.67
BR-23	Bulk	SF	<11	456	15	56	2,043	1,508	<65	759	0.22	2.69	0.60
BR-25	Bulk	SF	<11	428	13	62	1,995	1,689	<65	746	0.21	2.67	0.57
BR-25	<0.063	SF	<11	493	14	61	2,233	1,538	<65	762	0.22	2.93	0.65
BR-24	Bulk	SF	<11	381	12	64	1,710	1,722	<65	548	0.22	3.12	0.70
BR-24	<0.063	SF	<11	444	15	74	2,603	1,702	<65	662	0.17	3.93	0.67
Mean			--	438	18	55	1,746	1,447	--	731	0.26	2.64	0.67
Downstream from Washington County Barite District													
Big River													
BR-19	Bulk	SF	<11	894	<12	53	1,988	1,497	<65	590	0.45	3.37	1.52
BR-19	<0.063	SF	<11	926	<12	54	2,082	1,469	<65	604	0.44	3.45	1.53
BR-18	Bulk	SF	<11	1,058	<12	55	2,049	1,652	<65	660	0.52	3.11	1.60
BR-18	<0.063	SF	<11	1,032	<12	52	1,984	1,543	<65	635	0.52	3.12	1.63
BR-18-SL	Bulk	SL	<11	1,420	<12	48	1,848	1,344	<65	570	0.77	3.24	2.49
BR-18-SL	<0.063	SL	<11	1,473	<12	42	1,806	1,305	<65	567	0.82	3.18	2.60
BR-16	Bulk	SF	<11	761	14	65	2,168	1,662	<65	769	0.35	2.82	0.99
BR-16	<0.063	SF	<11	782	12	58	2,163	1,697	<65	749	0.36	2.89	1.04
BR-17	Bulk	SF	<11	957	<12	50	2,232	1,434	<65	451	0.43	4.95	2.12

Table 10. Concentrations of select trace elements determined by x-ray fluorescence in sediment deposited on the flood plain from the December 2015 flood and in underlying soils, Missouri, 2016.—Continued

[mg/kg, milligram per kilogram; Ba, barium; Pb, lead; Zn, zinc; Bulk, unsieved sample; SF, surface sample consisting of only newly deposited fines from recent flood; <, less than; SL, pre-2015 deposit soil from 6 to 8 inches below original grade; --, not determined]

Sample identifier	Grain size	Sample type	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg	Mass ratio		
											Ba/Pb, in mg/kg	Pb/Zn, in mg/kg	Ba/Zn, in mg/kg
Downstream from Washington County Barite District—Continued													
Big River—Continued													
BR-17	<0.063	SF	<11	1,175	<12	67	2,679	1,382	<65	490	0.44	5.47	2.40
BR-20	Bulk	SF	<11	1,486	<12	35	1,249	1,048	<65	318	1.19	3.92	4.67
BR-20	<0.063	SF	<11	1,868	<12	<35	1,334	1,048	<65	324	1.40	4.12	5.76
BR-20-SL	Bulk	SL	<11	1,259	<12	<35	1,100	1,002	<65	333	1.15	3.30	3.78
BR-20-SL	<0.063	SL	<11	1,609	<12	<35	1,233	1,078	<65	358	1.30	3.44	4.49
BR-15	Bulk	SF	<11	1,167	<12	41	1,734	969	<65	323	0.67	5.37	3.61
BR-15	<0.063	SF	<11	1,651	<12	54	2,437	1,300	<65	395	0.68	6.16	4.18
BR-15-SL	Bulk	SL	<11	1,679	<12	41	1,681	1,014	<65	389	1.00	4.32	4.32
BR-15-SL	<0.063	SL	<11	1,931	<12	45	2,050	1,226	<65	460	0.94	4.46	4.20
BR-14	Bulk	SF	<11	2,954	<12	<35	1,447	872	<65	279	2.04	5.18	10.58
BR-14	<0.063	SF	<11	3,697	<12	40	1,813	1,152	<65	308	2.04	5.89	12.02
BR-14-SL	Bulk	SL	<11	1,309	<12	42	1,676	964	<65	398	0.78	4.21	3.29
BR-14-SL	<0.063	SL	<11	1,506	<12	45	1,783	1,055	<65	405	0.84	4.40	3.72
BR-13	Bulk	SF	<11	1,310	<12	51	2,008	1,243	<65	504	0.65	3.99	2.60
BR-13	<0.063	SF	<11	1,406	<12	50	2,047	1,266	<65	499	0.69	4.10	2.82
Mean			--	1,471	13	49	1,858	1,259	--	474	0.85	4.10	3.66
Jefferson County District tributary													
Butcher Brook													
DC-01	Bulk	SF	<11	489	<12	<35	39	548	<65	94	12.51	0.42	5.22
DC-01	<0.063	SF	<11	657	<12	<35	55	784	<65	137	11.87	0.40	4.80
DC-01-SL	Bulk	SL	<11	511	<12	<35	38	823	<65	64	13.48	0.59	7.95
DC-01-SL	<0.063	SL	<11	582	<12	<35	38	782	<65	66	15.36	0.58	8.86
Mean				560	--	--	43	734	--	90	13	0	7

Table 10. Concentrations of select trace elements determined by x-ray fluorescence in sediment deposited on the flood plain from the December 2015 flood and in underlying soils, Missouri, 2016.—Continued

[mg/kg, milligram per kilogram; Ba, barium; Pb, lead; Zn, zinc; Bulk, unsieved sample; SF, surface sample consisting of only newly deposited fines from recent flood; <, less than; SL, pre-2015 deposit soil from 6 to 8 inches below original grade; --, not determined]

Sample identifier	Grain size	Sample type	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg	Mass ratio		
											Ba/Pb, in mg/kg	Pb/Zn, in mg/kg	Ba/Zn, in mg/kg
Washington County Barite District tributary													
Mineral Fork													
MF-01	Bulk	SF	<11	369	<12	<35	56	178	<65	110	6.56	0.51	3.36
MF-01	<0.063	SF	<11	2,882	<12	<35	184	661	<65	227	15.69	0.81	12.72
MF-01-SL	Bulk	SL	<11	2,156	<12	<35	132	517	<65	189	16.34	0.70	11.43
MF-01-SL	<0.063	SL	<11	3,422	<12	<35	208	764	<65	280	16.43	0.74	12.21
OMC-01	Bulk	SF	<11	3,749	<12	<35	202	572	<65	282	18.59	0.72	13.31
OMC-01	<0.063	SF	<11	17,224	<12	<35	409	1,342	<65	600	42.11	0.68	28.71
MF-02	Bulk	SF	<11	2,289	<12	<35	167	564	<65	192	13.73	0.87	11.94
MF-02	<0.063	SF	<11	3,298	<12	<35	236	741	<65	254	13.95	0.93	12.97
MF-03	Bulk	SF	<11	5,122	<12	<35	195	678	<65	227	26.22	0.86	22.60
MF-03	<0.063	SF	<11	6,129	<12	<35	198	739	<65	237	30.95	0.84	25.86
Mill Creek													
FBT-01	Bulk	SF	<11	6,004	<12	<35	485	1,595	<65	964	12.37	0.50	6.23
FBT-01	<0.063	SF	<11	10,481	<12	<35	450	1,571	<65	984	23.29	0.46	10.66
UK-01	<0.063	SF	<11	6,610	<12	<35	220	645	<65	637	30.05	0.35	10.38
UK-01	Bulk	SF	<11	8,549	<12	<35	223	939	<65	773	38.28	0.29	11.05
ML-01	Bulk	SF	<11	4,926	<12	<35	125	424	<65	255	39.52	0.49	19.32
ML-01	<0.063	SF	<11	20,859	<12	<35	267	1,114	<65	553	78.22	0.48	37.70
Mean			--	6,504	--	--	235	815	--	423	26.4	0.6	15.7

Lead concentrations in samples from Barite District tributaries ranged from 56 to 485 mg/kg with 14 out of 16 samples exceeding the PEC (128 mg/kg), but only 3 out of 16 exceeded the EPA residential cleanup level (400 mg/kg). Samples collected along the Big River upstream and downstream exceeded the EPA residential cleanup level by a minimum of 220 percent and maximum of 670 percent.

A comparison of the ratios of barium to lead, lead to zinc, and barium to zinc show higher barium to lead and barium to zinc ratios downstream from the Barite District and are greatest in the finer sediment fractions (fig. 15*B*, *D*, and *E*). The lead to zinc ratios were also greater downstream from the Barite District with the greatest ratios in the <0.250-mm fraction (fig. 15*D*). The amplitude increase of the barium to lead and barium to zinc ratios downstream from the Barite District in the Big River for the smaller size fractions (fig. 15*D*, *E*, *F*) may reflect the greater mobility of barium-rich sediment <0.250 mm and the proximity to the source of the barium. Barium to lead and barium to zinc ratios in sediments deposited by the December 2015 flood and streambed sediments in Mineral Fork Creek and Mill Creek tended to increase downstream (fig. 16). Lead to zinc ratios in sediments deposited by the December 2015 flood and streambed sediments in Mineral Fork Creek and Mill Creek remained stable throughout the two streams (fig. 16).

Large increases in barium concentrations and barium to lead and zinc ratios in streambed and flood sediments at Big River sites downstream from the Barite District indicate an influx of barium into the Big River from tributaries in the Barite District. Despite a known influx of Barite District sediments into the Big River, as evidenced by the large increase in barium concentrations in sediment downstream from the Barite District in the Big River, sediments from the Barite District are only a small contributor of lead and zinc to the Big River system, which is evidenced by the smaller lead and zinc concentrations in Barite District sediments (streambed, flood-plain core, and flood) compared to Big River sediments upstream from the Barite District, and smaller lead and zinc concentrations in Big River sediments (streambed and flood) downstream from the Barite District compared to Big River sediments upstream from the Barite District.

Summary and Conclusions

Missouri has been a leading producer of lead in the world for more than 100 years. Ore minerals of lead (mostly galena and lead sulfide), zinc (sphalerite and zinc sulfide), and barium (barite and barium sulfate) are present across southeast Missouri. Some of the most abundant deposits are within the Big River watershed in parts of Washington, Jefferson, and St. Francois Counties, Mo. Lead mining first began in the Big River watershed during the 1700s with shallow diggings in surficial materials that in the early 1800s evolved into shallow shafts less than (<) about 50 feet (ft) deep in the middle part of the watershed. In the 1860s, lead and zinc mining shifted to vast deposits of lead ore that were discovered several hundred feet beneath the surface in what is referred to as the Old Lead Belt in the vicinity of Bonne Terre and Park Hills, Mo. More than 200 years of lead and zinc mining and 100 years of barite mining has left a legacy of mine waste contamination in the Big River watershed. The most obvious traces of past mining activity are large mine waste piles (hundreds of acres in size and often more than 100 ft tall), large tracts of disturbed and partially vegetated land and mill ponds, and metal-rich sediments in local Old Lead Belt streams. Although considerable attention has been given to concentrations of mining-related trace elements (mostly cadmium, lead, and zinc) in the Big River and its tributaries draining the Old Lead Belt, there is less information regarding concentrations of mining-related trace elements in tributaries draining the Barite District and how much they contribute to metal contamination in lower reaches of the Big River.

The purpose of this report is to present results of an investigation of the distribution of mining-related trace elements in sediments in the middle reach of the Big River downstream from the Old Lead Belt and its tributaries that drain a large part of the Barite District. A focus of the study was to contrast mining-related trace-element concentrations in tributaries draining mined areas in the Barite District with trace-element concentrations in the middle reach of the Big River that drains the Old Lead Belt Subdistrict of the Southeast Missouri Lead District, which is about 35 miles upstream from the Barite District. Three general geomorphological features were the focus of sediment collection. Streambed-sediment samples were collected during 2012 at 10 locations along three tributaries draining the Barite District and at 5 locations on the Big River. Core samples of flood-plain deposits were collected in 2013 from 26 cores along two tributaries draining the Barite District (Mineral Fork Creek and Mill Creek) and along a tributary of Mineral Fork Creek upstream from the Barite District (Fourche Renault Creek). Fine sediments deposited by the December 2015 flood event were collected from locations along the Big River flood plain upstream and downstream from the Barite District and along Barite District tributaries.

In general, concentrations of cadmium and lead in streambed sediment were largest in samples from the Big River (average of 5.4 milligrams per kilogram [mg/kg] for cadmium and 1,011 mg/kg for lead) and smallest in samples from the Barite District tributaries (average of 1.1 mg/kg for cadmium and 223 mg/kg for lead). Of the individual 45 streambed-sediment samples sent to the laboratory for analysis, the probable effects concentration (PEC) values were exceeded for cadmium (6 samples), lead (35 samples), and zinc (17 samples). Of the 45 samples, 14 exceeded the U.S. Environmental Protection Agency residential yard cleanup level of 400 mg/kg for lead. Concentrations of zinc were somewhat similar in the Big River (average of 371 mg/kg) and Barite District tributaries (average of 400 mg/kg) but tended to be larger in upstream Big River sites and at single sites on Old Mines Creek and Mineral Fork Creek. Barium concentrations

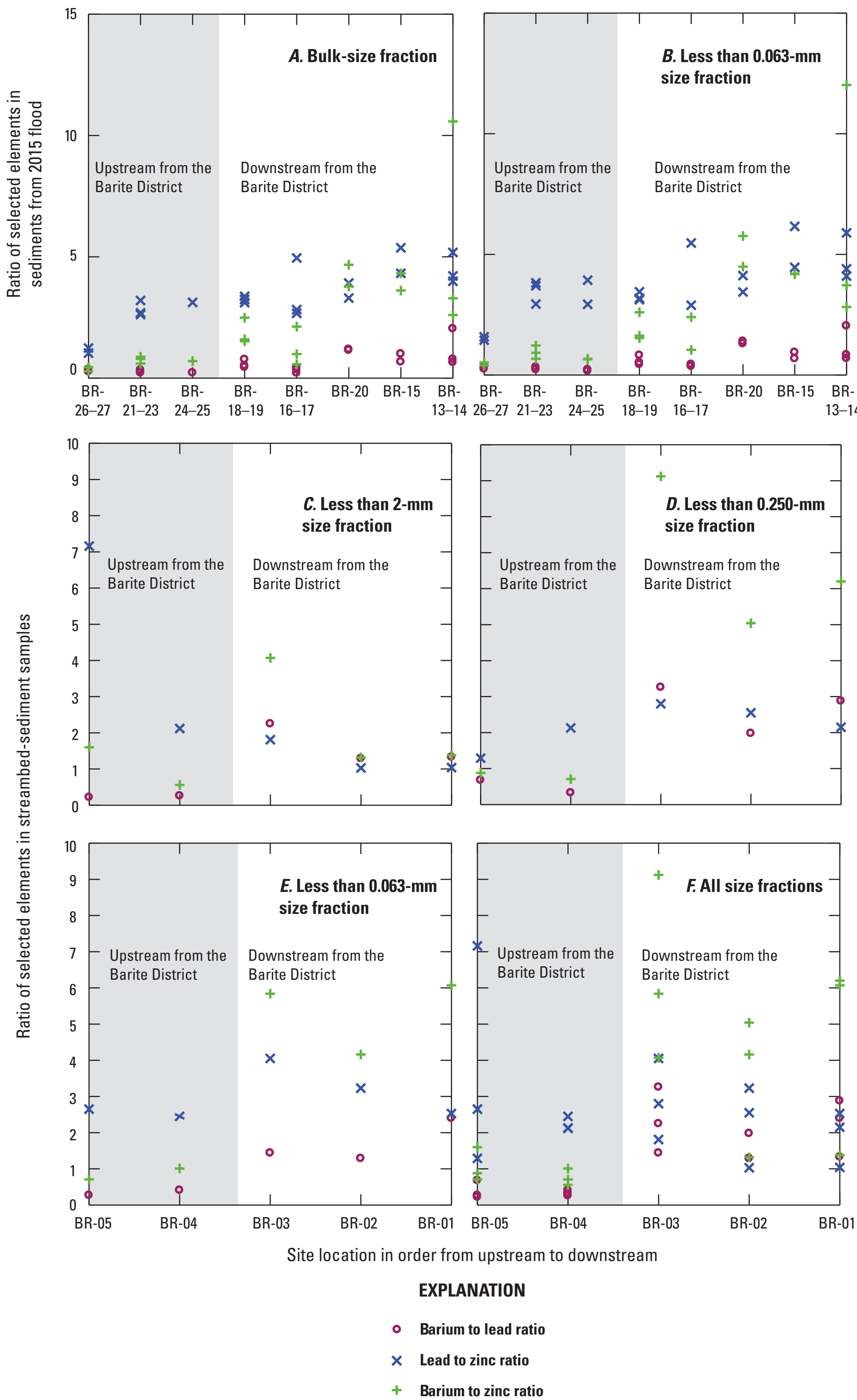


Figure 15. Ratios of selected elements in deposited sediments from *A–B*, the December 2015 flood (table 10) and *C–F*, streambed-sediment samples (table 7). The site order is from upstream to downstream. All native soil samples are included in the charts.

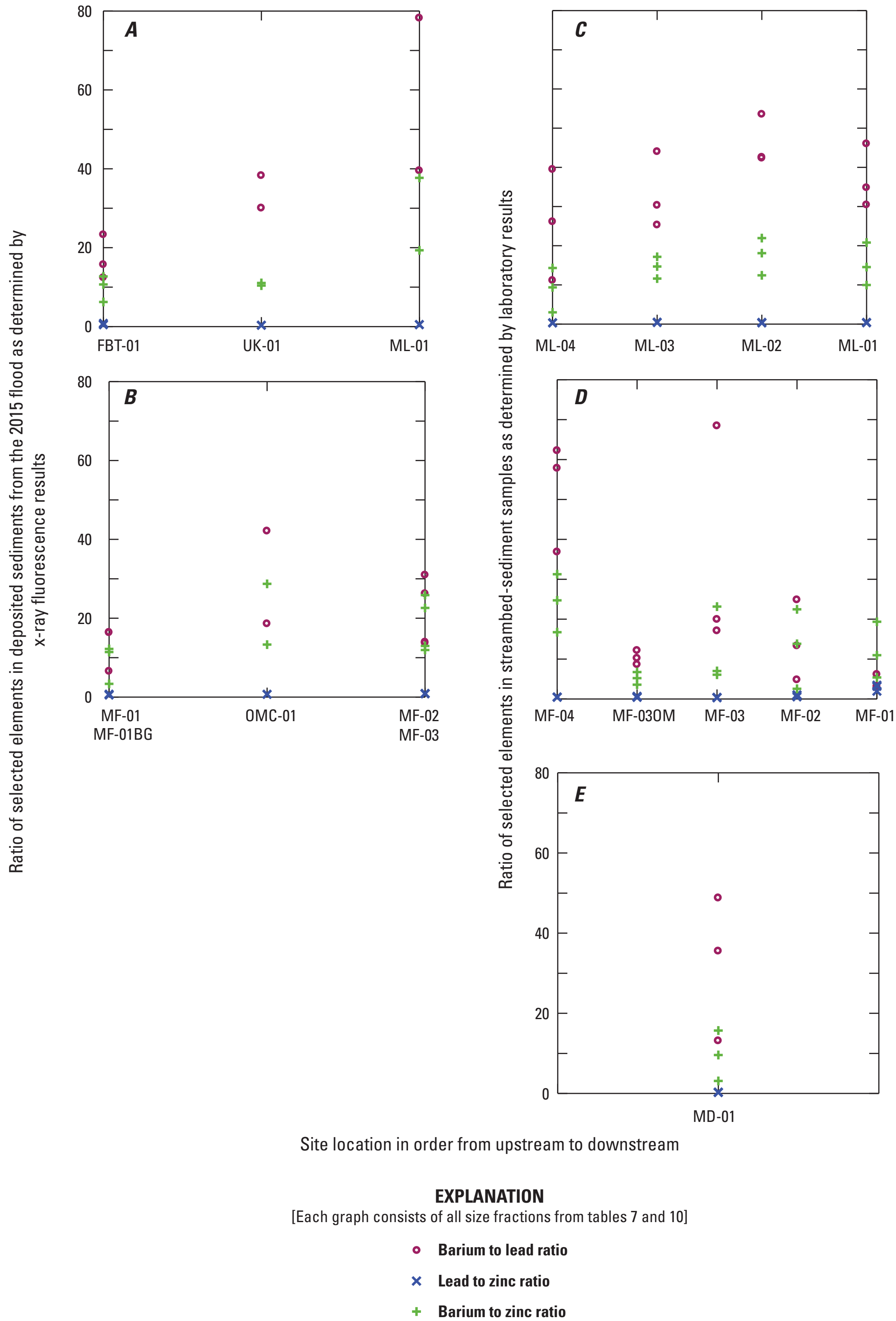


Figure 16. Ratios of selected elements in deposited sediments from *A*–*B*, the December 2015 flood (table 10) and *C*–*E*, streambed-sediment samples (table 7). The site order is from upstream to downstream.

were considerably larger in samples from Barite District tributaries (average of 4,725 mg/kg) compared to the Big River (average of 965 mg/kg). Mass ratios of barium to lead and lead to zinc varied in streambed-sediment samples but indicated an influx metal contamination from the various barite and lead-zinc mining areas. Most noticeable are the large barium to lead ratios in Barite District tributaries (average of 31.8 excluding site MF-01 that is near the Big River) that are nearly 15 to 100 times greater compared to the Big River (average of 2.01 at sites BR-01, BR-02, and BR-03 downstream from the Barite District and average of 0.36 at sites BR-04 and BR-05 upstream from the Barite District).

Flood-plain core samples were collected from 26 cores along 5 transect locations along streams draining the Barite District—one along Fourche Renault Creek in the upper part of the Mineral Fork Creek watershed and upstream from most of the Barite District, two transects along the lower reach of Mineral Fork Creek, and two transects along the lower reach of Mill Creek. Of the individual 693 bulk samples from these cores analyzed by the x-ray fluorescence (XRF), the PEC values were exceeded for cadmium (218 samples), lead (91 samples), nickel (45 samples), and zinc (77 samples). Of the 693 samples, 21 exceeded the U.S. Environmental Protection Agency residential yard cleanup level of 400 mg/kg for lead and 19 of these were samples from a transect on the Mineral Fork Creek near its mouth where its flood plain joins the Big River flood plain. The sediments from this area are likely a mixture of sediments deposited by both Mineral Fork Creek and Big River. Because the XRF reporting level of 12 mg/kg for cadmium is larger than the PEC (4.98 mg/kg), the frequency of cadmium exceeding the PEC is likely underreported.

Scanning bulk core samples provided a rapid determination of metal profiles with depth; however, this can introduce error because trace elements may be irregularly distributed between the various sediment grain-size fractions, causing the XRF beam to disproportionately measure singular large grains. Concentrations of trace elements in the bulk core also do not provide information on metal concentrations for different size fractions, which is important because smaller grain sizes may dissolve more easily in stomachs of animals, making the metal have greater bioavailability to animals. To determine the usability of the XRF data from the bulk core scans and determine if grain size had a measureable effect on reported metal concentrations, 47 samples from five cores were split into four fractions (<0.063 millimeters, 0.063 to 0.250 millimeters, 0.250 to 2 millimeters, and greater than 2 millimeters) that were analyzed by an XRF and compared to the average bulk core XRF scans of these same intervals. Metal concentrations tended to be larger in the smaller size fractions.

Twenty-three flood-deposit sediment samples were collected after the December 2015 flood—15 from the Big River flood plain (7 samples upstream and 8 samples downstream from the Barite District), 7 samples along the flood plains of Barite District tributaries (Mill Creek and Mineral Fork Creek), and 1 sample from the Dry Creek flood plain that represents a Big River tributary in Jefferson County with little known mining within its watershed. Metal concentrations reported by XRF in the 2015 flood-deposit sediments indicated samples collected along the Big River had the largest lead and zinc concentrations, whereas samples collected from Barite District tributaries had the largest barium concentrations. The mean lead concentration in flood samples collected along the Big River was 1,746 mg/kg upstream from the Barite District and 1,858 mg/kg downstream from the Barite District, and the mean lead concentration in flood samples collected in the Barite District tributaries was 235 mg/kg. The mean zinc concentration in flood samples collected along the Big River was 731 mg/kg upstream from the Barite District and 474 mg/kg downstream from the Barite District, and the mean zinc concentration in flood samples collected in the Barite District tributaries was 423 mg/kg. Barium concentrations in flood sediment samples collected along the Big River downstream from the Barite District were larger overall than those in samples collected along the Big River upstream from the Barite District. The mean barium concentration in flood samples collected along the Big River was 438 mg/kg upstream from the Barite District and 1,471 mg/kg downstream from the Barite District, and the mean barium concentration in flood samples collected in the Barite District tributaries was 6,504 mg/kg. The sample from Dry Creek contained the smallest concentrations of barium (<700 mg/kg), lead (<60 mg/kg), and zinc (<140 mg/kg) in the bulk or fine fraction, which was consistent with the minimal mining in its watershed.

Large increases in barium concentrations and barium to lead and zinc ratios in streambed and flood sediments at Big River sites downstream from the Barite District indicate an influx of barium into the Big River from tributaries in the Barite District. Despite a known influx of Barite District sediments into the Big River, as evidenced by the large increase in barium concentrations in sediment downstream from the Barite District in the Big River, sediments from the Barite District are only a small contributor of lead and zinc to the Big River system which is evidenced by the smaller lead and zinc concentrations in Barite District sediments (streambed, flood-plain core, and flood) compared to Big River sediments upstream from the Barite District, and smaller lead and zinc concentrations in Big River sediments (streambed and flood) downstream from the Barite District compared to Big River sediments upstream from the Barite District.

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Tables 6–9

Table 6. Comparison of concentrations of selected trace elements in various size fractions of flood-plain core samples analyzed by the laboratory and U.S. Environmental Protection Agency x-ray fluorescence unit.

[Light gray shaded cells indicate a percent difference greater than 30. Dark gray shaded cells indicate a percent difference less than –30. mg/kg, milligram per kilogram; USGS, U.S. Geological Survey; XRF, x-ray fluorescence; Lab, laboratory; <, less than; --, not determined; na, not applicable]

Sample identifier	USGS site identifier	Grain size group[1]	Sample depth, in feet	Lead, in mg/kg			Barium, in mg/kg			Manganese, in mg/kg		
				XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]
FR-01_0.5-0.75	380161490873801	1	0.5–0.75	53	69.6	−27.9	281	551	−65.0	639	1,040	−47.8
FR-02_12-16	380162190874002	1	12–16	42	70.3	−49.8	206	357	−53.8	588	916	−43.7
FR-03_1-2	380163290874302	1	1–2	52	63.3	−18.8	176	499	−95.6	581	815	−33.4
FR-03_15-16	380163290874312	1	15–16	55	67.1	−20.2	303	510	−50.9	1,001	1,567	−44.1
FR-03_6-7	380163290874307	1	6–7	66	190	−96.4	<100	321	--	374	1,189	−104.4
MFC-A-01_2-3	380950090684901	1	2–3	7,510	7,793.	−3.7	848	929	−9.2	1,565	2,012	−25.0
MFC-B-00_0.75-1	380946490711101	1	0.75–1	250	270.	−7.6	1,793	4,552	−87.0	742	1,114	−40.1
MFC-B-02_10-11	380971190710711	1	10–11	114	57.3	66.0	935	822	12.8	679	1,387	−68.5
MLC-A-01_0.25-0.33	380315990629501	1	0.25–0.33	119	125	−5.2	1,610	4,101	−87.2	396	591	−39.4
MLC-A-02_1-2	380312190629202	1	1–2	436	423	3.1	9,006	4,371	69.3	898	871	3.0
MLC-A-02_12-13	380312190629211	1	12–13	100	101	−0.6	9,698	4,006	83.1	569	436	26.4
MLC-A-03_5-8	380310990629002	1	5–8	95	128	−29.3	778	2,176	−94.6	430	733	−52.0
FR-03_15-16	380163290874312	2	15–16	37	62.7	−52.1	137	318	−79.5	906	1,145	−23.3
MLC-B-05_10-11.4	380136290651710	2	10–11.4	22	34.	−44.3	238	387	−47.6	223	255	−13.2
MLC-B-05_1-2	380136290651702	2	1–2	103	110	−6.7	996	2,600	−89.2	727	861	−16.9
MLC-B-05_5-6	380136290651705	2	5–6	121	125	−3.2	2,670	6,645	−85.3	700	856	−20.0
MLC-A-02_1-2	380312190629202	2	1–2	396	390	1.6	12,908	4,405	98.2	901	779	14.5
MLC-A-02_6.6-7	380312190629206	2	6.6–7	93	108	−14.5	1,147	3,089	−91.7	760	1,122	−38.5
MLC-A-05_0-1	380308790628701	2	0–1	319	314	1.6	5,033	6,107	−19.3	949	990	−4.3
MLC-A-05_3-4	380308790628704	2	3–4	269	165	47.9	875	7,111	−156.2	972	830	15.7
FR-01_0.5-0.75	380161490873801	3	0.5–0.75	60	67.8	−12.6	139	430	−102.0	815	1,058	−25.9
FR-02_12-16	380162190874002	3	12–16	<13	26.2	--	114	111	2.8	184	320	−54.2
FR-03_6-7	380163290874307	3	6–7	<13	59.2	--	107	108	−1.4	138	332	−82.7
MFC-A-01_2-3	380950090684901	3	2–3	6,835	7,793	−13.1	709	993	−33.4	1,564	2,091	−28.8
MFC-B-00_0.75-1	380946490711101	3	0.75–1	163	192	−16.6	1,661	5,004	−100.3	524	693	−27.8
MFC-B-02_10-11	380971190710711	3	10–11	47	79.6	−51.7	494	826	−50.4	375	2,091	−139.2
MLC-A-02_12-13	380312190629211	3	12–13	52	69.	−27.6	4,797	6,482	−29.9	240	209	13.8
MLC-A-03_5-8	380310990629002	3	5–8	21	59.9	−94.6	296	790	−90.9	288	239	18.6
FR-03_1-2	380163290874302	4	1–2	26	39.9	−42.3	366	197	60.1	497	458	8.2
MLC-A-02_6.6-7	380312190629206	4	6.6–7	59	76.6	−25.3	845	1,488	−55.1	466	594	−24.3

Table 6. Comparison of concentrations of selected trace elements in various size fractions of flood-plain core samples analyzed by the laboratory and U.S. Environmental Protection Agency x-ray fluorescence unit.—Continued

[Light gray shaded cells indicate a percent difference greater than 30. Dark gray shaded cells indicate a percent difference less than –30. mg/kg, milligram per kilogram; USGS, U.S. Geological Survey; XRF, x-ray fluorescence; Lab, laboratory; <, less than; --, not determined; na, not applicable]

Sample identifier	USGS site identifier	Grain size group[1]	Sample depth, in feet	Lead, in mg/kg			Barium, in mg/kg			Manganese, in mg/kg		
				XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]
Summary												
na	Number of results where XRF is greater than laboratory result		na	na	na	5	na	na	6	na	na	7
na	Number of results where XRF is less than laboratory result		na	na	na	23	na	na	23	na	na	23
na	Overall average	na	na	585	638	−19	1,976	2,343	−43	656	920	−30
na	Group 1 average	na	na	741	780	−16	2,144	1,933	−34	705	1,056	−39
na	Group 2 average	na	na	170	164	−9	3,001	3,833	−59	767	855	−11
na	Group 3 average	na	na	901	1,043	−36	1,039	1,843	−51	516	879	−41
na	Group 4 average	na	na	43	58	−34	606	843	2	481	526	−8

Table 6. Comparison of concentrations of selected trace elements in various size fractions of flood-plain core samples analyzed by the laboratory and U.S. Environmental Protection Agency x-ray fluorescence unit.—Continued

[Light gray shaded cells indicate a percent difference greater than 30. Dark gray shaded cells indicate a percent difference less than –30. mg/kg, milligram per kilogram; USGS, U.S. Geological Survey; XRF, x-ray fluorescence; Lab, laboratory; <, less than; --, not determined; na, not applicable]

Sample identifier	USGS site identifier	Grain size group[1]	Sample depth, in feet	Nickel, in mg/kg			Zinc, in mg/kg			Cadmium, in mg/kg		
				XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]
FR-01_0.5-0.75	380161490873801	1	0.5–0.75	<65	16.7	--	78	108	−32.3	27	0.4	194.2
FR-02_12-16	380162190874002	1	12–16	<65	28.3	--	89	122	−31.5	25	0.3	195.3
FR-03_1-2	380163290874302	1	1–2	<65	21.6	--	100	105	−4.5	<12	0.1	--
FR-03_15-16	380163290874312	1	15–16	<65	32.9	--	79	115	−36.6	17	0.5	188.6
FR-03_6-7	380163290874307	1	6–7	<65	44.7	--	82	130	−45.0	13	0.2	193.7
MFC-A-01_2-3	380950090684901	1	2–3	<65	34.2	--	887	768	14.4	34	12.7	91.5
MFC-B-00_0.75-1	380946490711101	1	0.75–1	69	19	114.1	292	308	−5.3	16	0.9	178.4
MFC-B-02_10-11	380971190710711	1	10-11	<65	26.5	--	355	255	32.7	25	1.0	184.8
MLC-A-01_0.25-0.33	380315990629501	1	0.25–0.33	<65	14.7	--	234	252	−7.4	17	0.4	190.6
MLC-A-02_1-2	380312190629202	1	1–2	<65	30.7	--	818	862	−5.3	<12	0.7	--
MLC-A-02_12-13	380312190629211	1	12–13	72	22.4	104.7	311	301	3.1	<12	0.6	--
MLC-A-03_5-8	380310990629002	1	5–8	<65	33.4	--	330	458	−32.4	29	0.9	187.8
FR-03_15-16	380163290874312	2	15–16	69	17.3	119.4	78	88	−11.5	15	0.4	189.4
MLC-B-05_10-11.4	380136290651710	2	10–11.4	72	5.2	173.2	141	116	19.2	<12	0.5	--
MLC-B-05_1-2	380136290651702	2	1–2	<65	19.1	--	298	328	−9.6	<12	0.3	--
MLC-B-05_5-6	380136290651705	2	5–6	70	22.8	101.7	294	311	−5.5	<12	0.8	--
MLC-A-02_1-2	380312190629202	2	1–2	85	26.2	105.7	730	764	−4.6	<12	0.7	--
MLC-A-02_6.6-7	380312190629206	2	6.6–7	<65	19.2	--	504	550	−8.7	<12	1.5	--
MLC-A-05_0-1	380308790628701	2	0–1	<65	25.7	--	618	648	−4.8	<12	1.0	--
MLC-A-05_3-4	380308790628704	2	3–4	<65	13.8	--	610	304	67.0	<12	0.7	--
FR-01_0.5-0.75	380161490873801	3	0.5–0.75	<65	14.4	--	93	92	1.1	<12	0.4	--
FR-02_12-16	380162190874002	3	12–16	<65	7.4	--	26	36	−33.8	<12	0.1	--
FR-03_6-7	380163290874307	3	6–7	<65	6.2	--	38	39	−1.7	12	0.1	196.7
MFC-A-01_2-3	380950090684901	3	2–3	<65	36	--	1,017	824	21.0	14	12.7	9.2
MFC-B-00_0.75-1	380946490711101	3	0.75–1	75	12.8	141.6	222	224	−0.9	<12	0.6	--
MFC-B-02_10-11	380971190710711	3	10–11	<65	27.7	--	214	268	−22.5	<12	1.1	--
MLC-A-02_12-13	380312190629211	3	12–13	<65	10.8	--	182	238	−26.5	<12	0.3	--
MLC-A-03_5-8	380310990629002	3	5–8	68	8.3	156.3	159	237	−39.4	<12	0.3	--
FR-03_1-2	380163290874302	4	1–2	<65	11.4	--	58	52	11.5	<12	0.1	--
MLC-A-02_6.6-7	380312190629206	4	6.6–7	<65	13.2	--	359	385	−7.0	14	0.9	175.5

Table 6. Comparison of concentrations of selected trace elements in various size fractions of flood-plain core samples analyzed by the laboratory and U.S. Environmental Protection Agency x-ray fluorescence unit.—Continued

[Light gray shaded cells indicate a percent difference greater than 30. Dark gray shaded cells indicate a percent difference less than –30. mg/kg, milligram per kilogram; USGS, U.S. Geological Survey; XRF, x-ray fluorescence; Lab, laboratory; <, less than; --, not determined; na, not applicable]

Sample identifier	USGS site identifier	Grain size group[1]	Sample depth, in feet	Nickel, in mg/kg			Zinc, in mg/kg			Cadmium, in mg/kg		
				XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]
Summary												
na	Number of results where XRF is greater than laboratory result		na	na	na	8	na	na	8	na	na	13
na	Number of results where XRF is less than laboratory result		na	na	na	0	na	na	22	na	na	0
na	Overall average	na	na	67	21	127	310	310	−7	15	1	167
na	Group 1 average	na	na	66	27	109	305	315	−12	20	2	178
na	Group 2 average	na	na	69	19	125	409	389	5	12	1	189
na	Group 3 average	na	na	67	15	149	244	245	−13	12	2	103
na	Group 4 average	na	na	<65	12	--	209	219	2	13	1	176

Table 6. Comparison of concentrations of selected trace elements in various size fractions of flood-plain core samples analyzed by the laboratory and U.S. Environmental Protection Agency x-ray fluorescence unit.—Continued

[Light gray shaded cells indicate a percent difference greater than 30. Dark gray shaded cells indicate a percent difference less than –30. mg/kg, milligram per kilogram; USGS, U.S. Geological Survey; XRF, x-ray fluorescence; Lab, laboratory; <, less than; --, not determined; na, not applicable]

Sample identifier	USGS site identifier	Grain size group[1]	Sample depth, in feet	Colbalt, in mg/kg			Copper, in mg/kg			Arsenic, in mg/kg		
				XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]
FR-01_0.5-0.75	380161490873801	1	0.5–0.75	<260	10.1	--	42	18.4	78.8	<11	6	--
FR-02_12-16	380162190874002	1	12–16	<260	13.2	--	36	31.3	14.5	<11	14	--
FR-03_1-2	380163290874302	1	1–2	<260	10.2	--	42	17.2	84.4	<11	7	--
FR-03_15-16	380163290874312	1	15–16	<260	13.3	--	<35	16.3	--	<11	12	--
FR-03_6-7	380163290874307	1	6–7	<260	13.1	--	<35	14.4	--	<11	14	--
MFC-A-01_2-3	380950090684901	1	2–3	<260	28.1	--	160	165	−3.3	<11	8	--
MFC-B-00_0.75-1	380946490711101	1	0.75–1	<260	12.	--	41	22.8	56.0	<11	9	--
MFC-B-02_10-11	380971190710711	1	10-11	<260	10.4	--	<35	16.5	--	18	9	65.9
MLC-A-01_0.25-0.33	380315990629501	1	0.25–0.33	<260	8	--	46	17.7	88.1	<11	9	--
MLC-A-02_1-2	380312190629202	1	1–2	<260	14.4	--	45	34.4	25.8	<11	27	--
MLC-A-02_12-13	380312190629211	1	12–13	<260	9.3	--	47	25.9	58.5	<11	7	--
MLC-A-03_5-8	380310990629002	1	5–8	<260	11.5	--	48	42.7	11.8	<11	10	--
FR-03_15-16	380163290874312	2	15–16	<260	9.5	--	<35	13	--	<11	10	--
MLC-B-05_10-11.4	380136290651710	2	10–11.4	<260	2.4	--	<35	7.4	--	<11	4	--
MLC-B-05_1-2	380136290651702	2	1–2	<260	13	--	38	13.9	92.3	<11	12	--
MLC-B-05_5-6	380136290651705	2	5–6	<260	13.3	--	<35	16.3	--	16	12	26.6
MLC-A-02_1-2	380312190629202	2	1–2	<260	13	--	57	29.6	63.2	<11	24	--
MLC-A-02_6.6-7	380312190629206	2	6.6–7	<260	10.1	--	40	15.9	85.5	<11	9	--
MLC-A-05_0-1	380308790628701	2	0–1	<260	12.7	--	55	27.1	68.6	<11	18	--
MLC-A-05_3-4	380308790628704	2	3–4	<260	9.3	--	42	12.5	108.6	<11	9	--
FR-01_0.5-0.75	380161490873801	3	0.5–0.75	<260	9.3	--	<35	14.9	--	<11	5	--
FR-02_12-16	380162190874002	3	12–16	<260	4.2	--	<35	6.1	--	11	6	59.9
FR-03_6-7	380163290874307	3	6–7	<260	4.4	--	<35	3.9	--	<11	6	--
MFC-A-01_2-3	380950090684901	3	2–3	<260	33.6	--	156	163	−4.5	<11	9	--
MFC-B-00_0.75-1	380946490711101	3	0.75–1	<260	7.9	--	39	15.7	85.5	<11	7	--
MFC-B-02_10-11	380971190710711	3	10–11	<260	14	--	<35	17.1	--	<11	11	--
MLC-A-02_12-13	380312190629211	3	12–13	<260	5	--	<35	13.1	--	<11	8	--
MLC-A-03_5-8	380310990629002	3	5–8	<260	5	--	<35	7.4	--	<11	6	--
FR-03_1-2	380163290874302	4	1–2	<260	7.6	--	<35	7.3	--	13	7	62.1
MLC-A-02_6.6-7	380312190629206	4	6.6–7	<260	7.3	--	<35	10	--	<11	7	--

Table 6. Comparison of concentrations of selected trace elements in various size fractions of flood-plain core samples analyzed by the laboratory and U.S. Environmental Protection Agency x-ray fluorescence unit.—Continued

[Light gray shaded cells indicate a percent difference greater than 30. Dark gray shaded cells indicate a percent difference less than –30. mg/kg, milligram per kilogram; USGS, U.S. Geological Survey; XRF, x-ray fluorescence; Lab, laboratory; <, less than; --, not determined; na, not applicable]

Sample identifier	USGS site identifier	Grain size group[1]	Sample depth, in feet	Colbalt, in mg/kg			Copper, in mg/kg			Arsenic, in mg/kg		
				XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]	XRF	Lab	Percent difference[2]
Summary												
Number of results where XRF is greater than laboratory result				na	na	0	na	na	14	na	na	4
Number of results where XRF is less than laboratory result				na	na	0	na	na	2	na	na	0
Overall average				260	11	--	47	27	57	11	10	54
Group 1 average				260	13	--	51	35	46	12	11	66
Group 2 average				260	10	--	42	17	84	12	12	27
Group 3 average				260	10	--	51	30	40	11	7	60
Group 4 average				260	7	--	35	9	--	12	7	62

[a]Grain size groups defined in order of increasing grain size: 1, less than 0.063 millimeters (mm); 2, 0.063—0.250 mm; 3, 0.250—2 mm; 4, greater than 2 mm.

Table 7. Concentrations of major and trace constituents determined by laboratory analysis of various size fractions of streambed-sediment collected from the middle Big River and tributaries draining the Barite District, Missouri, 2012.

[Dark gray shaded cells indicate values that exceeded the PEC for constituents. Bold font indicates values that exceeded the U.S. Environmental Protection Agency residential yard cleanup level. mm, millimeter, w%, percent by weight; --, no data; mg/kg, milligram per kilogram; PEC, consensus-based probable effects concentration, in parentheses (MacDonald and others, 2000); Ba, barium; Pb, lead; Zn, zinc; NA, not applicable; <, less than]

Site number	Size fraction (mm)	Aluminum (w%) --	Calcium (w%) --	Iron (w%) --	Potassium (w%) --	Magnesium (w%) --	Sodium (w%) --	Sulfur (w%) --	Titanium (w%) --	Barium (mg/kg) --	Cadmium (mg/kg) PEC (4.98)	Lead (mg/kg) PEC (128)	Zinc (mg/kg) PEC (459)	Antimony (mg/kg) --	Arsenic (mg/kg) PEC (33)
BR-01	<0.063	2.92	2.47	1.32	2.01	0.9	0.42	0.03	0.21	1,360	2.4	**567**	224	0.46	5
	<0.250	0.8	0.41	0.38	0.7	0.19	0.03	<0.01	0.03	403	0.7	140	65	0.06	2
	<2	0.46	0.19	1.36	0.21	0.06	0.02	<0.01	0.01	191	0.6	144	138	0.18	6
BR-02	<0.063	3.1	3.24	1.56	1.68	1.27	0.4	0.03	0.22	2,090	6.8	**1,620**	502	0.48	5
	<0.250	1.71	2.25	1.14	1.17	0.96	0.15	0.02	0.1	1,800	3.8	**910**	357	0.27	3
	<2	0.48	0.25	1.21	0.26	0.09	0.02	0.01	0.02	338	0.9	263	256	0.22	6
BR-03	<0.063	3.23	3.5	1.83	1.73	1.3	0.38	0.06	0.23	2,700	6.9	**1,870**	462	0.57	7
	<0.250	1.08	1.92	0.99	0.84	0.88	0.06	0.04	0.06	2,080	2.1	**638**	228	0.21	4
	<2	0.55	0.49	1.37	0.36	0.21	0.03	0.01	0.02	671	0.8	298	165	0.27	6
BR-04	<0.063	3.27	5.65	1.74	1.51	1.87	0.35	0.05	0.21	804	14.7	**1,960**	799	0.51	5
	<0.250	1.94	6.37	1.73	1.64	2.97	0.11	<0.01	0.09	379	10.	**1,140**	534	0.34	4
	<2	0.76	5.98	1.91	0.75	2.97	0.04	<0.01	0.03	155	03.2	**586**	276	0.27	7
BR-05	<0.063	2.8	6.53	1.6	2.3	2.16	0.3	0.05	0.17	503	13.9	**1,880**	709	0.41	4
	<0.250	0.92	6.86	1.72	0.92	3.43	0.03	<0.01	0.04	440	9.1	**649**	502	0.18	3
	<2	0.76	7.99	2.01	0.78	4.14	0.04	0.02	0.03	557	4.4	**2,500**	349	0.25	6
MD-01	<0.063	4.33	1.31	4.1	0.9	0.8	0.12	0.12	0.16	2,560	1	195	818	1.6	20
	<0.250	2.12	4.55	3.	0.32	2.68	0.03	0.09	0.06	5,720	0.7	161	597	1.25	15
	<2	1.26	2.75	2.7	0.21	1.49	0.03	0.09	0.04	8,490	0.7	174	541	0.97	13
MF-01	<0.063	3.5	2.73	1.72	1.55	0.9	0.42	0.05	0.26	3,080	2.6	**972**	281	0.64	6
	<0.250	2.24	2.09	1.33	1.31	0.83	0.19	0.08	0.15	4,200	1.8	**683**	217	0.44	4
	<2	0.9	0.57	1.36	0.49	0.24	0.06	0.01	0.06	860	0.8	310	160	0.34	6
MF-02	<0.063	3.31	2.46	1.39	1.77	0.43	0.42	0.07	0.25	3,290	1.1	247	238	0.58	5
	<0.250	2.04	1.54	1.11	1.08	0.44	0.18	0.09	0.14	4,200	0.8	169	187	0.42	5
	<2	0.61	0.24	1.38	0.18	0.08	0.03	<0.01	0.03	365	0.3	75.9	143	0.4	8
MF-03	<0.063	4.32	1.83	1.84	1.94	0.44	0.54	0.03	0.28	1,750	0.9	87.7	288	0.57	7
	<0.250	2.49	1.48	1.4	1.05	0.55	0.2	0.11	0.15	5,160	0.7	75.4	223	0.49	5
	<2	0.99	0.44	1.44	0.35	0.19	0.07	0.02	0.05	1,150	0.4	67.3	164	0.36	7

Table 7. Concentrations of major and trace constituents determined by laboratory analysis of various size fractions of streambed-sediment collected from the middle Big River and tributaries draining the Barite District, Missouri, 2012.—Continued

[Dark gray shaded cells indicate values that exceeded the PEC for constituents. Bold font indicates values that exceeded the U.S. Environmental Protection Agency residential yard cleanup level. mm, millimeter, w%, percent by weight; --, no data; mg/kg, milligram per kilogram; PEC, consensus-based probable effects concentration, in parentheses (MacDonald and others, 2000); Ba, barium; Pb, lead; Zn, zinc; NA, not applicable; <, less than]

Site number	Size fraction (mm)	Aluminum (w%) --	Calcium (w%) --	Iron (w%) --	Potassium (w%) --	Magnesium (w%) --	Sodium (w%) --	Sulfur (w%) --	Titanium (w%) --	Barium (mg/kg) --	Cadmium (mg/kg) PEC (4.98)	Lead (mg/kg) PEC (128)	Zinc (mg/kg) PEC (459)	Antimony (mg/kg) --	Arsenic (mg/kg) PEC (33)
MF-04	<0.063	2.03	11.9	0.94	1.04	0.73	0.26	0.16	0.16	6,130	1.4	106	248	0.39	3
	<0.250	0.79	2.03	0.55	0.19	0.61	0.03	0.02	0.03	1,640	0.4	44.5	98	<0.05	3
	<2	0.46	0.3	1.78	0.09	0.14	0.02	0.1	0.02	6,970	0.3	112	223	0.32	10
MF-03OM	<0.063	1.36	23.5	1.29	0.56	1.14	0.11	0.12	0.08	3,950	3.2	325	756	0.64	5
	<0.250	0.79	16.6	1.31	0.21	2.1	0.04	0.24	0.04	3,920	2.4	384	581	0.57	6
	<2	0.35	1.72	4.68	0.05	0.76	0.01	0.3	0.01	3,690	2.4	**428**	1,030	1.4	27
ML-01	<0.063	3.13	2.46	1.91	1.13	0.62	0.33	0.18	0.2	6,720	1	193	462	0.74	10
	<0.250	2.13	2.59	1.91	0.56	1.04	0.13	0.22	0.11	9,110	1	198	438	0.72	9
	<2	0.66	0.51	1.37	0.13	0.22	0.03	0.06	0.03	2,550	0.4	83.8	256	0.39	7
ML-02	<0.063	3.4	2.15	2.13	1.24	0.6	0.35	0.2	0.23	7,750	0.9	183	428	0.83	11
	<0.250	2.56	2.79	2.14	0.71	1.13	0.17	0.21	0.15	9,370	0.9	175	427	0.75	10
	<2	0.78	0.63	1.6	0.17	0.26	0.04	0.08	0.04	3,670	0.4	86.2	295	0.49	8
ML-03	<0.063	2.18	11.4	1.7	0.75	1.36	0.2	0.21	0.14	8,230	1.4	187	479	0.69	8
	<0.250	1.49	8.82	1.74	0.37	2.15	0.09	0.19	0.08	6,700	1.2	221	456	0.75	9
	<2	0.37	0.39	5.79	0.04	0.14	<0.01	0.22	0.01	7,260	0.7	287	626	1.5	19
ML-04	<0.063	3.2	6.52	1.73	0.91	0.86	0.24	0.18	0.17	4,810	1.5	184	514	0.8	11
	<0.250	2.74	5.3	2.15	0.63	1.13	0.14	0.23	0.13	7,620	1.4	193	532	0.79	11
	<2	0.48	0.31	1.65	0.06	0.09	0.01	0.03	0.02	848	0.3	76.1	282	0.45	9
Cases above the instrument limit of detection		45	45	45	45	45	44	39	45	45	45	45	45	44	45
Maximum		4.33	23.5	5.79	2.3	4.14	0.54	0.3	0.28	9,370	14.7	**2,500**	1,030	1.6	27
Minimum		0.35	0.19	.38	0.04	0.06	0.01	0.01	0.01	155	0.3	44.5	65	0.06	2
Mean		1.82	3.91	1.8	0.82	1.06	0.16	0.1	0.11	3,472	2.52	**486**	390	0.57	7.78

Table 7. Concentrations of major and trace constituents determined by laboratory analysis of various size fractions of streambed-sediment collected from the middle Big River and tributaries draining the Barite District, Missouri, 2012.—Continued

[Dark gray shaded cells indicate values that exceeded the PEC for constituents. Bold font indicates values that exceeded the U.S. Environmental Protection Agency residential yard cleanup level. mm, millimeter, w%, percent by weight; --, no data; mg/kg, milligram per kilogram; PEC, consensus-based probable effects concentration, in parentheses (MacDonald and others, 2000); Ba, barium; Pb, lead; Zn, zinc; NA, not applicable; <, less than]

Site number	Size fraction (mm)	Beryllium (mg/kg) --	Bismuth (mg/kg) --	Cerium (mg/kg) --	Cobalt (mg/kg) --	Chromium (mg/kg) --	Cesium (mg/kg) --	Copper (mg/kg) PEC (149)	Gallium (mg/kg) --	Indium (mg/kg) --	Lanthanum (mg/kg) --	Lithium (mg/kg) --	Manganese (mg/kg) --	Molybdenum (mg/kg) --	Niobium (mg/kg) --
BR-01	<0.063	0.8	0.12	52.2	15.5	45	<5	19.7	6.54	0.05	25.5	12	4,300	0.81	7
	<0.250	0.2	<0.04	9.41	4	5	<5	7.7	1.82	<0.02	4.9	4	645	0.32	1.3
	<2	0.4	<0.04	11.5	6.5	9	<5	5.4	1.77	<0.02	5.9	4	341	0.54	0.8
BR-02	<0.063	1	0.12	57.5	22.2	44	<5	41.5	7.09	0.12	27.4	13	3,740	0.72	7.7
	<0.250	0.6	0.08	29.9	13.5	20	<5	19.5	4.06	0.08	14.2	8	2,090	0.54	3.7
	<2	0.3	0.05	9.64	6.6	11	<5	9.2	1.95	<0.02	5.2	4	330	0.6	1
BR-03	<0.063	1.2	0.16	59.2	27.4	35	<5	41.4	7.46	0.13	28.3	15	5,370	0.94	8.7
	<0.250	0.5	0.05	18.4	10.8	9	<5	13.5	2.71	0.06	8.9	6	1,620	0.52	2.4
	<2	0.4	0.04	9.45	7.5	11	<5	13.1	1.94	<0.02	5.1	5	531	0.73	1.1
BR-04	<0.063	1.2	0.13	51.9	31.9	34	<5	69.6	6.83	0.2	23.3	13	4,180	0.76	7.5
	<0.250	1.1	0.08	34.2	21.2	16	<5	34.6	4.13	0.23	15.7	8	3,300	0.65	3.7
	<2	0.9	0.06	18	13	12	<5	16.8	2.14	0.2	7.4	4	2,410	0.79	1.5
BR-05	<0.063	1	0.1	43.9	28.1	38	<5	88	5.97	0.23	20.4	9	2,390	0.79	6.1
	<0.250	0.8	0.05	19.3	10.9	10	<5	51.9	2.4	0.27	7.9	4	1,950	0.55	1.8
	<2	1.1	0.07	22.9	14.6	8	<5	9.1	2.13	0.24	8.3	4	2,820	0.91	1.4
MD-01	<0.063	1.5	0.21	42.4	11.5	45	<5	38.2	10.3	0.04	19.5	24	1,000	1.52	5.9
	<0.250	0.8	0.13	29	7.9	30	<5	25.8	5.56	0.02	10.8	13	1,140	1.43	2.7
	<2	0.6	0.09	17.3	6.3	28	<5	23.2	3.75	<0.02	6.5	8	662	1.17	1.7
MF-01	<0.063	1.2	0.13	57.8	13.8	36	<5	32.2	7.62	0.09	28.6	17	1,510	0.82	9.4
	<0.250	0.9	0.1	34.5	10.4	21	<5	28	5.2	0.07	17.3	12	1,120	0.64	5.6
	<2	0.5	0.07	14.7	6.7	12	<5	13.4	2.73	0.02	8	7	465	0.71	2.2
MF-02	<0.063	1	0.13	56.1	10.6	37	<5	21.4	7.47	0.03	28.9	17	1,550	0.89	9
	<0.250	0.7	0.1	32.6	7.4	16	<5	14.6	4.55	0.02	16.5	12	925	0.66	4.9
	<2	0.5	0.06	9.62	5.1	11	<5	9.5	2.17	<0.02	5.4	6	362	0.84	1.4
MF-03	<0.063	1.1	0.16	61.1	12.5	36	<5	15.2	9.74	0.03	31.5	22	950	0.82	9.6
	<0.250	0.9	0.13	32.6	8.5	20	<5	12.2	5.97	0.02	16.6	15	763	0.73	5.4
	<2	0.5	0.09	14	5.9	13	<5	7.6	2.92	<0.02	7.4	8	365	0.76	2.2

Table 7. Concentrations of major and trace constituents determined by laboratory analysis of various size fractions of streambed-sediment collected from the middle Big River and tributaries draining the Barite District, Missouri, 2012.—Continued

[Dark gray shaded cells indicate values that exceeded the PEC for constituents. Bold font indicates values that exceeded the U.S. Environmental Protection Agency residential yard cleanup level. mm, millimeter, w%, percent by weight; --, no data; mg/kg, milligram per kilogram; PEC, consensus-based probable effects concentration, in parentheses (MacDonald and others, 2000); Ba, barium; Pb, lead; Zn, zinc; NA, not applicable; <, less than]

Site number	Size fraction (mm)	Beryllium (mg/kg) --	Bismuth (mg/kg) --	Cerium (mg/kg) --	Cobalt (mg/kg) --	Chromium (mg/kg) --	Cesium (mg/kg) --	Copper (mg/kg) PEC (149)	Gallium (mg/kg) --	Indium (mg/kg) --	Lanthanum (mg/kg) --	Lithium (mg/kg) --	Manganese (mg/kg) --	Molybdenum (mg/kg) --	Niobium (mg/kg) --
MF-04	<0.063	0.6	0.12	43.8	9.5	28	<5	17.1	4.47	<0.02	23.4	11	2,670	0.78	4.3
	<0.250	0.3	0.05	7.95	3.5	5	<5	8.2	2.17	<0.02	4.6	6	517	0.46	1.3
	<2	0.5	0.06	5.71	5.1	15	<5	17	2.01	<0.02	4.1	4	297	0.96	1.1
MF-03OM	<0.063	0.5	0.07	30.6	8.6	22	<5	19.1	3.2	<0.02	15.2	6	1,310	0.79	3.3
	<0.250	0.4	0.06	15.3	5.5	17	<5	15.3	2.23	<0.02	7.8	5	873	1	1.7
	<2	0.5	0.07	7.22	6.3	27	<5	44.9	2.11	<0.02	6.5	4	211	2.53	0.8
ML-01	<0.063	1	0.16	52.2	10.1	50	<5	24.5	7.59	0.03	25.6	16	1,080	0.84	6.1
	<0.250	0.8	0.14	33.2	9	37	<5	24.3	5.72	0.02	16.5	13	834	1	4.5
	<2	0.4	0.12	11.1	5.5	20	<5	9.5	2.37	<0.02	5.5	5	229	0.84	1.4
ML-02	<0.063	1.2	0.16	58.5	11	48	<5	19.5	8.55	0.03	28.7	18	1,030	0.99	7.6
	<0.250	0.8	0.13	40.4	9.2	39	<5	21.8	6.38	0.03	19.5	14	1,090	1	5
	<2	0.4	0.07	12.2	4.7	23	<5	9.9	2.5	<0.02	5.9	6	309	0.85	1.8
ML-03	<0.063	0.7	0.11	40.5	9.2	46	<5	19.5	5.35	0.02	20.3	11	2,930	1.06	5.4
	<0.250	0.6	0.1	25.2	7.5	36	<5	15.9	4.09	<0.02	12.2	8	1,850	1.04	3.3
	<2	0.5	0.08	7.4	5.6	53	<5	16.7	2.5	<0.02	4.2	3	339	1.88	0.9
ML-04	<0.063	1	0.15	48	9.7	42	<5	25.3	7.71	0.03	23.2	17	831	0.99	6.3
	<0.250	1	0.15	39.2	9.6	38	<5	23.8	6.93	0.03	18.9	16	707	1.02	5.6
	<2	0.4	0.07	6.92	4.3	28	<5	13.8	2.16	<0.02	3.5	4	144	1.01	1
Cases above the instrument limit of detection		45	43	45	45	45	--	45	45	27	45	45	45	45	45
Maximum		1.5	0.21	61.1	31.9	53	--	88	10.3	0.27	31.5	24	5,370	2.53	9.6
Minimum		0.2	0.04	5.71	3.5	5	--	5.4	1.77	0.02	3.5	3	144	0.32	0.8
Mean		0.74	0.1	29.7	10.5	26	--	22.9	4.55	0.09	14.5	9.8	1,424	0.89	3.94

Table 7. Concentrations of major and trace constituents determined by laboratory analysis of various size fractions of streambed-sediment collected from the middle Big River and tributaries draining the Barite District, Missouri, 2012.—Continued

[Dark gray shaded cells indicate values that exceeded the PEC for constituents. Bold font indicates values that exceeded the U.S. Environmental Protection Agency residential yard cleanup level. mm, millimeter, w%, percent by weight; --, no data; mg/kg, milligram per kilogram; PEC, consensus-based probable effects concentration, in parentheses (MacDonald and others, 2000); Ba, barium; Pb, lead; Zn, zinc; NA, not applicable; <, less than]

Site number	Size fraction (mm)	Nickel (mg/kg) PEC (48.6)	Phosphorus (mg/kg) --	Rubidium (mg/kg) --	Scandium (mg/kg) --	Silver (mg/kg) --	Tin (mg/kg) --	Strontium (mg/kg) --	Tellurium (mg/kg) --	Thorium (mg/kg) --	Thallium (mg/kg) --	Tungsten (mg/kg) --	Uranium (mg/kg) --	Vanadium (mg/kg) --	Yttrium (mg/kg) --
BR-01	<0.063	25.7	330	41.6	3.8	<1	1.6	87.9	<0.1	7.9	0.3	0.7	2.3	30	15.9
	<0.250	5.7	100	12.3	0.8	<1	0.4	25.5	<0.1	1.7	<0.1	0.1	0.6	8	4.5
	<2	8.2	210	5.2	0.6	<1	0.2	27	<0.1	1.3	<0.1	0.2	1.1	23	4.5
BR-02	<0.063	27.4	350	45.5	4.2	<1	1.3	85.9	<0.1	8	0.4	0.8	2.3	34	16.5
	<0.250	14.9	230	29.1	2.3	<1	0.7	52.1	<0.1	4.1	0.2	0.4	1.3	20	9.1
	<2	7.9	140	8.2	0.8	<1	0.3	13.6	<0.1	1.6	<0.1	0.2	1	19	4.1
BR-03	<0.063	33.4	500	47.3	4.7	<1	1.4	92.5	<0.1	8.4	0.4	0.8	2.3	39	18.1
	<0.250	13.1	220	23.6	1.5	<1	0.4	42.5	<0.1	2.6	0.1	0.3	1	15	6.7
	<2	9.8	180	10.7	0.8	<1	0.3	16.9	<0.1	1.6	<0.1	0.2	1.2	22	4.6
BR-04	<0.063	41.5	600	36	4.1	<1	1.6	82.6	<0.1	7.2	0.4	0.7	2.3	34	17.5
	<0.250	25.4	430	39.9	2.5	<1	1.3	48.1	<0.1	5.2	0.2	0.4	1.5	20	16.8
	<2	15.6	240	17.2	1.3	<1	16.3	27.5	<0.1	2	<0.1	0.5	1.1	16	8.1
BR-05	<0.063	33.3	440	41.7	3.6	<1	2.6	79	<0.1	6.1	0.3	0.7	2	22	15.6
	<0.250	10.9	210	16.3	1.4	<1	2.5	39	<0.1	2.5	0.1	0.3	0.9	10	8.3
	<2	15	240	16.1	1.4	<1	0.6	38.9	<0.1	2.2	<0.1	1.3	1.2	15	9.1
MD-01	<0.063	35.5	440	58.5	5.5	<1	1.7	320	<0.1	7	0.4	0.7	2.5	77	11.6
	<0.250	19.9	280	26.8	2.8	<1	1.3	254	<0.1	3.2	0.2	0.4	2.3	47	7.2
	<2	14.7	200	16.2	1.7	<1	0.8	144	<0.1	2.1	0.2	0.3	2.4	38	4.9
MF-01	<0.063	21.9	330	46.7	5	<1	1.1	97.9	<0.1	8.7	0.4	0.8	2.3	45	16.8
	<0.250	14.7	250	42.9	3.1	<1	0.8	79.5	<0.1	5.3	0.3	0.5	1.6	31	10.5
	<2	10	150	16	1.3	<1	0.3	25.2	<0.1	2.7	0.2	0.2	1.4	29	5.7
MF-02	<0.063	19.6	340	55.6	4.7	<1	1.1	98.7	<0.1	8.4	0.4	1.7	2.2	41	16
	<0.250	13.7	240	37.9	2.8	<1	1.1	75.9	<0.1	5	0.2	0.5	1.5	30	9.6
	<2	7.7	170	7.9	.8	<1	0.2	15.1	<0.1	1.8	0.1	0.3	1.5	32	4.3
MF-03	<0.063	25	380	67.7	6.2	<1	1.2	99.6	<0.1	9.2	0.4	0.8	2.4	58	17.5
	<0.250	16.2	270	44.2	3.6	<1	1	93.4	<0.1	5.4	0.3	1.1	1.6	40	10.8
	<2	9.3	200	15.6	1.4	<1	0.3	28.5	<0.1	2.6	0.2	0.4	1.5	34	5.9

Table 7. Concentrations of major and trace constituents determined by laboratory analysis of various size fractions of streambed-sediment collected from the middle Big River and tributaries draining the Barite District, Missouri, 2012.—Continued

[Dark gray shaded cells indicate values that exceeded the PEC for constituents. Bold font indicates values that exceeded the U.S. Environmental Protection Agency residential yard cleanup level. mm, millimeter, w%, percent by weight; --, no data; mg/kg, milligram per kilogram; PEC, consensus-based probable effects concentration, in parentheses (MacDonald and others, 2000); Ba, barium; Pb, lead; Zn, zinc; NA, not applicable; <, less than]

Site number	Size fraction (mm)	Nickel (mg/kg) PEC (48.6)	Phosphorus (mg/kg) --	Rubidium (mg/kg) --	Scandium (mg/kg) --	Silver (mg/kg) --	Tin (mg/kg) --	Strontium (mg/kg) --	Tellurium (mg/kg) --	Thorium (mg/kg) --	Thallium (mg/kg) --	Tungsten (mg/kg) --	Uranium (mg/kg) --	Vanadium (mg/kg) --	Yttrium (mg/kg) --
MF-04	<0.063	20.1	500	36.1	2.8	<1	1.3	163	<0.1	5.7	0.2	0.5	1.5	27	14.4
	<0.250	5.7	160	9.3	0.8	<1	0.5	32.7	<0.1	1.6	<0.1	0.1	0.8	13	3.2
	<2	8	170	4.4	0.6	<1	0.2	222	<0.1	1.6	0.1	0.2	1.4	33	4
MF-03OM	<0.063	16.8	290	24.2	2	<1	2.6	355	<0.1	3.5	0.2	2.2	0.9	20	9.1
	<0.250	8.8	180	11.9	1.2	<1	1.7	836	<0.1	1.7	0.1	1.8	1	18	5.1
	<2	15.8	160	4.1	0.6	<1	0.5	920	<0.1	1.1	0.1	0.3	1.6	46	3.2
ML-01	<0.063	22.2	320	45.4	4.4	<1	1.6	182	<0.1	7.4	0.4	0.7	2	44	13.2
	<0.250	14.9	260	28.3	3.1	<1	2.4	157	<0.1	4.8	0.3	0.5	1.8	37	9.4
	<2	6.8	130	7.9	1	<1	0.3	28.5	<0.1	1.9	0.1	0.2	1.6	26	3.4
ML-02	<0.063	19.3	310	50.4	5	<1	1.4	201	<0.1	8.7	0.4	3.6	2.3	47	14.5
	<0.250	16.1	290	33.9	3.5	<1	1.3	161	<0.1	6.1	0.3	0.6	1.9	41	10.7
	<2	8.2	150	8.9	1	<1	0.3	39	<0.1	2.2	0.1	0.3	1.7	29	4
ML-03	<0.063	24	510	31.9	3.1	<1	1.3	322	<0.1	5.3	0.3	0.5	1.4	30	12.2
	<0.250	16.5	390	19.4	2.1	<1	1.3	378	<0.1	3.3	0.2	0.4	1.3	27	7.8
	<2	12.5	220	2.9	0.6	<1	1.3	227	<0.1	1.7	<0.1	0.3	1.6	53	3.6
ML-04	<0.063	21.1	470	42.3	4.3	<1	1.8	262	<0.1	6.9	0.3	0.6	1.8	41	13.6
	<0.250	18.1	460	34.3	3.9	<1	1.9	218	<0.1	5.6	0.3	0.6	1.8	41	10.9
	<2	6.4	290	3.8	0.7	<1	0.2	14.3	<0.1	1.5	0.1	0.2	1.6	33	2.8
Cases above the instrument limit of detection		45	45	45	45	--	45	45	--	45	37	45	45	45	45
Maximum		41.5	600	67.7	6.2	--	16.3	920	--	9.2	0.4	3.6	2.5	77	18.1
Minimum		5.7	100	2.9	0.6	--	0.2	13.6	--	1.1	0.1	0.1	0.6	8	2.8
Mean		16.8	287	27.3	2.5	--	1.4	151	--	4.32	0.25	0.64	1.63	31.89	9.45

Table 7. Concentrations of major and trace constituents determined by laboratory analysis of various size fractions of streambed-sediment collected from the middle Big River and tributaries draining the Barite District, Missouri, 2012.—Continued

[Dark gray shaded cells indicate values that exceeded the PEC for constituents. Bold font indicates values that exceeded the U.S. Environmental Protection Agency residential yard cleanup level. mm, millimeter, w%, percent by weight; --, no data; mg/kg, milligram per kilogram; PEC, consensus-based probable effects concentration, in parentheses (MacDonald and others, 2000); Ba, barium; Pb, lead; Zn, zinc; NA, not applicable; <, less than]

Site number	Size fraction (mm)	Ratio		
		Ba/Pb NA --	Pb/Zn NA --	Ba/Zn NA --
BR-01	<0.063	2.4	2.53	6.07
	<0.250	2.88	2.15	6.2
	<2	1.33	1.04	1.38
BR-02	<0.063	1.29	3.23	4.16
	<0.250	1.98	2.55	5.04
	<2	1.29	1.03	1.32
BR-03	<0.063	1.44	4.05	5.84
	<0.250	3.26	2.8	9.12
	<2	2.25	1.81	4.07
BR-04	<0.063	0.41	2.45	1.01
	<0.250	0.33	2.13	0.71
	<2	0.26	2.12	0.56
BR-05	<0.063	0.27	2.65	0.71
	<0.250	0.68	1.29	0.88
	<2	0.22	7.16	1.6
MD-01	<0.063	13.13	0.24	3.13
	<0.250	35.53	0.27	9.58
	<2	48.79	0.32	15.69
MF-01	<0.063	3.17	3.46	10.96
	<0.250	6.15	3.15	19.35
	<2	2.77	1.94	5.38
MF-02	<0.063	13.32	1.04	13.82
	<0.250	24.85	0.9	22.46
	<2	4.81	0.53	2.55
MF-03	<0.063	19.95	0.3	6.08
	<0.250	68.44	0.34	23.14
	<2	17.09	0.41	7.01
MF-04	<0.063	57.83	0.43	24.72
	<0.250	36.85	0.45	16.73
	<2	62.23	0.5	31.26
MF-03OM	<0.063	12.15	0.43	5.22
	<0.250	10.21	0.66	6.75
	<2	8.62	0.42	3.58
ML-01	<0.063	34.82	0.42	14.55
	<0.250	46.01	0.45	20.8
	<2	30.43	0.33	9.96
ML-02	<0.063	42.35	0.43	18.11
	<0.250	53.54	0.41	21.94
	<2	42.58	0.29	12.44
ML-03	<0.063	44.01	0.39	17.18
	<0.250	30.32	0.48	14.69
	<2	25.3	0.46	11.6
ML-04	<0.063	26.14	0.36	9.36
	<0.250	39.48	0.36	14.32
	<2	11.14	0.27	3.01
Cases above the instrument limit of detection		45	45	45
Maximum		68.44	7.16	31.26
Minimum		0.22	0.24	0.56
Mean		19.83	1.32	9.87

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; <, less than; --, no data]

Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault												
FR-03	FR-03_0-1	1	0–1	<11	204	<12	<260	38	61	649	<65	109
FR-03	FR-03_0-1	2	0–1	<11	150	<12	<260	39	59	802	<65	79
FR-03	FR-03_0-1	3	0–1	<11	222	<12	<260	<35	50	702	<65	86
FR-03	FR-03_0-1	4	0–1	<11	315	15	<260	<35	31	579	<65	41
FR-03	FR-03_0-1_avg	Bulk average	0–1	<11	312	15	<260	<35	39	574	<65	79
FR-03	FR-03_1-2	1	1–2	<11	176	<12	<260	42	52	581	<65	100
FR-03	FR-03_1-2	2	1–2	<11	<100	<12	<260	<35	47	578	77	101
FR-03	FR-03_1-2	3	1–2	13	146	<12	<260	38	37	553	<65	61
FR-03	FR-03_1-2	4	1–2	13	366	<12	<260	<35	26	497	<65	58
FR-03	FR-03_1-2_avg	Bulk average	1–2	<11	220	<12	<260	<35	32	539	70	73
FR-03	FR-03_2-3	1	2–3	14	221	<12	<260	<35	52	573	71	91
FR-03	FR-03_2-3	2	2–3	<11	<100	<12	<260	36	40	464	69	73
FR-03	FR-03_2-3	3	2–3	12	137	<12	<260	36	15	307	<65	46
FR-03	FR-03_2-3	4	2–3	<11	161	<12	<260	<35	<13	130	<65	27
FR-03	FR-03_2-3_avg	Bulk average	2–3	<11	213	15	<260	<35	23	411	<65	38
FR-03	FR-03_3-4	1	3–4	<11	129	30	<260	<35	27	275	<65	57
FR-03	FR-03_3-4	2	3–4	<11	127	24	<260	<35	<13	251	<65	28
FR-03	FR-03_3-4	3	3–4	<11	146	<12	<260	<35	<13	137	<65	25
FR-03	FR-03_3-4	4	3–4	17	305	19	<260	<35	41	487	<65	72
FR-03	FR-03_3-4_avg	Bulk average	3–4	<11	194	20	<260	<35	<13	124	<65	31
FR-03	FR-03_4-5	1	4–5	<11	127	36	<260	<35	29	135	<65	49
FR-03	FR-03_4-5	2	4–5	<11	165	28	<260	<35	<13	120	<65	36
FR-03	FR-03_4-5	3	4–5	<11	120	<12	<260	<35	<13	112	<65	26
FR-03	FR-03_4-5	4	4–5	<11	206	15	<260	<35	<13	<85	<65	25
FR-03	FR-03_4-5_avg	Bulk average	4–5	<11	417	27	<260	<35	<13	105	<65	26
FR-03	FR-03_5-6	1	5–6	14	157	43	<260	<35	41	464	<65	83
FR-03	FR-03_5-6	2	5–6	<11	226	36	<260	<35	34	419	<65	74
FR-03	FR-03_5-6	3	5–6	<11	154	<12	<260	<35	<13	176	<65	61

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; <, less than; --, no data]

Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault—Continued												
FR-03	FR-03_5-6	4	5–6	<11	288	<12	<260	<35	19	254	<65	47
FR-03	FR-03_5-6_avg	Bulk average	5–6	<11	424	26	<260	<35	18	191	<65	33
FR-03	FR-03_6-7	1	6–7	<11	<100	13	<260	<35	66	374	<65	82
FR-03	FR-03_6-7	2	6–7	<11	169	29	<260	<35	78	312	<65	66
FR-03	FR-03_6-7	3	6–7	<11	107	<12	<260	<35	<13	138	<65	38
FR-03	FR-03_6-7	4	6–7	<11	315	15	<260	<35	<13	132	<65	31
FR-03	FR-03_6-7_avg	Bulk average	6–7	<11	247	16	<260	<35	<13	100	<65	25
FR-03	FR-03_7-8	1	7–8	<11	226	43	<260	<35	31	389	<65	75
FR-03	FR-03_7-8	2	7–8	<11	215	24	<260	<35	28	339	<65	60
FR-03	FR-03_7-8	3	7–8	<11	105	<12	<260	<35	17	337	<65	38
FR-03	FR-03_7-8	4	7–8	<11	250	14	<260	<35	<13	239	<65	33
FR-03	FR-03_7-8_avg	Bulk average	7–8	<11	291	15	<260	<35	<13	283	<65	33
FR-03	FR-03_12-13	1	12–13	<11	299	14	<260	<35	50	723	<65	78
FR-03	FR-03_12-13	2	12–13	<11	136	<12	<260	<35	33	691	<65	57
FR-03	FR-03_12-13	3	12–13	12	107	<12	<260	<35	16	323	<65	28
FR-03	FR-03_12-13	4	12–13	<11	267	15	<260	44	15	173	<65	37
FR-03	FR-03_12-13_avg	Bulk average	12–13	<11	286	23	<260	<35	21	393	<65	33
FR-03	FR-03_13-14	1	13–14	<11	140	28	<260	<35	37	639	<65	60
FR-03	FR-03_13-14	2	13–14	<11	<100	<12	<260	37	35	623	<65	45
FR-03	FR-03_13-14	3	13–14	<11	148	<12	<260	<35	<13	412	<65	45
FR-03	FR-03_13-14	4	13–14	<11	334	15	<260	<35	17	219	<65	30
FR-03	FR-03_13-14_avg	Bulk average	13–14	<11	283	22	<260	<35	20	285	<65	37
FR-03	FR-03_14-15	1	14–15	<11	262	25	<260	<35	53	974	72	67
FR-03	FR-03_14-15	2	14–15	13	157	<12	<260	<35	34	870	<65	62
FR-03	FR-03_14-15	3	14–15	<11	143	<12	<260	37	18	553	<65	40
FR-03	FR-03_14-15	4	14–15	<11	243	14	<260	38	21	635	<65	45
FR-03	FR-03_14-15_avg	Bulk average	14–15	<11	347	16	<260	<35	24	863	<65	70
FR-03	FR-03_15-16	1	15–16	<11	303	17	<260	<35	55	1,001	<65	79

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

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Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault—Continued												
FR-03	FR-03_15-16	2	15–16	<11	137	15	<260	<35	37	906	69	78
FR-03	FR-03_15-16	3	15–16	14	127	12	<260	39	<13	733	<65	71
FR-03	FR-03_15-16	4	15–16	12	309	17	<260	<35	19	597	<65	34
FR-03	FR-03_15-16_avg	Bulk average	15–16	<11	365	24	<260	38	19	627	<65	54
Mineral Fork												
MFC-B-02	MFC-B-02_0-1	1	0–1	<11	332	<12	<260	43	45	306	72	160
MFC-B-02	MFC-B-02_0-1	2	0–1	<11	348	<12	<260	45	101	763	69	201
MFC-B-02	MFC-B-02_0-1	3	0–1	<11	389	<12	<260	52	127	1,067	<65	179
MFC-B-02	MFC-B-02_0-1	4	0–1	<11	559	22	<260	39	105	912	<65	160
MFC-B-02	MFC-B-02_0-1_avg	Bulk average	0–1	<11	575	<12	<260	<35	62	268	<65	142
MFC-B-02	MFC-B-02_1-2	1	1–2	<11	268	<12	<260	37	37	217	70	151
MFC-B-02	MFC-B-02_1-2	2	1–2	<11	205	<12	<260	<35	50	255	<65	218
MFC-B-02	MFC-B-02_1-2	3	1–2	<11	281	<12	<260	<35	48	239	<65	210
MFC-B-02	MFC-B-02_1-2_avg	Bulk average	1–2	<11	448	<12	<260	40	37	213	73	175
MFC-B-02	MFC-B-02_2-3	1	2–3	<11	347	<12	<260	45	44	422	<65	220
MFC-B-02	MFC-B-02_2-3	2	2–3	<11	445	<12	<260	48	59	536	<65	241
MFC-B-02	MFC-B-02_2-3	3	2–3	15	491	<12	<260	39	58	530	72	219
MFC-B-02	MFC-B-02_2-3_avg	Bulk average	2–3	<11	594	<12	<260	38	81	1,604	84	225
MFC-B-02	MFC-B-02_3-4	1	3–4	<11	274	254	311	79	70	626	144	226
MFC-B-02	MFC-B-02_3-4	2	3–4	19	417	<12	<260	40	55	701	<65	202
MFC-B-02	MFC-B-02_3-4	3	3–4	<11	520	<12	<260	48	49	447	<65	205
MFC-B-02	MFC-B-02_3-4	4	3–4	<11	622	13	<260	42	52	408	<65	185
MFC-B-02	MFC-B-02_3-4_avg	Bulk average	3–4	<11	609	<12	<260	<35	39	204	<65	169
MFC-B-02	MFC-B-02_4-5	1	4–5	14	338	17	<260	40	53	625	<65	137
MFC-B-02	MFC-B-02_4-5	2	4–5	16	426	<12	265	49	64	923	<65	191
MFC-B-02	MFC-B-02_4-5	3	4–5	<11	421	<12	<260	38	55	624	70	162
MFC-B-02	MFC-B-02_4-5_avg	Bulk average	4–5	<11	635	<12	<260	<35	43	276	<65	144
MFC-B-02	MFC-B-02_5-6	1	5–6	14	343	<12	<260	52	46	615	<65	151

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

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Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
					Mineral Fork —Continued							
MFC-B-02	MFC-B-02_5-6	2	5–6	<11	372	<12	<260	42	61	844	74	187
MFC-B-02	MFC-B-02_5-6	3	5–6	15	400	<12	<260	<35	49	648	<65	143
MFC-B-02	MFC-B-02_5-6	4	5–6	<11	<100	<12	<260	<35	<13	96	<65	156
MFC-B-02	MFC-B-02_5-6_avg	Bulk average	5–6	<11	766	<12	<260	<35	101	913	<65	135
MFC-B-02	MFC-B-02_6-7	1	6–7	<11	334	<12	<260	43	50	509	<65	146
MFC-B-02	MFC-B-02_6-7	2	6–7	15	311	<12	<260	45	55	729	<65	164
MFC-B-02	MFC-B-02_6-7	3	6–7	13	425	<12	<260	<35	38	581	<65	171
MFC-B-02	MFC-B-02_6-7	4	6–7	<11	540	<12	<260	<35	47	730	85	160
MFC-B-02	MFC-B-02_6-7_avg	Bulk average	6–7	<11	639	<12	<260	<35	39	709	<65	122
MFC-B-02	MFC-B-02_7-8	1	7–8	<11	328	<12	<260	<35	46	499	<65	134
MFC-B-02	MFC-B-02_7-8	2	7–8	<11	351	<12	<260	39	50	697	<65	145
MFC-B-02	MFC-B-02_7-8	3	7–8	13	433	<12	<260	<35	47	552	<65	132
MFC-B-02	MFC-B-02_7-8	4	7–8	<11	730	<12	<260	44	83	1,522	<65	136
MFC-B-02	MFC-B-02_7-8_avg	Bulk average	7–8	<11	576	<12	<260	<35	28	444	<65	105
MFC-B-02	MFC-B-02_8-9	1	8–9	<11	347	25	<260	<35	17	453	69	109
MFC-B-02	MFC-B-02_8-9	2	8–9	13	339	<12	<260	49	28	913	<65	123
MFC-B-02	MFC-B-02_8-9	3	8–9	<11	542	<12	<260	45	23	685	<65	122
MFC-B-02	MFC-B-02_8-9	4	8–9	12	558	33	<260	<35	<13	312	74	93
MFC-B-02	MFC-B-02_8-9_avg	Bulk average	8–9	<11	653	<12	<260	<35	15	482	<65	98
MFC-B-02	MFC-B-02_9-10	1	9–10	<11	360	30	<260	<35	17	280	<65	98
MFC-B-02	MFC-B-02_9-10	2	9–10	<11	326	<12	<260	<35	19	330	<65	142
MFC-B-02	MFC-B-02_9-10	3	9–10	13	407	<12	<260	51	<13	183	<65	128
MFC-B-02	MFC-B-02_9-10	4	9–10	<11	782	<12	<260	40	42	976	<65	126
MFC-B-02	MFC-B-02_9-10_avg	Bulk average	9–10	12	662	<12	<260	<35	17	304	68	103
MFC-B-02	MFC-B-02_10-11	1	10–11	<11	441	25	<260	<35	32	833	<65	200
MFC-B-02	MFC-B-02_10-11	2	10–11	<11	356	<12	<260	40	54	1,498	<65	255
MFC-B-02	MFC-B-02_10-11	3	10–11	<11	517	<12	<260	38	49	905	<65	225
MFC-B-02	MFC-B-02_10-11	4	10–11	<11	811	41	<260	42	62	2,096	<65	201
MFC-B-02	MFC-B-02_10-11_avg	Bulk average	10–11	<11	585	13	<260	<35	31	244	<65	220

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

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Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
					Mill Creek							
MLC-B-05	ML-B-05_0-1	1	0–1	15	1,121	<12	<260	43	106	668	<65	372
MLC-B-05	ML-B-05_0-1	2	0–1	18	935	<12	<260	<35	114	679	<65	355
MLC-B-05	ML-B-05_0-1	3	0–1	<11	719	<12	<260	<35	86	568	70	297
MLC-B-05	ML-B-05_0-1	4	0–1	<11	494	<12	<260	<35	47	375	<65	214
MLC-B-05	ML-B-05_0-1_avg	Bulk average	0–1	<11	934	14	<260	<35	72	866	<65	292
MLC-B-05	ML-B-05_1-2	1	1–2	<11	469	<12	<260	47	97	694	<65	296
MLC-B-05	ML-B-05_1-2	2	1–2	<11	996	<12	<260	38	103	727	<65	298
MLC-B-05	ML-B-05_1-2	3	1–2	15	595	<12	<260	40	68	507	<65	270
MLC-B-05	ML-B-05_1-2	4	1–2	<11	549	14	<260	<35	52	626	<65	246
MLC-B-05	ML-B-05_1-2_avg	Bulk average	1–2	<11	741	14	<260	42	72	526	<65	265
MLC-B-05	ML-B-05_2-3	1	2–3	<11	650	<12	<260	<35	82	542	81	261
MLC-B-05	ML-B-05_2-3	2	2–3	<11	2,211	<12	<260	<35	94	517	<65	262
MLC-B-05	ML-B-05_2-3	3	2–3	<11	950	<12	<260	<35	58	343	<65	215
MLC-B-05	ML-B-05_2-3	4	2–3	<11	840	<12	<260	<35	52	356	<65	171
MLC-B-05	ML-B-05_2-3_avg	Bulk average	2–3	15	1,200	<12	<260	<35	61	400	<65	237
MLC-B-05	ML-B-05_4-5	1	4–5	<11	878	<12	<260	<35	85	651	<65	224
MLC-B-05	ML-B-05_4-5	2	4–5	<11	1,722	<12	<260	42	82	624	75	239
MLC-B-05	ML-B-05_4-5	3	4–5	<11	1,124	<12	<260	<35	72	549	<65	223
MLC-B-05	ML-B-05_4-5	4	4–5	<11	1,309	<12	<260	<35	86	583	<65	230
MLC-B-05	ML-B-05_4-5_avg	Bulk average	4–5	<11	1,617	13	<260	39	68	419	<65	209
MLC-B-05	ML-B-05_5-6	1	5–6	16	1,303	<12	<260	44	109	733	<65	235
MLC-B-05	ML-B-05_5-6	2	5–6	16	2,670	<12	<260	<35	121	700	70	294
MLC-B-05	ML-B-05_5-6	3	5–6	15	1,533	<12	<260	39	76	698	72	248
MLC-B-05	ML-B-05_5-6	4	5–6	<11	1,850	<12	<260	<35	83	486	76	209
MLC-B-05	ML-B-05_5-6_avg	Bulk average	5–6	<11	1,973	14	<260	40	83	439	<65	229
MLC-B-05	ML-B-05_6-7	1	6–7	15	1,272	<12	271	40	115	883	<65	300
MLC-B-05	ML-B-05_6-7	2	6–7	<11	2,687	<12	<260	40	113	794	<65	315
MLC-B-05	ML-B-05_6-7	3	6–7	<11	1,324	<12	<260	<35	64	506	<65	241

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

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Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek—Continued												
MLC-B-05	ML-B-05_6-7	4	6–7	<11	1,535	<12	268	<35	61	272	<65	241
MLC-B-05	ML-B-05_6-7_avg	Bulk average	6–7	15	1,973	<12	<260	<35	61	304	<65	219
MLC-B-05	ML-B-05_7-8	1	7–8	16	1,218	<12	265	41	112	653	<65	329
MLC-B-05	ML-B-05_7-8	2	7–8	<11	2,911	<12	<260	44	115	780	<65	311
MLC-B-05	ML-B-05_7-8	3	7–8	<11	1,094	<12	<260	<35	66	514	<65	225
MLC-B-05	ML-B-05_7-8	4	7–8	<11	536	21	<260	<35	29	163	<65	222
MLC-B-05	ML-B-05_7-8_avg	Bulk average	7–8	<11	1,423	16	<260	<35	64	328	<65	210
MLC-B-05	ML-B-05_8-9	1	8–9	<11	1,137	31	<260	<35	155	2,978	81	506
MLC-B-05	ML-B-05_8-9	2	8–9	46	1,588	14	<260	<35	139	2,700	75	499
MLC-B-05	ML-B-05_8-9	3	8–9	21	1,051	<12	<260	<35	129	2,078	<65	432
MLC-B-05	ML-B-05_8-9	4	8–9	<11	1,070	16	<260	<35	129	1,418	<65	451
MLC-B-05	ML-B-05_8-9_avg	Bulk average	8–9	<11	479	39	<260	<35	<13	296	<65	66
MLC-B-05	ML-B-05_9-10	1	9–10	29	923	38	<260	45	171	1,256	<65	516
MLC-B-05	ML-B-05_9-10	2	9–10	19	1,168	29	<260	<35	155	759	<65	500
MLC-B-05	ML-B-05_9-10	3	9–10	24	759	<12	<260	41	147	830	<65	482
MLC-B-05	ML-B-05_9-10	4	9–10	<11	486	19	<260	<35	40	<85	<65	258
MLC-B-05	ML-B-05_9-10_avg	Bulk average	9–10	<11	396	21	<260	<35	61	297	<65	181
MLC-B-05	ML-B-05_10-11.4	1	10–11.4	<11	266	<12	<260	<35	46	368	<65	169
MLC-B-05	ML-B-05_10-11.4	2	10–11.4	<11	238	<12	<260	<35	22	223	72	141
MLC-B-05	ML-B-05_10-11.4	3	10–11.4	12	268	<12	<260	<35	22	179	<65	178
MLC-B-05	ML-B-05_10-11.4	4	10–11.4	<11	409	16	<260	<35	45	156	<65	265
MLC-B-05	ML-B-05_10-11_avg	Bulk average	10–11	<11	469	<12	<260	<35	44	211	<65	188
MLC-B-05	ML-B-05_11-11.4_avg	Bulk average	11–11.4	<11	592	19	<260	<35	55	867	<65	208
Mill Creek												
MLC-A-02	MLC-A-02_0-1	1	0–1	<11	8,185	<12	<260	40	370	1,006	<65	747
MLC-A-02	MLC-A-02_0-1	2	0–1	<11	7,784	<12	<260	43	328	968	<65	683

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; <, less than; --, no data]

Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
				Mill Creek—Continued								
MLC-A-02	MLC-A-02_0-1	3	0–1	<11	7,792	<12	<260	45	329	885	<65	672
MLC-A-02	MLC-A-02_0-1	4	0–1	<11	8,752	<12	<260	50	325	870	89	684
MLC-A-02	MLC-A-02_0-1_avg	Bulk average	0–1	39	5,612	22	<260	<35	246	1,506	<65	634
MLC-A-02	MLC-A-02_1-2	1	1–2	<11	9,006	<12	<260	45	**436**	898	<65	818
MLC-A-02	MLC-A-02_1-2	2	1–2	<11	12,908	<12	<260	57	396	901	85	730
MLC-A-02	MLC-A-02_1-2	3	1–2	<11	9,761	<12	<260	<35	391	832	<65	758
MLC-A-02	MLC-A-02_1-2	4	1–2	<11	7,520	33	<260	52	358	802	<65	678
MLC-A-02	MLC-A-02_1-2_avg	Bulk average	1–2	25	11,888	14	<260	63	**440**	945	<65	891
MLC-A-02	MLC-A-02_2-3	1	2–3	<11	7,071	<12	<260	<35	228	868	<65	352
MLC-A-02	MLC-A-02_2-3	2	2–3	<11	6,273	<12	<260	<35	182	819	75	341
MLC-A-02	MLC-A-02_2-3	3	2–3	<11	5,161	<12	<260	43	211	715	<65	343
MLC-A-02	MLC-A-02_2-3	4	2–3	<11	5,607	18	<260	54	222	774	<65	385
MLC-A-02	MLC-A-02_2-3_avg	Bulk average	2–3	<11	5,898	16	<260	35	195	927	<65	368
MLC-A-02	MLC-A-02_3-4	1	3–4	<11	6,214	<12	<260	42	169	873	<65	309
MLC-A-02	MLC-A-02_3-4	2	3–4	<11	4,400	<12	<260	43	166	741	<65	285
MLC-A-02	MLC-A-02_3-4	3	3–4	<11	4,235	<12	<260	43	157	737	<65	304
MLC-A-02	MLC-A-02_3-4	4	3–4	<11	5,424	<12	<260	<35	150	741	<65	264
MLC-A-02	MLC-A-02_3-4_avg	Bulk average	3–4	<11	5,163	<12	<260	40	168	819	<65	315
MLC-A-02	MLC-A-02_4-5.2	1	4–5.2	<11	1,355	<12	<260	51	123	900	<65	586
MLC-A-02	MLC-A-02_4-5.2	2	4–5.2	14	1,523	<12	<260	<35	98	738	<65	481
MLC-A-02	MLC-A-02_4-5.2	3	4–5.2	<11	1,149	<12	<260	<35	96	678	<65	441
MLC-A-02	MLC-A-02_4-5.2	4	4–5.2	<11	1,423	13	<260	48	106	732	71	466
MLC-A-02	MLC-A-02_4-5_avg	Bulk average	4–5	<11	1,959	23	<260	<35	102	603	<65	523
MLC-A-02	MLC-A-02_5-5.2_avg	Bulk average	5–5.2	<11	1,501	17	<260	<35	89	843	<65	445
MLC-A-02	MLC-A-02_6.6-7	1	6.6–7	<11	894	39	<260	<35	96	596	<65	463
MLC-A-02	MLC-A-02_6.6-7	2	6.6–7	<11	1,147	<12	<260	40	93	760	<65	504
MLC-A-02	MLC-A-02_6.6-7	3	6.6–7	<11	676	<12	<260	<35	63	419	<65	358
MLC-A-02	MLC-A-02_6.6-7	4	6.6–7	<11	845	14	<260	<35	59	466	<65	359

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; <, less than; --, no data]

Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek—Continued												
MLC-A-02	MLC-A-02_6.6-7_avg	Bulk average	6.6–7	<11	1,052	19	<260	<35	68	541	<65	352
MLC-A-02	MLC-A-02_7-8	1	7–8	<11	869	13	<260	<35	106	1,112	<65	543
MLC-A-02	MLC-A-02_7-8	2	7–8	<11	854	<12	<260	38	68	610	<65	416
MLC-A-02	MLC-A-02_7-8	3	7–8	<11	342	<12	<260	<35	25	356	<65	222
MLC-A-02	MLC-A-02_7-8	4	7–8	<11	894	18	337	<35	67	567	<65	450
MLC-A-02	MLC-A-02_7-8_avg	Bulk average	7–8	<11	592	26	<260	<35	17	266	<65	120
MLC-A-02	MLC-A-02_8-9	1	8–9	<11	2,558	28	<260	39	118	420	<65	343
MLC-A-02	MLC-A-02_8-9	2	8–9	<11	2,258	13	<260	<35	80	248	<65	290
MLC-A-02	MLC-A-02_8-9	3	8–9	<11	754	<12	<260	<35	33	158	<65	303
MLC-A-02	MLC-A-02_8-9	4	8–9	<11	419	16	<260	<35	49	128	<65	720
MLC-A-02	MLC-A-02_8-9_avg	Bulk average	8–9	<11	1,774	27	<260	<35	48	230	<65	723
MLC-A-02	MLC-A-02_9-10	1	9–10	<11	2,717	<12	<260	<35	158	383	<65	362
MLC-A-02	MLC-A-02_9-10	2	9–10	<11	2,132	<12	<260	40	85	209	<65	217
MLC-A-02	MLC-A-02_9-10	3	9–10	<11	921	<12	<260	39	49	148	<65	164
MLC-A-02	MLC-A-02_9-10	4	9–10	<11	303	19	<260	<35	<13	122	<65	42
MLC-A-02	MLC-A-02_9-10_avg	Bulk average	9–10	<11	4,249	22	<260	<35	99	431	<65	255
MLC-A-02	MLC-A-02_10-12	1	10–12	<11	4,596	<12	<260	52	138	560	73	385
MLC-A-02	MLC-A-02_10-12	2	10–12	<11	4,141	<12	<260	<35	89	446	70	285
MLC-A-02	MLC-A-02_10-12	3	10–12	<11	1,747	<12	<260	<35	42	197	<65	192
MLC-A-02	MLC-A-02_10-12	4	10–12	<11	437	20	<260	<35	<13	<85	<65	66
MLC-A-02	MLC-A-02_10-11_avg	Bulk average	10–11	<11	3,033	22	<260	<35	61	365	<65	208
MLC-A-02	MLC-A-02_11-12_avg	Bulk average	11–12	15	2,423	24	<260	41	51	296	<65	226
MLC-A-02	MLC-A-02_12-13	1	12–13	<11	9,698	<12	<260	47	100	569	72	311
MLC-A-02	MLC-A-02_12-13	2	12–13	<11	9,292	<12	<260	<35	72	365	<65	251
MLC-A-02	MLC-A-02_12-13	3	12–13	<11	4,797	<12	<260	<35	52	240	<65	182
MLC-A-02	MLC-A-02_12-13	4	12–13	12	733	13	<260	40	<13	203	<65	62
MLC-A-02	MLC-A-02_12-13_avg	Bulk average	12–13	<11	3,466	30	<260	<35	28	203	<65	150
MLC-A-02	MLC-A-02_13-14	1	13–14	<11	4,019	<12	<260	<35	66	490	<65	243

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; <, less than; --, no data]

Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek—Continued												
MLC-A-02	MLC-A-02_13-14	2	13–14	<11	5,963	<12	<260	<35	42	480	76	198
MLC-A-02	MLC-A-02_13-14	3	13–14	<11	3,432	<12	<260	49	40	309	<65	169
MLC-A-02	MLC-A-02_13-14	4	13–14	<11	942	15	<260	<35	27	189	<65	137
MLC-A-02	MLC-A-02_13-14_avg	Bulk average	13–14	<11	3,718	40	<260	<35	26	245	<65	111
MLC-A-02	MLC-A-02_14-15	1	14–15	<11	3,250	<12	<260	50	71	521	<65	239
MLC-A-02	MLC-A-02_14-15	2	14–15	14	5,121	<12	<260	45	60	509	<65	224
MLC-A-02	MLC-A-02_14-15	3	14–15	<11	2,813	<12	<260	<35	48	239	<65	151
MLC-A-02	MLC-A-02_14-15	4	14–15	<11	824	17	<260	45	57	272	<65	237
MLC-A-02	MLC-A-02_14-15_avg	Bulk average	14–15	<11	2,588	60	<260	<35	41	210	<65	97
Mill Creek												
MLC-A-05	MLC-A-05_0-1	1	0–1	<11	5,533	<12	<260	43	281	843	73	623
MLC-A-05	MLC-A-05_0-1	2	0–1	<11	5,033	<12	<260	55	319	949	<65	618
MLC-A-05	MLC-A-05_0-1	3	0–1	<11	5,155	<12	<260	52	293	835	<65	586
MLC-A-05	MLC-A-05_0-1	4	0–1	<11	3,481	<12	<260	<35	212	627	<65	486
MLC-A-05	MLC-A-05_0-1_avg	Bulk average	0–1	<11	5,539	15	<260	<35	274	1,262	<65	535
MLC-A-05	MLC-A-05_1-2	1	1–2	18	3,779	<12	<260	45	189	771	<65	389
MLC-A-05	MLC-A-05_1-2	2	1–2	<11	3,624	<12	<260	<35	202	832	71	377
MLC-A-05	MLC-A-05_1-2	3	1–2	<11	3,410	<12	<260	<35	185	780	<65	350
MLC-A-05	MLC-A-05_1-2	4	1–2	<11	2,351	13	<260	39	121	576	<65	312
MLC-A-05	MLC-A-05_1-2_avg	Bulk average	1–2	<11	3,664	15	<260	<35	158	683	<65	325
MLC-A-05	MLC-A-05_2-3	1	2–3	<11	1,081	<12	<260	45	269	744	<65	337
MLC-A-05	MLC-A-05_2-3	2	2–3	<11	1,218	<12	<260	<35	330	852	<65	402
MLC-A-05	MLC-A-05_2-3	3	2–3	<11	1,183	<12	<260	42	322	782	73	350
MLC-A-05	MLC-A-05_2-3	4	2–3	<11	1,170	<12	<260	39	244	766	<65	326
MLC-A-05	MLC-A-05_2-3_avg	Bulk average	2–3	<11	1,416	13	<260	<35	264	702	<65	333
MLC-A-05	MLC-A-05_3-4	1	3–4	<11	749	<12	<260	49	235	819	<65	512
MLC-A-05	MLC-A-05_3-4	2	3–4	<11	875	<12	<260	42	269	972	<65	610
MLC-A-05	MLC-A-05_3-4	3	3–4	<11	855	<12	<260	39	239	826	<65	538

Table 8. Select trace element concentrations determined using x-ray fluorescence in various size fractions of sieved samples from flood-plain boreholes along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; <, less than; --, no data]

Borehole identifier	Sample identifier	Grain size group[1]	Sample depth (ft)	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek—Continued												
MLC-A-05	MLC-A-05_3-4	4	3–4	<11	996	13	<260	<35	211	783	<65	570
MLC-A-05	MLC-A-05_3-4_avg	Bulk average	3–4	<11	982	13	<260	<35	217	732	<65	459
Reporting level				11	100	12	260	35	13	85	65	25
Probable effects concentration (PEC) from MacDonald and others (2000)				33	--	4.98	--	149	128	--	48.60	459
EPA residential cleanup level				--	--	--	--	--	400	--	--	--
Summary												
Number of samples analyzed				250	250	250	250	250	250	250	250	250
Number of detections				46	245	98	6	99	227	247	39	250
Maximum detection				46	12,908	254	337	79	440	2,978	144	891
Number of detections above PEC				2	--	98	--	0	48	--	39	33
Number of detections above EPA residential cleanup level				--	--	--	--	--	2	--	--	--
Frequency of PEC exceedance				0.01	--	0.39	--	0.00	0.19	--	0.16	0.13

[1]Grain-size groups defined in order of increasing grain size: 1, less than 0.063 millimeter; 2, 0.063–0.250 millimeter; 3, 0.250–2 millimeters; 4, greater than 2 millimeters; bulk average, average of all scans of bulk from selected interval.

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Big River flood plain												
BR-FP	BR-FP_0-1”	0.04	Manual	<11	408	<12	<260	47	230	1,102	69	150
BR-FP	BR-FP_1-2”	0.13	Manual	<11	492	<12	<260	47	240	1,126	<65	149
BR-FP	BR-FP_2-3”	0.21	Manual	<11	421	<12	<260	41	200	934	<65	130
BR-FP	BR-FP_3-4”	0.29	Manual	<11	539	<12	<260	35	197	982	<65	143
BR-FP	BR-FP_4-5”	0.38	Manual	<11	585	<12	<260	41	200	1,091	<65	149
BR-FP	BR-FP_5-6”	0.46	Manual	<11	598	<12	<260	48	186	1,140	<65	146
BR-FP	BR-FP_6-9”	0.63	Manual	<11	644	<12	<260	42	186	1,090	70	131
BR-FP	BR-FP_9-12”	0.88	Manual	<11	671	<12	<260	41	110	1,142	71	126
Mineral Fork flood plain												
MFC-A-01	MFC-A-01 _0-1”	0.04	Manual	<11	1,290	<12	<260	<35	**814**	928	<65	372
MFC-A-01	MFC-A-01 _1-2”	0.13	Manual	<11	1,190	<12	<260	54	**828**	779	<65	357
MFC-A-01	MFC-A-01 _2-3”	0.21	Manual	<11	1,520	13	<260	<35	**1,030**	969	<65	377
MFC-A-01	MFC-A-01 _3-4”	0.29	Manual	<11	1,240	<12	<260	51	**1,040**	861	<65	346
MFC-A-01	MFC-A-01 _4-5”	0.38	Manual	<11	1,180	<12	<260	48	**1,160**	985	80	365
MFC-A-01	MFC-A-01 _5-6”	0.46	Manual	<11	1,470	<12	<260	50	**1,320**	1,160	<65	396
MFC-A-01	MFC-A-01 _6-9”	0.63	Manual	<11	1,150	<12	<260	45	**1,160**	1,030	<65	372
MFC-A-01	MFC-A-01 _9-12”	0.88	Manual	<11	1,060	<12	292	49	**1,420**	1,120	<65	389
MFC-A-01	MFC-A-01 _12-18”	1.25	Manual	<11	847	13	<260	73	**2,580**	1,170	<65	476
MFC-A-01	MFC-A-01 _18-24”	1.75	Manual	<11	603	<12	<260	93	**4,080**	1,340	<65	591
MFC-A-01	MFC-A-01 _24-36”	2.50	Manual	<11	806	17	<260	169	**7,340**	1,540	78	967
MFC-A-03	MFC-A-03_0-1”	0.04	Manual	<11	1,170	<12	<260	50	**928**	896	<65	438
MFC-A-03	MFC-A-03_1-2”	0.13	Manual	<11	1,140	<12	<260	60	**1,040**	1,050	<65	455
MFC-A-03	MFC-A-03_2-3”	0.21	Manual	<11	1,290	<12	<260	66	**1,080**	1,040	<65	442
MFC-A-03	MFC-A-03_3-4”	0.29	Manual	<11	1,400	<12	<260	82	**1,140**	1,100	75	439
MFC-A-03	MFC-A-03_4-5”	0.38	Manual	<11	1,430	<12	<260	69	**1,330**	1,170	<65	456
MFC-A-03	MFC-A-03_5-6”	0.46	Manual	<11	1,430	<12	<260	78	**1,410**	1,210	<65	445
MFC-A-03	MFC-A-03_6-9”	0.63	Manual	<11	1,510	<12	<260	<35	**1,420**	1,100	<65	442
MFC-A-03	MFC-A-03_9-12”	0.88	Manual	33	1,400	<12	273	95	**1,530**	1,190	<65	438
MFC-B-00	MFC-B-00_0-1”	0.04	Manual	<11	1,730	<12	<260	<35	151	585	<65	236

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mineral Fork flood plain—Continued												
MFC-B-00	MFC-B-00_1-2”	0.13	Manual	<11	1,590	<12	<260	<35	150	532	<65	220
MFC-B-00	MFC-B-00_2-3”	0.21	Manual	<11	1,460	<12	<260	<35	134	469	<65	190
MFC-B-00	MFC-B-00_3-4”	0.29	Manual	<11	1,370	<12	<260	<35	105	390	<65	146
MFC-B-00	MFC-B-00_4-5”	0.38	Manual	<11	1,470	<12	<260	<35	80	291	73	127
MFC-B-00	MFC-B-00_5-6”	0.46	Manual	<11	1,320	<12	<260	<35	86	380	<65	127
MFC-B-00	MFC-B-00_6-9”	0.63	Manual	<11	1,260	<12	<260	<35	93	369	<65	139
MFC-B-00	MFC-B-00_9-12”	0.88	Manual	<11	2,110	<12	<260	<35	160	452	<65	189
MFC-B-01	MFC-B-01_0-1”	0.04	Manual	<11	175	<12	<260	<35	97	678	<65	162
MFC-B-01	MFC-B-01_1-2”	0.13	Manual	<11	553	<12	<260	<35	128	791	<65	205
MFC-B-01	MFC-B-01_2-3”	0.21	Manual	<11	464	<12	<260	43	103	591	<65	173
MFC-B-01	MFC-B-01_3-4”	0.29	Manual	<11	711	<12	<260	40	128	861	<65	191
MFC-B-01	MFC-B-01_4-5”	0.38	Manual	<11	549	<12	<260	38	101	718	73	182
MFC-B-01	MFC-B-01_5-6”	0.46	Manual	<11	695	<12	<260	40	120	830	<65	192
MFC-B-01	MFC-B-01_6-9”	0.63	Manual	<11	656	<12	<260	<35	130	865	<65	212
MFC-B-01	MFC-B-01_9-12”	0.88	Manual	<11	573	<12	<260	38	100	804	<65	189
MFC-B-01	MFC-B-01_0.2	0.2	Core	<11	705	<12	<260	51	118	517	<65	203
MFC-B-01	MFC-B-01_0.5	0.5	Core	<11	786	<12	<260	<35	110	822	<65	169
MFC-B-01	MFC-B-01_0.8	0.8	Core	<11	659	<12	<260	<35	86	699	<65	175
MFC-B-01	MFC-B-01_1.2	1.2	Core	<11	679	<12	<260	<35	83	522	<65	151
MFC-B-01	MFC-B-01_1.5	1.5	Core	<11	675	<12	<260	<35	65	319	<65	117
MFC-B-01	MFC-B-01_1.8	1.8	Core	<11	781	<12	<260	<35	72	422	<65	123
MFC-B-01	MFC-B-01_2.2	2.2	Core	<11	641	<12	<260	<35	56	449	<65	125
MFC-B-01	MFC-B-01_2.4	2.4	Core	<11	796	<12	<260	<35	65	463	<65	104
MFC-B-01	MFC-B-01_2.8	2.8	Core	<11	687	<12	<260	<35	72	411	<65	117
MFC-B-01	MFC-B-01_3.2	3.2	Core	<11	799	<12	<260	<35	77	677	<65	114
MFC-B-01	MFC-B-01_3.5	3.5	Core	<11	601	<12	304	<35	85	513	<65	122
MFC-B-01	MFC-B-01_3.8	3.8	Core	<11	691	<12	<260	<35	74	609	<65	111
MFC-B-01	MFC-B-01_4.2	4.2	Core	<11	723	<12	<260	<35	63	335	<65	114
MFC-B-01	MFC-B-01_4.5	4.5	Core	<11	730	<12	<260	<35	70	254	<65	122

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mineral Fork flood plain—Continued												
MFC-B-01	MFC-B-01_4.8	4.8	Core	<11	603	<12	<260	<35	45	304	<65	114
MFC-B-01	MFC-B-01_5.2	5.2	Core	<11	730	<12	<260	<35	55	362	<65	100
MFC-B-01	MFC-B-01_5.5	5.5	Core	<11	654	<12	<260	<35	79	596	<65	88
MFC-B-01	MFC-B-01_5.8	5.8	Core	<11	628	<12	<260	<35	60	599	<65	112
MFC-B-01	MFC-B-01_6.2	6.2	Core	<11	683	<12	<260	<35	67	571	<65	120
MFC-B-01	MFC-B-01_6.5	6.5	Core	<11	667	<12	<260	<35	69	564	<65	118
MFC-B-01	MFC-B-01_6.8	6.8	Core	<11	642	<12	<260	<35	41	299	<65	100
MFC-B-01	MFC-B-01_7.2	7.2	Core	<11	701	<12	<260	<35	48	661	<65	126
MFC-B-01	MFC-B-01_7.5	7.5	Core	<11	738	<12	<260	43	74	466	<65	105
MFC-B-01	MFC-B-01_7.8	7.8	Core	<11	728	<12	<260	<35	69	480	<65	131
MFC-B-01	MFC-B-01_8.2	8.2	Core	<11	667	<12	<260	<35	71	682	<65	129
MFC-B-01	MFC-B-01_8.5	8.5	Core	<11	676	<12	<260	53	60	462	<65	108
MFC-B-01	MFC-B-01_8.8	8.8	Core	<11	607	<12	<260	<35	63	977	<65	107
MFC-B-01	MFC-B-01_9.2	9.2	Core	<11	651	<12	<260	57	64	669	<65	108
MFC-B-01	MFC-B-01_9.5	9.5	Core	<11	600	<12	<260	<35	44	147	<65	103
MFC-B-01	MFC-B-01_9.8	9.8	Core	<11	636	<12	<260	<35	28	85	<65	94
MFC-B-01	MFC-B-01_10.2	10.2	Core	<11	646	<12	331	<35	69	85	<65	112
MFC-B-01	MFC-B-01_10.5	10.5	Core	<11	625	<12	<260	<35	44	410	<65	120
MFC-B-01	MFC-B-01_10.8	10.8	Core	<11	683	<12	<260	<35	48	847	<65	114
MFC-B-01	MFC-B-01_11.2	11.2	Core	<11	661	<12	<260	<35	72	1,020	<65	92
MFC-B-01	MFC-B-01_11.5	11.5	Core	<11	836	17	<260	<35	46	1,860	<65	131
MFC-B-01	MFC-B-01_11.8	11.8	Core	<11	756	<12	<260	<35	32	705	<65	137
MFC-B-01	MFC-B-01_12.2	12.2	Core	<11	663	<12	<260	<35	22	255	<65	140
MFC-B-01	MFC-B-01_12.5	12.5	Core	<11	771	<12	<260	<35	69	2,500	<65	165
MFC-B-01	MFC-B-01_12.8	12.8	Core	16	618	<12	<260	<35	<13	169	<65	186
MFC-B-01	MFC-B-01_13.2	13.2	Core	<11	1,160	21	<260	<35	63	10,230	106	287
MFC-B-01	MFC-B-01_13.5	13.5	Core	<11	688	<12	<260	<35	34	1,180	<65	191
MFC-B-01	MFC-B-01_13.8	13.8	Core	<11	583	<12	<260	<35	19	405	<65	192
MFC-B-01	MFC-B-01_14.2	14.2	Core	<11	718	16	<260	<35	43	1,410	<65	236

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mineral Fork flood plain—Continued												
MFC-B-01	MFC-B-01_14.5	14.5	Core	<11	714	<12	<260	<35	50	1,040	<65	255
MFC-B-01	MFC-B-01_14.8	14.8	Core	<11	817	<12	<260	<35	37	1,370	<65	310
MFC-B-01	MFC-B-01_15.2	15.2	Core	<11	760	<12	<260	<35	125	1,270	71	389
MFC-B-02	MFC-B-02_0.2	0.2	Core	<11	547	<12	<260	<35	82	250	<65	170
MFC-B-02	MFC-B-02_0.5	0.5	Core	<11	659	<12	<260	<35	55	187	<65	123
MFC-B-02	MFC-B-02_0.75	0.8	Core	<11	518	<12	<260	<35	49	365	<65	133
MFC-B-02	MFC-B-02_1.2	1.2	Core	<11	479	<12	<260	<35	30	275	<65	167
MFC-B-02	MFC-B-02_1.5	1.5	Core	<11	436	<12	<260	<35	46	278	<65	180
MFC-B-02	MFC-B-02_1.7	1.7	Core	<11	430	<12	<260	50	34	85	88	178
MFC-B-02	MFC-B-02_2.2	2.2	Core	<11	607	<12	<260	<35	151	4,010	97	247
MFC-B-02	MFC-B-02_2.5	2.5	Core	<11	602	<12	<260	43	50	302	<65	217
MFC-B-02	MFC-B-02_2.7	2.7	Core	<11	573	<12	<260	<35	42	506	90	211
MFC-B-02	MFC-B-02_3.2	3.2	Core	<11	629	<12	<260	<35	35	396	<65	167
MFC-B-02	MFC-B-02_3.5	3.5	Core	<11	613	<12	<260	<35	28	85	<65	186
MFC-B-02	MFC-B-02_3.7	3.7	Core	<11	584	<12	<260	<35	54	132	<65	155
MFC-B-02	MFC-B-02_4.2	4.2	Core	<11	737	<12	<260	<35	45	337	<65	162
MFC-B-02	MFC-B-02_4.5	4.5	Core	<11	592	<12	<260	<35	49	350	<65	133
MFC-B-02	MFC-B-02_4.8	4.8	Core	<11	577	<12	<260	<35	35	140	<65	139
MFC-B-02	MFC-B-02_5.2	5.2	Core	<11	965	<12	<260	<35	161	1,390	<65	146
MFC-B-02	MFC-B-02_5.5	5.5	Core	<11	646	<12	<260	<35	99	929	<65	131
MFC-B-02	MFC-B-02_5.8	5.8	Core	<11	686	<12	<260	<35	43	424	<65	128
MFC-B-02	MFC-B-02_6.2	6.2	Core	<11	638	<12	<260	<35	<13	243	<65	136
MFC-B-02	MFC-B-02_6.5	6.5	Core	<11	695	<12	<260	<35	40	426	<65	117
MFC-B-02	MFC-B-02_6.8	6.8	Core	<11	583	<12	<260	<35	64	1,460	<65	112
MFC-B-02	MFC-B-02_7.2	7.2	Core	<11	516	<12	<260	<35	40	847	<65	116
MFC-B-02	MFC-B-02_7.5	7.5	Core	<11	623	<12	<260	<35	25	85	<65	93
MFC-B-02	MFC-B-02_7.8	7.8	Core	<11	589	<12	<260	<35	19	399	<65	105
MFC-B-02	MFC-B-02_8.2	8.2	Core	<11	556	<12	<260	<35	<13	173	<65	123
MFC-B-02	MFC-B-02_8.5	8.5	Core	<11	694	<12	<260	<35	20	367	<65	73

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mineral Fork flood plain—Continued												
MFC-B-02	MFC-B-02_8.8	8.8	Core	<11	709	<12	<260	<35	<13	907	<65	98
MFC-B-02	MFC-B-02_9.1	9.1	Core	<11	582	<12	<260	<35	<13	85	78	100
MFC-B-02	MFC-B-02_9.3	9.3	Core	<11	635	<12	<260	<35	<13	85	<65	81
MFC-B-02	MFC-B-02_9.5	9.5	Core	<11	708	<12	<260	<35	31	862	<65	77
MFC-B-02	MFC-B-02_9.7	9.7	Core	16	706	<12	<260	<35	<13	190	<65	119
MFC-B-02	MFC-B-02_9.9	9.9	Core	<11	679	<12	<260	<35	<13	298	<65	137
MFC-B-02	MFC-B-02_10.2	10.2	Core	<11	663	<12	<260	<35	55	563	<65	173
MFC-B-02	MFC-B-02_10.5	10.5	Core	<11	592	14	<260	<35	<13	85	<65	170
MFC-B-02	MFC-B-02_10.8	10.8	Core	<11	498	<12	<260	<35	24	85	<65	316
MFC-B-03	MFC-B-03_0-1”	0.04	Manual	17	156	<12	<260	49	42	366	<65	138
MFC-B-03	MFC-B-03_1-2”	0.13	Manual	<11	128	<12	<260	37	34	294	<65	108
MFC-B-03	MFC-B-03_2-3”	0.21	Manual	<11	212	<12	<260	<35	46	359	<65	118
MFC-B-03	MFC-B-03_3-4”	0.29	Manual	<11	481	<12	<260	<35	78	559	<65	148
MFC-B-03	MFC-B-03_4-5”	0.38	Manual	<11	360	<12	<260	<35	54	429	<65	126
MFC-B-03	MFC-B-03_5-6”	0.46	Manual	<11	211	<12	<260	38	52	402	67	126
MFC-B-03	MFC-B-03_6-9”	0.63	Manual	<11	328	<12	<260	38	52	325	<65	130
MFC-B-03	MFC-B-03_9-12”	0.88	Manual	<11	446	<12	<260	42	62	314	<65	137
MFC-B-03	MFC-B-03_0.2	0.2	Core	<11	583	<12	<260	57	51	1,180	<65	154
MFC-B-03	MFC-B-03_0.5	0.5	Core	<11	452	<12	<260	<35	36	688	<65	115
MFC-B-03	MFC-B-03_0.8	0.8	Core	<11	620	<12	<260	<35	44	280	<65	97
MFC-B-03	MFC-B-03_1.2	1.2	Core	<11	339	<12	<260	48	43	232	<65	132
MFC-B-03	MFC-B-03_1.5	1.5	Core	<11	477	<12	<260	<35	33	231	<65	116
MFC-B-03	MFC-B-03_1.8	1.8	Core	<11	596	16	<260	<35	47	301	<65	153
MFC-B-03	MFC-B-03_2.2	2.2	Core	<11	486	<12	<260	<35	34	289	<65	178
MFC-B-03	MFC-B-03_2.5	2.5	Core	<11	570	19	<260	<35	45	712	<65	186
MFC-B-03	MFC-B-03_2.8	2.8	Core	<11	577	<12	<260	<35	37	280	<65	181
MFC-B-03	MFC-B-03_3.2	3.2	Core	<11	579	<12	<260	<35	40	887	<65	209
MFC-B-03	MFC-B-03_3.5	3.5	Core	<11	579	<12	279	<35	26	147	<65	147
MFC-B-03	MFC-B-03_3.8	3.8	Core	<11	602	<12	<260	45	<13	85	<65	210

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ", denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mineral Fork flood plain—Continued												
MFC-B-03	MFC-B-03_4.2	4.2	Core	<11	589	<12	<260	<35	61	896	<65	124
MFC-B-03	MFC-B-03_4.5	4.5	Core	<11	565	<12	<260	<35	40	263	<65	131
MFC-B-03	MFC-B-03_4.8	4.8	Core	<11	606	<12	<260	<35	77	1,270	<65	168
MFC-B-03	MFC-B-03_5.2	5.2	Core	<11	597	<12	<260	<35	32	168	<65	133
MFC-B-03	MFC-B-03_5.5	5.5	Core	<11	532	<12	<260	<35	35	173	<65	138
MFC-B-03	MFC-B-03_5.8	5.8	Core	<11	591	<12	<260	<35	27	158	<65	126
MFC-B-03	MFC-B-03_6.2	6.2	Core	<11	612	<12	<260	<35	58	1,100	<65	159
MFC-B-03	MFC-B-03_6.5	6.5	Core	<11	621	<12	<260	<35	34	654	<65	138
MFC-B-03	MFC-B-03_6.8	6.8	Core	<11	575	<12	<260	<35	<13	85	77	91
MFC-B-03	MFC-B-03_7.2	7.2	Core	<11	665	<12	<260	54	<13	85	<65	105
MFC-B-03	MFC-B-03_7.5	7.5	Core	<11	593	<12	<260	<35	86	177	<65	100
MFC-B-03	MFC-B-03_7.8	7.8	Core	<11	804	<12	<260	<35	61	2,400	<65	133
MFC-B-03	MFC-B-03_8.2	8.2	Core	<11	603	<12	<260	<35	21	85	<65	98
MFC-B-03	MFC-B-03_8.4	8.4	Core	<11	636	<12	<260	63	<13	85	<65	97
MFC-B-03	MFC-B-03_8.6	8.6	Core	<11	635	<12	<260	<35	<13	85	<65	99
MFC-B-03	MFC-B-03_8.8	8.8	Core	<11	601	<12	<260	<35	<13	85	<65	92
MFC-B-03	MFC-B-03_8.9	8.9	Core	<11	699	<12	<260	<35	<13	223	<65	128
MFC-B-03	MFC-B-03_9	9.0	Core	<11	708	<12	<260	<35	<13	1,840	103	92
MFC-B-03	MFC-B-03_9.2	9.2	Core	<11	710	<12	<260	<35	<13	261	<65	96
MFC-B-03	MFC-B-03_9.4	9.4	Core	<11	680	<12	<260	<35	<13	85	<65	98
MFC-B-04	MFC-B-04_0.2	0.2	Core	<11	400	<12	<260	<35	36	785	<65	117
MFC-B-04	MFC-B-04_0.5	0.5	Core	<11	562	15	<260	<35	43	1,920	<65	149
MFC-B-04	MFC-B-04_0.8	0.8	Core	<11	538	<12	<260	<35	36	1,390	<65	149
MFC-B-04	MFC-B-04_1.2	1.2	Core	<11	544	<12	<260	<35	42	263	<65	158
MFC-B-04	MFC-B-04_1.5	1.5	Core	<11	617	14	<260	<35	40	204	<65	158
MFC-B-04	MFC-B-04_1.8	1.8	Core	<11	589	<12	<260	<35	39	236	<65	167
MFC-B-04	MFC-B-04_2.2	2.2	Core	<11	625	<12	<260	<35	37	324	<65	150
MFC-B-04	MFC-B-04_2.5	2.5	Core	<11	587	<12	<260	<35	51	739	<65	188
MFC-B-04	MFC-B-04_2.8	2.8	Core	<11	601	<12	<260	48	46	518	<65	196

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mineral Fork flood plain—Continued												
MFC-B-04	MFC-B-04_3.2	3.2	Core	<11	510	<12	<260	<35	37	943	<65	155
MFC-B-04	MFC-B-04_3.5	3.5	Core	<11	575	<12	<260	<35	40	139	<65	152
MFC-B-04	MFC-B-04_3.8	3.8	Core	<11	606	<12	<260	<35	35	504	<65	177
MFC-B-04	MFC-B-04_4.2	4.2	Core	<11	494	<12	<260	<35	31	372	<65	191
MFC-B-04	MFC-B-04_4.5	4.5	Core	<11	616	<12	<260	<35	48	731	<65	153
MFC-B-04	MFC-B-04_4.8	4.8	Core	<11	521	<12	<260	<35	30	189	<65	176
MFC-B-04	MFC-B-04_5.2	5.2	Core	<11	559	<12	<260	<35	39	916	<65	149
MFC-B-04	MFC-B-04_5.5	5.5	Core	<11	592	<12	<260	<35	22	296	<65	159
MFC-B-04	MFC-B-04_5.8	5.8	Core	<11	524	<12	<260	<35	25	453	<65	149
MFC-B-04	MFC-B-04_6.2	6.2	Core	<11	511	<12	<260	58	24	267	<65	167
MFC-B-04	MFC-B-04_6.5	6.5	Core	<11	546	<12	<260	<35	28	198	<65	156
MFC-B-04	MFC-B-04_6.8	6.8	Core	<11	559	<12	<260	<35	38	1,220	<65	139
MFC-B-04	MFC-B-04_7.2	7.2	Core	<11	586	<12	<260	<35	44	725	<65	145
MFC-B-04	MFC-B-04_7.5	7.5	Core	<11	629	<12	<260	<35	29	969	<65	145
MFC-B-04	MFC-B-04_7.8	7.8	Core	<11	565	<12	<260	<35	21	589	<65	123
MFC-B-04	MFC-B-04_8.2	8.2	Core	16	578	<12	<260	<35	<13	480	<65	129
MFC-B-04	MFC-B-04_8.5	8.5	Core	<11	551	<12	<260	53	31	343	<65	137
MFC-B-04	MFC-B-04_8.8	8.8	Core	<11	523	<12	<260	<35	<13	393	<65	122
MFC-B-04	MFC-B-04_9.2	9.2	Core	<11	544	<12	<260	<35	<13	85	<65	108
MFC-B-04	MFC-B-04_9.5	9.5	Core	<11	531	<12	<260	<35	18	85	<65	109
MFC-B-04	MFC-B-04_9.8	9.8	Core	<11	595	<12	<260	<35	25	176	<65	118
MFC-B-04	MFC-B-04_10.2	10.2	Core	<11	580	<12	<260	<35	28	669	76	109
MFC-B-04	MFC-B-04_10.5	10.5	Core	<11	542	<12	<260	<35	29	569	<65	127
MFC-B-04	MFC-B-04_10.8	10.8	Core	<11	592	<12	<260	<35	35	607	<65	148
MFC-B-04	MFC-B-04_11.2	11.2	Core	<11	536	<12	<260	50	19	85	<65	150
MFC-B-04	MFC-B-04_11.5	11.5	Core	<11	752	<12	<260	<35	59	5,680	127	158
MFC-B-04	MFC-B-04_11.7	11.7	Core	<11	592	<12	<260	58	<13	85	<65	153
MFC-B-05	MFC-B-05_0-1”	0.04	Manual	<11	<100	<12	<260	38	38	306	66	154
MFC-B-05	MFC-B-05_1-2”	0.13	Manual	<11	<100	<12	<260	37	46	353	66	138

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mineral Fork flood plain—Continued												
MFC-B-05	MFC-B-05_2-3”	0.21	Manual	<11	177	<12	<260	40	49	370	<65	169
MFC-B-05	MFC-B-05_3-4”	0.29	Manual	<11	253	<12	<260	41	53	380	<65	171
MFC-B-05	MFC-B-05_4-5”	0.38	Manual	<11	245	<12	<260	<35	45	273	<65	163
MFC-B-05	MFC-B-05_5-6”	0.46	Manual	13	302	<12	<260	<35	44	404	<65	181
MFC-B-05	MFC-B-05_6-9”	0.63	Manual	<11	269	<12	<260	<35	42	432	<65	179
MFC-B-05	MFC-B-05_9-12”	0.88	Manual	<11	228	<12	<260	<35	35	301	67	185
MFC-B-05	MFC-B-05_0.2	0.2	Core	<11	302	<12	<260	<35	61	536	<65	163
MFC-B-05	MFC-B-05_0.5	0.5	Core	<11	501	<12	<260	55	45	579	<65	156
MFC-B-05	MFC-B-05_0.8	0.8	Core	<11	443	<12	<260	<35	<13	298	<65	154
MFC-B-05	MFC-B-05_1.2	1.2	Core	17	541	<12	<260	<35	19	543	<65	152
MFC-B-05	MFC-B-05_1.5	1.5	Core	<11	547	<12	<260	47	46	1,110	<65	162
MFC-B-05	MFC-B-05_1.8	1.8	Core	<11	561	<12	<260	62	57	515	<65	220
MFC-B-05	MFC-B-05_2.2	2.2	Core	<11	602	15	<260	<35	39	621	<65	230
MFC-B-05	MFC-B-05_2.5	2.5	Core	<11	665	<12	<260	<35	27	449	<65	191
MFC-B-05	MFC-B-05_2.8	2.8	Core	<11	747	<12	<260	<35	50	541	<65	229
MFC-B-05	MFC-B-05_3.2	3.2	Core	<11	656	<12	<260	<35	35	265	<65	203
MFC-B-05	MFC-B-05_3.5	3.5	Core	<11	626	<12	<260	<35	41	459	<65	199
MFC-B-05	MFC-B-05_3.8	3.8	Core	20	650	<12	<260	<35	25	633	<65	184
MFC-B-05	MFC-B-05_4.2	4.2	Core	<11	708	19	<260	<35	32	263	<65	213
MFC-B-05	MFC-B-05_4.5	4.5	Core	<11	674	15	<260	<35	42	1,300	<65	194
MFC-B-05	MFC-B-05_4.8	4.8	Core	15	641	<12	<260	<35	<13	512	85	220
MFC-B-05	MFC-B-05_5.2	5.2	Core	<11	591	<12	<260	<35	31	491	<65	191
MFC-B-05	MFC-B-05_5.5	5.5	Core	<11	669	<12	<260	<35	37	388	<65	189
MFC-B-05	MFC-B-05_5.8	5.8	Core	<11	667	<12	<260	<35	45	479	<65	214
MFC-B-05	MFC-B-05_6.2	6.2	Core	<11	571	<12	<260	<35	43	1,160	<65	163
MFC-B-05	MFC-B-05_6.5	6.5	Core	<11	634	14	<260	47	45	1,100	<65	196
MFC-B-05	MFC-B-05_6.8	6.8	Core	20	627	<12	<260	<35	25	752	<65	161
MFC-B-05	MFC-B-05_7.2	7.2	Core	22	618	<12	<260	<35	65	3,460	83	201
MFC-B-05	MFC-B-05_7.5	7.5	Core	<11	556	<12	<260	<35	30	292	<65	115

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ", denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mineral Fork flood plain—Continued												
MFC-B-05	MFC-B-05_7.8	7.8	Core	<11	651	<12	<260	<35	<13	544	<65	124
MFC-B-05	MFC-B-05_8.2	8.2	Core	<11	563	<12	<260	<35	<13	488	<65	130
MFC-B-05	MFC-B-05_8.5	8.5	Core	<11	561	<12	<260	<35	24	381	<65	142
MFC-B-05	MFC-B-05_8.8	8.8	Core	<11	574	<12	<260	<35	24	314	<65	129
MFC-B-05	MFC-B-05_9.2	9.2	Core	<11	454	<12	<260	<35	22	215	<65	101
MFC-B-05	MFC-B-05_9.5	9.5	Core	<11	508	<12	<260	<35	<13	85	<65	156
MFC-B-05	MFC-B-05_9.8	9.8	Core	<11	650	<12	<260	<35	31	486	<65	171
MFC-B-05	MFC-B-05_10.2	10.2	Core	<11	550	<12	<260	<35	<13	460	<65	149
MFC-B-05	MFC-B-05_10.5	10.5	Core	<11	535	<12	<260	<35	<13	250	<65	146
MFC-B-05	MFC-B-05_10.8	10.8	Core	<11	615	17	<260	<35	30	904	<65	215
MFC-B-05	MFC-B-05_11.2	11.2	Core	<11	935	16	<260	<35	32	5,680	<65	225
MFC-B-05	MFC-B-05_11.5	11.5	Core	<11	409	<12	<260	<35	26	141	<65	171
MFC-B-05	MFC-B-05_11.8	11.8	Core	<11	537	<12	<260	41	18	85	<65	187
MFC-B-05	MFC-B-05_12.2	12.2	Core	21	646	16	<260	<35	48	160	<65	257
MFC-B-05	MFC-B-05_12.5	12.5	Core	<11	531	<12	<260	<35	28	85	<65	239
MFC-B-05	MFC-B-05_12.8	12.8	Core	<11	451	16	<260	48	34	85	<65	255
MFC-B-05	MFC-B-05_13.2	13.2	Core	<11	547	<12	<260	<35	25	179	<65	234
MFC-B-05	MFC-B-05_13.5	13.5	Core	<11	579	22	<260	<35	22	85	<65	234
MFC-B-05	MFC-B-05_13.8	13.8	Core	<11	488	<12	<260	<35	<13	85	<65	174
MFC-B-05	MFC-B-05_14.1	14.1	Core	<11	585	<12	<260	<35	<13	85	<65	173
MFC-B-05	MFC-B-05_14.3	14.3	Core	<11	577	<12	<260	<35	20	85	<65	188
MFC-B-05	MFC-B-05_14.5	14.5	Core	<11	669	<12	<260	<35	<13	168	<65	175
Fourche Renault Creek flood plain (tributary of Mineral Fork)												
FR-01	FR-01_0-1"	0.04	Manual	<11	<100	<12	<260	46	56	668	<65	93
FR-01	FR-01_1-2"	0.13	Manual	<11	145	<12	<260	<35	64	684	<65	101
FR-01	FR-01_2-3"	0.21	Manual	<11	157	<12	<260	<35	54	660	<65	81
FR-01	FR-01_3-4"	0.29	Manual	<11	196	<12	<260	44	52	699	<65	81
FR-01	FR-01_4-5"	0.38	Manual	<11	184	<12	<260	41	60	715	<65	94
FR-01	FR-01_5-6"	0.46	Manual	<11	214	<12	<260	37	48	672	<65	85

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault Creek flood plain (tributary of Mineral Fork)—Continued												
FR-01	FR-01_6-9”	0.63	Manual	<11	256	<12	<260	41	52	746	70	88
FR-01	FR-01_9-12”	0.88	Manual	<11	272	<12	<260	37	60	860	70	119
FR-01	FR-01_0.5	0.5	Core	<11	457	15	<260	<35	56	711	<65	93
FR-01	FR-01_0.8	0.8	Core	21	447	<12	<260	<35	31	619	<65	78
FR-01	FR-01_1.2	1.2	Core	<11	407	<12	<260	<35	57	797	<65	109
FR-01	FR-01_1.5	1.5	Core	<11	391	<12	<260	<35	77	1,130	<65	119
FR-01	FR-01_1.8	1.8	Core	<11	372	<12	<260	<35	62	992	<65	133
FR-01	FR-01_2.2	2.2	Core	<11	379	<12	<260	<35	74	941	<65	131
FR-01	FR-01_2.5	2.5	Core	<11	<100	<12	<260	<35	62	753	<65	118
FR-01	FR-01_2.8	2.8	Core	<11	625	20	<260	<35	56	779	<65	117
FR-01	FR-01_3.2	3.2	Core	<11	291	<12	<260	<35	70	777	<65	123
FR-01	FR-01_3.5	3.5	Core	<11	428	<12	<260	<35	78	823	<65	110
FR-01	FR-01_3.8	3.8	Core	<11	488	<12	<260	<35	63	897	<65	115
FR-01	FR-01_4.2	4.2	Core	<11	506	<12	<260	<35	44	541	<65	110
FR-01	FR-01_4.6	4.6	Core	<11	228	<12	<260	<35	46	174	<65	99
FR-01	FR-01_5	5.0	Core	<11	464	20	<260	<35	<13	85	124	<25
FR-02	FR-02_0.2	0.2	Core	<11	178	<12	<260	<35	64	841	<65	100
FR-02	FR-02_0.5	0.5	Core	<11	466	15	<260	<35	47	719	<65	95
FR-02	FR-02_0.8	0.8	Core	<11	200	<12	<260	<35	51	661	<65	87
FR-02	FR-02_1.2	1.2	Core	<11	211	<12	<260	<35	32	300	<65	76
FR-02	FR-02_1.5	1.5	Core	<11	322	<12	<260	<35	39	547	<65	90
FR-02	FR-02_1.8	1.8	Core	<11	298	<12	<260	<35	39	598	<65	85
FR-02	FR-02_2.2	2.2	Core	<11	343	<12	<260	<35	58	616	<65	75
FR-02	FR-02_2.5	2.5	Core	<11	182	<12	<260	<35	52	710	88	89
FR-02	FR-02_2.8	2.8	Core	<11	417	14	<260	<35	36	523	<65	63
FR-02	FR-02_3.2	3.2	Core	<11	262	15	<260	<35	31	436	<65	48
FR-02	FR-02_3.5	3.5	Core	<11	295	<12	<260	<35	<13	261	<65	57
FR-02	FR-02_3.8	3.8	Core	<11	410	44	<260	<35	<13	755	<65	34
FR-02	FR-02_4.2	4.2	Core	<11	263	27	<260	<35	<13	85	<65	<25

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

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Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault Creek flood plain (tributary of Mineral Fork)—Continued												
FR-02	FR-02_4.5	4.5	Core	<11	449	26	<260	<35	<13	212	<65	<25
FR-02	FR-02_4.8	4.8	Core	12	263	<12	<260	<35	<13	85	<65	32
FR-02	FR-02_5.2	5.2	Core	19	428	33	<260	<35	<13	85	<65	39
FR-02	FR-02_5.5	5.5	Core	<11	344	18	<260	<35	<13	85	<65	<25
FR-02	FR-02_5.8	5.8	Core	<11	409	18	<260	<35	<13	203	<65	<25
FR-02	FR-02_6.2	6.2	Core	<11	274	<12	<260	<35	<13	186	<65	31
FR-02	FR-02_6.5	6.5	Core	<11	492	32	<260	<35	<13	262	<65	31
FR-02	FR-02_6.8	6.8	Core	<11	351	23	<260	<35	<13	136	<65	<25
FR-02	FR-02_7.2	7.2	Core	<11	242	16	<260	<35	<13	85	78	<25
FR-02	FR-02_7.5	7.5	Core	<11	<100	<12	<260	<35	<13	180	<65	<25
FR-02	FR-02_7.8	7.8	Core	<11	367	37	<260	<35	<13	302	<65	37
FR-02	FR-02_8.2	8.2	Core	<11	<100	20	<260	<35	<13	270	<65	<25
FR-02	FR-02_8.5	8.5	Core	<11	386	28	<260	<35	<13	145	<65	28
FR-02	FR-02_8.8	8.8	Core	<11	335	16	<260	<35	<13	85	<65	39
FR-02	FR-02_9.2	9.2	Core	<11	261	<12	<260	<35	<13	85	<65	35
FR-02	FR-02_9.5	9.5	Core	<11	275	22	<260	<35	<13	85	<65	<25
FR-02	FR-02_9.8	9.8	Core	<11	220	20	<260	<35	<13	85	<65	31
FR-02	FR-02_10.2	10.2	Core	<11	164	15	<260	<35	<13	125	<65	<25
FR-02	FR-02_10.5	10.5	Core	<11	<100	<12	<260	<35	<13	85	<65	<25
FR-02	FR-02_10.8	10.8	Core	<11	179	35	<260	<35	<13	85	<65	32
FR-02	FR-02_11.2	11.2	Core	<11	180	40	<260	<35	<13	85	<65	<25
FR-02	FR-02_11.5	11.5	Core	15	440	32	<260	<35	<13	85	<65	<25
FR-02	FR-02_11.8	11.8	Core	<11	328	40	<260	<35	<13	85	<65	37
FR-02	FR-02_12.2	12.2	Core	<11	315	24	<260	<35	<13	85	<65	<25
FR-02	FR-02_12.5	12.5	Core	<11	173	<12	<260	<35	<13	85	<65	<25
FR-02	FR-02_12.8	12.8	Core	<11	274	26	<260	<35	34	85	<65	<25
FR-02	FR-02_13.2	13.2	Core	<11	382	25	<260	<35	<13	192	<65	<25
FR-02	FR-02_13.5	13.5	Core	<11	283	18	<260	<35	<13	255	<65	44
FR-02	FR-02_13.8	13.8	Core	<11	282	19	<260	<35	<13	184	<65	<25

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault Creek flood plain (tributary of Mineral Fork)—Continued												
FR-02	FR-02_14.2	14.2	Core	<11	425	26	<260	<35	<13	394	<65	58
FR-02	FR-02_14.5	14.5	Core	<11	119	<12	<260	<35	<13	288	<65	51
FR-02	FR-02_14.8	14.8	Core	<11	339	31	<260	<35	<13	447	<65	59
FR-02	FR-02_15.2	15.2	Core	<11	216	17	<260	<35	<13	435	<65	49
FR-02	FR-02_15.5	15.5	Core	<11	345	24	<260	<35	<13	373	<65	39
FR-02	FR-02_15.8	15.8	Core	<11	288	<12	<260	<35	<13	402	<65	40
FR-02	FR-02_16.2	16.2	Core	<11	568	77	<260	<35	<13	85	<65	<25
FR-02	FR-02_16.5	16.5	Core	<11	421	21	<260	<35	24	373	<65	53
FR-02	FR-02_16.8	16.8	Core	<11	326	<12	<260	<35	19	431	77	35
FR-02	FR-02_17.2	17.2	Core	<11	320	23	<260	<35	29	395	<65	32
FR-02	FR-02_17.5	17.5	Core	<11	326	19	<260	<35	<13	396	<65	<25
FR-02	FR-02_17.8	17.8	Core	<11	404	25	<260	<35	<13	261	<65	37
FR-02	FR-02_18.2	18.2	Core	<11	306	31	<260	<35	<13	277	<65	32
FR-02	FR-02_18.4	18.4	Core	<11	296	30	<260	<35	27	462	<65	42
FR-02	FR-02_18.6	18.6	Core	<11	519	43	<260	<35	<13	181	<65	<25
FR-03	FR-03_0-1”	0.04	Manual	<11	193	<12	<260	41	52	610	<65	85
FR-03	FR-03_1-2”	0.13	Manual	13	204	<12	<260	44	35	614	<65	86
FR-03	FR-03_2-3”	0.21	Manual	<11	184	<12	<260	<35	46	668	<65	81
FR-03	FR-03_3-4”	0.29	Manual	<11	172	<12	<260	<35	43	622	<65	79
FR-03	FR-03_4-5”	0.38	Manual	<11	191	<12	<260	<35	45	534	<65	83
FR-03	FR-03_5-6”	0.46	Manual	<11	164	<12	<260	45	44	600	<65	77
FR-03	FR-03_6-9”	0.63	Manual	<11	248	<12	<260	<35	48	626	<65	93
FR-03	FR-03_9-12”	0.88	Manual	<11	260	<12	<260	38	35	631	73	77
FR-03	FR-03_0.2	0.2	Core	<11	<100	21	<260	<35	33	494	<65	85
FR-03	FR-03_0.5	0.5	Core	<11	360	<12	<260	<35	39	477	<65	76
FR-03	FR-03_0.8	0.8	Core	<11	475	<12	<260	<35	44	752	<65	78
FR-03	FR-03_1.2	1.2	Core	<11	106	<12	<260	<35	36	560	<65	89
FR-03	FR-03_1.5	1.5	Core	<11	318	<12	<260	<35	23	473	<65	67
FR-03	FR-03_1.8	1.8	Core	<11	237	<12	<260	<35	38	584	81	62

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault Creek flood plain (tributary of Mineral Fork)—Continued												
FR-03	FR-03_2.2	2.2	Core	<11	179	<12	<260	<35	28	615	<65	39
FR-03	FR-03_2.5	2.5	Core	<11	282	<12	<260	<35	29	336	<65	38
FR-03	FR-03_2.8	2.8	Core	<11	176	20	<260	<35	<13	283	<65	36
FR-03	FR-03_3.2	3.2	Core	<11	<100	<12	<260	<35	<13	85	<65	<25
FR-03	FR-03_3.5	3.5	Core	<11	141	20	<260	<35	<13	85	<65	<25
FR-03	FR-03_3.8	3.8	Core	<11	342	27	<260	<35	<13	202	<65	42
FR-03	FR-03_4.2	4.2	Core	<11	487	27	<260	<35	<13	144	<65	27
FR-03	FR-03_4.5	4.5	Core	<11	263	<12	<260	<35	<13	85	<65	<25
FR-03	FR-03_4.8	4.8	Core	<11	502	42	<260	<35	<13	85	<65	<25
FR-03	FR-03_5.2	5.2	Core	<11	397	19	<260	<35	28	141	<65	30
FR-03	FR-03_5.5	5.5	Core	<11	326	23	<260	<35	<13	279	<65	38
FR-03	FR-03_5.8	5.8	Core	<11	548	37	<260	<35	<13	153	<65	31
FR-03	FR-03_6.2	6.2	Core	<11	276	<12	<260	<35	<13	131	<65	<25
FR-03	FR-03_6.5	6.5	Core	<11	241	17	<260	<35	<13	85	<65	25
FR-03	FR-03_6.8	6.8	Core	<11	225	18	<260	<35	<13	85	<65	<25
FR-03	FR-03_7.2	7.2	Core	<11	234	<12	<260	<35	<13	343	<65	39
FR-03	FR-03_7.5	7.5	Core	<11	243	17	<260	<35	<13	272	<65	<25
FR-03	FR-03_7.8	7.8	Core	<11	395	16	<260	<35	<13	234	<65	33
FR-03	FR-03_12.2	12.2	Core	<11	386	19	<260	<35	37	389	<65	48
FR-03	FR-03_12.5	12.5	Core	<11	183	32	<260	<35	<13	85	<65	<25
FR-03	FR-03_12.8	12.8	Core	<11	290	19	<260	<35	<13	706	<65	<25
FR-03	FR-03_13.2	13.2	Core	<11	286	21	<260	<35	26	291	<65	41
FR-03	FR-03_13.5	13.5	Core	<11	309	22	<260	<35	21	250	<65	36
FR-03	FR-03_13.8	13.8	Core	<11	255	23	<260	<35	<13	313	<65	34
FR-03	FR-03_14.2	14.2	Core	<11	359	25	<260	<35	<13	788	<65	56
FR-03	FR-03_14.5	14.5	Core	<11	348	<12	<260	<35	35	998	<65	78
FR-03	FR-03_14.8	14.8	Core	<11	333	<12	<260	<35	22	804	<65	75
FR-03	FR-03_15.2	15.2	Core	<11	455	32	<260	45	<13	489	<65	34
FR-03	FR-03_15.5	15.5	Core	<11	255	16	<260	<35	26	694	<65	75

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault Creek flood plain (tributary of Mineral Fork)—Continued												
FR-03	FR-03_15.8	15.8	Core	<11	385	24	<260	<35	18	698	<65	52
FR-04	FR-04_0.2	0.2	Core	<11	293	<12	<260	<35	67	1,090	<65	120
FR-04	FR-04_0.5	0.5	Core	<11	491	18	<260	<35	47	888	<65	99
FR-04	FR-04_0.8	0.8	Core	<11	339	<12	<260	<35	72	841	<65	100
FR-04	FR-04_1.2	1.2	Core	<11	500	15	<260	<35	58	686	<65	106
FR-04	FR-04_1.5	1.5	Core	<11	449	<12	<260	<35	50	813	<65	83
FR-04	FR-04_1.8	1.8	Core	<11	549	<12	<260	<35	42	664	<65	101
FR-04	FR-04_2.2	2.2	Core	<11	530	<12	<260	45	70	861	<65	88
FR-04	FR-04_2.5	2.5	Core	24	302	17	<260	<35	45	581	<65	86
FR-04	FR-04_2.8	2.8	Core	20	493	<12	<260	60	54	1,100	<65	105
FR-04	FR-04_3.2	3.2	Core	<11	515	<12	<260	57	71	839	<65	102
FR-04	FR-04_3.5	3.5	Core	<11	532	<12	<260	<35	55	667	<65	80
FR-04	FR-04_3.8	3.8	Core	<11	677	19	<260	<35	54	691	81	91
FR-04	FR-04_4.2	4.2	Core	<11	514	15	<260	<35	68	732	<65	107
FR-04	FR-04_4.5	4.5	Core	21	408	<12	<260	57	52	773	<65	104
FR-04	FR-04_4.8	4.8	Core	<11	247	31	<260	<35	<13	173	<65	47
FR-04	FR-04_5.2	5.2	Core	<11	268	15	<260	<35	<13	85	<65	39
FR-04	FR-04_5.5	5.5	Core	<11	431	<12	<260	<35	34	339	<65	63
FR-04	FR-04_5.8	5.8	Core	<11	349	17	<260	<35	<13	85	<65	25
FR-05	FR-05_0-1”	0.04	Manual	<11	106	<12	<260	36	16	581	<65	71
FR-05	FR-05_1-2”	0.13	Manual	<11	107	<12	<260	<35	21	580	<65	47
FR-05	FR-05_2-3”	0.21	Manual	<11	114	<12	<260	<35	29	511	<65	50
FR-05	FR-05_3-4”	0.29	Manual	<11	143	<12	<260	<35	19	515	<65	47
FR-05	FR-05_4-5”	0.38	Manual	<11	262	<12	<260	<35	28	546	<65	47
FR-05	FR-05_5-6”	0.46	Manual	<11	233	<12	<260	<35	28	728	<65	54
FR-05	FR-05_6-9”	0.63	Manual	<11	173	<12	<260	<35	29	610	<65	63
FR-05	FR-05_9-12”	0.88	Manual	<11	215	<12	<260	<35	38	581	<65	65
FR-05	FR-05_0.2	0.2	Core	15	364	<12	<260	<35	18	696	<65	35
FR-05	FR-05_0.5	0.5	Core	<11	477	<12	<260	<35	25	662	<65	48

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Fourche Renault Creek flood plain (tributary of Mineral Fork)—Continued												
FR-05	FR-05_0.8	0.8	Core	<11	450	<12	<260	<35	22	717	<65	52
FR-05	FR-05_1.2	1.2	Core	<11	457	14	<260	<35	28	605	<65	66
FR-05	FR-05_1.5	1.5	Core	<11	452	<12	<260	<35	31	498	<65	64
FR-05	FR-05_1.8	1.8	Core	<11	412	<12	<260	<35	32	536	<65	62
FR-05	FR-05_2.2	2.2	Core	<11	408	<12	<260	<35	34	318	<65	69
FR-05	FR-05_2.5	2.5	Core	<11	590	17	<260	<35	37	425	<65	53
FR-05	FR-05_2.8	2.8	Core	<11	473	15	<260	<35	50	572	<65	73
FR-05	FR-05_3.2	3.2	Core	<11	441	20	<260	<35	<13	181	<65	50
FR-05	FR-05_3.5	3.5	Core	<11	324	<12	<260	<35	<13	85	<65	59
FR-05	FR-05_3.8	3.8	Core	<11	409	23	<260	<35	<13	172	<65	56
FR-05	FR-05_4.2	4.2	Core	<11	<100	<12	<260	<35	<13	364	<65	<25
FR-05	FR-05_4.5	4.5	Core	<11	311	<12	<260	<35	28	512	<65	31
FR-05	FR-05_4.8	4.8	Core	<11	503	33	<260	<35	<13	241	<65	52
FR-05	FR-05_5.2	5.2	Core	<11	728	31	<260	<35	24	266	<65	68
FR-05	FR-05_5.5	5.5	Core	<11	413	55	<260	<35	<13	85	<65	<25
FR-05	FR-05_5.8	5.8	Core	<11	127	<12	<260	<35	<13	85	<65	<25
FR-05	FR-05_6.2	6.2	Core	<11	133	<12	<260	<35	41	417	<65	54
FR-05	FR-05_6.4	6.4	Core	<11	134	<12	<260	<35	49	518	143	77
Mill Creek flood plain												
MLC-B-01	ML-B-01_0-1”	0.04	Manual	<11	799	<12	<260	38	96	756	71	214
MLC-B-01	ML-B-01_1-2”	0.13	Manual	<11	969	<12	<260	<35	87	647	<65	223
MLC-B-01	ML-B-01_2-3”	0.21	Manual	<11	890	<12	<260	<35	92	646	<65	227
MLC-B-01	ML-B-01_3-4”	0.29	Manual	16	1,130	<12	<260	<35	96	725	<65	242
MLC-B-01	ML-B-01_4-5”	0.38	Manual	<11	1,110	<12	<260	39	101	789	71	260
MLC-B-01	ML-B-01_5-6”	0.46	Manual	<11	1,120	<12	<260	38	106	720	<65	260
MLC-B-01	ML-B-01_6-9”	0.63	Manual	<11	944	<12	<260	<35	97	719	<65	271
MLC-B-01	ML-B-01_9-12”	0.88	Manual	<11	660	<12	<260	<35	93	648	72	270
MLC-B-01	ML-B-01_0.2	0.2	Core	<11	951	<12	<260	<35	108	801	<65	218
MLC-B-01	ML-B-01_0.5	0.5	Core	<11	1,330	16	<260	74	130	1,100	<65	295

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

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Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-B-01	ML-B-01_0.8	0.8	Core	<11	816	<12	<260	<35	104	747	<65	334
MLC-B-01	ML-B-01_1.2	1.2	Core	<11	826	16	<260	<35	91	557	<65	258
MLC-B-01	ML-B-01_1.5	1.5	Core	<11	881	<12	<260	<35	77	660	<65	250
MLC-B-01	ML-B-01_1.8	1.8	Core	25	632	20	<260	<35	67	491	<65	241
MLC-B-01	ML-B-01_2.2	2.2	Core	<11	779	<12	<260	<35	91	509	<65	278
MLC-B-01	ML-B-01_2.5	2.5	Core	<11	823	<12	<260	<35	63	805	<65	251
MLC-B-01	ML-B-01_2.8	2.8	Core	<11	646	<12	<260	<35	75	484	<65	295
MLC-B-01	ML-B-01_3.2	3.2	Core	<11	950	18	<260	50	53	494	<65	294
MLC-B-01	ML-B-01_3.5	3.5	Core	<11	1,160	17	<260	<35	52	482	<65	260
MLC-B-01	ML-B-01_3.8	3.8	Core	<11	1,070	<12	<260	<35	77	507	<65	377
MLC-B-01	ML-B-01_4.2	4.2	Core	24	892	15	<260	<35	84	562	<65	581
MLC-B-01	ML-B-01_4.5	4.5	Core	<11	571	<12	<260	<35	78	596	<65	519
MLC-B-01	ML-B-01_4.8	4.8	Core	35	656	20	<260	<35	71	508	<65	656
MLC-B-01	ML-B-01_5.2	5.2	Core	<11	510	<12	<260	<35	111	490	<65	672
MLC-B-01	ML-B-01_5.5	5.5	Core	<11	592	22	<260	<35	78	478	<65	565
MLC-B-01	ML-B-01_5.8	5.8	Core	<11	674	24	<260	<35	69	367	<65	506
MLC-B-01	ML-B-01_6.2	6.2	Core	<11	244	21	<260	<35	59	285	<65	472
MLC-B-01	ML-B-01_6.5	6.5	Core	25	641	16	<260	<35	92	615	<65	942
MLC-B-01	ML-B-01_6.8	6.8	Core	<11	523	18	<260	<35	90	737	<65	710
MLC-B-01	ML-B-01_7.2	7.2	Core	<11	588	24	<260	<35	92	664	<65	517
MLC-B-01	ML-B-01_7.5	7.5	Core	<11	459	15	<260	<35	80	410	<65	549
MLC-B-01	ML-B-01_7.8	7.8	Core	<11	419	24	<260	<35	95	348	<65	515
MLC-B-02	ML-B-02_0.2	0.2	Core	<11	242	<12	<260	<35	56	548	<65	202
MLC-B-02	ML-B-02_0.5	0.5	Core	<11	999	<12	<260	<35	92	561	<65	252
MLC-B-02	ML-B-02_0.8	0.8	Core	26	873	<12	<260	<35	64	921	<65	276
MLC-B-02	ML-B-02_1.2	1.2	Core	<11	712	<12	<260	<35	65	707	<65	246
MLC-B-02	ML-B-02_1.5	1.5	Core	<11	569	<12	<260	<35	51	721	<65	238
MLC-B-02	ML-B-02_1.8	1.8	Core	<11	823	23	<260	<35	59	566	<65	292
MLC-B-02	ML-B-02_2.2	2.2	Core	<11	810	<12	<260	<35	60	617	<65	382

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-B-02	ML-B-02_2.5	2.5	Core	21	781	<12	<260	<35	73	707	<65	479
MLC-B-02	ML-B-02_2.8	2.8	Core	<11	789	17	<260	45	95	635	<65	566
MLC-B-02	ML-B-02_3.2	3.2	Core	<11	733	14	<260	<35	86	597	85	593
MLC-B-02	ML-B-02_3.5	3.5	Core	<11	598	<12	<260	<35	91	609	<65	583
MLC-B-02	ML-B-02_3.8	3.8	Core	<11	638	16	<260	<35	151	637	<65	874
MLC-B-02	ML-B-02_4.2	4.2	Core	<11	665	<12	<260	48	183	980	<65	917
MLC-B-02	ML-B-02_4.5	4.5	Core	<11	552	<12	<260	<35	115	796	101	864
MLC-B-02	ML-B-02_4.8	4.8	Core	30	609	<12	<260	<35	112	440	<65	748
MLC-B-02	ML-B-02_5.2	5.2	Core	<11	354	18	<260	<35	80	474	<65	579
MLC-B-02	ML-B-02_5.5	5.5	Core	28	223	<12	<260	<35	47	290	<65	790
MLC-B-02	ML-B-02_5.7	5.7	Core	<11	479	<12	455	<35	71	180	<65	928
MLC-B-03	ML-B-03_0-1”	0.04	Manual	<11	625	<12	<260	43	69	496	<65	227
MLC-B-03	ML-B-03_1-2”	0.13	Manual	<11	498	<12	<260	<35	68	553	<65	215
MLC-B-03	ML-B-03_2-3”	0.21	Manual	<11	660	<12	<260	38	65	532	<65	225
MLC-B-03	ML-B-03_3-4”	0.29	Manual	<11	607	<12	<260	39	71	571	<65	243
MLC-B-03	ML-B-03_4-5”	0.38	Manual	<11	692	<12	<260	<35	70	606	<65	223
MLC-B-03	ML-B-03_5-6”	0.46	Manual	<11	689	<12	<260	43	80	515	<65	240
MLC-B-03	ML-B-03_6-9”	0.63	Manual	<11	633	<12	<260	<35	69	574	<65	225
MLC-B-03	ML-B-03_9-12”	0.88	Manual	<11	686	<12	<260	38	66	623	<65	259
MLC-B-04	ML-B-04_0.2	0.2	Core	<11	681	<12	<260	57	52	326	<65	170
MLC-B-04	ML-B-04_0.5	0.5	Core	<11	858	<12	<260	<35	70	609	<65	168
MLC-B-04	ML-B-04_0.8	0.8	Core	<11	659	<12	<260	<35	52	413	<65	189
MLC-B-04	ML-B-04_1.2	1.2	Core	<11	610	<12	<260	<35	53	401	<65	205
MLC-B-04	ML-B-04_1.5	1.5	Core	<11	606	<12	<260	<35	46	442	<65	199
MLC-B-04	ML-B-04_1.8	1.8	Core	<11	824	17	<260	<35	61	501	<65	216
MLC-B-04	ML-B-04_2.2	2.2	Core	<11	668	<12	<260	<35	52	434	<65	210
MLC-B-04	ML-B-04_2.5	2.5	Core	<11	652	<12	<260	<35	34	451	<65	291
MLC-B-04	ML-B-04_2.8	2.8	Core	<11	696	<12	<260	<35	55	452	<65	390
MLC-B-04	ML-B-04_3.2	3.2	Core	<11	584	<12	<260	<35	50	752	<65	412

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-B-04	ML-B-04_3.5	3.5	Core	<11	640	16	<260	<35	61	568	<65	460
MLC-B-04	ML-B-04_3.8	3.8	Core	<11	560	<12	<260	<35	79	350	<65	383
MLC-B-04	ML-B-04_4.2	4.2	Core	29	674	<12	<260	<35	104	775	<65	659
MLC-B-04	ML-B-04_4.5	4.5	Core	<11	647	17	<260	<35	107	1,050	<65	711
MLC-B-04	ML-B-04_4.8	4.8	Core	<11	275	<12	<260	<35	99	1,270	<65	568
MLC-B-04	ML-B-04_5.2	5.2	Core	23	302	22	<260	<35	33	469	<65	428
MLC-B-04	ML-B-04_5.5	5.5	Core	<11	179	31	<260	<35	<13	85	<65	117
MLC-B-04	ML-B-04_5.8	5.8	Core	<11	220	<12	<260	<35	59	523	<65	351
MLC-B-04	ML-B-04_6.2	6.2	Core	<11	<100	20	<260	<35	<13	85	<65	48
MLC-B-04	ML-B-04_6.5	6.5	Core	<11	386	31	<260	<35	63	720	<65	519
MLC-B-04	ML-B-04_6.8	6.8	Core	<11	512	21	<260	<35	74	1,230	<65	568
MLC-B-04	ML-B-04_7.4	7.4	Core	<11	<100	18	<260	<35	41	679	<65	457
MLC-B-05	ML-B-05_0-1”	0.04	Manual	<11	2,040	<12	<260	<35	114	600	<65	343
MLC-B-05	ML-B-05_1-2”	0.13	Manual	15	1,810	<12	<260	<35	111	644	69	348
MLC-B-05	ML-B-05_2-3”	0.21	Manual	<11	1,370	<12	<260	<35	109	642	<65	301
MLC-B-05	ML-B-05_3-4”	0.29	Manual	16	1,150	<12	<260	47	84	553	<65	296
MLC-B-05	ML-B-05_4-5”	0.38	Manual	14	968	<12	<260	<35	84	510	<65	314
MLC-B-05	ML-B-05_5-6”	0.46	Manual	<11	954	<12	260	40	89	534	<65	299
MLC-B-05	ML-B-05_6-9”	0.63	Manual	<11	786	<12	<260	38	98	560	<65	308
MLC-B-05	ML-B-05_9-12”	0.88	Manual	<11	568	<12	<260	<35	82	386	<65	311
MLC-B-05	ML-B-05_0.2	0.2	Core	<11	1,630	19	<260	<35	92	590	<65	335
MLC-B-05	ML-B-05_0.5	0.5	Core	<11	418	<12	<260	<35	67	574	<65	309
MLC-B-05	ML-B-05_0.8	0.8	Core	<11	758	<12	<260	<35	56	1,440	<65	232
MLC-B-05	ML-B-05_1.2	1.2	Core	<11	646	17	<260	<35	70	517	<65	243
MLC-B-05	ML-B-05_1.5	1.5	Core	<11	763	<12	<260	57	67	674	<65	276
MLC-B-05	ML-B-05_1.8	1.8	Core	<11	815	<12	<260	<35	78	386	<65	277
MLC-B-05	ML-B-05_2.2	2.2	Core	23	1,100	<12	<260	<35	34	347	<65	256
MLC-B-05	ML-B-05_2.5	2.5	Core	<11	1,200	<12	<260	<35	64	331	<65	231
MLC-B-05	ML-B-05_2.8	2.8	Core	<11	1,310	<12	<260	<35	86	523	<65	224

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-B-05	ML-B-05_3.2	3.2	Core	<11	1,340	21	<260	<35	66	383	<65	226
MLC-B-05	ML-B-05_3.5	3.5	Core	<11	1,650	15	<260	<35	52	330	<65	221
MLC-B-05	ML-B-05_3.8	3.8	Core	<11	1,410	<12	<260	<35	82	407	<65	221
MLC-B-05	ML-B-05_4.2	4.2	Core	<11	1,630	15	<260	<35	77	510	<65	215
MLC-B-05	ML-B-05_4.5	4.5	Core	<11	1,570	<12	<260	47	60	277	<65	229
MLC-B-05	ML-B-05_4.8	4.8	Core	<11	1,650	<12	<260	<35	68	471	<65	183
MLC-B-05	ML-B-05_5.2	5.2	Core	<11	1,860	14	<260	<35	89	689	<65	232
MLC-B-05	ML-B-05_5.5	5.5	Core	<11	2,170	17	<260	50	90	295	<65	230
MLC-B-05	ML-B-05_5.8	5.8	Core	<11	1,900	<12	<260	<35	69	333	<65	224
MLC-B-05	ML-B-05_6.2	6.2	Core	<11	1,420	<12	<260	<35	57	134	<65	168
MLC-B-05	ML-B-05_6.5	6.5	Core	23	2,380	<12	<260	<35	78	441	<65	248
MLC-B-05	ML-B-05_6.8	6.8	Core	<11	2,130	<12	<260	<35	48	336	<65	242
MLC-B-05	ML-B-05_7.2	7.2	Core	<11	1,430	<12	<260	<35	78	194	<65	237
MLC-B-05	ML-B-05_7.5	7.5	Core	<11	1,970	<12	<260	<35	74	203	<65	227
MLC-B-05	ML-B-05_7.8	7.8	Core	<11	871	25	<260	<35	39	589	<65	167
MLC-B-05	ML-B-05_8.2	8.2	Core	<11	464	<12	<260	<35	<13	718	<65	149
MLC-B-05	ML-B-05_8.5	8.5	Core	<11	719	54	<260	<35	<13	85	<65	<25
MLC-B-05	ML-B-05_8.8	8.8	Core	<11	255	52	<260	<35	<13	85	<65	<25
MLC-B-05	ML-B-05_9.2	9.2	Core	<11	270	<12	<260	<35	<13	720	<65	<25
MLC-B-05	ML-B-05_9.5	9.5	Core	<11	335	<12	<260	<35	78	85	<65	203
MLC-B-05	ML-B-05_9.8	9.8	Core	<11	582	39	<260	<35	92	85	<65	315
MLC-B-05	ML-B-05_10.2	10.2	Core	<11	631	<12	<260	<35	74	217	<65	289
MLC-B-05	ML-B-05_10.5	10.5	Core	<11	309	<12	<260	<35	30	263	<65	158
MLC-B-05	ML-B-05_10.8	10.8	Core	<11	466	<12	<260	<35	29	153	<65	118
MLC-B-05	ML-B-05_11.2	11.2	Core	<11	592	19	<260	<35	55	867	<65	208
MLC-A-01	MLC-A-01_0-1”	0.04	Manual	<11	2,150	<12	<260	44	120	529	70	305
MLC-A-01	MLC-A-01_1-2”	0.13	Manual	<11	2,260	<12	<260	40	139	496	<65	281
MLC-A-01	MLC-A-01_2-3”	0.21	Manual	<11	2,150	<12	<260	37	134	549	<65	286
MLC-A-01	MLC-A-01_3-4”	0.29	Manual	<11	1,900	<12	<260	<35	127	550	<65	248

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-A-01	MLC-A-01_4-5”	0.38	Manual	<11	1,740	<12	<260	<35	134	526	<65	225
MLC-A-01	MLC-A-01_5-6”	0.46	Manual	<11	1,640	<12	<260	<35	118	484	<65	239
MLC-A-01	MLC-A-01_6-9”	0.63	Manual	15	1,460	<12	<260	<35	108	448	<65	219
MLC-A-01	MLC-A-01_9-12”	0.88	Manual	<11	1,060	13	<260	<35	94	566	<65	251
MLC-A-01	MLC-A-01_0.2	0.2	Core	<11	6,330	<12	<260	<35	43	85	<65	183
MLC-A-01	MLC-A-01_0.5	0.5	Core	<11	5,540	43	<260	<35	<13	85	<65	34
MLC-A-01	MLC-A-01_0.8	0.8	Core	<11	4,400	26	<260	<35	<13	163	<65	99
MLC-A-01	MLC-A-01_1.2	1.2	Core	<11	1,970	<12	<260	<35	105	568	<65	249
MLC-A-01	MLC-A-01_1.5	1.5	Core	<11	2,030	16	<260	<35	157	157	<65	259
MLC-A-01	MLC-A-01_1.8	1.8	Core	<11	3,250	<12	<260	<35	189	2,110	<65	340
MLC-A-01	MLC-A-01_2.2	2.2	Core	<11	1,950	<12	<260	<35	120	655	<65	261
MLC-A-01	MLC-A-01_2.5	2.5	Core	<11	1,620	<12	<260	<35	107	591	<65	240
MLC-A-01	MLC-A-01_2.8	2.8	Core	<11	827	<12	<260	47	110	811	<65	271
MLC-A-01	MLC-A-01_3.2	3.2	Core	<11	1,060	<12	<260	<35	99	788	<65	315
MLC-A-01	MLC-A-01_3.5	3.5	Core	<11	1,030	<12	<260	<35	89	545	<65	290
MLC-A-01	MLC-A-01_3.8	3.8	Core	<11	1,240	20	<260	<35	97	743	<65	341
MLC-A-02	MLC-A-02_0-1”	0.04	Manual	<11	5,930	<12	<260	41	272	1,050	<65	617
MLC-A-02	MLC-A-02_1-2”	0.13	Manual	<11	6,230	<12	<260	52	254	978	80	609
MLC-A-02	MLC-A-02_2-3”	0.21	Manual	<11	5,790	<12	<260	47	241	853	74	557
MLC-A-02	MLC-A-02_3-4”	0.29	Manual	<11	5,710	<12	<260	39	236	820	<65	550
MLC-A-02	MLC-A-02_4-5”	0.38	Manual	<11	5,700	<12	<260	39	227	854	<65	549
MLC-A-02	MLC-A-02_5-6”	0.46	Manual	<11	7,700	<12	<260	42	293	955	<65	630
MLC-A-02	MLC-A-02_6-9”	0.63	Manual	<11	6,870	<12	<260	45	260	863	<65	596
MLC-A-02	MLC-A-02_9-12”	0.88	Manual	<11	8,060	<12	<260	46	307	866	<65	664
MLC-A-02	MLC-A-02_0.2	0.2	Core	62	5,590	<12	<260	<35	271	2,530	<65	745
MLC-A-02	MLC-A-02_0.5	0.5	Core	<11	7,320	<12	<260	<35	342	1,470	<65	801
MLC-A-02	MLC-A-02_0.8	0.8	Core	43	3,930	43	<260	<35	124	515	<65	357
MLC-A-02	MLC-A-02_1.2	1.2	Core	<11	12,200	<12	<260	70	**484**	1,090	<65	1,040
MLC-A-02	MLC-A-02_1.5	1.5	Core	53	13,100	<12	<260	84	**485**	880	<65	985

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-A-02	MLC-A-02_1.8	1.8	Core	<11	10,400	18	<260	<35	351	867	<65	648
MLC-A-02	MLC-A-02_2.2	2.2	Core	<11	6,490	23	<260	<35	269	1,110	<65	496
MLC-A-02	MLC-A-02_2.5	2.5	Core	<11	6,740	<12	<260	<35	157	773	<65	279
MLC-A-02	MLC-A-02_2.8	2.8	Core	<11	4,460	<12	<260	<35	158	899	<65	329
MLC-A-02	MLC-A-02_3.2	3.2	Core	<11	5,590	<12	<260	<35	166	788	<65	291
MLC-A-02	MLC-A-02_3.5	3.5	Core	<11	6,100	<12	<260	49	157	759	<65	284
MLC-A-02	MLC-A-02_3.8	3.8	Core	<11	3,800	<12	<260	<35	181	912	<65	370
MLC-A-02	MLC-A-02_4.2	4.2	Core	<11	2,250	24	<260	<35	130	597	<65	406
MLC-A-02	MLC-A-02_4.5	4.5	Core	<11	1,850	34	<260	<35	83	462	<65	479
MLC-A-02	MLC-A-02_4.8	4.8	Core	<11	1,770	<12	<260	<35	94	750	<65	685
MLC-A-02	MLC-A-02_5.2	5.2	Core	<11	1,500	17	<260	<35	89	843	<65	445
MLC-A-02	MLC-A-02_6.6	6.6	Core	<11	1,130	17	<260	<35	82	602	<65	403
MLC-A-02	MLC-A-02_6.9	6.9	Core	<11	974	21	<260	<35	54	481	<65	301
MLC-A-02	MLC-A-02_7.2	7.2	Core	<11	591	23	<260	<35	25	338	<65	181
MLC-A-02	MLC-A-02_7.5	7.5	Core	<11	679	37	<260	<35	<13	287	<65	105
MLC-A-02	MLC-A-02_7.8	7.8	Core	<11	505	18	<260	<35	<13	172	<65	73
MLC-A-02	MLC-A-02_8.2	8.2	Core	<11	1,060	<12	<260	<35	52	85	<65	1,435
MLC-A-02	MLC-A-02_8.5	8.5	Core	<11	872	42	<260	<35	<13	85	<65	504
MLC-A-02	MLC-A-02_8.8	8.8	Core	<11	3,390	27	<260	<35	81	521	<65	229
MLC-A-02	MLC-A-02_9.2	9.2	Core	<11	5,180	28	<260	<35	102	525	<65	271
MLC-A-02	MLC-A-02_9.5	9.5	Core	<11	3,550	16	<260	<35	105	311	<65	220
MLC-A-02	MLC-A-02_9.8	9.8	Core	<11	4,010	21	<260	<35	88	456	<65	275
MLC-A-02	MLC-A-02_10.2	10.2	Core	<11	4,090	16	<260	<35	66	451	<65	240
MLC-A-02	MLC-A-02_10.5	10.5	Core	<11	2,260	19	<260	<35	55	295	<65	223
MLC-A-02	MLC-A-02_10.8	10.8	Core	<11	2,750	30	<260	<35	61	349	<65	160
MLC-A-02	MLC-A-02_11.2	11.2	Core	22	2,910	34	<260	<35	47	450	<65	214
MLC-A-02	MLC-A-02_11.5	11.5	Core	<11	3,160	18	<260	<35	61	234	<65	191
MLC-A-02	MLC-A-02_11.8	11.8	Core	<11	1,200	20	<260	52	45	206	<65	274
MLC-A-02	MLC-A-02_12.2	12.2	Core	<11	2,410	45	<260	<35	<13	85	<65	80

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-A-02	MLC-A-02_12.5	12.5	Core	<11	3,380	33	<260	<35	29	318	<65	200
MLC-A-02	MLC-A-02_12.8	12.8	Core	<11	4,610	<12	<260	<35	43	205	<65	171
MLC-A-02	MLC-A-02_13.2	13.2	Core	<11	3,980	65	<260	<35	<13	85	<65	65
MLC-A-02	MLC-A-02_13.5	13.5	Core	<11	3,120	27	<260	<35	31	406	<65	148
MLC-A-02	MLC-A-02_13.8	13.8	Core	<11	4,050	27	<260	<35	34	244	<65	120
MLC-A-02	MLC-A-02_14.2	14.2	Core	<11	4,920	37	<260	<35	77	461	<65	208
MLC-A-02	MLC-A-02_14.5	14.5	Core	<11	1,810	62	<260	<35	33	85	<65	59
MLC-A-02	MLC-A-02_14.8	14.8	Core	<11	1,040	81	<260	<35	<13	85	<65	<25
MLC-A-03	MLC-A-03_0.2	0.2	Core	43	6,270	<12	<260	<35	304	1,780	<65	897
MLC-A-03	MLC-A-03_0.5	0.5	Core	<11	604	52	<260	<35	<13	455	<65	95
MLC-A-03	MLC-A-03_0.8	0.8	Core	<11	1,410	<12	<260	<35	88	713	<65	218
MLC-A-03	MLC-A-03_1.2	1.2	Core	<11	1,800	48	<260	<35	<13	264	<65	103
MLC-A-03	MLC-A-03_1.5	1.5	Core	<11	2,170	<12	<260	<35	97	452	<65	239
MLC-A-03	MLC-A-03_1.8	1.8	Core	<11	7,390	22	<260	<35	314	693	<65	547
MLC-A-03	MLC-A-03_2.2	2.2	Core	<11	7,160	<12	<260	83	245	647	<65	535
MLC-A-03	MLC-A-03_2.5	2.5	Core	<11	2,740	19	<260	<35	156	476	<65	415
MLC-A-03	MLC-A-03_2.8	2.8	Core	<11	1,420	29	<260	<35	118	831	<65	467
MLC-A-03	MLC-A-03_3.2	3.2	Core	<11	1,600	<12	<260	<35	91	598	<65	427
MLC-A-03	MLC-A-03_3.5	3.5	Core	<11	1,560	19	<260	67	81	637	<65	506
MLC-A-03	MLC-A-03_3.8	3.8	Core	<11	1,680	20	<260	<35	104	680	<65	524
MLC-A-03	MLC-A-03_4.2	4.2	Core	<11	1,170	21	<260	<35	62	460	<65	367
MLC-A-03	MLC-A-03_4.5	4.5	Core	<11	476	<12	<260	<35	<13	355	<65	215
MLC-A-03	MLC-A-03_4.8	4.8	Core	<11	646	15	<260	<35	33	207	<65	190
MLC-A-03	MLC-A-03_5.2	5.2	Core	<11	552	26	<260	<35	<13	508	<65	97
MLC-A-03	MLC-A-03_5.5	5.5	Core	<11	664	28	<260	<35	<13	512	<65	213
MLC-A-03	MLC-A-03_5.8	5.8	Core	<11	568	20	<260	57	24	3,620	<65	294
MLC-A-03	MLC-A-03_6.2	6.2	Core	<11	334	24	<260	<35	<13	85	<65	141
MLC-A-03	MLC-A-03_6.5	6.5	Core	<11	607	19	<260	<35	22	85	<65	170
MLC-A-03	MLC-A-03_6.8	6.8	Core	<11	461	33	<260	<35	31	85	<65	86

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-A-03	MLC-A-03_7.2	7.2	Core	<11	373	39	<260	<35	48	85	<65	194
MLC-A-03	MLC-A-03_7.5	7.5	Core	<11	<100	<12	<260	<35	<13	85	<65	88
MLC-A-03	MLC-A-03_7.8	7.8	Core	<11	369	37	<260	<35	31	85	<65	126
MLC-A-03	MLC-A-03_8.2	8.2	Core	<11	630	73	<260	<35	<13	237	<65	<25
MLC-A-03	MLC-A-03_8.5	8.5	Core	<11	834	<12	<260	<35	71	594	<65	335
MLC-A-03	MLC-A-03_8.8	8.8	Core	<11	848	34	<260	<35	33	524	<65	172
MLC-A-03	MLC-A-03_9.2	9.2	Core	<11	777	59	<260	<35	<13	85	<65	84
MLC-A-03	MLC-A-03_9.5	9.5	Core	<11	687	28	<260	<35	84	446	<65	316
MLC-A-03	MLC-A-03_9.8	9.8	Core	<11	951	20	<260	<35	72	602	<65	301
MLC-A-03	MLC-A-03_10.2	10.2	Core	<11	1,120	18	<260	<35	73	482	<65	374
MLC-A-03	MLC-A-03_10.5	10.5	Core	<11	789	36	<260	<35	39	574	<65	219
MLC-A-03	MLC-A-03_10.8	10.8	Core	<11	633	32	<260	<35	39	387	<65	281
MLC-A-03	MLC-A-03_11.2	11.2	Core	24	420	<12	<260	<35	73	288	<65	311
MLC-A-03	MLC-A-03_11.5	11.5	Core	<11	667	34	<260	<35	41	196	<65	230
MLC-A-03	MLC-A-03_11.8	11.8	Core	<11	489	27	<260	<35	33	85	<65	172
MLC-A-03	MLC-A-03_12.2	12.2	Core	<11	530	22	<260	<35	<13	258	<65	115
MLC-A-03	MLC-A-03_12.5	12.5	Core	<11	727	<12	<260	<35	59	1,450	<65	219
MLC-A-03	MLC-A-03_12.8	12.8	Core	<11	1,110	60	<260	<35	<13	566	<65	74
MLC-A-03	MLC-A-03_13.2	13.2	Core	<11	1,090	<12	<260	130	61	1,700	<65	251
MLC-A-03	MLC-A-03_13.5	13.5	Core	<11	1,050	<12	<260	<35	53	983	<65	127
MLC-A-03	MLC-A-03_13.8	13.8	Core	<11	1,200	<12	<260	<35	66	1,740	<65	255
MLC-A-03	MLC-A-03_14.2	14.2	Core	<11	1,360	<12	<260	<35	81	1,500	<65	201
MLC-A-03	MLC-A-03_14.5	14.5	Core	<11	1,260	29	<260	<35	47	920	<65	184
MLC-A-03	MLC-A-03_14.8	14.8	Core	<11	1,340	<12	<260	<35	76	1,030	<65	178
MLC-A-03	MLC-A-03_15.1	15.1	Core	<11	1,080	26	<260	<35	52	687	<65	146
MLC-A-03	MLC-A-03_15.4	15.4	Core	<11	507	28	<260	<35	<13	304	<65	66
MLC-A-04	MLC-A-04_0-1”	0.04	Manual	<11	4,380	<12	<260	42	243	877	<65	588
MLC-A-04	MLC-A-04_1-2”	0.13	Manual	<11	5,680	<12	<260	51	308	874	<65	673
MLC-A-04	MLC-A-04_2-3”	0.21	Manual	<11	5,920	<12	<260	55	297	870	<65	652

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

[Gray shaded cells indicate values that exceeded the probable effects concentration (MacDonald and others, 2000). Bold font indicates values that exceeded the U.S. Environmental Protection Agency (EPA) residential yard cleanup level. ft, foot; mg/kg, milligram per kilogram; ”, denotes a depth in inches of the sample; <, less than; --, no data; na, not applicable]

Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Mill Creek flood plain—Continued												
MLC-A-04	MLC-A-04_3-4”	0.29	Manual	18	4,320	<12	<260	<35	263	804	71	585
MLC-A-04	MLC-A-04_4-5”	0.38	Manual	<11	5,830	<12	275	52	291	856	<65	621
MLC-A-04	MLC-A-04_5-6”	0.46	Manual	<11	6,320	<12	<260	55	305	837	78	676
MLC-A-04	MLC-A-04_6-9”	0.63	Manual	<11	5,620	<12	<260	<35	282	759	<65	571
MLC-A-04	MLC-A-04_9-12”	0.88	Manual	<11	6,160	<12	<260	44	308	771	<65	646
MLC-A-04	MLC-A-04_0.2	0.2	Core	39	5,360	<12	<260	<35	300	2,670	<65	629
MLC-A-04	MLC-A-04_0.5	0.5	Core	<11	6,560	<12	<260	<35	311	1,110	<65	726
MLC-A-04	MLC-A-04_0.8	0.8	Core	<11	7,200	<12	<260	<35	321	1,210	<65	723
MLC-A-04	MLC-A-04_1.2	1.2	Core	<11	6,400	<12	<260	47	298	893	<65	573
MLC-A-04	MLC-A-04_1.5	1.5	Core	<11	2,420	<12	<260	53	251	1,300	<65	402
MLC-A-04	MLC-A-04_1.8	1.8	Core	<11	1,410	15	<260	<35	261	902	<65	353
MLC-A-04	MLC-A-04_2.2	2.2	Core	<11	1,360	<12	<260	<35	153	604	<65	562
MLC-A-04	MLC-A-04_2.5	2.5	Core	<11	1,410	19	<260	<35	105	700	<65	473
MLC-A-04	MLC-A-04_2.8	2.8	Core	<11	1,300	<12	<260	<35	116	783	<65	552
MLC-A-04	MLC-A-04_3.2	3.2	Core	<11	1,240	19	<260	<35	120	617	<65	524
MLC-A-04	MLC-A-04_3.5	3.5	Core	<11	1,500	<12	<260	<35	71	556	<65	378
MLC-A-04	MLC-A-04_3.8	3.8	Core	<11	1,060	19	<260	<35	38	441	<65	296
MLC-A-05	MLC-A-05_0.2	0.2	Core	<11	5,330	<12	<260	<35	272	1,100	<65	512
MLC-A-05	MLC-A-05_0.5	0.5	Core	<11	5,480	<12	<260	<35	273	1,750	<65	572
MLC-A-05	MLC-A-05_0.8	0.8	Core	<11	5,810	22	<260	<35	277	941	<65	522
MLC-A-05	MLC-A-05_1.2	1.2	Core	<11	2,830	21	<260	<35	148	623	<65	342
MLC-A-05	MLC-A-05_1.5	1.5	Core	<11	4,180	<12	<260	<35	161	767	<65	315
MLC-A-05	MLC-A-05_1.8	1.8	Core	<11	3,990	<12	<260	<35	165	659	<65	319
MLC-A-05	MLC-A-05_2.2	2.2	Core	<11	2,370	<12	<260	<35	158	775	<65	290
MLC-A-05	MLC-A-05_2.5	2.5	Core	<11	893	<12	<260	<35	274	700	<65	381
MLC-A-05	MLC-A-05_2.8	2.8	Core	<11	987	14	<260	<35	360	630	<65	329
MLC-A-05	MLC-A-05_3.2	3.2	Core	<11	1,070	<12	<260	<35	397	698	<65	362
MLC-A-05	MLC-A-05_3.5	3.5	Core	<11	725	<12	<260	<35	152	480	<65	509
MLC-A-05	MLC-A-05_3.8	3.8	Core	<11	1,150	15	<260	<35	102	1,020	<65	506

Table 9. Select trace-element concentrations determined using x-ray fluorescence in bulk (unsieved) samples from flood-plain cores along tributaries draining the Washington County Barite District, Missouri, 2014.—Continued

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Borehole identifier	Sample identifier	Sample depth (ft)	Collection method	Arsenic, in mg/kg	Barium, in mg/kg	Cadmium, in mg/kg	Cobalt, in mg/kg	Copper, in mg/kg	Lead, in mg/kg	Manganese, in mg/kg	Nickel, in mg/kg	Zinc, in mg/kg
Reporting level				11	100	12	260	35	13	85	65	25
Probable effects concentration (PEC) from McDonald and others (2009)				33.0	--	4.98	--	149	128	--	48.6	459
EPA residential yard cleanup level				--	--	--	--	--	400	--	--	--
Summary												
Number of samples analyzed				693	693	693	693	693	693	693	693	693
Number of detections				46	680	218	8	123	561	693	45	654
Maximum detection				62	13,100	81	455	169	7,340	10,200	143	1,435
Number of detections above PEC				7	na	218	na	1	91	na	45	77
Number of detections above EPA residential yard cleanup level				--	--	--	--	--	21	--	--	--
Frequency of PEC exceedance				0.01	--	0.31	--	0.00	0.13	--	0.06	0.11

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