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Scientific Investigations Report 2019–5046

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

Cover. Photograph showing Short Creek at Vine Street near Galena, Kansas, taken July 10, 2018. (Back) Photograph showing Turkey Creek at 110th Street near Galena, Kansas, taken July 25, 2017. Photographs by Brian Klager, U.S. Geological Survey.

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DAVID BERNHARDT, Secretary

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

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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	
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Chemical constituents	
milligram per kilogram (mg/kg)	1.0	part per million (ppm)

Datum

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

Abbreviations

EPA	U.S. Environmental Protection Agency
PEC	probable-effect concentration
PEL	probable-effects level
RPD	relative percentage difference
SQG	sediment-quality guideline
TEL	threshold-effects level
TSMD	Tri-State Mining District
USGS	U.S. Geological Survey

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Abstract

To evaluate the magnitude of, and change in, mining-related contamination, streambed-sediment samples were collected from 30 sampling sites in the Spring River Basin in the Cherokee County Superfund site, southeast Kansas, in July and August 2017. The Cherokee County Superfund site is part of the Tri-State Mining District, an area that covers parts of Kansas, Missouri, and Oklahoma that was historically mined for lead and zinc. The sampling sites corresponded to 30 sites sampled in 2004 as part of a previous study.

Concentrations of cadmium, lead, and zinc in the 2017 streambed-sediment samples were compared with the 2004 concentrations and with available sediment-quality guidelines. Cadmium concentrations from 2004 and 2017 samples were not compared if both samples had concentrations less than the lower of the sediment-quality guidelines because of poor performance of cadmium replicate-samples analyses at lower concentrations. Streambed-sediment concentrations of cadmium, lead, and zinc in the 2017 samples compared to the 2004 samples were decreased by at least 20 percent at 12, 16, and 16 sites, respectively; increased by at least 20 percent at 2, 5, and 7 sites, respectively; and had less than a 20-percent change at 5, 9, and 7 sites, respectively. In 2017, cadmium, lead, and zinc concentrations exceeded general consensus-based sediment-quality guidelines at 17, 14, and 18 sites, respectively, compared to 19, 17, and 20 sites, respectively, in 2004. In 2017, cadmium, lead, and zinc concentrations exceeded Tri-State Mining District-specific sediment-quality guidelines at 12, 14, and 11 sites, respectively, compared to 16, 16, and 13 sites, respectively, in 2004. The highest 2017 concentrations of cadmium, lead, and zinc were measured at sites along Short Creek near Galena, Kansas.

Introduction

The Spring River Basin in Cherokee County, southeast Kansas, drains part of the Tri-State Mining District (TSMD) that also includes parts of southwest Missouri and northeast Oklahoma (fig. 1). For about 100 years (1850–1950), the TSMD was one of the primary sources of lead and zinc ore in the world (Brosius and Sawin, 2001). Over time, particularly in and near the town of Galena, Kansas, the landscape in large areas of Cherokee County became dominated by open pits, tailings piles, and ore-smelter waste dumps. Although the mining has stopped and some remediation has been completed (Juracek and Drake, 2016), the legacy of contamination in the Spring River Basin remains; for example, in Cherokee County, highly contaminated sediments on streambeds, lakebeds, and flood plains have been documented (Pope, 2005; Juracek, 2006, 2013). The ongoing mining-related input of cadmium, lead, and zinc to the environment has adversely affected biota including mussels (Angelo and others, 2007; Besser and others, 2015), waterfowl (Beyer and others, 2004; van der Merwe and others, 2011), and fish (Wildhaber and others, 2000; Schmitt and others, 2005). In recent years, a shellfish consumption advisory was issued in Kansas (Kansas Department of Health and Environment, 2007, 2012) and a fish consumption advisory was issued in Oklahoma (Oklahoma Department of Environmental Quality, 2008) because of cadmium and (or) lead contamination. Human health problems and risks also have been attributed to mining-related contamination (Neuberger and others, 1990; Malcoe and others, 2002; Neuberger and others, 2009).

In response to concern about the mining-related environmental contamination, southeast Cherokee County was listed on the U.S. Environmental Protection Agency's National Priority List as a Superfund hazardous waste site in 1983 (U.S. Environmental Protection Agency, 2018). The State of Kansas, in 2004, established total maximum daily loads for the Spring River valley to address sediment and water-quality issues caused by metals (Kansas Department of Health and Environment, 2004). As of 2018, the total maximum daily loads were still active (Trevor Flynn, Kansas Department of Health and Environment, oral commun., 2018).

For restoration purposes, information is required about the magnitude and spatial distribution of cadmium, lead, and zinc concentrations in streambed sediment in the Spring River Basin throughout the Cherokee County Superfund site. A baseline of such information was provided by Pope (2005) in a

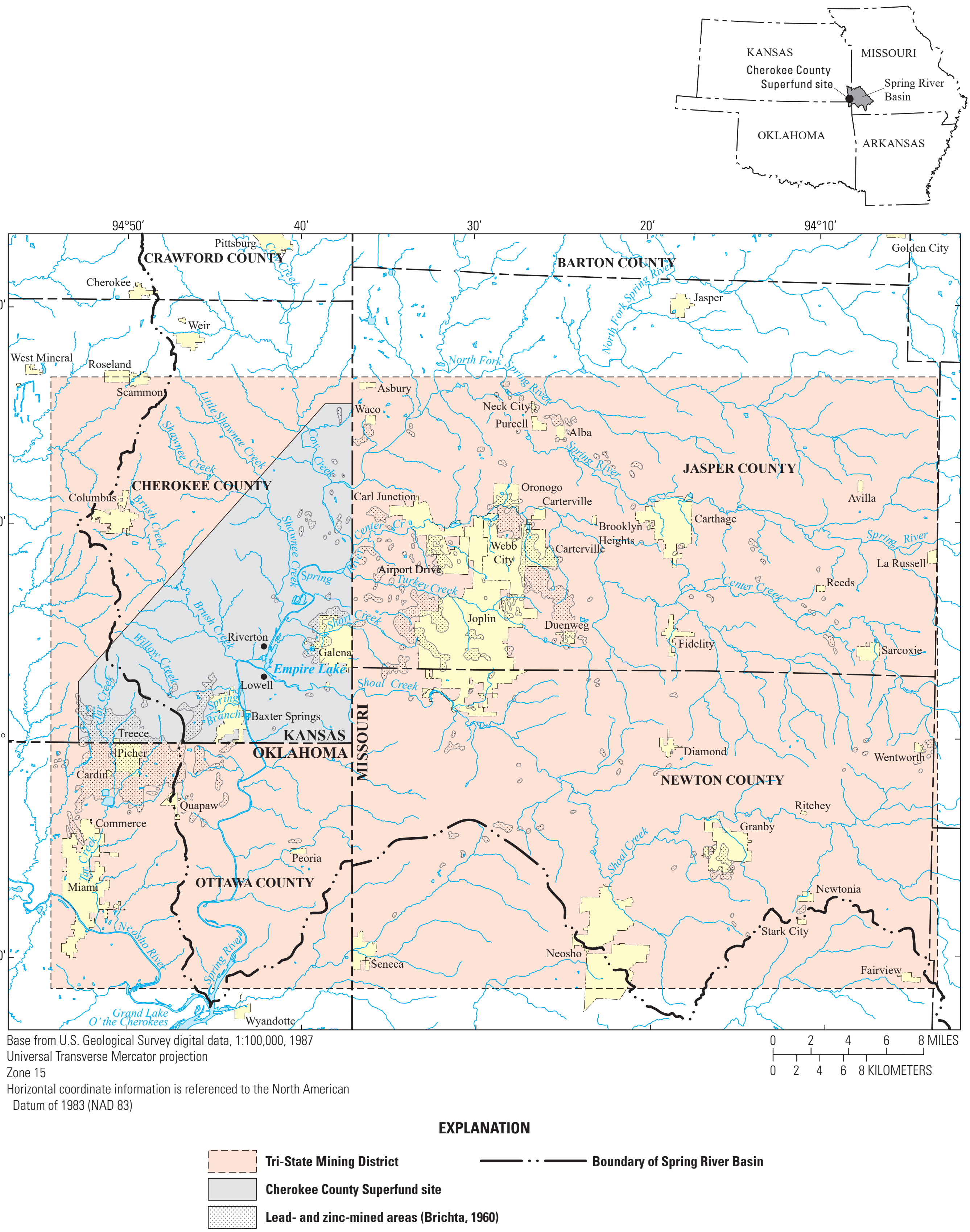

Figure 1. Location of the Spring River Basin, the Cherokee County Superfund site, and lead- and zinc-mined areas in the Tri-State Mining District, Kansas, Missouri, and Oklahoma.

study that analyzed surficial streambed-sediment samples collected in 2004 from 87 sites in the Superfund site. In general, the sampling sites in the most intensive mining-affected areas had cadmium, lead, and zinc concentrations that exceeded probable-effects levels for adverse aquatic biological effects (Pope, 2005). Updated information is needed to provide an assessment of changes in streambed-sediment contamination with time and evaluate the efficacy of ongoing remediation efforts in decreasing metals concentrations. An understanding of the magnitude, spatial patterns, and temporal changes of streambed-sediment contamination is important for the prioritization, planning, and taking on of future restoration projects designed to improve the ecological health of the Spring River Basin.

A 2-year study by the U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency (EPA), was begun in 2017 to evaluate mining-related streambed-sediment contamination at selected sites in the Cherokee County Superfund site. The specific objectives of the study were to

1. determine the presence of cadmium, lead, and zinc in surficial streambed sediment at 30 previously studied sites in the Cherokee County Superfund site;
2. evaluate the concentration of cadmium, lead, and zinc at each site using available sediment-quality guidelines (SQGs); and
3. determine how the concentrations of cadmium, lead, and zinc have changed since the baseline assessment for which samples were collected in 2004.

Purpose and Scope

The purpose of this report is to present the results of the USGS study to evaluate mining-related streambed-sediment metals concentrations at 30 selected sites in the Cherokee County Superfund site, hereafter referred to as the “Superfund site.” Results presented provide some of the information needed by the EPA to assess the efficacy of ongoing remediation efforts. Nationally, the methods and results presented in this report can provide guidance and perspective for future studies concerned with the documentation of mining-related contamination, assessment of the efficacy of implemented remediation measures in former mining areas, and planning for future remediation efforts.

Description of Study Area

The Superfund site is an area of about 115 square miles in southeast Cherokee County, Kans. (fig. 1). The Superfund site is drained by the Spring River, its tributaries, and Tar Creek. Principal tributaries to the Spring River in Cherokee County include Brush Creek, Cow Creek, Center Creek, Shawnee Creek, Shoal Creek, Short Creek, Turkey Creek, and Willow Creek. Several of the tributaries, as well as Tar Creek, drain areas that were substantially affected by historical lead and zinc mining (fig. 1).

The Superfund site extends across two physiographic provinces as described by Fenneman (1938). The northwest part of the Superfund site, in the Osage Plains section of the Central Lowland Province (not shown), is underlain by shale with interbedded limestone and sandstone of Pennsylvanian age. The southeast part, in the Springfield Plateau section of the Ozark Plateaus Province (not shown), is underlain by limestone of Mississippian age (Fenneman, 1938). The topography of the Superfund site is typified by gently rolling uplands dissected by streams. The historically mined lead and zinc ores are in cherty limestone of Mississippian age (Brosius and Sawin, 2001).

Land use in the Superfund site is predominantly a mix of cropland, grassland, and woodland. The Spring River Basin, upstream from the Superfund site, includes the city of Joplin, Missouri, but otherwise has similar land use as the Superfund site (Homer and others, 2015). Historically, lead and zinc were mined at numerous locations within, as well as upstream and downstream from, the Superfund site (Brichta, 1960; fig. 1). Lead and zinc mining in the TSMD began around 1850 in Missouri and ended in 1970 in Kansas. Major lead and zinc production in the Missouri part of the TSMD was from about 1880 to 1920. In the Kansas and Oklahoma parts of the TSMD, major production was from about 1920 to 1950 and 1910 to 1950, respectively (Spruill, 1987). Ongoing remediation in the Superfund site and the TSMD, summarized in Juracek and Drake (2016), has included the removal and disposal of contaminated residential soils and the cleanup of surficial mining wastes.

Climate in the Superfund site is characterized as humid subtropical (Peel and others, 2007) with well-defined seasons and variable precipitation. Long-term, mean annual precipitation at nearby Joplin, Mo. (period of record 1902–2016), is about 43 inches (in.) (High Plains Regional Climate Center, 2017; fig. 1).

Previous Investigation

Mining-related streambed-sediment contamination in the Superfund site was evaluated by Pope (2005). In that study, streambed sediment was sampled in 2004 at 87 sites (75 sites in the Spring River Basin and 12 sites in the Tar Creek Basin). The samples were collected from the upper 2 centimeters [cm] of sediment deposition. Before chemical analyses, the samples were sieved to isolate the less than 63-micrometer (µm) fraction (silt- and clay-size particles), thereby reducing particle-size induced variability between sites.

The concentration ranges were 0.6 to 460 milligrams per kilogram (mg/kg) for cadmium, 22 to 7,400 mg/kg for lead, and 100 to 45,000 mg/kg for zinc. Median concentrations of cadmium, lead, and zinc were 13, 180, and 1,800 mg/kg, respectively. The largest concentrations of these metals were measured for sites along Short and Tar Creeks (fig. 1). Along the 22-mile length of the Spring River in the Superfund site, cadmium, lead, and zinc concentrations increased about 18, 7, and 17 times in the downstream direction, respectively. Streambed-sediment samples collected from sites within or downstream from the most intensive mining-affected areas generally had cadmium, lead, and zinc concentrations that exceeded probable-effects guidelines for adverse aquatic biological effects. Background concentrations of cadmium, lead, and zinc were estimated to be 0.6, 20, and 100 mg/kg, respectively (Pope, 2005).

Methods

The objectives of this study were completed using a combination of available and newly collected information. Available information included streambed-sediment chemistry data from the Pope (2005) investigation. New information was obtained as described in the following sections.

Sampling Site Selection

For this reassessment, 30 sites in the Superfund site that previously were sampled by Pope (2005) were chosen. The 30 sites were selected to provide a representative sample of conditions in the part of the Superfund site drained by the Spring River and its tributaries. The distribution of the sampling sites is provided in figure 2. For consistency, the sampling site numbers are the same as those used by Pope (2005). The latitude and longitude coordinates for the sampling sites, obtained using global positioning system technology, are provided in appendix table 1.1, available for download at https://doi.org/10.3133/sir20195046.

Sample Collection, Handling, and Processing

Within the Superfund site, streambed-sediment samples were collected at the 30 selected sites (fig. 2) during low-flow conditions in July and August 2017. For consistency with the Pope (2005) study, streambed-sediment samples were collected from the upper 2 cm of sediment deposition with a plastic scoop to obtain only the most recently deposited material. Sampling the upper 2 cm of deposition follows protocols of the USGS National Water-Quality Assessment Program (Shelton and Capel, 1994). At each site, sediment was collected from 5 to 10 locations within the channel and composited. Each composite sample was triple bagged in plastic zip-lock bags, labeled, sealed with a chain-of-custody sticker, and stored on ice or refrigerated in a secure area until shipped to the laboratory for processing and analysis. A total of 33 samples were collected (1 sample per site plus a sequential-replicate sample for sites 36, 48, and 86).

Sample processing involved several steps. First, all 33 samples were wet sieved to isolate the less than 2-millimeter (mm) fraction (Shelton and Capel, 1994). The sieved samples were homogenized. The homogenized samples for sites 15, 20, and 49 were split to obtain split-replicate samples. Next, all 36 samples (the 33 collected samples plus the 3 split-replicate samples) were split to isolate the material to be used for the “unsieved” analyses. All 36 samples were wet sieved to isolate the less than 63-µm fraction (that is, the silt and clay). This step served to minimize potential bias in constituent concentrations that could be attributable to differences in the amounts of coarse particles (for example, sand). Also, the less than 63-µm fraction was isolated for consistency with the Pope (2005) study. The 36 sieved samples, and 16 unsieved samples (15 regular and 1 split replicate, consisting of material less than 2 mm in size), were air dried.

Sample Analysis

The streambed-sediment samples (36 sieved, 16 unsieved) were chemically analyzed for 53 constituents (table 1) by AGAT Laboratories in Mississauga, Ontario. A total of 49 elements were analyzed using a multiacid digestion and inductively coupled plasma-optical emission spectrometry and inductively coupled plasma-mass spectrometry. In addition, mercury was analyzed by cold vapor atomic absorption spectrometry and selenium was analyzed by hydride generation atomic absorption spectrometry. Total carbon and carbonate carbon (inorganic carbon) were determined by combustion. Organic carbon was determined by subtracting the carbonate carbon from the total carbon (AGAT Laboratories, 2015; U.S. Geological Survey, 2017). The samples collected by Pope (2005) were analyzed at the USGS sediment trace element laboratory in Atlanta, Georgia. Pope (2005) reports that the chemical analysis techniques used included inductively coupled plasma-atomic emission spectroscopy, flame atomic absorption spectroscopy, and hydride generation atomic absorption spectroscopy.

Particle-size analyses were completed for the 15 regular unsieved sediment samples to determine the percentage of sand (particles greater than 63 µm in size), silt (particles 4 to 63 µm in size), and clay (particles less than 4 µm in size). The samples were analyzed at the USGS Geosciences and Environmental Change Science Center Soils Laboratory in Denver, Colorado, using a Malvern Mastersizer 2000 laser particle-size analyzer (Malvern, 2013). Quality control was provided by the duplicate analysis of three samples. The particle-size data and associated quality-control data are provided in appendix table 1.2, available for download at https://doi.org/10.3133/sir20195046. The particle-size data are also available from the USGS National Water Information System database (U.S. Geological Survey, 2019).

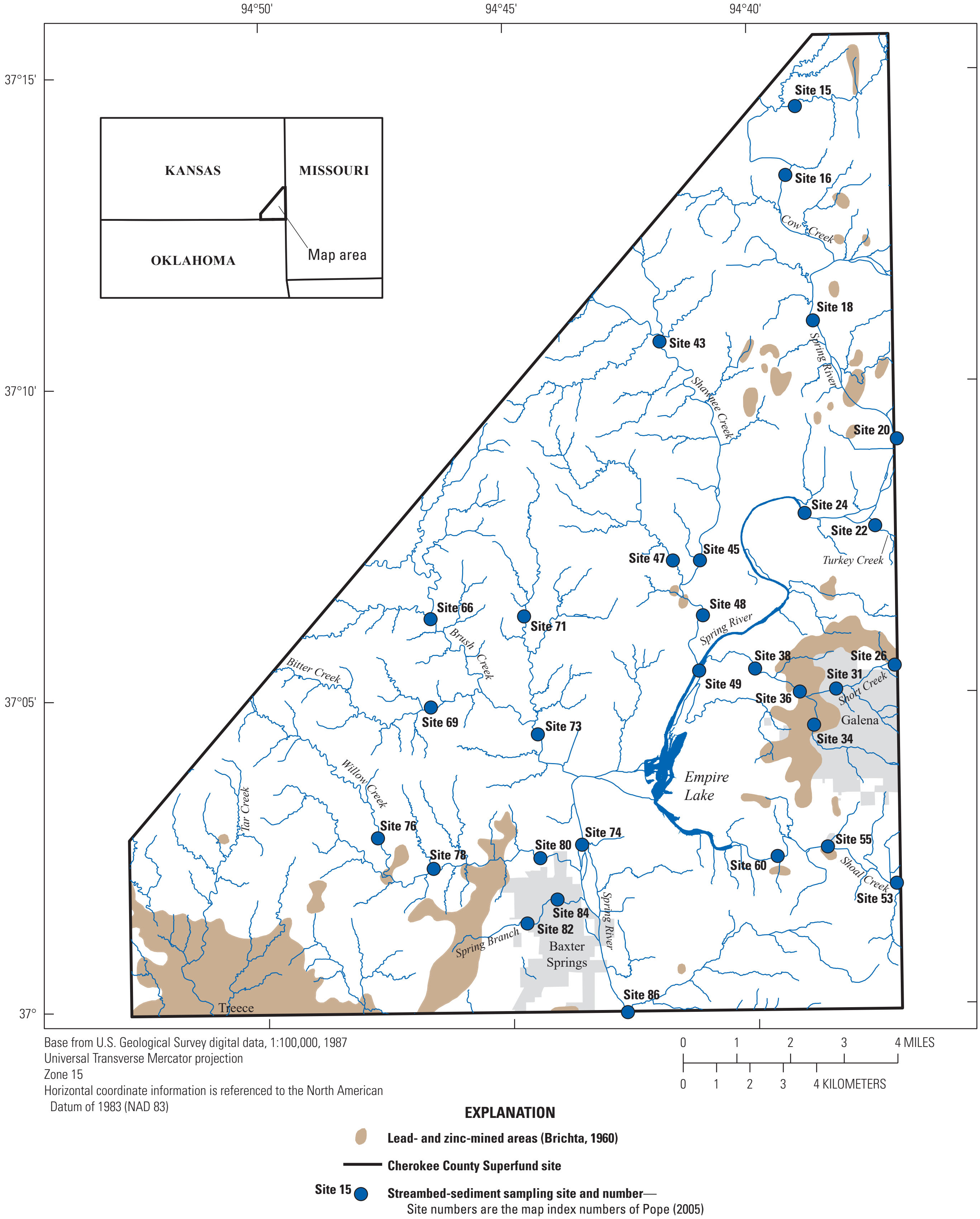

Figure 2. Location of streambed-sediment sampling sites in the Cherokee County Superfund site, southeast Kansas.

Table 1. Chemical analyses performed on streambed-sediment samples collected in the Cherokee County Superfund site, southeast Kansas, 2017.

[%, percent dry weight; mg/kg, milligram per kilogram]

Constituent	Method reporting limit
Aluminum	0.01%
Antimony	0.05 mg/kg
Arsenic	0.2 mg/kg
Barium	1 mg/kg
Beryllium	0.05 mg/kg
Bismuth	0.01 mg/kg
Cadmium	0.02 mg/kg
Calcium	0.01%
Carbon, inorganic	0.01%
Carbon, organic	0.01%
Carbon, total	0.01%
Cerium	0.01 mg/kg
Cesium	0.01 mg/kg
Chromium	0.5 mg/kg
Cobalt	0.05 mg/kg
Copper	0.5 mg/kg
Gallium	0.05 mg/kg
Hafnium	0.1 mg/kg
Indium	0.005 mg/kg
Iron	0.01%
Lanthanum	0.5 mg/kg
Lead	0.1 mg/kg
Lithium	0.1 mg/kg
Lutetium	0.01 mg/kg
Magnesium	0.01%
Manganese	1 mg/kg

Constituent	Method reporting limit
Mercury	0.001 mg/kg
Molybdenum	0.05 mg/kg
Nickel	0.5 mg/kg
Niobium	0.1 mg/kg
Phosphorus	10 mg/kg
Potassium	0.01%
Rubidium	0.1 mg/kg
Scandium	0.1 mg/kg
Selenium	0.5 mg/kg
Silver	0.01 mg/kg
Sodium	0.01%
Strontium	0.2 mg/kg
Sulfur	0.01%
Tantalum	0.05 mg/kg
Tellurium	0.01 mg/kg
Terbium	0.05 mg/kg
Thallium	0.01 mg/kg
Thorium	0.1 mg/kg
Tin	0.2 mg/kg
Titanium	0.01%
Tungsten	0.1 mg/kg
Uranium	0.005 mg/kg
Vanadium	0.5 mg/kg
Ytterbium	0.1 mg/kg
Yttrium	0.1 mg/kg
Zinc	0.5 mg/kg
Zirconium	0.5 mg/kg

Quality Assurance

Standard reference samples were submitted by USGS sample control to the analyzing laboratory. A total of 3 reference samples were submitted with the 36 samples (30 regular and 6 replicate) that had been sieved to the less than 63-µm fraction, and 2 reference samples were submitted with the 16 unsieved samples (15 regular and 1 split replicate). The cadmium, lead, and zinc analyses were deemed acceptable by USGS sample control because the analyzed values were within 15 percent of the preferred values of the reference samples. The results of the chemical analyses of these samples are presented in appendix table 1.3, available for download at https://doi.org/10.3133/sir20195046.

A total of 6 replicate samples were analyzed (3 sequential replicates and 3 split replicates) along with the 30 regular samples. The 3 sequential replicates were collected at sites 36, 48, and 86. The 3 split replicates were produced at the laboratory by splitting the samples collected at sites 15, 20, and 49. Cadmium, lead, and zinc concentrations of the replicates and corresponding regular samples and the relative percentage differences (RPDs) are presented in table 2. RPDs were calculated by dividing the absolute value of the difference between the regular and replicate sample concentrations by the average of the concentrations and multiplying by 100. Acceptable variability for sequential and split replicates was an RPD of less than or equal to 20 percent, except when concentrations were at or near the reporting limit. The chemical results for other constituents in the replicate samples are included in appendix table 1.4, available for download at https://doi.org/10.3133/sir20195046.

Sediment-Quality Guidelines

Several SQGs were available for use in this study. Nonenforceable SQGs adopted by the EPA consisted of level-of-concern concentrations for various trace elements (U.S. Environmental Protection Agency, 1997). The level-of-concern concentrations were derived from biological-effects correlations made from paired laboratory and onsite data to relate adverse biological effects in aquatic organisms to dry-weight sediment concentrations. Level-of-concern guidelines adopted by the EPA include the threshold-effects level (TEL) and the probable-effects level (PEL). Presumably, the TEL represents the concentration below which toxic aquatic biological effects are rare. For concentrations between the TEL and PEL, toxic

Table 2. Cadmium, lead, and zinc concentrations in split- and sequential-replicate streambed-sediment samples collected from six sites in the Cherokee County Superfund site, southeast Kansas, 2017.

[mg/kg, milligram per kilogram]

Sampling site identifier (fig. 2)	Replicate type	Concentration (mg/kg)		Relative percentage difference
		Regular sample	Replicate sample	
		Cadmium		
36	Sequential	128	140	8.96
48	Sequential	0.61	0.29	71
86	Sequential	15.5	15.5	0
15	Split	0.63	0.28	77
20	Split	18.5	19.2	3.71
49	Split	1.63	2.35	36.2
		Lead		
36	Sequential	1,270	1,250	1.59
48	Sequential	19.2	18.1	5.90
86	Sequential	184	188	2.15
15	Split	26.9	19.2	33.4
20	Split	180	180	0
49	Split	38.9	38.8	0.257
		Zinc		
36	Sequential	23,100	26,100	12.2
48	Sequential	119	85.9	32.3
86	Sequential	2,310	2,380	2.99
15	Split	142	92.4	42.3
20	Split	2,570	2,620	1.93
49	Split	416	407	2.19

effects are occasional. Toxic effects are common at concentrations greater than the PEL.

The EPA states that the TEL and PEL guidelines are intended as screening tools to identify possible hazardous levels of chemicals and are not regulatory criteria. This cautionary statement is made in recognition of the fact that biological-effects correlations may not indicate direct cause-and-effect relations because sediment may contain a mixture of chemicals that contribute to the adverse effects to some degree. Therefore, for any given location, the guidelines may be over- or underprotective (U.S. Environmental Protection Agency, 1997).

Consensus-based SQGs for several trace elements, developed by MacDonald and others (2000), were computed as the geometric mean of several previously published SQGs. The consensus-based SQGs include a threshold-effect concentration and a probable-effect concentration (PEC). The threshold-effect concentration represents the concentration below which adverse effects are not anticipated, whereas the PEC represents the concentration above which adverse effects are expected more often than not. Most of the individual threshold-effect concentrations and PECs provide an accurate basis for predicting the presence or absence of sediment toxicity (MacDonald and others, 2000).

More recently, TSMD-specific PECs for cadmium, lead, and zinc were developed by MacDonald and others (2009). The TSMD-specific PECs represent sediment concentrations predicted to reduce the survival of the amphipod *Hyalella azteca* (Saussure; a species known to be sensitive to trace element contamination) by 10 percent, relative to reference conditions in the TSMD (MacDonald and others, 2009). In this study, the general PECs provided by MacDonald and others (2000; hereafter referred to as the “consensus-based PECs”) and the TSMD-specific PECs provided by MacDonald and others (2009; hereafter referred to as the “TSMD-specific PECs”) were used to assess sediment quality in the Superfund site. A comparison of the three sets of guidelines for cadmium, lead, and zinc is provided in table 3.

Selected Chemical Constituents in Streambed Sediments in 2017 Compared to 2004 and to Sediment-Quality Guidelines

Concentrations of cadmium, lead, and zinc in the 2017 samples (less than 63-µm fraction), compared to concentrations in the 2004 samples as reported in Pope (2005) and SQGs, are described in this section. The RPDs in the 2004 and 2017 replicate samples were used to guide how the 2004 and 2017 cadmium, lead, and zinc concentrations are compared to each other. Higher RPDs would indicate that a higher percentage difference between the 2004 and 2017 samples would be necessary to determine that a substantial change was present at a site. In the 2004 and 2017 samples, there were several replicate pairs with RPDs greater than 20 percent (Pope, 2005; table 2). There was one outlying replicate pair from the 2004 sampling that had RPDs of 157, 77, and 140 percent for cadmium, lead, and zinc, respectively. For all three metals, the RPDs that exceeded 20 percent had both concentrations in the replicate pair below the consensus-based PEC, except for the previously described outlier (fig. 3). The replicate pairs with concentrations less than the consensus-based PEC had RPDs greater than 20 percent in 4 of 8 cadmium replicate pairs, 1 of 11 lead replicate pairs, and 2 of 9 zinc replicate pairs. For the purposes of this report, a percentage change of 20 percent is used as a minimum threshold to evaluate if the 2017 concentration was substantially different from the 2004 concentration at each sampling site, except for cadmium concentrations less than the consensus-based PEC because of the poor performance in cadmium replicate analyses at those concentrations. For the cadmium concentrations less than the consensus-based PEC, a determination about the change from 2004 to 2017 is not made in this report. Comparisons of the cadmium, lead, and zinc concentrations to the consensus-based PECs of MacDonald and others (2000) and the TSMD-specific PECs

Table 3. Sediment-quality guidelines and associated bioaccumulation index for cadmium, lead, and zinc.

[Values are in milligrams per kilogram. Shading indicates guidelines to which sediment concentrations were compared in this report. EPA, U.S. Environmental Protection Agency; TEL, threshold-effects level; PEL, probable-effects level; TEC, threshold-effect concentration; PEC, probable-effect concentration]

Trace element	EPA (1997)[1]		MacDonald and others (2000)[1]		MacDonald and others (2009)[2]	Bioaccumulation index[3]
	TEL	PEL	TEC	PEC	PEC	
Cadmium	0.676	4.21	0.99	4.98	11.1	Moderate.
Lead	30.2	112	35.8	128	150	Moderate.
Zinc	124	271	121	459	2,083	High.

[1]General sediment-quality guidelines.

[2]Sediment-quality guidelines specific to the Tri-State Mining District.

[3]Bioaccumulation index information for trace elements from Pais and Jones (1997).

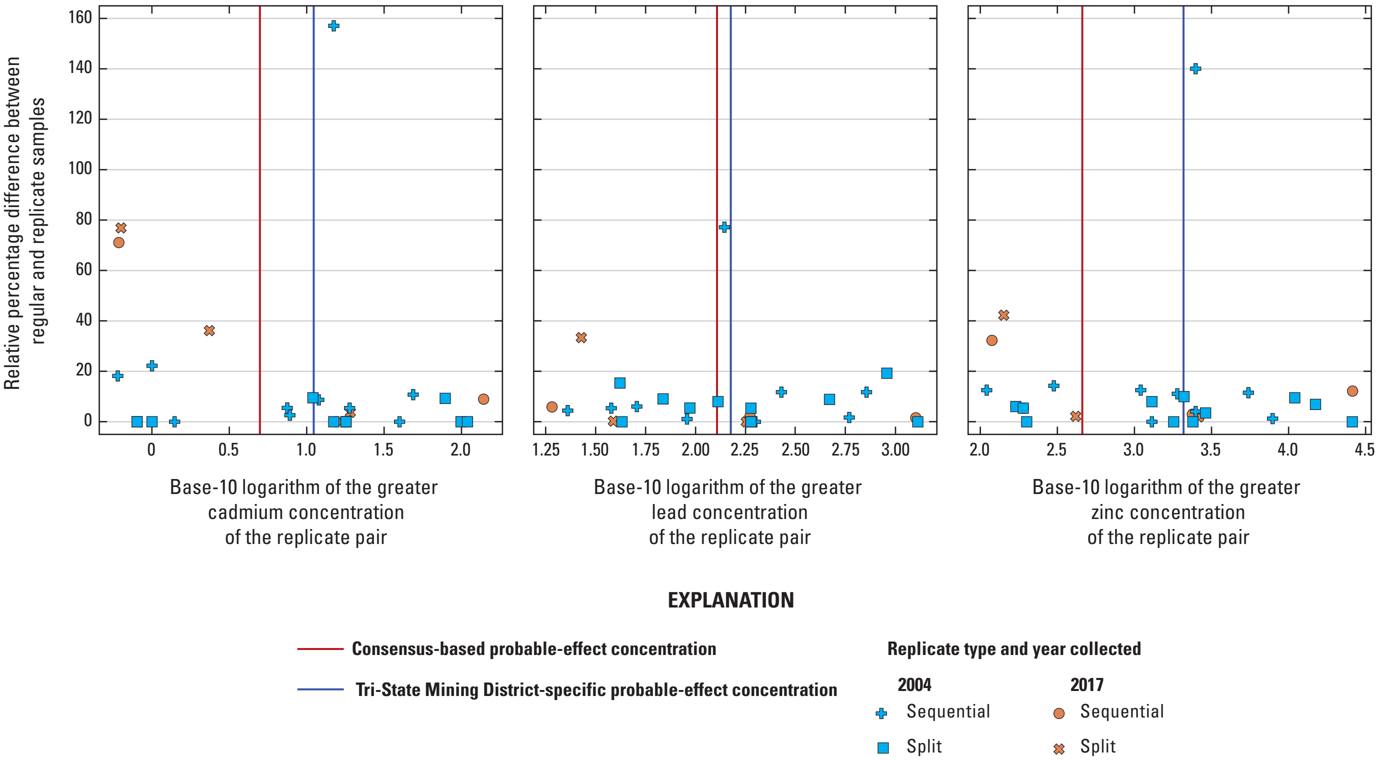

Figure 3. Relative percentage differences between regular and replicate samples plotted against the base-10 logarithm of the greater sample concentration in the replicate pair of cadmium, lead, and zinc for the 2004 (Pope, 2005) and 2017 samples.

of MacDonald and others (2009) (table 3) also are presented in this section. The results of all chemical analyses (53 constituents) are presented in appendix tables 1.4 (sieved samples from all 30 sites sampled) and 1.5 (unsieved samples from 15 sites), available for download at https://doi.org/10.3133/sir20195046.

Streambed-sediment concentrations of cadmium, lead, and zinc followed the same spatial pattern in 2017 as observed by Pope (2005) in the 2004 samples (table 4). The largest concentrations of these metals were on streams that drain the most heavily mined areas. Sediments collected from sites with drainage areas that had more than about a 5-percent mined area had cadmium, lead, and zinc concentrations that were greater than the consensus-based and TSMD-specific PECs (fig. 4), whereas sediments from sites with drainage areas with less percentage mined mostly had concentrations of these metals that were less than the PECs. Sediments collected at the Short Creek and Spring Branch sites had the largest concentrations of these metals. These streams drain historical lead and zinc mining areas in the Superfund site (fig. 2). Sediment collected at the Turkey Creek site (site 22) near the eastern boundary of the Superfund site had large concentrations of cadmium, lead, and zinc (table 4). Turkey Creek drains areas in Missouri that were historically mined (fig. 1). The site on Spring River (site 20) with the highest cadmium, lead, and zinc concentrations (table 4) in the streambed sediment collected was just downstream from the confluence with Center Creek, which drains historically mined areas in Missouri (fig. 1).

Most streambed-sediment cadmium, lead, and zinc concentrations were above estimated background concentrations. Pope (2005) estimated the background concentrations of cadmium, lead, and zinc to be 0.6, 20, and 100 mg/kg, respectively, based on the lowest concentrations measured in the 2004 samples. Pope (2005) notes that these background concentration estimates were consistent with previous estimates and estimates of national background concentrations. Of the 2017 samples, two had concentrations that were less than the estimated background concentrations. The sample from Shawnee Creek site 43 in 2017 had a cadmium concentration of 0.58 mg/kg, and the sample from Shawnee Creek site 48 in 2017 had a lead concentration of 19.2 mg/kg. Overall, the sites on Cow Creek, Shawnee Creek, and Brush Creek were closest to the estimated background concentrations (table 4).

The sources of recently deposited streambed sediment and the causes of the changes in metals concentrations between 2004 and 2017 were not determined in this study. Smith (2016) documented contaminated material present in cores collected from gravel bars in the TSMD. Contaminated material was commonly present over nearly the entire thickness of the sediment (maximum sediment depths of samples ranged from 0.2 to 19.1 feet), indicating that there is a large

Table 4. Cadmium, lead, and zinc concentrations for streambed-sediment samples collected from 30 selected sites in the Cherokee County Superfund site, southeast Kansas, 2004 and 2017.

[All chemical results are for the less than 63-micrometer fraction of the streambed-sediment samples. The 2004 results are from Pope (2005). Shaded values are greater than the Tri-State Mining District-specific probable-effect concentration (PEC) of MacDonald and others (2009). Bold values are greater than the consensus-based PEC of MacDonald and others (2000). mg/kg, milligram per kilogram; %, percent change between 2004 and 2017 samples; E, zinc concentrations greater than 10,000 mg/kg were outside of the analysis method reporting range in the 2017 samples, so the values given were provided by the laboratory for informational purposes and should be considered estimated]

Sampling site identifier (fig. 2)	Cadmium			Lead			Zinc		
	Concentration (mg/kg)		Percent change (%)	Concentration (mg/kg)		Percent change (%)	Concentration (mg/kg)		Percent change (%)
	2004	2017		2004	2017		2004	2017	
Spring River									
18	0.9	1.09	21	22	31.7	44	180	218	21
20	**41**	**18.5**	−55	**510**	**180**	−65	**5,400**	**2,570**	−52
24	**7.1**	**5.45**	−23	91	83.6	−8.1	**1,100**	**869**	−21
49	**16**	1.63	−90	**130**	38.9	−70	**1,800**	416	−77
74	**13**	**6.05**	−53	100	77.5	−23	**1,800**	**1,030**	−43
86	**16**	**15.5**	−3.1	**180**	**184**	2.2	**2,500**	**2,310**	−7.6
Cow Creek									
15	3.7	0.63	−83	31	26.9	−13	**730**	142	−81
16	1.8	1.26	−30	40	39.0	−2.5	380	336	−12
Turkey Creek									
22	**52**	**52.5**	0.96	**1,000**	**693**	−31	**6,900**	**6,970**	1.0
Short Creek									
26	**200**	**78.8**	−61	**300**	**630**	110	**17,000**	**12,800E**	−25
31	**160**	**95.4**	−40	**7,400**	**2,880**	−61	**25,000**	**12,100E**	−52
34	**55**	**106**	93	**310**	**922**	197	**8,200**	**11,600E**	41
36	**110**	**128**	16	**1,300**	**1,270**	−2.3	**14,000**	**23,100E**	65
38	**260**	**291**	12	**2,700**	**1,630**	−40	**44,000**	**93,400E**	112
Shawnee Creek									
43	1	0.58	−42	63	30.5	−52	200	130	−35
45	0.9	1.24	38	38	43.8	15	180	252	40
47	1	0.81	−19	39	33.3	−15	180	198	10
48	0.9	0.61	−32	34	19.2	−44	220	119	−46
Shoal Creek									
53	**14**	**13.5**	−3.6	**160**	**193**	21	**1,600**	**1,750**	9.4
55	**18**	**9.27**	−49	**180**	126	−30	**2,300**	**1,110**	−52
60	**18**	**11.6**	−36	**190**	**153**	−19	**2,100**	**1,740**	−17
Brush Creek									
66	1.4	1.27	−9.3	43	33.5	−22	290	223	−23
69	2.2	1.77	−20	82	48.1	−41	450	336	−25
71	0.7	1.08	54	40	28.2	−30	300	235	−22
73	1	1.5	50	36	43.4	21	180	236	31

Table 4. Cadmium, lead, and zinc concentrations for streambed-sediment samples collected from 30 selected sites in the Cherokee County Superfund site, southeast Kansas, 2004 and 2017.—Continued

[All chemical results are for the less than 63-micrometer fraction of the streambed-sediment samples. The 2004 results are from Pope (2005). Shaded values are greater than the Tri-State Mining District-specific probable-effect concentration (PEC) of MacDonald and others (2009). Bold values are greater than the consensus-based PEC of MacDonald and others (2000). mg/kg, milligram per kilogram; %, percent change between 2004 and 2017 samples; E, zinc concentrations greater than 10,000 mg/kg were outside of the analysis method reporting range in the 2017 samples, so the values given were provided by the laboratory for informational purposes and should be considered estimated]

Sampling site identifier (fig. 2)	Cadmium			Lead			Zinc		
	Concentration (mg/kg)		Percent change (%)	Concentration (mg/kg)		Percent change (%)	Concentration (mg/kg)		Percent change (%)
	2004	2017		2004	2017		2004	2017	
Willow Creek									
76	**7.8**	2.52	−68	**200**	77.1	−61	**1,300**	**537**	−59
78	**7.8**	**6.24**	−20	**250**	**171**	−32	**1,400**	**1,300**	−7.1
80	**29**	**5.77**	−80	**520**	**186**	−64	**8,800**	**3,460**	−61
Spring Branch									
82	**29**	**68.0**	134	**370**	**312**	−16	**4,200**	**11,300E**	169
84	**180**	**37.7**	−79	**810**	**284**	−65	**16,000**	**7,670**	−52

reservoir of contaminated material in the stream channels. Changes in the stream channel over time could cause this reservoir of contaminated material to be redistributed in the stream channel. Sediment carried into the stream during runoff events is another possible source of recent deposits.

Given the uncertainty of the source, the causes of the changes of metals concentrations between 2004 and 2017 also are uncertain. The remixing and redistribution of material already in the stream channel could result in changes in metals concentrations. Remediation activities in a basin that could affect the sediment quality in runoff also are a possible cause of the changes in metals concentrations in recently deposited streambed sediment.

Cadmium

Streambed-sediment cadmium concentrations in the 2017 samples ranged from 0.58 to 291 mg/kg (table 4; appendix table 1.4). Of the 30 samples collected in 2017, samples from 12 sites had substantially decreased cadmium concentrations compared to the 2004 concentrations reported in Pope (2005), samples from 2 sites had substantially increased concentrations, and samples from 5 sites had concentrations that were not substantially different; for samples from 11 sites, a determination about the change could not be made because of the poor performance of cadmium replicate pairs with concentrations less than the consensus-based PEC (table 4). Those 11 sites all had cadmium concentrations in the 2004 and 2017 samples that were less than the consensus-based PEC. Samples collected at 17 sites had cadmium concentrations greater than the consensus-based PEC (4.98 mg/kg) in 2017, compared to 19 sites in 2004. Samples collected at 12 sites had cadmium concentrations greater than the TSMD-specific PEC (11.1 mg/kg) in 2017, compared to 16 sites in 2004. Compared to the 2004 samples, 2 of the 12 sites in the 2017 samples with concentrations greater than the TSMD-specific PEC had substantially increased concentrations, 5 of the sites had samples with substantially decreased concentrations, and samples from the remaining 5 sites did not have substantially different concentrations (table 4). A map of the sampling sites indicating changes in cadmium concentration and comparison to the TSMD-specific PEC is presented in figure 5. Plots for each subbasin sampled showing the cadmium concentrations in the 2004 and 2017 samples are presented in figure 6.

Samples collected at the Spring River sites (sites 18, 20, 24, 49, 74, and 86) had streambed-sediment cadmium concentrations ranging from 1.09 to 18.5 mg/kg in 2017. Compared to the 2004 samples, the cadmium concentrations in the 2017 samples decreased substantially at sites 20, 24, 49, and 74; cadmium concentrations were not substantially different at site 86; and a determination about the change could not be made at site 18. Samples collected at four sites (sites 20, 24, 74, and 86) had cadmium concentrations in 2017 that were greater than the consensus-based PEC, compared to samples collected at five sites (sites 20, 24, 49, 74, and 86) in 2004. Samples collected at two sites (sites 20 and 86) had cadmium concentrations in 2017 that were greater than the TSMD-specific PEC, compared to samples collected at four sites (sites 20, 49, 74, and 86) in 2004 (tables 3 and 4).

Samples collected at the Cow Creek sites (sites 15 and 16) in 2017 had streambed-sediment cadmium concentrations of 0.63 and 1.26 mg/kg, respectively. Determinations about the changes in cadmium concentration from 2004 to 2017 at the

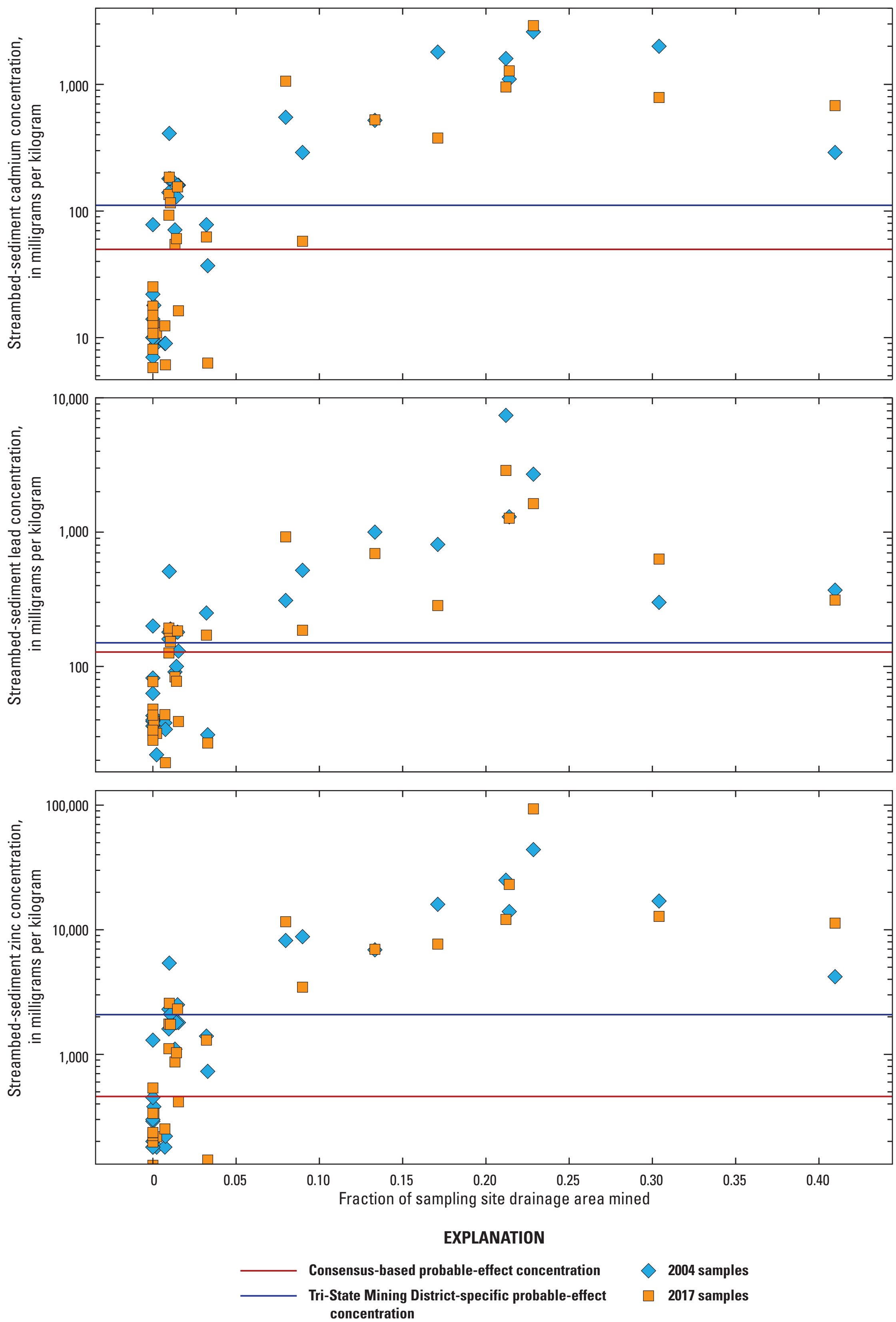

Figure 4. Streambed-sediment concentrations of cadmium, lead, and zinc plotted against the fraction of sampling site drainage area mined. Mined area data are from Brichta (1960).

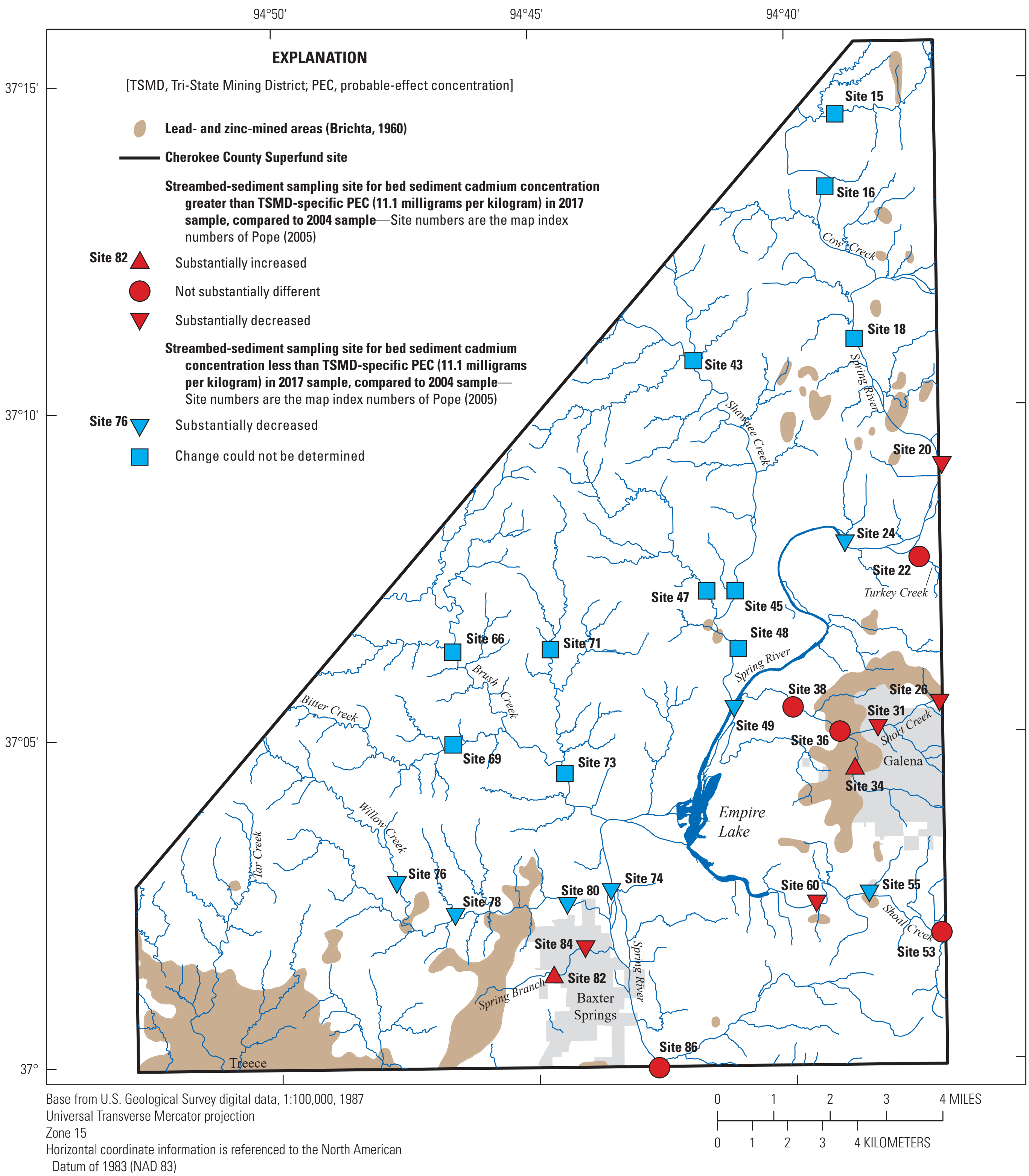

Figure 5. Streambed-sediment cadmium concentration changes between 2004 and 2017 samples and comparison of 2017 concentrations to sediment-quality guidelines at 30 sites in the Cherokee County Superfund site, southeast Kansas.

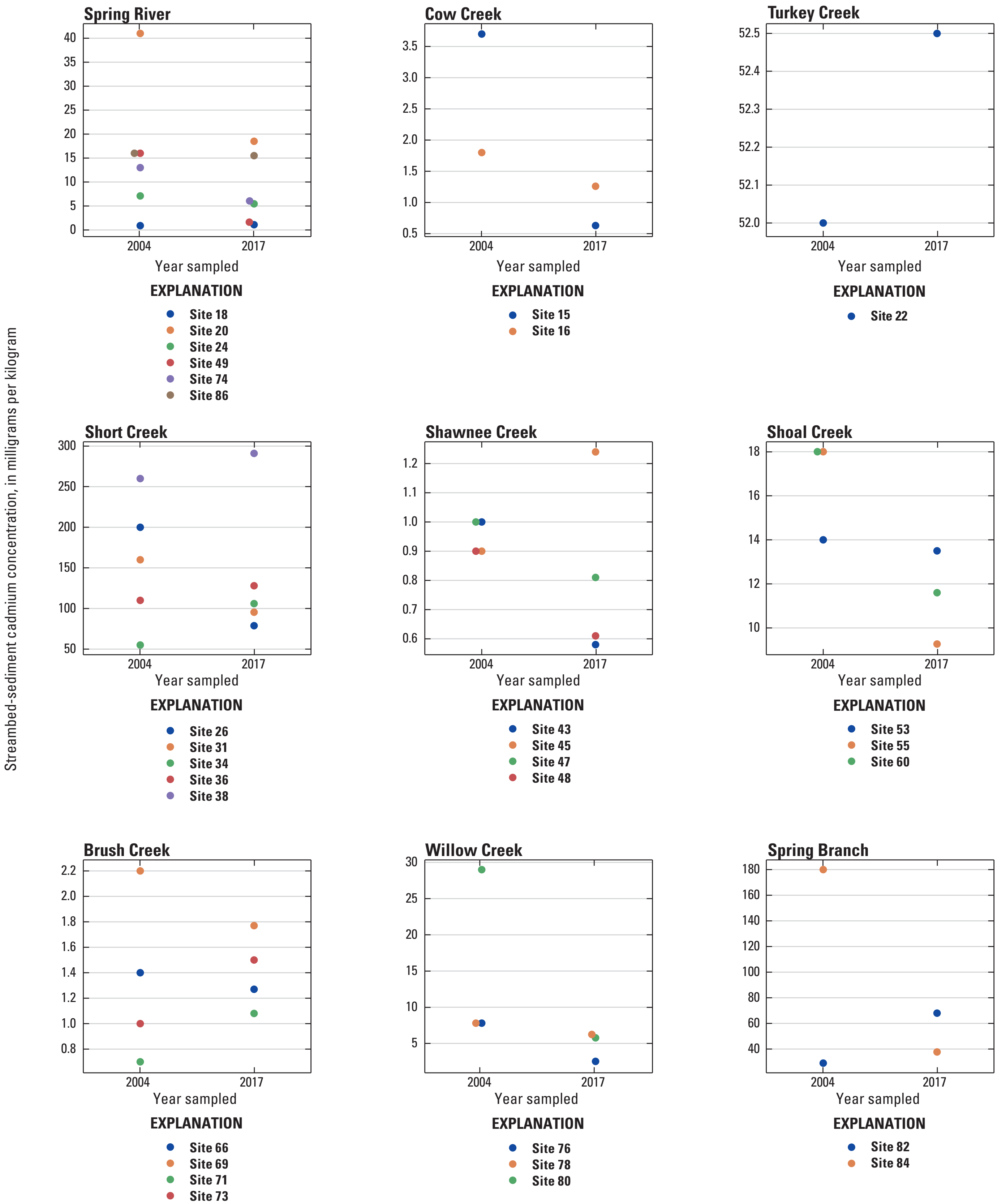

Figure 6. Streambed-sediment cadmium concentrations in samples collected in 2004 and 2017 at 30 sites in the Cherokee County Superfund site, southeast Kansas.

two sites could not be made because of the poor performance of cadmium replicate pairs at sites with concentrations less than the consensus-based PEC. Cadmium concentrations in samples collected at both Cow Creek sites were less than the consensus-based PEC in 2004 and 2017 (tables 3 and 4).

The sample collected at the Turkey Creek site (site 22) had a streambed-sediment cadmium concentration of 52.5 mg/kg in 2017. Compared to the 2004 sample, the cadmium concentration in 2017 was not substantially different. The cadmium concentration was substantially greater than the consensus-based PEC and the TSMD-specific PEC in the 2004 and 2017 samples (tables 3 and 4).

Samples collected at the Short Creek sites (sites 26, 31, 34, 36, and 38) had streambed-sediment cadmium concentrations ranging from 78.8 to 291 mg/kg in 2017. Compared to the 2004 samples, the cadmium concentrations in 2017 decreased substantially at sites 26 and 31, increased substantially at site 34, and were not substantially different at sites 36 and 38. Samples collected at all five sites had cadmium concentrations in 2004 and 2017 that were substantially greater than the consensus-based PEC and the TSMD-specific PEC (tables 3 and 4).

Samples collected at the Shawnee Creek sites (sites 43, 45, 47, and 48) had streambed-sediment cadmium concentrations ranging from 0.58 to 1.24 mg/kg in 2017. Determinations about the changes in cadmium concentration from 2004 to 2017 at the sites could not be made because of the poor performance of cadmium replicate pairs at sites with concentrations less than the consensus-based PEC. Cadmium concentrations in samples collected at all Shawnee Creek sites were less than the consensus-based PEC in 2004 and 2017 (tables 3 and 4).

Samples collected at the Shoal Creek sites (sites 53, 55, and 60) had streambed-sediment cadmium concentrations ranging from 9.27 to 13.5 mg/kg in 2017. Compared to the 2004 samples, the cadmium concentrations in 2017 decreased substantially at sites 55 and 60 and were not substantially different at site 53. Samples collected at all three sites had cadmium concentrations in 2004 and 2017 that were greater than the consensus-based PEC. Samples collected at two sites (sites 53 and 60) had cadmium concentrations in 2017 that were greater than the TSMD-specific PEC, compared to all three sites in 2004 (tables 3 and 4).

Samples collected at the Brush Creek sites (sites 66, 69, 71, and 73) had streambed-sediment cadmium concentrations ranging from 1.08 to 1.77 mg/kg in 2017. Determinations about the changes in cadmium concentration from 2004 to 2017 at the sites could not be made because of the poor performance of cadmium replicate pairs at sites with concentrations less than the consensus-based PEC. Cadmium concentrations at all Brush Creek sites were less than the consensus-based PEC in 2004 and 2017 (tables 3 and 4).

Samples collected at the Willow Creek sites (sites 76, 78, and 80) had streambed-sediment cadmium concentrations ranging from 2.52 to 6.24 mg/kg in 2017. Compared to the 2004 samples, the cadmium concentrations in 2017 decreased substantially in samples collected at all three sites. Samples collected at two sites (sites 78 and 80) had cadmium concentrations in 2017 that were greater than the consensus-based PEC, compared to all three sites in 2004. None of samples collected at the Willow Creek sites had cadmium concentrations in 2017 that were greater than the TSMD-specific PEC, compared to one site (site 80) in 2004 (tables 3 and 4).

Samples collected at the Spring Branch sites (sites 82 and 84) in 2017 had streambed-sediment cadmium concentrations of 68.0 and 37.7 mg/kg, respectively. Compared to the 2004 samples, the cadmium concentration in 2017 decreased substantially at site 84 and increased substantially at site 82. Samples collected at both sites had cadmium concentrations that were greater than the consensus-based PEC and the TSMD-specific PEC in 2004 and 2017 (tables 3 and 4).

Lead

Streambed-sediment lead concentrations in the 2017 samples ranged from 19.2 to 2,880 mg/kg (table 4; appendix table 1.4). Of the 30 samples collected in 2017, samples from 16 sites had substantially decreased lead concentrations compared to the 2004 concentrations reported in Pope (2005), samples from 5 sites had substantially increased concentrations, and the concentrations for samples from 9 sites were not substantially different (table 4). Samples collected at 14 sites had lead concentrations greater than the consensus-based PEC (128 mg/kg) in 2017, compared to 17 sites in 2004. Samples collected at 14 sites had lead concentrations greater than the TSMD-specific PEC (150 mg/kg) in 2017, compared to samples from 16 sites in 2004. Compared to the 2004 samples, samples collected in 2017 at 3 of the 14 sites that had concentrations greater than the TSMD-specific PEC had substantially increased concentrations, samples from 7 sites had substantially decreased concentrations, and samples from 4 sites did not have substantially different concentrations (table 4). A map of the sampling sites indicating changes in lead concentration and comparison of the 2017 concentrations to the TSMD-specific PEC is presented in figure 7. Plots for each subbasin sampled showing the lead concentration in 2004 and 2017 samples are presented in figure 8.

Samples collected at the Spring River sites (sites 18, 20, 24, 49, 74, and 86) had streambed-sediment lead concentrations ranging from 31.7 to 184 mg/kg in 2017. Compared to the 2004 samples, the lead concentrations in 2017 decreased substantially at sites 20, 49, and 74; increased substantially at site 18; and were not substantially different at sites 24 and 86. Samples collected at two sites (sites 20 and 86) had lead concentrations in 2017 that were greater than the consensus-based PEC, compared to samples collected at three sites (sites 20, 49, and 86) in 2004. Samples collected at two sites (sites 20 and 86) had lead concentrations that were greater than the TSMD-specific PEC in the 2004 and 2017 samples (tables 3 and 4).

Samples collected at the Cow Creek sites (sites 15 and 16) had streambed-sediment lead concentrations in the 2017

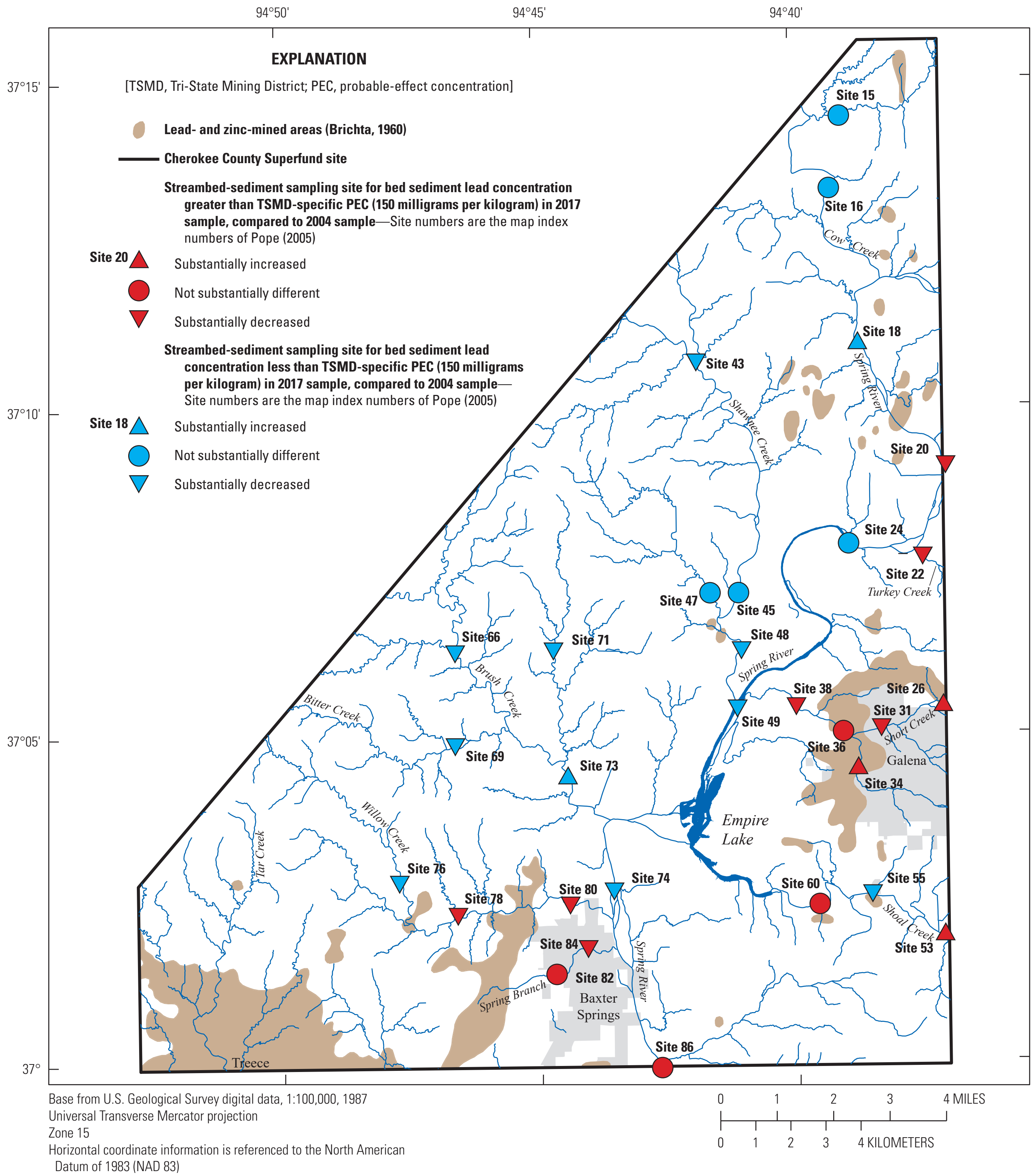

Figure 7. Streambed-sediment lead concentration changes between 2004 and 2017 samples and comparison of 2017 concentrations to sediment-quality guidelines at 30 sites in the Cherokee County Superfund site, southeast Kansas.

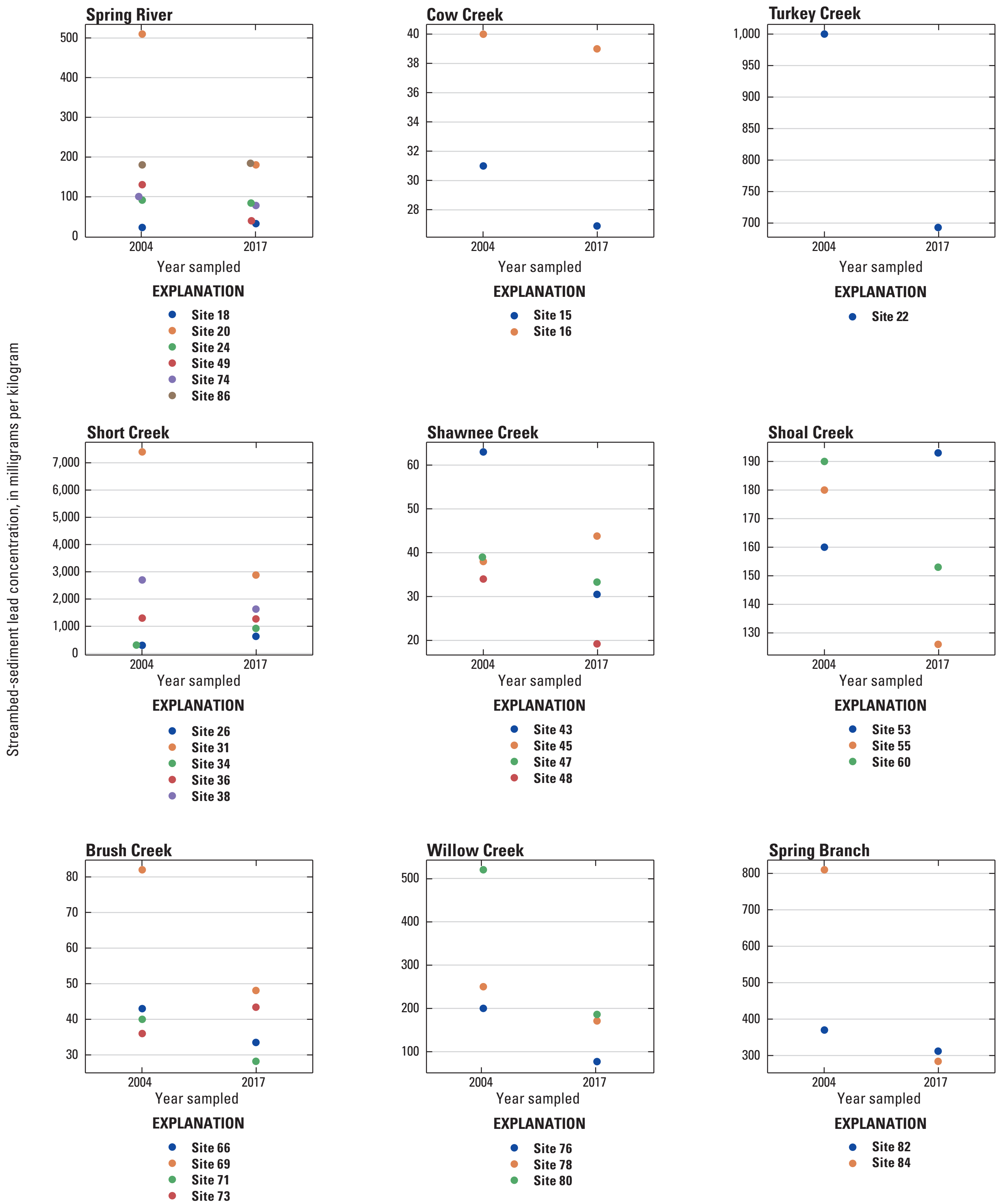

Figure 8. Streambed-sediment lead concentrations in samples collected in 2004 and 2017 at 30 sites in the Cherokee County Superfund site, southeast Kansas.

samples of 26.9 and 39.0 mg/kg, respectively. Compared to the 2004 samples, the lead concentrations in 2017 were not substantially different at both sites. Lead concentrations in samples collected at both Cow Creek sites were less than the consensus-based PEC in 2004 and 2017 (tables 3 and 4).

The sample collected at the Turkey Creek site (site 22) had a streambed-sediment lead concentration of 693 mg/kg in 2017. Compared to the 2004 sample, the lead concentration in 2017 decreased substantially. The lead concentration was greater than the consensus-based PEC and the TSMD-specific PEC in the 2004 and 2017 samples (tables 3 and 4).

Samples collected at the Short Creek sites (sites 26, 31, 34, 36, and 38) had streambed-sediment lead concentrations ranging from 630 to 2,880 mg/kg in 2017. Compared to the 2004 samples, the lead concentrations in 2017 decreased substantially at sites 31 and 38, increased substantially at sites 26 and 34, and were not substantially different at site 36. Samples collected at all five sites had lead concentrations in 2004 and 2017 that were substantially greater than the consensus-based PEC and the TSMD-specific PEC (tables 3 and 4).

Samples collected at the Shawnee Creek sites (sites 43, 45, 47, and 48) had streambed-sediment lead concentrations ranging from 19.2 to 43.8 mg/kg in 2017. Compared to the 2004 samples, the lead concentrations in 2017 decreased substantially at sites 43 and 48 and were not substantially different at sites 45 and 47. Lead concentrations in samples collected at the Shawnee Creek sites were less than the consensus-based PEC in 2004 and 2017 (tables 3 and 4).

Samples collected at the Shoal Creek sites (sites 53, 55, and 60) had streambed-sediment lead concentrations ranging from 126 to 193 mg/kg in 2017. Compared to the 2004 samples, the lead concentration in 2017 decreased substantially at site 55, increased substantially at site 53, and was not substantially different at site 60. Samples collected at two sites (sites 53 and 60) had lead concentrations in 2017 that were greater than the consensus-based PEC, compared to samples from three sites in 2004. Samples collected at two sites (sites 53 and 60) had lead concentrations in 2017 that were greater than the TSMD-specific PEC, compared to samples from three sites in 2004 (tables 3 and 4).

Samples collected at the Brush Creek sites (sites 66, 69, 71, and 73) had streambed-sediment lead concentrations ranging from 28.2 to 48.1 mg/kg in 2017. Compared to the 2004 samples, the lead concentrations in 2017 decreased substantially at sites 66, 69, and 71 and increased substantially at site 73. Lead concentrations in samples collected at all Brush Creek sites were less than the consensus-based PEC in 2004 and 2017 (tables 3 and 4).

Samples collected at the Willow Creek sites (sites 76, 78, and 80) had streambed-sediment lead concentrations ranging from 77.1 to 186 mg/kg in 2017. Compared to the 2004 samples, the lead concentrations in 2017 decreased substantially at all three sites. Samples collected at two sites (sites 78 and 80) had lead concentrations in 2017 that were greater than the consensus-based PEC and the TSMD-specific PEC, compared to three sites in 2004 (tables 3 and 4).

Samples collected at the Spring Branch sites (sites 82 and 84) had streambed-sediment lead concentrations in the 2017 samples of 312 and 284 mg/kg, respectively. Compared to the 2004 samples, the lead concentration in 2017 decreased substantially at site 84 and was not substantially different at site 82. Samples collected at both sites had lead concentrations that were greater than the consensus-based PEC and the TSMD-specific PEC in 2004 and 2017 (tables 3 and 4).

Zinc

Streambed-sediment zinc concentrations in the 2017 samples ranged from 119 to greater than 10,000 mg/kg (table 4; appendix table 1.4). Zinc concentrations of greater than 10,000 mg/kg were observed at six sites (all five Short Creek sites and site 82 on Spring Branch) in 2017 and were outside the reporting range for the analysis method but were provided by the laboratory for informational purposes upon request. These values were used for comparison to the 2004 zinc concentrations but should be considered estimated. Of the 30 samples collected in 2017, 16 had substantially decreased zinc concentrations compared to the 2004 concentrations reported in Pope (2005), 7 had substantially increased concentrations, and 7 did not have substantially different concentrations (table 4). Samples collected at 18 sites had zinc concentrations greater than the consensus-based PEC (459 mg/kg) in 2017, compared to 20 sites in 2004. Samples collected at 11 sites had zinc concentrations greater than the TSMD-specific PEC (2,083 mg/kg) in 2017, compared to 13 sites in 2004. Compared to the 2004 samples, samples collected in 2017 at 4 of the 11 sites that had concentrations greater than the TSMD-specific PEC had substantially increased concentrations, samples collected from 5 sites had substantially decreased concentrations, and samples collected from 2 sites did not have substantially different concentrations (table 4). A map of the sampling sites indicating changes in zinc concentration and comparison of the 2017 concentrations to the TSMD-specific PEC is presented in figure 9. Plots for each subbasin sampled showing the zinc concentrations in the 2004 and 2017 samples are presented in figure 10.

Samples collected at the Spring River sites (sites 18, 20, 24, 49, 74, and 86) had streambed-sediment zinc concentrations ranging from 218 to 2,570 mg/kg in 2017. Compared to the 2004 samples, the zinc concentrations in 2017 decreased substantially at sites 20, 24, 49, and 74; increased substantially at site 18; and were not substantially different at site 86. Samples collected at four sites (sites 20, 24, 74, and 86) had zinc concentrations in 2017 that were greater than the consensus-based PEC, compared to five sites (sites 20, 24, 49, 74, and 86) in 2004. Samples collected at two sites (sites 20 and 86) had zinc concentrations that were greater than the TSMD-specific PEC in the 2004 and 2017 samples (tables 3 and 4).

Samples collected at the Cow Creek sites (sites 15 and 16) had streambed-sediment zinc concentrations in the 2017 samples of 142 and 336 mg/kg, respectively. Compared to

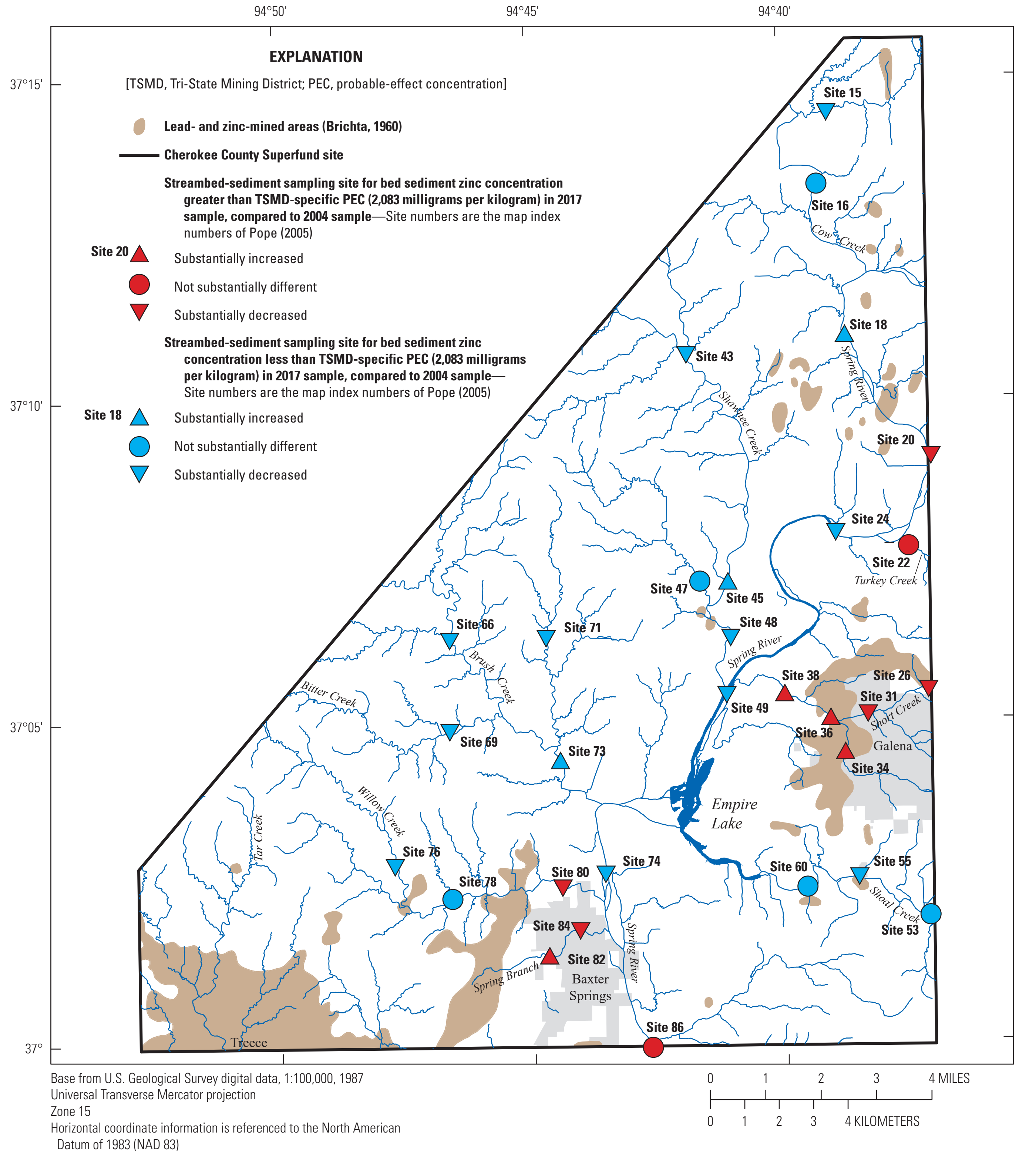

Figure 9. Streambed-sediment zinc concentration changes between 2004 and 2017 samples and comparison of 2017 concentrations to sediment-quality guidelines at 30 sites in the Cherokee County Superfund site, southeast Kansas.

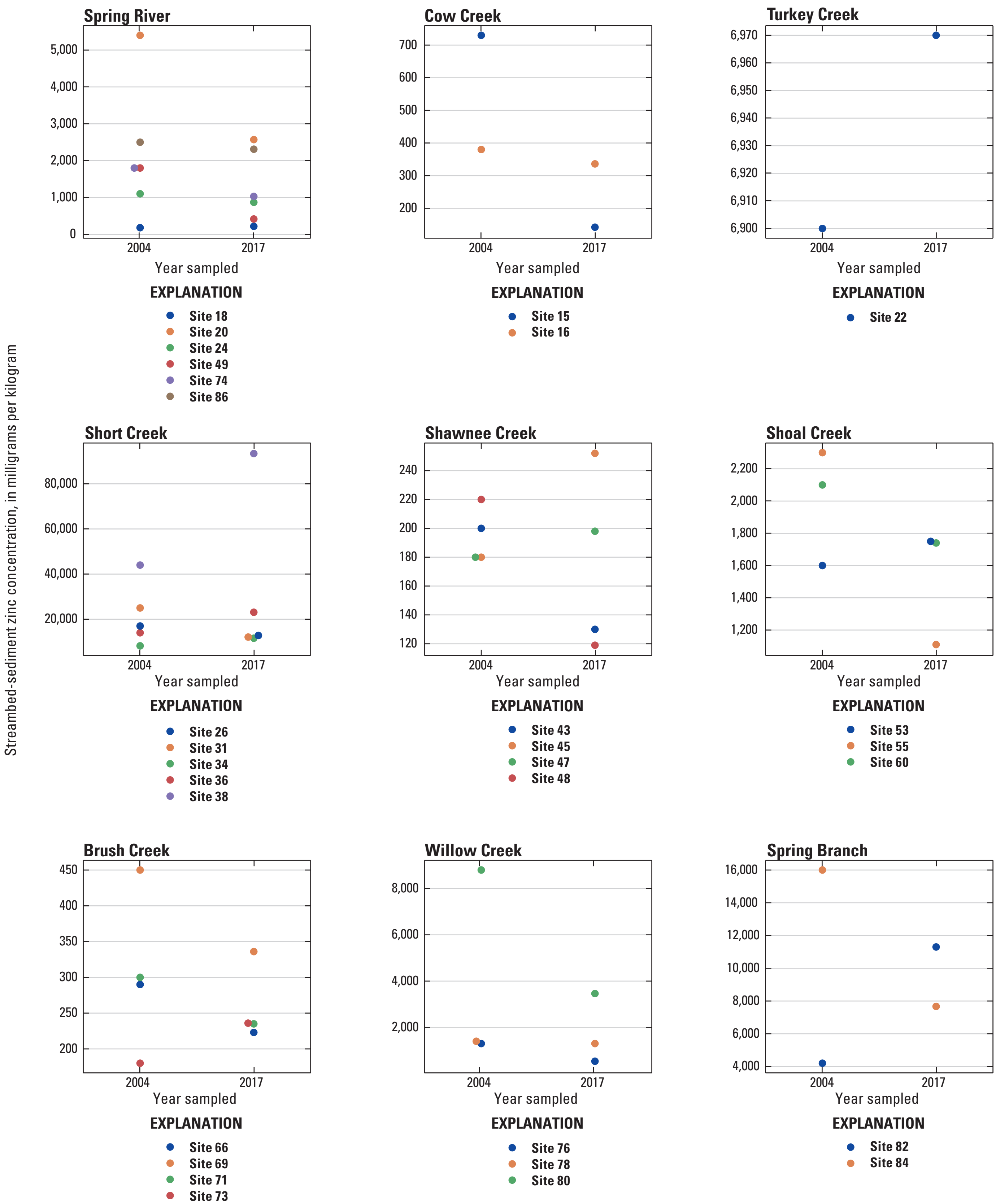

Figure 10. Streambed-sediment zinc concentrations in samples collected in 2004 and 2017 at 30 sites in the Cherokee County Superfund site, southeast Kansas.

the 2004 samples, the zinc concentration in 2017 decreased substantially at site 15 and was not substantially different at site 16. Neither of the samples collected at the Cow Creek sites in 2017 had a zinc concentration that was greater than the consensus-based PEC, compared to one site (site 15) in 2004. None of the samples collected from the Cow Creek sites in 2004 and 2017 had a zinc concentration greater than the TSMD-specific PEC (tables 3 and 4).

The samples collected at the Turkey Creek site (site 22) had a streambed-sediment zinc concentration of 6,970 mg/kg in 2017. Compared to the 2004 sample, the zinc concentration in 2017 was not substantially different. The zinc concentration in the sample collected at site 22 was substantially greater than the consensus-based PEC and the TSMD-specific PEC in the 2004 and 2017 samples (tables 3 and 4).

Samples collected at the Short Creek sites (sites 26, 31, 34, 36, and 38) had streambed-sediment zinc concentrations ranging from 11,600 to 93,400 mg/kg in 2017 (zinc concentration values greater than 10,000 mg/kg were beyond the reporting range for the analyzing method; the values presented were provided by the analyzing laboratory for informational purposes and should be considered estimated). Compared to the 2004 samples, the zinc concentrations in 2017 decreased substantially at sites 26 and 31 and increased substantially at sites 34, 36, and 38. Samples collected at all five sites had zinc concentrations in 2004 and 2017 that greatly exceeded the consensus-based PEC and the TSMD-specific PEC (tables 3 and 4).

Samples collected at the Shawnee Creek sites (sites 43, 45, 47, and 48) had streambed-sediment zinc concentrations ranging from 119 to 252 mg/kg in 2017. Compared to the 2004 samples, the zinc concentration in 2017 decreased substantially at sites 43 and 48, increased substantially at site 45, and was not substantially different at site 47. Zinc concentrations in samples collected at all Shawnee Creek sites were less than the consensus-based PEC in 2004 and 2017 (tables 3 and 4).

Samples collected at the Shoal Creek sites (sites 53, 55, and 60) had streambed-sediment zinc concentrations ranging from 1,110 to 1,750 mg/kg in 2017. Compared to the 2004 samples, the zinc concentrations in 2017 decreased substantially at site 55 and were not substantially different at sites 53 and 60. Samples collected at all three sites had zinc concentrations in 2004 and 2017 that were greater than the consensus-based PEC. None of the samples collected at the Shoal Creek sites had zinc concentrations in 2017 that were greater than the TSMD-specific PEC, compared to two sites (sites 55 and 60) in 2004 (tables 3 and 4).

Samples collected at the Brush Creek sites (sites 66, 69, 71, and 73) had streambed-sediment zinc concentrations ranging from 223 to 336 mg/kg in 2017. Compared to the 2004 samples, the zinc concentrations in 2017 decreased substantially at sites 66, 69, and 71 and increased substantially at site 73. Zinc concentrations in all samples collected at the Brush Creek sites were less than the consensus-based PEC in 2004 and 2017 (tables 3 and 4).

Samples collected at the Willow Creek sites (sites 76, 78, and 80) had streambed-sediment zinc concentrations ranging from 537 to 3,460 mg/kg in 2017. Compared to the 2004 samples, the zinc concentration in 2017 decreased substantially at sites 76 and 80 and was not substantially different at site 78. Samples collected at all three sites had zinc concentrations greater than the consensus-based PEC in the 2004 and 2017 samples. The samples collected at site 80 in 2004 and 2017 had zinc concentrations that were greater than the TSMD-specific PEC (tables 3 and 4).

Samples collected at the Spring Branch sites (sites 82 and 84) had streambed-sediment zinc concentrations in the 2017 samples of 11,300 and 7,670 mg/kg, respectively. Compared to the 2004 samples, the zinc concentration in 2017 decreased substantially at site 84 and increased substantially at site 82. Samples collected at both sites had zinc concentrations that were greater than the consensus-based PEC and the TSMD-specific PEC in 2004 and 2017 (tables 3 and 4).

Other Trace Elements

MacDonald and others (2000) developed consensus-based PECs for several other constituents that the 2017 streambed-sediment samples were analyzed for. The streambed-sediment copper concentrations in samples collected at Short Creek sites 31 and 38 (217 and 181 mg/kg, respectively) were greater than the consensus-based PEC of 149 mg/kg. Samples collected at 10 sites in 2017 had streambed-sediment nickel concentrations greater than the consensus-based PEC of 48.6 mg/kg: Willow Creek sites 80 and 78 (87.5 and 59.9 mg/kg, respectively); Spring Branch site 82 (71.2 mg/kg); Brush Creek sites 69, 71, and 73 (61.2, 66.0, and 50.9 mg/kg, respectively); Short Creek sites 38 and 26 (64.6 and 59.9 mg/kg, respectively); Cow Creek site 16 (59.2 mg/kg); and Shawnee Creek site 45 (50.0 mg/kg) (appendix table 1.4).

Summary and Conclusions

A 2-year study by the U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, was begun in 2017 to assess mining-related streambed-sediment contamination at 30 selected sites in the Cherokee County Superfund site in southeast Kansas. Streambed-sediment concentrations of cadmium, lead, and zinc were determined at the 30 sites and compared to concentrations from samples collected in 2004. An increase of at least 20 percent was classified as substantially increased, a decrease of at least 20 percent was classified as substantially decreased, and a change that was less than 20 percent was classified as not substantially different. The severity of the cadmium, lead, and zinc contamination was assessed using available sediment-quality guidelines that were developed in previous studies that evaluated the harmful effects of these metals on aquatic biota. Results of the assessment are summarized below:

1. In 2017, as in 2004, samples collected at the Short Creek sites had the highest streambed-sediment concentrations of cadmium, lead, and zinc. Other sites with relatively high streambed-sediment concentrations of cadmium, lead, and zinc compared to the rest of the sites sampled were the Spring Branch sites, the Turkey Creek site, and the Spring River site near the confluence with Center Creek. All the aforementioned sites drain areas historically mined for lead and zinc.

2. The 2017 cadmium concentrations were substantially increased at 2 sites, substantially decreased at 12 sites, and not substantially different at 5 sites compared to the 2004 concentrations; at 11 sites, a determination about the change could not be determined. Samples collected at 17 sites had cadmium concentrations greater than the consensus-based probable-effect concentration (PEC) of 4.98 milligrams per kilogram (mg/kg) in the 2017 samples, compared to 19 sites in 2004. Samples collected at 12 sites had cadmium concentrations greater than the Tri-State Mining District (TSMD)-specific PEC of 11.1 mg/kg in the 2017 samples, compared to 16 sites in 2004. Compared to the 2004 samples, samples collected in 2017 at 2 of the 12 contaminated sites had substantially increased concentrations, samples collected at 5 sites had substantially decreased concentrations, and samples collected at the remaining 5 sites did not have substantially different concentrations.

3. The 2017 lead concentrations were substantially increased at 5 sites, substantially decreased at 16 sites, and not substantially different at 9 sites compared to the 2004 concentrations. Samples collected at 14 sites had lead concentrations greater than the consensus-based PEC of 128 mg/kg in the 2017 samples, compared to 17 sites in 2004. Samples collected at 14 sites had lead concentrations greater than the TSMD-specific PEC of 150 mg/kg in the 2017 samples, compared to 16 sites in 2004. Compared to the 2004 samples, samples collected at 3 of the 14 contaminated sites in 2017 had substantially increased concentrations, samples collected at 7 sites had substantially decreased concentrations, and samples collected at 4 sites did not have substantially different concentrations.

4. The 2017 zinc concentrations were substantially increased at 7 sites, substantially decreased at 16 sites, and not substantially different at 7 sites compared to the 2004 concentrations. Samples collected at 18 sites had zinc concentrations greater than the consensus-based PEC of 459 mg/kg in the 2017 samples, compared to 20 sites in 2004. Samples collected at 11 sites had zinc concentrations greater than the TSMD-specific PEC of 2,083 mg/kg in the 2017 samples, compared to 13 sites in 2004. Compared to the 2004 samples, samples collected at 4 of the 11 contaminated sites in 2017 had substantially increased concentrations, samples collected at 5 sites had substantially decreased concentrations, and samples collected at 2 sites did not have substantially different concentrations.

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Appendix 1.

The tables in appendix 1 are available for download at https://doi.org/10.3133/sir20195046.

Table 1.1. Dates sampled and latitude and longitude coordinates for streambed-sediment sampling sites in the Cherokee County Superfund site, southeast Kansas.

Table 1.2. Percentage of sand, silt, and clay in 15 streambed-sediment samples collected from the Cherokee County Superfund site, southeast Kansas, July and August 2017.

Table 1.3. Results of chemical analyses of standard reference samples.

Table 1.4. Results of chemical analyses of regular and replicate streambed-sediment samples, sieved to the less than 63-micrometer fraction, collected from the Cherokee County Superfund site, southeast Kansas, July and August 2017.

Table 1.5. Results of chemical analyses of regular and replicate streambed-sediment unsieved samples collected from the Cherokee County Superfund site, southeast Kansas, July and August 2017.

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