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Assessment of Energetic Compounds, Semi-volatile Organic Compounds, and Trace Elements in Streambed Sediment and Stream Water from Streams Draining Munitions Firing Points and Impact Areas, Fort Riley, Kansas, 2007–08

Scientific Investigations Report 2010–5021

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

Cover Photograph: M1A1 Abrams tank and crew member near sampling site 3MC-1, Fort Riley, Kansas (photograph by L.M. Pope, U.S. Geological Survey)

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By R.L. Coiner, L.M. Pope, and H.E. Mehl

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KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

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Conversion Factors, Abbreviations, and Datum

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.39370	inch (in.)
	Area	
acre	4,047	square meter (m^2)
	Volume	
gallon (gal)	3.7854	liter (L)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
gram (g)	0.03527	ounce (oz)
pound, avoirdupois (lb)	0.4536	kilogram (kg)
	Chemical constituents	
microgram per kilogram (µg/kg) microgram per liter (µg/L)	1.0	part per billion (ppb)
milligram per kilogram (mg/kg) milligram per liter (mg/L)	1.0	part per million (ppm)

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

$$°F=(1.8 \times °C)+32.$$

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

$$°C=(°F-32)/1.8$$

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

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

Altitude, as used in this report, refers to distance above the vertical datum.

Acronyms and Other Abbreviations Used in this Report

µS/cm	microsiemens per centimeter at 25 degrees Celsius
AAS	atomic absorption spectroscopy
ATA	Artillery Target Area
BrCl	bromine monochloride
CNF	Chilean nitrate fertilizer
DWEL	Drinking Water Equivalent Level, U.S. Environmental Protection Agency
E	estimated value
EWI	equal-width increment
FNU	formazin nephelometric unit
GC	gas chromatography
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HPLC	high-performance liquid chromatography
IAC	Impact Area complex
IHA	Interim Health Advisory, U.S. Environmental Protection Agency
$KClO_4$	potassium perchlorate
KDHE	Kansas Department of Health and Environment
KSWSC	Kansas Water Science Center, U.S. Geological Survey
LHA	Lifetime Health Advisory, U.S. Environmental Protection Agency
MCL	Maximum Contaminant Level, U.S. Evironmental Protection Agency
MPRC	Multiple-Purpose Range Complex
MPV	most probable value
MRL	minimum reporting level
MS	mass spectrometry
mV	millivolts
NWQL	National Water Quality Laboratory, U.S. Geological Survey
RDX	1,3,5-hexahydro-1,3,5-trinitrotriazine
RPD	relative percentage difference
SDWR	Secondary Drinking Water Regulation, U.S. Environmental Protection Agency
SVOC	semi-volatile organic compound
TNT	2,4,6-trinitrotoluene
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

Assessment of Energetic Compounds, Semi-Volatile Organic Compounds, and Trace Elements in Streambed Sediment and Stream Water from Streams Draining Munitions Firing Points and Impact Areas, Fort Riley, Kansas, 2007–08

By R.L. Coiner, L.M. Pope, and H.E. Mehl

Abstract

An assessment of energetic compounds (explosive and propellant residues) and associated semi-volatile organic compounds (SVOCs) and trace elements in streambed sediment and stream water from streams draining munitions firing points and impact areas at Fort Riley, northeast Kansas, was performed during 2007–08 by the U.S. Geological Survey (USGS) in cooperation with the U.S. Army. Streambed sediment from 16 sampling sites and stream-water samples from 5 sites were collected at or near Fort Riley and analyzed for as many as 17 energetic compounds, 65 SVOCs, and 27 trace elements.

None of the energetic compounds or SVOCs were detected in streambed sediment collected from sites within the Fort Riley Military Reservation. This may indicate that these compounds either are not transported from dispersal areas or that analytical methods are not sensitive enough to detect the small concentrations that may be transported. Concentrations of munitions-associated trace elements did not exceed sediment-quality guidelines recommended by the U.S. Environmental Protection Agency (USEPA) and are not indicative of contamination of streambed sediment at selected streambed sampling sites, at least in regards to movement from dispersal areas.

Analytical results of stream-water samples provided little evidence of contamination by energetic compounds, SVOCs, or associated trace elements. Perchlorate was detected in 19 of 20 stream-water samples at concentrations ranging from an estimated 0.057 to an estimated 0.236 µg/L (micrograms per liter) with a median concentration of an estimated 0.114 µg/L, substantially less than the USEPA Interim Health Advisory criterion (15 µg/L), and is in the range of documented background concentrations. Because of these small concentrations and possible natural sources (precipitation and groundwater), it is likely that the occurrence of perchlorate in stream water is naturally occurring, although a definitive identification of the source of perchlorate in stream water at Fort Riley is difficult. The only SVOCs detected in stream-water samples were bis(2-ethylhexyl) phthalate and di-n-butyl phthalate but at concentrations substantially less than the most stringent aquatic-life criteria established by the Kansas Department of Health and Environment. All trace element concentrations in stream-water samples were less than the most stringent aquatic-life criteria. The implication of these stream-water results is that contamination arising from firing-range activities, if it exists, is so small as to be nondetectable with current analytical methods or is not distinguishable from background concentrations for constituents that also are naturally occurring. Overall, the munitions-related constituents analyzed in streambed sediment and stream water, when detected, were at concentrations that were less than regulatory criteria.

Introduction

Problem and Background

The operational effectiveness of military organizations is strongly tied to the extent and quality of prior training. This is particularly true for the combat readiness of military units that rely extensively on live-fire training to develop the skills and proficiency required to effectively perform assigned functions. Many military installations throughout the United States have live-fire training ranges used to develop these skills, including Fort Riley, Kansas, home of the First Infantry Division (fig. 1).

Live-fire training ranges include areas used for small arms and machine-gun fire, hand-grenade training, crew-served indirect-fire weapons systems (mortar and artillery), anti-armor rockets, and tank main-gun fire (fig. 2). Although live-fire training ranges are necessary for the operational readiness of military units, the use of these facilities has the

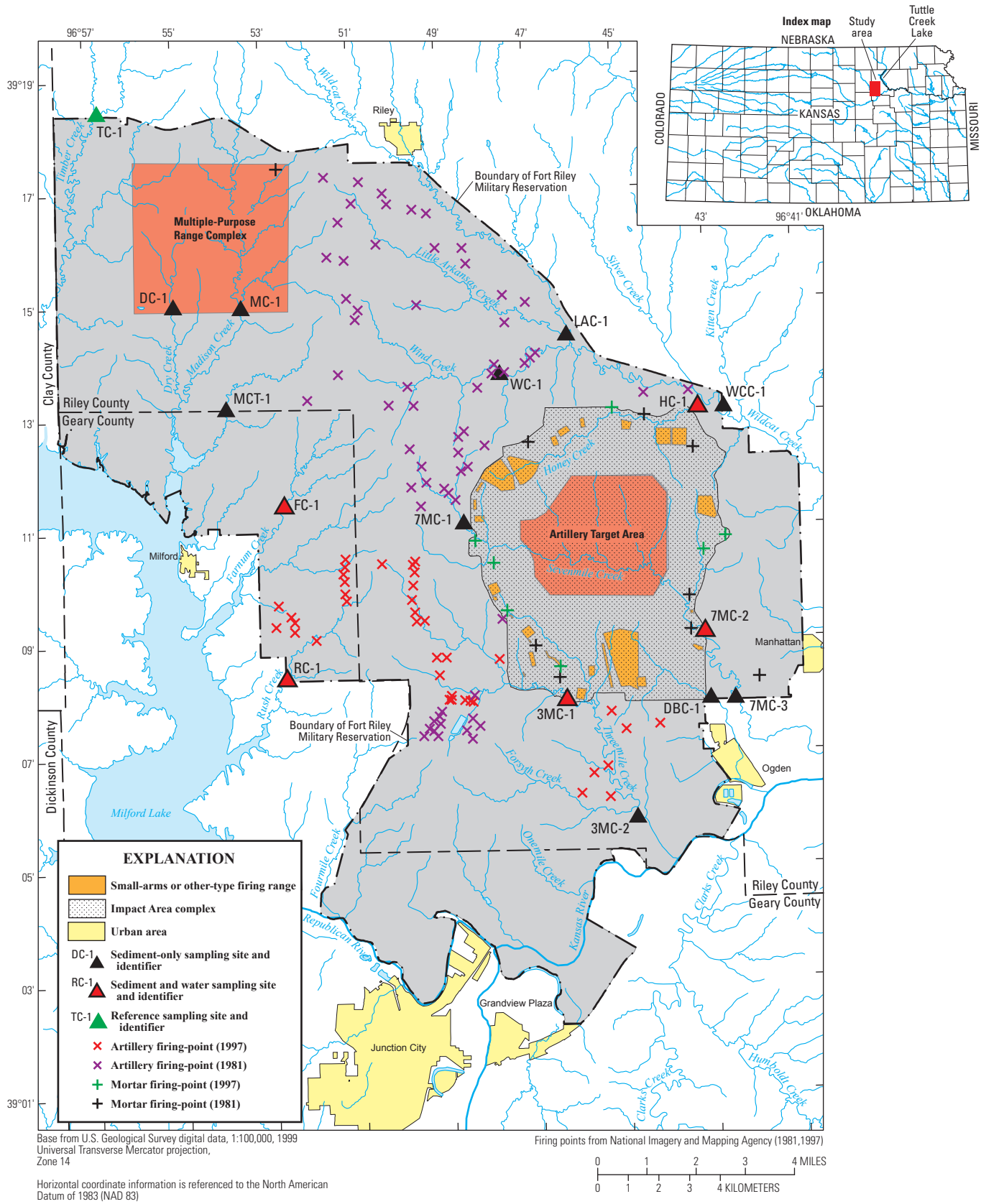


Figure 1. Location of Fort Riley, sampling sites, munitions firing points, and live-fire training range complexes, northeast Kansas (munitions firing points and live-fire training range complexes locations from National Imagery and Mapping Agency, 1981, 1997).

Figure 2. M1A1 Abrams tanks conducting live-fire training at Fort Riley, 2008 (photograph courtesy of First Infantry Division, U.S. Army, Fort Riley, Kansas).

potential for detrimental environmental consequences, particularly for water resources in and near the facilities.

The use of live-fire training ranges can result in the dispersal of residues of energetic compounds (explosive and propellant residues), semi-volatile organic compounds (SVOCs), and trace elements that are components of munitions as explosives and propellants or part of the explosive casing. Energetic compounds include octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX), 1,3,5-hexahydro-1,3,5-trinitrotriazine (RDX), and 2,4,6-trinitrotoluene (TNT), which are used as high-explosives, and 2,4-dinitrotoluene, nitrocellulose, nitroglycerin, and perchlorate, which are used in gun or rocket propellants (Jenkins and others, 2005). SVOCs used in munitions include di-n-butyl phthalate and di-n-octyl phthalate (plasticizers associated with propellants or explosives) and diphenylamine (a propellant stabilizer). Trace elements may be found in the casings, projectiles, explosives, or detonators of munitions and include aluminum, antimony, barium, copper, iron, lead, mercury, molybdenum, titanium, uranium, and zinc (Hewitt, 1997; U.S. Department of Defense, 2002; Jenkins and others, 2005; Global Security, 2008). The occurrence and distribution of energetic compounds in soils and around munitions firing points and impact areas have been well documented at military installations throughout the United States (Phelan and others, 1998; Pennington and others, 2001; Jenkins and others, 2005), and trace element contamination frequently is associated with energetic compound residues (Savard and others, 2007).

The dispersal of energetic compounds, SVOCs, and trace elements in impact areas may result from the ordinary intended operation of munitions such as the complete detonation of a warhead, or may occur with the partial detonation of munitions. For example, it has been shown that most soil contamination by energetic compounds in impact areas is from “low-order” detonations of warheads (Jenkins and others, 2005). Low-order detonations are partial explosions where quantities of unexploded energetic compounds are dispersed as particles or chunks to the surrounding soil. In contrast, contamination at munitions firing points results from unburned or partially burned propellant fibers being deposited to the soil under normal firing procedures. Soil concentrations of energetic compounds may be distributed heterogeneously over firing ranges. Distribution of energetic compounds in soil at impact areas can be described as randomly distributed point sources. However, most of the land area of firing ranges has very small or undetectable concentrations of energetic compounds in soils (Jenkins and others, 2005). Less known is the

Table 1. Partitioning coefficients, water solubility, and degree of mobility-through-soil of selected energetic compounds (National Library of Medicine, 2008; except where noted).

[log K_{ow}, logarithm of the octanol/water partitioning coefficient; °C, degrees Celsius; mg/L, milligrams per liter; --, not available; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; $KClO_4$, potassium perchlorate; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene. Number in parentheses ( ) indicates that the solubility data were obtained at another temperature.]

Compound	log K_{ow}	Water solubility at 25 °C (mg/L)	Degree of mobility-through-soil
1,3-Dinitrobenzene	1.49	533	large
1,3,5-Trinitrobenzene	1.18	(278)	large
2,4-Dinitrotoluene	1.98	(270)	moderate
2,6-Dinitrotoluene	2.10	--	very large to large
2-Amino-4,6-dinitrotoluene	--	--	--
4-Amino-2,6-dinitrotoluene	--	--	--
2-Nitrotoluene	2.30	(650)	moderate
3-Nitrotoluene	2.45	(500)	small
4-Nitrotoluene	2.37	(442)	moderate
HMX	.16	--	very large to moderate
Nitrobenzene	1.85	1,797	very large to moderate
Nitroglycerin	1.62	1,800	moderate
Pentaerythritol tetranitrate	1.61	43	moderate to small
Perchlorate[1] ($KClO_4$)	−7.18	15,000	mobile in groundwater
RDX	.87	59.7	large to moderate
Tetryl	1.64	74	small
TNT	1.60	(115)	small

[1]U.S. Environmental Protection Agency (2009a).

extent to which these compounds, SVOCs, and trace elements move from their source areas and into water and bottom sediment of streams draining munitions firing points and impact areas, although some investigations of this phenomenon have been conducted (Craig and others, 1999; McConnell and others, 2000; Clark and others, 2005).

Energetic compounds, SVOCs, and trace elements can be mobilized into streams during runoff (adsorbed to soil particles or dissolved in water) or as a component of groundwater discharged to adjacent streams during base flow. Trace elements have only a small degree of solubility and tend to occur in a solid phase or adsorbed to soil or sediment particles (Hem, 1992). Trace elements transported with sediment during runoff may form deposits in receiving streams and is a potential source of contamination. McConnell and others (2000) reported concentrations of the trace elements chromium, lead, mercury, and silver in bed sediment of surface-water sources receiving runoff or drainage from munitions impact areas that exceeded the U.S. Environmental Protection Agency (2004) sediment-quality criteria used in this report.

Energetic compounds have varying degrees of water solubility and affinity for adsorption to soil or sediment (table 1). For example, RDX is less water soluble than TNT, but the latter is more strongly bound to soil, and thus, RDX has a greater potential for mobility in groundwater (Larson and others, 2008). The transport of energetic compounds with soil from source areas into streambed sediment or stream water will be associated with sediment transport in runoff or groundwater flow to varying degrees depending upon the characteristics of the compound. For example, perchlorate, an anion with a large solubility value, readily migrates to groundwater or surface water (Parker and others, 2008). Therefore, the possibility of groundwater transport is likely much greater for perchlorate than for the other energetic compounds or trace elements.

The log K_{ow} indicated in table 1 is the octanol/water partitioning coefficient, which quantifies the proportion of a substance that dissolves in each solvent in an octanol/water mixture. It is calculated by dividing the concentration of the compound dissolved in octanol by the concentration of the compound dissolved in water and is expressed as a logarithm. Positive log K_{ow} values indicate that the compound is more

Table 2. Regulatory criteria for selected energetic compounds in surface water or drinking water.

[KDHE, Kansas Department of Health and Environment; USEPA, U.S. Environmental Protection Agency; DWEL, Drinking Water Equivalent Level; LHA, Lifetime Health Advisory; IHA, Interim Health Advisory; µg/L, micrograms per liter; D, human cancer risk not-classifiable; --, not established; B2, probable human carcinogen; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; N, not likely a human carcinogen; C, possible human carcinogen; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6 trinitrotoluene]

Compound	KDHE aquatic-life- and -surface-water critera[1]		USEPA drinking-water health advisory critera[2]			USEPA drinking water cancer descriptor
	Acute (µg/L)	Chronic (µg/L)	DWEL (µg/L)	LHA (µg/L)	IHA (µg/L)	
1,3-Dinitrobenzene	--	--	5	1	--	D
2,4-Dinitrotoluene	330	230	100	--	--	B2
2,6-Dinitrotoluene	--	--	40	--	--	B2
HMX	--	--	2,000	400	--	D
Nitrobenzene	27,000	--	--	--	--	--
Nitroglycerin	--	--	--	5	--	--
Perchlorate	--	--	--	--	[3]15	[4]N
RDX	--	--	100	2	--	C
TNT	--	--	20	2	--	C

[1]Kansas Department of Health and Environment (2005).

[2]U.S. Environmental Protection Agency (2006).

[3]U.S. Environmental Protection Agency (2009b).

[4]U.S. Environmental Protection Agency (2005).

readily dissolved in octanol, and larger positive numbers indicate increasing octanol solubility. Negative log K_{ow} values indicate that the compound is more readily dissolved in water, and larger negative numbers indicate increasing water solubility. Log K_{ow} values serve as a proxy measure of the tendency for compounds to be bound to soil organic matter (positive values) or dissolved in water (negative values). The degree of mobility through soil refers to the relative capacity that exists for a compound to be transported through soil by means of groundwater movement.

An analysis of the significance of contamination from live-fire ranges would be aided by considering streambed-sediment and water-quality criteria related to energetic compounds, SVOCs, and trace elements used in munitions. The U.S. Environmental Protection Agency (USEPA) has established Drinking Water Equivalent Level (DWEL), Lifetime Health Advisory (LHA), and Interim Health Advisory (IHA) guidelines for several energetic compounds in drinking water (table 2). The DWEL guideline provides a lifetime exposure concentration protective of adverse, noncancer health effects that assumes that all exposure to a contaminant is from drinking water. The LHA and IHA guidelines are defined similarly, except that they assume that additional exposure occurs apart from drinking water. The DWEL, LHA, and IHA guidelines are not enforceable Federal standards but are health advisories that provide guidance to officials responsible for public water supply (U.S. Environmental Protection Agency, 2006). USEPA also has classified the human cancer-causing properties of several energetic compounds (table 2).

The nonenforceable health advisories provided by USEPA can be contrasted with the enforceable Maximum Contaminant Level (MCL) drinking-water standards that have been established for the trace elements arsenic, barium, beryllium, cadmium, chromium, and mercury. Because stream water is not used as a public water supply at Fort Riley, the greater immediate concern may be the potential effects on aquatic ecosystems from the occurrence of energetic compounds or trace elements in streambed sediment or surface water. Correspondingly, USEPA has proposed streambed-sediment-quality guidelines, and the Kansas Department of Health and Environment (KDHE) has established surface-water-quality criteria for the protection of aquatic life for some of the constituents discussed in this report. The guidelines proposed by USEPA for streambed sediment do not include the energetic compounds discussed in this report but do include guidelines for 16 SVOCs and the trace elements antimony, arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc (U.S. Environmental Protection Agency, 2004). Water-quality criteria established by KDHE relate to the energetic compounds 2,4-dinitrotoluene and nitrobenzene (table 2), 25 SVOCs, and to the trace elements arsenic, chromium, mercury, and selenium (Kansas Department of Health and Environment (2005). Cadmium, copper, lead, nickel, silver, and zinc have KDHE water-hardness-dependent criteria, which are not discussed in this report because water-hardness values calculated on the basis of concentrations of dissolved calcium and magnesium (analysis of filtered samples) were not determined.

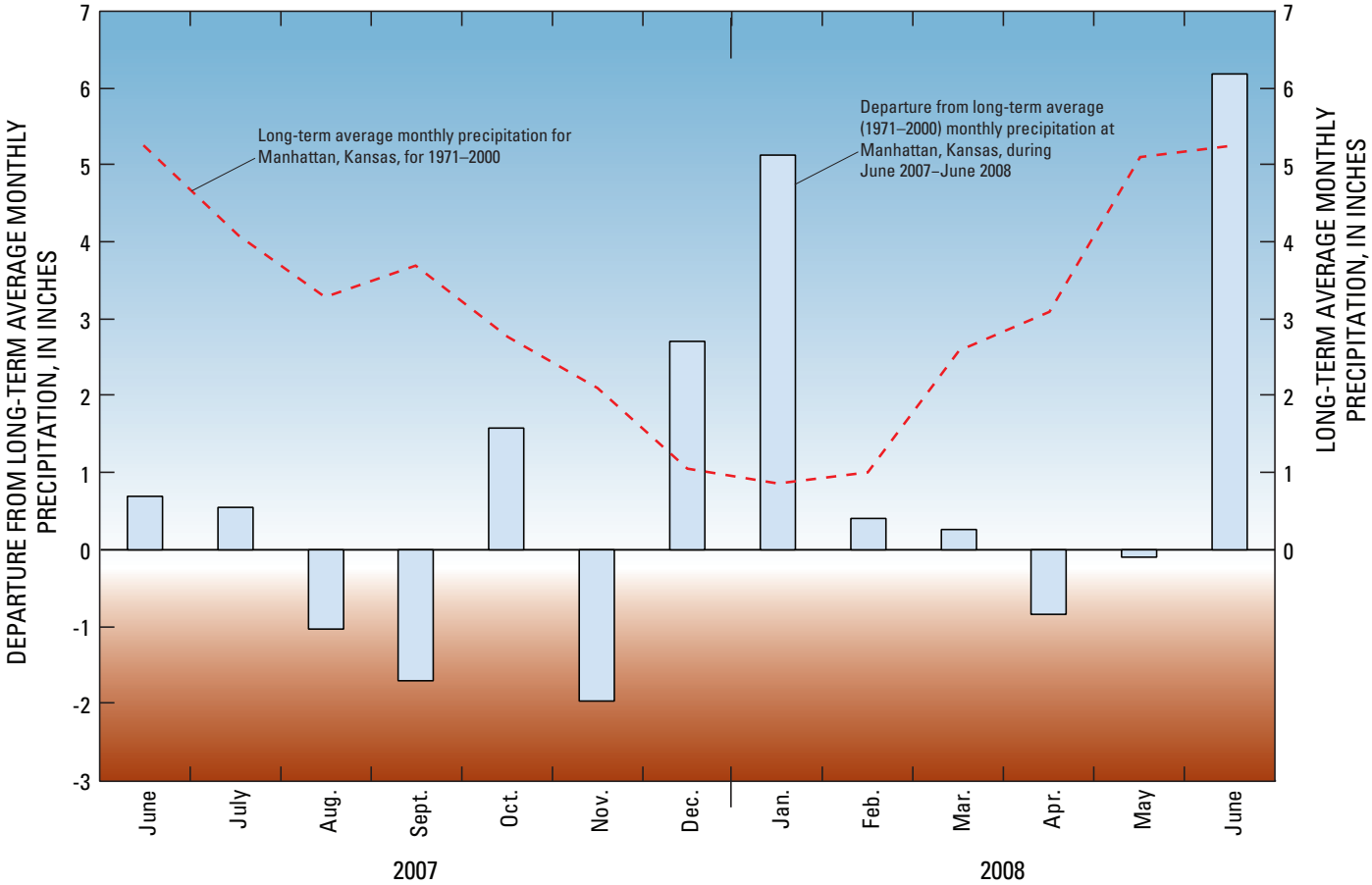


Figure 3. Average monthly precipitation, 1971-2000, at Manhattan, Kansas, and departure from average during study period, June 2007 through June 2008 (data from National Climatic Data Center, 2002, 2008).

Only unfiltered stream-water samples were collected and analyzed during the study described in this report.

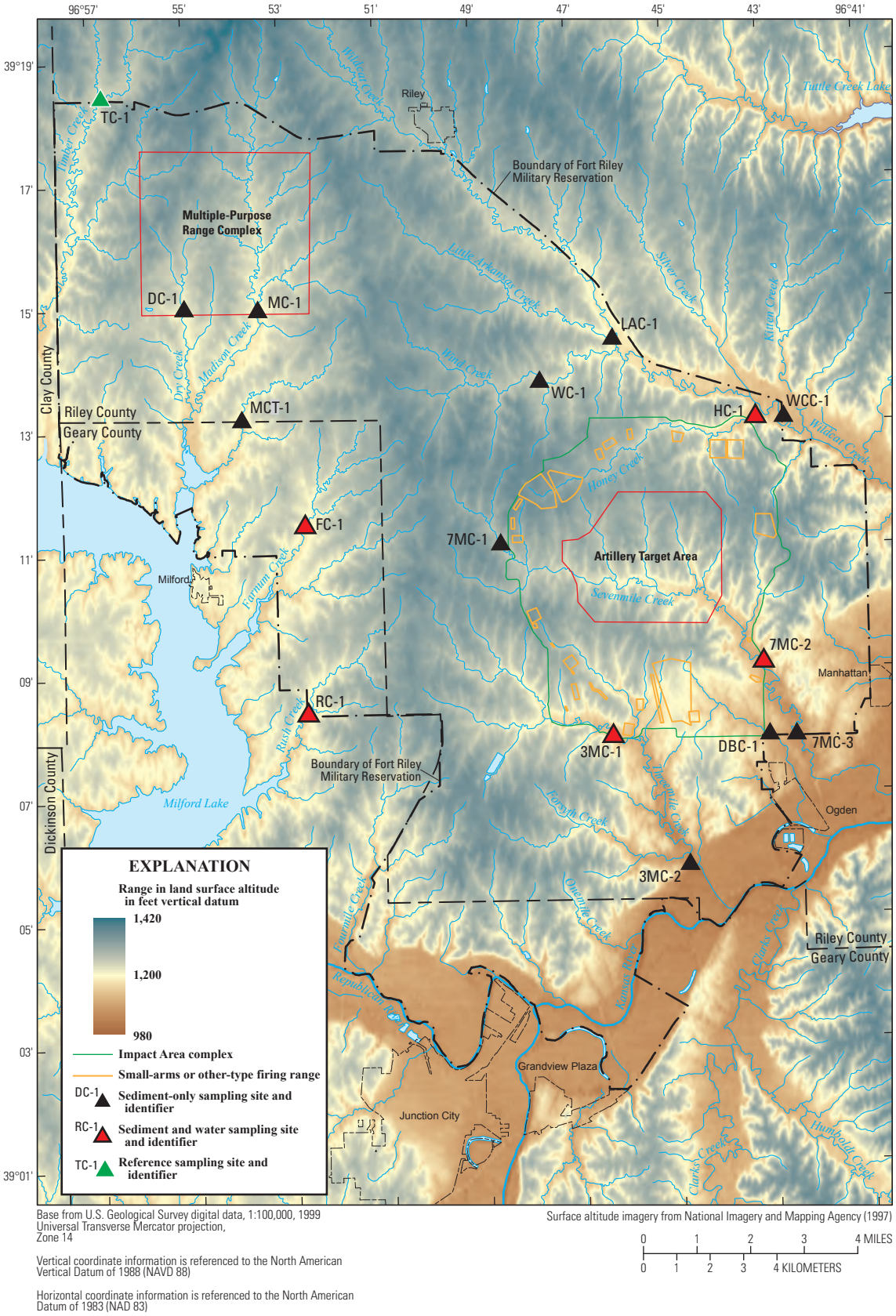
Purpose and Scope

The purpose of this report is to describe an assessment of the occurrence and distribution of energetic compounds, SVOCs, and trace elements in streambed sediment and stream water from streams draining munitions firing points and impact areas on the Fort Riley Military Reservation. The assessment was done by the U.S. Geological Survey (USGS) in cooperation with the U.S. Army from June 2007 through June 2008. The SVOCs di-n-butyl phthalate, di-n-octyl phthalate, and diphenylamine are compounds associated with propellant mixtures and were assessed in streambed sediment and stream water as part of a larger analytical schedule for SVOCs. Streambed sediment was collected from 16 sites (including one reference site; fig. 1) and analyzed for particle size, carbon, and 17 energetic compounds, 65 SVOCs, and 27 trace elements (table 13 in the "Supplemental Information" section at the back of this report). Stream-water samples were collected during base-flow conditions from three streams. Seventeen stream-water samples, including one split replicate and one concurrent replicate, were collected during runoff from five streams. Water samples were analyzed for 17 energetic compounds, 64 SVOCs, and 23 trace elements and major cations (table 14 in the "Supplemental Information" section at the back of this report). The occurrence and distribution of energetic compounds, SVOCs, and trace elements are discussed in relation to pertinent sediment- and water-quality guidelines or criteria.

Description of Study Area

Climate

The Fort Riley Military Reservation is located in northeast Kansas, a mid-latitude and continent-centered geographical area that has a temperate climate with marked seasonal variations in both temperature and precipitation. January is the coldest month with an average temperature of 27.8 °F (degrees Fahrenheit), July is the warmest month with an average temperature of 79.9 °F, and the average annual temperature is



Base from U.S. Geological Survey digital data, 1:100,000, 1999
Universal Transverse Mercator projection,
Zone 14

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

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

Surface altitude imagery from National Imagery and Mapping Agency (1997)

Figure 4. Land-surface altitude of Fort Riley Military Reservation and adjacent areas (live-fire training range complexes locations from National Imagery and Mapping Agency, 1997).

54.9 °F (for Manhattan, Kansas; National Climatic Data Center, 2002). Average annual precipitation is 34.8 in. (1971–2000) with most precipitation occurring between April and September (fig. 3). May and June have the highest average monthly precipitation, 5.08 and 5.23 in., respectively, and combined account for nearly one-third of the total annual precipitation for Manhattan, Kansas (National Climatic Data Center, 2002).

The 13-month study period (June 2007 through June 2008) described in this report was substantially wetter than the long-term average. Total departure from average for the study period was +11.9 in. January and June 2008 had the largest monthly departures from average of +5.14 and +6.19 in., respectively.

Physiography and Topography

The study area is located in the Osage Plains section of the Central Lowlands physiographic province (Fenneman and Johnson, 1946). The Osage Plains are characterized by scarped plains with layers of resistant rock that form east- or southeast-facing escarpments. Topographically, there are three main features – (1) streams and river valleys with associated alluvial floors and terraces, (2) uplands comprising of resistant limestone layers, and (3) scattered hill country that includes the Flint Hills. Fort Riley has a total topographic relief of about 330 ft (fig. 4). The reservation is located between two large reservoirs – Milford Lake to the west, a part of which defines the reservation boundary, and Tuttle Creek Lake to the northeast (fig. 4).

Surficial Geology and Soils

Fort Riley is located in a transitional zone between the Flint Hills and Smoky Hills ecoregions, an area of predominately tall-grass prairie. The area also marks the transition between the cherty, rocky soils of the Flint Hills and the silty, loamy, loess-formed soils of the Smoky Hills (Chapman and others, 2001). The area is underlain by sedimentary rocks, consisting of limestone, limestone with chert (flint), and shale (Jewett, 1941). Soils along streams are deep and typically fertile with thinning soils in hilly areas. Characteristics of soils vary with regards to permeability and particle size in relation to topographic features and proximity to streams. The most prevalent soil types on the reservation are silty clay loams and silty loams, although a few other soil types are present to a lesser extent (Jantz and others, 1975).

Land Use

The Fort Riley Military Reservation consists of parts of Riley and Geary Counties and contains more than 100,000 acres with barracks, offices, and other buildings located mostly in the southern areas of the post (U.S. Army, 1984). Located in the northwest part of the reservation is the Multiple-Purpose Range Complex (MPRC), an area that is used for various live-fire training exercises. The Impact Area complex (IAC) is located in the east-central part of the reservation (fig. 1). The IAC includes several live-fire ranges for small-arms, mortar, and tank main-gun training along its periphery and the Artillery Target Area (ATA) at its center. The MPRC and IAC are the primary munitions impact areas at the reservation. A large number of historic (1981) or contemporary (1997) artillery and mortar firing points are scattered throughout many parts the reservation, but artillery firing points are concentrated mostly to the west and northwest of the IAC and mortar firing points are typically located near the perimeter of the IAC (fig. 1).

History

Fort Riley was established in 1853 as a means of protecting westward-moving pioneers. It was also a post for cavalry units from its earliest days, including the 7th Cavalry under George A. Custer. Over the course of several decades, the post had been the home of different academies that taught horsemanship to mounted units, and traditional cavalry instruction continued until 1946 (fig. 5) (U.S. Army, 1984).

The location and large size of Fort Riley (20,000 acres during the 19th century) made it an important site for various military uses over the years. Fort Riley served as a distribution hub supplying other posts, especially with hay due to the reservation's abundant grasslands (Dobak, 1998). Artillery units began using the reservation as a live-fire training facility in the late 1800s (fig. 6) (U.S. Army, 1984).

The historic land holdings of Fort Riley were expanded during the 20th century. The most recent land acquisition was authorized in fiscal year 1965 and brought the total area of the reservation to more than 100,000 acres (U.S. Army, 1984). The location of weapons training ranges has shifted in the same direction as land acquisition – to the north and northwest

Figure 5. 10th Cavalry on maneuvers, Fort Riley, 1942 (photograph courtesy of Library of Congress).

of the historic areas on the post. Construction of contemporary live-fire ranges began in 1942 and now include the IAC and MPRC (U.S. Army, 2007). In addition to the development, expansion, and location of small-arms and artillery ranges, the 20th century included the transition from the traditional black-powder-based munitions of the 19th century to modern munitions containing synthetic, nitrated organic compounds such as those listed in table 1.

Figure 6. Cannon and soldiers at Fort Riley, circa 1870–80 (photograph courtesy of Kansas Historical Society).

Previous Study

A regional range study at Fort Riley was completed for the U.S. Army (2007) to assess potential contamination of live-fire ranges and associated human- or ecological-health risks. The study used a variety of methods to characterize the effects of artillery and other munitions use including analyses of surficial soil, streambed sediment, stream water, stream (benthic) macroinvertebrates, and groundwater. Environmental samples were analyzed for energetic compounds and selected trace elements. Semi-volatile organic compounds were not analyzed in the study. Streams sampled for streambed sediment or stream water in the U.S. Army (2007) study included five streams that also were sampled in the study described in this report, and some of the sampling sites were near one another or at the same general location.

In the U.S. Army (2007) study, perchlorate was the only energetic compound detected in 4 of 72 soil samples at relatively small concentrations of 5 micrograms per kilogram (µg/kg) or less. The authors noted that three of these detections occurred at a reference site in a historically agricultural area and that the presence of perchlorate may have resulted from fertilizer application (U.S. Army, 2007). Perchlorate has been found as a contaminant in some fertilizers, especially in Chilean nitrate fertilizer (CNF; Dasgupta and others, 2006). Perchlorate also is a component of pyrotechnic cartridges used to simulate artillery or tank main-gun fire in the MPRC. Concentrations of trace elements in soil samples did not indicate derivation from range activities. Arsenic, however, was found at relative large naturally occurring concentrations in some soil samples (U.S. Army, 2007).

Energetic compounds were not detected in streambed-sediment samples during the U.S. Army (2007) study. However, in some samples, concentrations of the trace elements antimony, arsenic, cadmium, lead, and nickel exceeded the USEPA sediment-quality guideline for a 25-percent probability (T25 level) of adverse biological effects (U.S. Environmental Protection Agency, 2004).

Perchlorate was the only energetic compound detected in stream-water samples during the U.S. Army (2007) study. It was detected in about one-fourth of the samples with concentrations that ranged from an estimated 0.069 to an estimated 0.194 µg/L (micrograms per liter). The USEPA IHA for perchlorate is 15 µg/L (U.S. Environmental Protection Agency, 2009b). Concentrations of trace elements in stream water were all less than aquatic-life criteria established by KDHE (Kansas Department of Health and Environment, 2005). Benthic macroinvertebrate diversity was not affected by range activities in any stream. The authors of the U.S. Army (2007) report acknowledged that only a few stream-water samples were collected, and because stream-water-quality characteristics can be variable, it was recommended that additional monitoring of stream water be conducted. The study described in this report represents the fulfillment of that recommendation.

Groundwater (depth to water about 11 to 105 ft below land surface) was sampled at the periphery of the IAC in the U.S. Army (2007) study. Perchlorate was the only energetic compound detected in groundwater where it was found in about one-half of the samples. The perchlorate detection concentrations ranged from an estimated 0.077 to 0.538 µg/L, with a median value of 0.166 µg/L. Concentrations of trace elements were less than USEPA drinking-water-quality standards except for manganese, which was detected at concentrations slightly exceeding the Secondary Drinking Water Regulation (SDWR) of 50 µg/L (U.S. Environmental Protection Agency, 2006). The study authors interpreted the relatively large manganese concentrations as being the result of the natural lithology of the area. The authors further concluded that groundwater surrounding the IAC was not contaminated from range activities and would not pose an unacceptable risk to humans or the environment.

Study Methods

Sampling-Site Selection

The selection of 16 streambed-sediment sampling sites (fig. 1; table 3) for the study described in this report was based on location relative to munitions firing points and impact areas. Streambed-sediment samples were collected at locations downstream from live-fire ranges and the IAC on Dry Branch

Table 3. Streambed-sediment and stream-water sampling sites at or near Fort Riley, Kansas, 2007–08.

[USGS, U.S. Geological Survey; S-S, streambed sediment sampled; W-S, stream water sampled; MPRC, Multiple-Purpose Range Complex]

Map index identifier (fig. 1)	USGS site identification number	Site name	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	S-S	W-S
RC-1	390822096523700	Rush Creek at Vinton Cemetery Road, Fort Riley	39°08' 22.1"	96°52' 37.3"	x	x
FC-1	391124096524100	Farnum Creek at South Area H Road, Fort Riley	39°11' 23.8"	96°52' 40.7"	x	x
7MC-1	391113096483600	Sevenmile Creek west of West Engineer Road, Fort Riley	39°11' 12.7"	96°48' 35.5"	x	
MC-1	391454096533000	Madison Creek at Middle MPRC Road, Fort Riley	39°14' 54.4"	96°53' 30.5"	x	
DC-1	391455096550400	Dry Creek at Middle MPRC Road, Fort Riley	39°14' 55.2"	96°55' 03.8"	x	
MCT-1	391312096535200	Madison Creek tributary at Supply Road, Fort Riley	39°13' 12.3"	96°53' 52.5"	x	
3MC-1	390756096461800	Threemile Creek at Vinton School Road, Fort Riley	39°07' 56.0"	96°46' 18.0"	x	x
HC-1	391304096431000	Honey Creek at Old Highway 82 near Keats	39°13' 03.8"	96°43' 10.1"	x	x
7MC-2	390857096430600	Seven mile Creek at East Engineer Road, Fort Riley	39°08' 56.6"	96°43' 06.0"	x	x
LAC-1	391422096460900	Little Arkansas Creek at Supply Road, Fort Riley	39°14' 21.5"	96°46' 08.7"	x	
WC-1	391341096473800	Wind Creek at Tank Road, Fort Riley	39°13' 41.2"	96°47' 38.0"	x	
3MC-2	390550096444800	Three mile Creek at Huebner Road, Fort Riley	39°05' 49.7"	96°44' 48.0"	x	
7MC-3	390753096422900	Seven mile Creek at Vinton School Road, Fort Riley	39°07' 53.0"	96°42' 28.6"	x	
DBC-1	390754096430600	Dry Branch Creek at Vinton School Road, Fort Riley	39°07' 53.6"	96°43' 05.6"	x	
WCC-1	391307096423600	Wildcat Creek at Reservation Road near Keats	39°13' 07.1"	96°42' 36.2"	x	
Reference site						
TC-1	391827096563900	Timber Creek at Bala Park, Bala	39°18' 27.3"	96°56' 39.0"	x	

(site DBC-1) and Honey Creeks (site HC-1), downstream from artillery and mortar firing points and the IAC on Threemile Creek (sites 3MC-1 and 3MC-2), and upstream (site 7MC-1) and downstream (sites 7MC-2 and 7MC-3) from the ATA on Sevenmile Creek (fig. 1). Sevenmile Creek provided a unique opportunity to evaluate streambed-sediment quality immediately before and after the stream traversed a munitions impact area of a major military installation. Because of contemporary or previous firing-point locations or the MPRC within their watersheds, samples of streambed sediment also were collected from Dry (site DC-1), Farnum (site FC-1), Little Arkansas (site LAC-1), Madison (site MC-1), Rush (site RC-1), a tributary to Madison (site MCT-1), Wildcat (site WCC-1), and Wind (site WC-1) Creeks. The Timber Creek reference site (TC-1) is located on a stream that drains from the north at a location immediately north of the military reservation. The reference site was used to assess background concentrations of energetic compounds, SVOCs, and trace elements in streambed sediment only. Stream-water samples were collected at five sites on Farnum (site FC-1), Honey (site HC-1), Rush (site RC-1), and Threemile Creeks (site 3MC-1) as well as on Sevenmile Creek (site 7MC-2) immediately downstream from the ATA (fig. 1).

Sample Collection, Handling, and Processing

Streambed-Sediment Samples

Streambed-sediment samples in this study were collected and processed according to methods described in Shelton and Capel (1994). Samples for analysis of streambed sediment were collected and sieved onsite to retain the less-than-2.0-mm (millimeter) size fraction for analysis of energetic compounds and SVOCs. Subsamples of nonsieved sediment collected for energetic compounds and SVOCs were retained for analysis of sediment particle-size fractions at each sampling site. Subsamples for trace element analysis were collected and sieved at the analyzing laboratory to retain the less-than-0.063-mm fraction (silt- and clay-sized particles). Concentrations of associated trace elements can vary substantially between particle-size classes, and generally, concentrations are largest in the silt/clay fraction (Horowitz, 1991). Restricting trace element analyses to the silt/clay fraction reduces particle-size variability between sampling sites and permits direct site-to-site comparisons. However, all trace element samples submitted to the analyzing laboratory also were analyzed in sediment particles finer than 0.063 mm prior to sieving. The concentration of

organic compounds such as energetic compounds and SVOCs in streambed sediment is not strongly tied to particle-size distribution but likely is related more to the concentration of organic material in the sediment (Shelton and Capel, 1994).

To obtain only the most recently deposited material, streambed-sediment samples were collected from the upper 2.0 cm (centimeters) of sediment deposition using a stainless-steel scoop for analysis of energetic compounds and SVOCs and a white plastic scoop for analysis of trace element samples. The use of a stainless-steel scoop for energetic compound and SVOC sampling reduced the likelihood of sample contamination from organic compounds such as phthalates that may occur when using a plastic scoop, whereas the use of a plastic scoop for trace element sampling reduced possible contamination from metals such as chromium and nickel. Sampling the upper 2.0 cm of deposition followed protocols of the USGS National Water-Quality Assessment Program (Shelton and Capel, 1994). At each streambed-sampling site, one composited sample was collected for analysis of energetic compounds and SVOCs, and one composited sample was collected for analysis of trace elements. Multiple subsamples (from 5 to 10 subsampling locations) were collected for each composited sample from depositional zones along the sides and center of sampled streams. The subsamples were composited into polyethylene zip-lock bags. The composited sample for energetic compounds and SVOCs was homogenized onsite in a glass container and sieved to obtain the less-than-2.0-mm size fraction. After sieving was completed, the less-than-2.0-mm sediment sample was placed in a clean zip-lock bag, sealed with a chain-of-custody sticker, and placed in a second clean zip-lock bag. A subsample of the homogenized, but non-sieved, composite sample was retained separately and transported to the Kansas Water Science Center (KSWSC) office in Lawrence, Kansas, for analysis of the percentage of sand-silt/clay-size particles in the sediment. The composite sample for trace element analysis was sealed with a chain-of-custody sticker, placed into a second clean zip-lock bag with a chain-of-custody sticker, and placed in a third clean zip-lock bag for shipment. The samples from each site were stored at 4 ºC in a secured area at the KSWSC until shipped to the appropriate analyzing laboratory. Energetic compound and SVOC samples sieved to 2.0 mm were sent to an U.S. Army Corps of Engineers (USACE) contract laboratory for analyses (AML Laboratories, Olathe, Kansas, subcontracted to GEL Laboratories, Charleston, South Carolina). Streambed-sediment samples for trace element analyses were sent to the USGS Sediment Trace Element Laboratory in Atlanta, Georgia.

Upon receipt at the USGS laboratory in Atlanta, the streambed-sediment samples for trace element analyses were freeze dried and placed in secure storage until preanalytical processing. Chain-of-custody procedures were followed during sample storage, processing, and analysis. Prior to analysis, the samples were sieved through a 2.0-mm polyester screen to remove large material such as wood and leaf debris and gravel. The less-than-2.0-mm samples were mechanically homogenized, and a less-than-0.063-mm fraction was obtained by sieving a representative aliquot of the homogenized sample through a 0.063-mm polyester screen held in a polycarbonate frame. Screens were replaced between samples.

Stream-Water Samples

Stream-water samples were collected according to methods described in U.S. Geological Survey (2006) to assess concentrations of energetic compounds, SVOCs, and trace elements during base-flow and runoff conditions. Base-flow conditions were defined by a single discharge measurement performed during periods of no precipitation when streamflow is supplied by groundwater and not by runoff from precipitation. Runoff conditions were defined by discharge measurements performed during or within 12 hours of precipitation events when the streamflow hydrograph demonstrated rising, peak, or falling stages. For sampling site 7MC-2, a discharge gage-height rating was developed and used to estimate discharge during automated sampling. Discharge measurements were made according to methods described by Rantz and others (1982). The discharge gage-height rating was developed according to methods described by Kennedy (1983). A single base-flow sample each was collected at sites HC-1, 3MC-1, and 7MC-2 (fig. 1). A total of 17 runoff samples were collected at five sites--one each at sites FC-1 and RC-1, two each at sites HC-1 and 3MC-1, and 11 at site 7MC-2—during rising-, falling-, and peak-stage conditions. Samples were collected manually at all sites or by an automatic sampler at site 7MC-2 for 5 of the 11 samples collected at that site. Manual sample collection was performed during base-flow and runoff conditions; the automatic sampler was used only during runoff conditions.

Manually collected stream-water samples were acquired through collection of several equally spaced, vertically integrated subsamples from the streamflow cross section (equal-width increment, EWI, method; U.S. Geological Survey, 2006). For each EWI sample, an appropriate sampler (hand-held or cable-suspended) and a Teflon collection bottle were used for collecting cross-sectional subsamples (Lane and others, 2003). All subsamples were composited into a Teflon churn for subsequent splitting of analytical samples. When streamflow was too small to permit EWI subsampling, several grab samples were collected using a hand-held sampler with a Teflon bottle and composited into a Teflon churn.

Samples collected by the automatic sampler at site 7MC-2 were pumped through Teflon tubing from a fixed sampling point in the stream and into 1-gal glass jars in the sampler storage compartment. Each sampling with the automatic sampler filled two 1-gal glass jars. Automatic sampling was triggered by an increase in discharge as recorded by a Sutron 8210 (Sutron Corporation, Sterling, Virginia) data-collection platform. The automatically collected samples (two 1-gal jars) were retrieved within 24 hours to meet analytical holding times for preventing biological alteration of the samples and were composited into a Teflon churn for subsequent splitting of analytical samples. The automatic sampler had the capacity

to collect two samples (total of four 1-gal jars) before servicing was required.

All stream-water samples were processed unfiltered and split from Teflon churns into amber glass sample bottles for energetic compounds and SVOCs analyses. Polyethylene sample bottles were used for perchlorate analyses, and acid-rinsed polyethylene sample bottles were used for trace element analyses except for samples analyzed for mercury, which were placed into acid-rinsed glass bottles with a Teflon-seal closure (Wilde and others, 2004). Samples collected for analyses of energetic compounds and SVOCs were preserved by storing at 4 ºC. Samples for analyses of trace elements were preserved with nitric acid to a pH of less than 2.0 standard units except for samples collected for analyses of mercury, which were preserved with hydrochloric acid to a pH of less than 2.0 standard units. All samples were refrigerated at 4 °C at the KSWSC office until shipped to the appropriate laboratory. Samples for analysis of trace elements in stream water were shipped to the USGS National Water-Quality Laboratory (NWQL) in Lakewood, Colorado, for analysis. Samples for analysis of energetic compounds and SVOCs in stream water were sent to the USACE contract laboratory (AML Laboratories, Olathe, Kansas, subcontracted to GEL Laboratories, Charleston, South Carolina, for some samples).

Sample Analysis

Energetic compounds, SVOCs, and trace elements analyzed in streambed-sediment and stream-water samples are listed in tables 13 and 14, respectively, in the "Supplemental Information" section at the back of this report. Analyses of energetic compounds or SVOCs in the less-than-2.0-mm fraction of streambed sediment and in stream-water samples were conducted by the USACE contract laboratory according to USEPA Method 8330 for nitroaromatic and nitramine compounds, USEPA Method 8332 for nitroglycerin, USEPA Method 8321 (modified) for perchlorate, and USEPA Method 8270C/8270D for SVOCs (table 4) (U.S. Environmental Protection Agency, 2007). Constituent concentrations analyzed in streambed sediment and stream water were reported as estimated (E) values when they fell between the analytical method detection level and the analytical method minimum reporting level (MRL). The estimated qualifier means that concentrations of constituents are less certain than concentrations reported greater than the MRL (Childress and others, 1999).

The less-than-0.063-mm fractions of streambed-sediment samples were analyzed for carbon and selected trace elements generally using procedures described in Fishman (1993) and modified by Horowitz and others (1989) (table 4). The essential procedures involved digestions of 0.5g (gram) homogenized aliquots of the less-than-0.063-mm fractions using a strong-acid combination (hydrochloric, hydrofluoric, perchloric, and nitric acids) in Teflon beakers at 210 °C for all constituents except total carbon, total organic carbon, mercury, total nitrogen, and total phosphorus. This strong-acid digestion breaks apart the mineral matrix and releases trace elements adsorbed to and (or) bound in the mineral matrix. The trace element salts produced from the digestion procedure were made soluble with 5-percent hydrochloric acid and analyzed by inductively coupled plasma-atomic emission spectroscopy, flame atomic absorption spectroscopy (AAS), or hydride generation AAS. Mercury was determined using cold vapor AAS (Grosbois and others, 2001). Carbon, nitrogen, and phosphorus were determined by procedures described in Fishman (1993).

Trace elements in stream-water samples were analyzed at NWQL according to procedures in Garbarino and Struzeski (1998) and Garbarino and Damrau (2001) (table 4). Samples for all selected trace elements except mercury were prepared for analysis by digesting in the sample bottle with nitric acid and filtering the digested sample. Stream-water samples were prepared for analysis of mercury by oxidation with a bromine monochloride (BrCl) digestion procedure. Analyses of all selected trace elements except mercury were performed by inductively coupled plasma optical emission spectrometry and inductively coupled plasma mass spectrometry. Mercury was analyzed by cold vapor atomic fluorescence spectrometry.

Table 4. Laboratory analytical methods used to analyze streambed-sediment and stream-water constituents in samples collected from Fort Riley, Kansas, 2007–08.

[USGS, U.S. Geological Survey; MS, mass spectrometry; HPLC, high-performance liquid chromatography; USEPA, U.S. Environmental Protection Agency; GC, gas chromatography. Method reference may contain revised versions of analytical methods]

Constituent group	Analysis method	Method reference
Trace elements in streambed sediment	Various methods	Fishman (1993); Horowitz and others (1989)
Trace elements in stream water (USGS schedule 2705)	Various methods	Gabarino and Struzeski (1998); Gabarino and Damrau (2001)
Energetic compounds (USEPA Method 8330)	HPLC	USEPA (2007)
Nitroglycerin (USEPA Method 8332)	HPLC	USEPA (2007)
Perchlorate (USEPA Method 8321, modified)	Liquid Chromatography/MS/MS	USEPA (2007)
Semi-volatile organic compounds (USEPA Method 8270C/8270D)	GC/MS	USEPA (2007)

Quality Assurance

Quality-assurance samples were collected to test precision and bias in streambed-sediment and stream-water sample collection, processing, and analyses. Quality-assurance samples for streambed sediment included concurrent, sequential, and split replicate environmental samples, laboratory split replicate samples (table 15 in the "Supplemental Information" section at the back of this report), standard-reference soil/sediment samples (table 17 in the "Supplemental Information" section at the back of this report), and laboratory quality-control samples. Quality-assurance samples for stream water included concurrent and split replicate samples, and laboratory quality-control samples. A target goal for variability among analyses of concurrent, sequential, and split replicate samples was an absolute relative percentage difference (RPD) of 20 percent except when constituent concentrations were at or near MRLs. RPD was calculated as the absolute value of the difference in environmental (primary) and replicate sample values divided by the mean and expressed as a percentage.

Streambed-Sediment Samples

Because energetic compounds and SVOCs were not detected in any streambed-sediment samples with replicates (table 15), RPD values for streambed-sediment samples were available only for trace element analyses. A target goal for acceptable results of analysis of standard-reference soil samples was within published limits (table 17) for each constituent for each standard or ±10 percent of the most probable value (MPV) for the constituent (whichever was greater) except when constituent concentrations were at or near MRLs. Analyses of standard-reference soil samples were conducted only for trace elements.

Streambed-sediment concurrent replicate samples consisted of alternately collected subsamples (from same subsampling site) composited into two sample-collection bags. Analysis of concurrent replicate samples measures the variability of sample-collection methods. One pair of concurrent replicate samples (table 15) was collected from site 7MC-3 (fig.1).

Streambed-sediment sequential replicate samples consisted of two independently collected (different subsampling sites) samples acquired at the same sampling site. Analysis of sequential replicate samples measures the effects of sampling-site (within site) variability and the degree to which data accurately and precisely represent a characteristic of a population at a sampling site. One pair of sequential replicate samples (table 15) was collected from site DC-1 (fig. 1).

Streambed-sediment split replicate environmental samples consisted of subsamples composited into a common glass container, homogenized, and split into separate sample-collection bags. Analysis of split replicate environmental samples measures the homogeneity of an environmental sample. One pair of split replicate environmental samples was collected from site 3MC-1 (fig. 1).

All RPD values between replicate pairs of streambed-sediment environmental samples were less than the 20-percent quality-assurance goal except for one paired analysis for cadmium in the split replicate samples from site 3MC-1 where the RPD was 28.6 percent (table 5). However, this unusually large RPD is not considered significant because cadmium concentrations for this pair of samples were small and near the MRL of 0.1 mg/kg (milligram per kilogram) (table 15). Therefore, any small difference between replicate analyses could result in a relatively large RPD. Generally, analysis of replicate environmental samples indicates that sampling methods, subsample site selection, and compositing methods did not produce an unacceptable degree of variability in analytical results.

Laboratory split replicate samples for streambed sediment consisted of two subsamples of a homogeneously prepared environmental sample that were selected randomly at the time of sample analysis. Analysis of split replicate samples measures the precision (reproducibility) among replicate measurements of the same property and represents the ability of laboratory methods to reproduce the same or nearly the same concentration of selected constituents in an environmental sample. Two laboratory split replicate samples were analyzed for trace elements in streambed sediment to evaluate precision in laboratory methods (table 5). Most of the trace elements had RPDs less than the 20-percent goal. The exceptions were cadmium and selenium where the maximum RPDs were 40 and 66.7 percent, respectively. However, these trace elements were detected at small concentrations (less than 1 mg/kg), and a small absolute difference at these concentrations may translate into a large RPD.

Standard-reference soil/sediment samples were obtained from sources indicated in table 17. Analysis of reference samples provides a measure of the accuracy of laboratory methods to produce the true value of a measured constituent and essentially represents the bias in methodology (instrumentation and procedures). As many as nine reference-sample analyses were performed for the trace elements evaluated in streambed sediment in this report (table 6). Censored results (not detected or reported as less than the MRL) were not used in comparison to reference limits or MPVs. Of the 202 trace elements analyses performed on reference samples, 90 percent met quality-assurance goals as previously defined. Seventeen of the 29 constituents listed in table 6 were within established quality-assurance criteria in 100 percent of reference analyses for those constituents. Cadmium, molybdenum, and silver were within established quality-assurance criteria in 71, 56, and 50 percent of analyses, respectively, but were detected at or near the analytical reporting limit when they were outside of quality goals. The trace elements antimony, barium, carbon (total), manganese, sulfur, and zinc were within established quality-assurance criteria in more than 80 percent of analyses. In contrast, mercury and selenium were within established quality-assurance criteria in 43 percent of analyses, and most of the concentrations determined were greater than the MRL for those trace elements (table 6). Overall, laboratory accuracy was of acceptable quality, and the analytical results for trace

Table 5. Statistical summary of absolute relative percentage differences between trace element , carbon, and nutrient analyses of concurrent-, sequential-, and split-replicate environmental samples, and laboratory split-replicate samples of the less-than -0.063-millimeter fraction of streambed sediment from selected sampling sites at Fort Riley, Kansas, 2007.

[N, number of replicate pair analyses; Min, minimum percentage; Med, median percentage; Max, maximum percentage; --, not determined]

Constituent	Environmental replicate samples					Laboratory split-replicate samples			
	N	Min	Med	Mean	Max	N	Min	Med/Mean	Max
Aluminum	3	1.8	2.0	3.0	5.3	2	0	0	0
Antimony	3	0	0	0	0	2	0	0	0
Arsenic	3	1.6	2.3	3.0	5.2	2	0	.7	1.4
Barium	3	1.5	1.6	1.6	1.6	2	3.3	3.9	4.6
Beryllium	3	0	6.1	4.3	6.9	2	0	0	0
Cadmium	3	0	0	9.5	28.6	2	28.6	34.3	40
Carbon, organic, total	3	0	0	2.7	8.0	2	8	8.8	9.5
Carbon, total	3	5.7	7.4	8.3	11.8	2	0	0	0
Chromium	3	0	1.9	1.4	2.2	2	0	7.2	14.4
Cobalt	3	0	0	2.7	8	2	0	0	0
Copper	3	0	0	2.5	7.4	2	0	3.2	6.5
Iron	3	0	4.3	4.4	9.1	2	0	0	0
Lead	3	0	0	1.7	5.1	2	0	2.3	4.7
Lithium	3	0	4.1	3.9	7.7	2	3.9	5	6.1
Manganese	3	4.1	5.4	6.7	10.7	2	1.8	2.9	3.9
Mercury	0	--	--	--	--	0	--	--	--
Molybdenum	0	--	--	--	--	0	--	--	--
Nickel	3	0	0	1.7	5.1	2	0	2.6	5.1
Nitrogen	3	0	0	0	0	2	0	0	0
Phosporus	3	0	1.9	1.3	2.1	2	0	1.1	2.1
Selenium	3	0	0	0	0	2	40	53.3	66.7
Silver	0	--	--	--	--	0	--	--	--
Strontium	3	0	0	0	0	2	0	4	8
Sulfur	3	0	0	0	0	2	0	0	0
Thallium	0	--	--	--	--	0	--	--	--
Titanium	3	0	2.7	1.8	2.7	2	0	0	0
Uranium	0	--	--	--	--	0	--	--	--
Vanadium	3	0	1.4	2.4	5.7	2	1.4	2.2	2.9
Zinc	3	1.3	3.4	4.5	8.8	2	0	.7	1.5
Total number of replicate pair analyses	72	--	--	--	--	48	--	--	--

elements in streambed sediment were considered representative of the samples submitted for analysis, with the exception of mercury and selenium. Quality-assurance analyses of replicate samples were not available for energetic compounds or SVOCs because none of these compounds were detected in streambed sediment from sites that had replicate samples (table 15 in the "Supplemental Information" section at the back of this report).

Laboratory quality-assurance measures were undertaken during analyses for energetic compounds and SVOCs in streambed-sediment samples. Laboratory quality-assurance measures included analyses of laboratory-control samples, matrix spike samples, and matrix spike duplicate samples (U.S. Environmental Protection Agency, 2007). The percentage of recoveries in laboratory-control samples or matrix spike samples and matrix spike duplicate samples were outside laboratory quality-assurance goals (usually smaller percentage of recoveries than stated goals) for some SVOCs--2,4-dinitrophenol, 3,3'-dichlorobenizidine, di-n-octylphthalate, 4-nitrophenol, and hexachlorocyclopentadiene. Nondetections in the

Table 6. Statistical summary of trace element , carbon, and nutrient analyses of standard-reference soil/sediment samples.

[MPV, most probable value; --, not determined]

Constituent	Number of reference analyses[1]	Range of MPVs[2]	Percentage difference from MPV (absolute values)				Percentage of reference analyses within established quality criteria[3]
			Minimum	Median	Mean	Maximum	
Aluminum	9	2.3–9.73	0	1.4	1.1	2.0	100
Antimony	8	0.3–19.4	0	7.1	7.3	12.4	88
Arsenic	8	4.6–105	.7	3.5	3.8	7.5	100
Barium	9	210–1,340	.6	5.3	6.5	16.9	89
Beryllium	6	1.06–9.6	0	2.6	2.2	3.8	100
Cadmium	7	0.14–41.7	0	7.5	16.6	50.0	71
Carbon, organic, total	1	24.8	8.9	8.9	8.9	8.9	100
Carbon, total	6	0.81–28	3.6	7.7	9.6	23.5	83
Chromium	9	4.3–130	2.1	7.4	10.3	39.5	100
Cobalt	8	5–46.8	0	4.2	3.6	7.8	100
Copper	9	4.6–114	1.3	4.7	6.0	13.0	100
Iron	9	2.00–6.53	0	2.0	1.9	3.8	100
Lead	9	12–1,162	0	5.3	4.9	10.5	100
Lithium	7	17–147	0	2.8	6.6	18.8	100
Manganese	9	234–1,700	1.5	5.9	5.7	13.9	89
Mercury	7	0.018–6.25	4	26.3	51.5	178	43
Molybdenum	9	1.37–134	3.8	11.9	17.2	50.0	56
Nickel	9	3.0–99.5	3.4	8.7	11.0	33.3	100
Nitrogen	1	.35	11.4	11.4	11.4	11.4	100
Phosphorus	9	270–1,430	1.4	3.7	4.9	16.1	100
Selenium	7	0.19–6.8	1.1	9.7	16.1	57.9	43
Silver	2	0.41–4.63	.6	11.3	11.3	22.0	50
Strontium	9	68–700	2.2	4.1	4.2	7.1	100
Sulfur	7	0.042–5.35	3.2	8.5	8.5	12.8	86
Thallium	0	--	--	--	--	--	--
Titanium	9	0.081–0.46	0	2.3	2.7	6.9	100
Uranium	1	48.8	2.5	2.5	2.5	2.5	100
Vanadium	9	8.7–160	0	4.4	9.7	54.0	100
Zinc	9	49–350.4	0	7.7	6.7	10.8	89
Total number of reference analyses and mean percentage of reference analyses within established quality criteria	202	--	--	--	--	--	90

[1]Does not include analyses reported as not detected or as less than the laboratory method reporting limit.

[2]In milligrams per kilogram except for aluminum, carbon, iron, nitrogen, and titanium, which are in percentage of dry weight.

[3]Acceptable variability among analyses of standard-reference samples is within the published limits for each constituent for each standard or ±10 percent of the MPV, whichever is greater.

environmental samples of these five SVOCs that had associated laboratory quality-assurance concerns were qualified by the laboratory with the understanding that the true concentration of these constituents may be obscured. All environmental streambed-sediment samples had laboratory quality-assurance concerns for one or more of the aforementioned five SVOCs. However, none of the SVOCs with laboratory quality-assurance concerns were detected in any of the streambed-sediment samples, and in the few instances when other SVOCs were detected, they were found at relatively small concentrations

(near or smaller than the MRL). Thus, it is reasonable to assume that the actual SVOC concentrations for these particular quality-concerned constituents would not be appreciably different than the reported nondetection values.

Stream-Water Samples

Stream-water replicate samples included concurrent and split replicate environmental samples collected from site 7MC-2 on June 2, 2008 (table 16 in the "Supplemental Information" section at the back of this report). The concurrent replicate sample (1335 hours) was collected by the automatic sampler at the point in time when the manual environmental sample (1320 hours) was about half collected. The concurrent replicate stream-water sample measures the comparability of automatically collected samples to manually collected samples. Results of analyses for the manually collected and automatically collected samples are evaluated by calculation of the ratio of the concentrations in the manually collected sample to the concentration of the constituent in the automatically collected sample. This ratio provides a simple measure of the degree and direction in which deviations occur between these two samples. Replicate-pair ratios were available only for perchlorate, trace elements, and major cations because no other energetic compounds or SVOCs were detected in either sample of the replicate pair. With the exception of sodium, all constituents had larger concentrations in the manually collected sample. The median and mean ratios were 1.316 and 1.311, respectively (table 7). Generally, these results indicate that cross-sectional mean constituent concentrations as represented by manually collected EWI samples at site 7MC-2 are underestimated by automatically collected point samples by a factor of about 1.3.

A stream-water split replicate sample (1325 hours) was collected at site 7MC-2 from the same sample churn as the environmental sample (1320 hours). RPDs between the two samples were calculated but were available only for perchlorate, trace elements, and major cations. The RPDs between replicate pairs generally were small, as evidenced by a 75th percentile value of 2.4 percent (table 8). The maximum RPD was 16.2 percent, still within the 20-percent quality-assurance goal.

Quality-assurance measures were part of laboratory analytical protocols for stream-water constituents. Analysis of a perchlorate matrix spike sample identified a large percentage recovery value that was larger than the laboratory quality-assurance goal. This resulted in "estimated" qualifiers for measured concentrations of perchlorate in samples from the following sites: RC-1, FC-1, 3MC-1 (5/26/08), HC-1 (5/27/08), 7MC-2 (5/26/08 at 1045 and 2140 hours), and 7MC-2 (5/27/08) (table 16). This exceedance of laboratory quality-assurance goals indicates that the actual concentration of perchlorate in these samples may be smaller than the reported concentrations. Additionally, four SVOC samples from site 7MC-2 (6/2/08 at 1130, 1325, 1335, and 2030 hours) were processed past twice the standard sample-holding time of 7 days. Percentage recoveries of SVOCs for some laboratory-control or matrix-spike duplicate samples also exceeded laboratory quality-assurance goals for stream-water samples collected from the following sites: 3MC-1 (6/20/07 and 7/4/07), HC-1 (6/20/07), and 7MC-2 (6/02/07) (table 16). Therefore, the nondetection of SVOCs in these samples was qualified by the laboratory with the understanding that the excessive holding time and quality-assurance concerns with laboratory-control or matrix-spike duplicate samples may obscure the true concentration of these constituents.

Table 7. Statistical summary of ratios of manually collected (1320 hours) to automatically collected (1335 hours) concurrent replicate analyses of perchlorate, trace elements, and major cations in stream-water samples collected at site 7MC-2, Fort Riley, Kansas, June 2, 2008.

[M, manually collected sample; A, automatically collected sample]

Summary statistic	Number of replicate analyses or ratios (M/A)
Number of replicate analyses	24
Minimum	.986
25th percentile	1.254
Median	1.316
Mean	1.311
75th percentile	1.394
Maximum	1.517

Table 8. Statistical summary of relative percentage differences between environmental (1320 hours) and split replicate (1325 hours) analyses of perchlorate, trace elements, and major cations in stream-water samples collected at site 7MC-2, Fort Riley, Kansas, June 2, 2008.

Summary statistic	Number of replicate analyses or relative percentage difference
Number of replicate analyses	24
Minimum	.1
25th percentile	.4
Median	.8
Mean	2.3
75th percentile	2.4
Maximum	16.2

Assessment of Streambed Sediment

Energetic compounds and particularly trace elements can accumulate in streambed sediment (Horowitz and others, 1989; Horowitz, 1991). Analysis of streambed sediment can provide useful information about the extent and magnitude

of constituent dispersal within watersheds and the affinity of constituents to move from dispersal areas. Samples of streambed sediment were collected at 16 sampling sites at or near the Fort Riley Military Reservation (fig. 1) and analyzed for selected energetic compounds, SVOCs, carbon, and trace elements. Results of these analyses were tabulated (table 15 in the "Supplemental Information" section at the back of this report), summarized, and assessed. Assessment of these data included the extent and magnitude of constituent occurrence and the potential for constituent concentrations to adversely affect aquatic life relative to recommended sediment-quality guidelines. For sampling sites with both environmental (primary) and replicate sample analyses (table 15), analytical results were averaged prior to statistical summary and assessment.

Statistical Summary and Spatial Variability

None of the energetic compounds or SVOCs analyzed in streambed sediment were detected in samples from selected stream sites (fig. 1) located within the Fort Riley Military Reservation (table 15). The only detections of any of these compounds were for the SVOCs benzo[a]pyrene (estimated 54.3 µg/kg), benzo[b]fluoranthene (165 µg/kg), fluoranthene (estimated 107 µg/kg), and pyrene (estimated 114 µg/kg) all of which were in the sample collected at reference site TC-1 (fig. 1) located just upstream from the northern boundary of Fort Riley. These results are in general agreement with the nondetection of energetic compounds in streambed sediment in the U.S. Army (2007) study. The implications of these nondetections for energetic compounds and SVOCs are that either the compounds are not being transported from areas of dispersal (munitions firing points and impact areas), the compounds do not favor adsorption to sediment in streambeds, or that current (2008) analytical methods are not sensitive enough to detect the small concentrations that may be transported adsorbed to suspended sediment and subsequently deposited on streambeds. It is not surprising, however, that perchlorate was not found in streambed sediment because its negative log K_{OW} value (table 1) means that the compound would partition strongly to the dissolved phase.

As mentioned in the "Introduction" of this report, trace elements may be components of casings, projectiles, explosives, or detonators of munitions and include aluminum, antimony, barium, copper, iron, lead, mercury, molybdenum, titanium, uranium, and zinc. These elements and others commonly are transported adsorbed to suspended sediment and, subsequently, may be deposited on streambeds. An analysis of streambed sediment for trace elements may provide insight into potential for contamination resulting from live fire of military munitions. Therefore, a statistical analysis (table 9, fig. 7) was conducted of trace element concentrations in streambed sediment for the 15 sampling sites within the Fort Riley Military Reservation and compared to the reference site TC-1 (fig. 1).

Generally, the range in concentrations for most trace elements among the 15 sampling sites was narrow and not too dissimilar from background concentrations determined in streambed sediment from reference site TC-1. Reference site concentrations usually equated to about the 50th to 75th percentile concentration range among the 15 sampling sites. These results provide little evidence of contamination relative to live-firing exercises. However, to further examine or quantify potential contamination, streams with multiple sampling locations that transect or receive intervening drainage from munitions firing points or the IAC were assessed in greater detail. Two streambed-sediment sampling sites were located on Threemile Creek, and three sampling sites were located on Sevenmile Creek (fig. 1, table 3). All of these sites receive drainage from firing points and (or) the IAC with each succeeding downstream site receiving additional drainage from affected areas relative to the preceding upstream site. Sevenmile Creek has the largest potential for trace element contamination because it transects not only the IAC but also the ATA. The ATA likely contains the largest dispersal of energetic compounds and associated trace elements from munitions firing or detonations of any location at Fort Riley. Therefore, Sevenmile Creek could be the most vulnerable to hydrologic contamination from munitions-related trace elements as verified by a comparison of trace element concentrations between sites upstream (site 7MC-1) from and downstream (sites 7MC-2 and 7MC-3) from the IAC. In reality, this vulnerability (potential contamination) was not supported by the streambed-sediment trace element data from Sevenmile Creek or by equivalent data from Threemile Creek (fig. 8). In fact, trace element concentrations in streambed sediment changed little along the upstream-to-downstream flow paths of Threemile and Sevenmile Creeks (table 15).

Data from selected streambed-sampling sites at Fort Riley are not indicative of trace elements contaminantion of streambed sediment at least in regards to movement from dispersal areas. This conclusion may indicate that (1) trace elements associated with military munitions may not be of sufficient mass to significantly increase background concentrations in streambed sediment of local streams, (2) trace elements become adsorbed to soil particles not readily transported from dispersal areas, (3) actual munitions dispersal areas (areas directly affected by detonations) may be small relative to the overall size and associated drainage area of the firing points and impact areas, or (4) some combination of the first three.

Relation to Sediment-Quality Guidelines

The USEPA has established sediment-quality guidelines for concentrations of certain compounds and trace elements in the form of level-of-concern concentrations (U.S. Environmental Protection Agency, 2004). These level-of-concern concentrations were derived from biological-effects correlations made on the basis of paired field (collected onsite) and laboratory data to relate incidence of adverse biological effects

Table 9. Statistical summary of sediment particle size and selected trace element, carbon, and nutrient concentrations in the less-than-0.063 millimeter fraction of streambed sediment collected from 15 sampling sites at Fort Riley, Kansas, with comparison to reference site TC-1, 2007.

[Concentrations may represent an average of environmental (primary) and replicate samples presented in table 15. Concentrations are in milligrams per kilogram unless otherwise indicated; T25, concentration with a 25-percent probability of toxic effects; <, less than; mm, millimeter; %, percentage of dry weight ; --, not applicable]

Constituent	Particle size or concentration						
	Minimum	Percentile			Maximum	Reference site (TC-1; fig. 1)	T25 sediment quality guideline value
		25	50 (median)	75			
Sediment, <0.063 mm, %	44	58	60	70	78	76	--
Trace element , carbon, or nutrient concentration in the less-than-0.063-mm fraction							
Aluminum, %	5.0	5.4	5.5	5.6	5.9	5.5	--
Antimony	.6	.6	.7	.7	.8	.7	1.09
Arsenic	4.4	5.4	6.1	6.8	7.3	6.6	11.29
Barium	610	630	640	660	680	650	--
Beryllium	1.4	1.6	1.6	1.6	1.7	1.6	--
Cadmium	.2	.3	.3	.4	.5	.4	.65
Carbon, organic, total, %	.8	.9	1.0	1.2	1.5	1.0	--
Carbon, total, %	1.1	1.3	1.4	1.7	1.8	1.6	--
Chromium	44	47	49	51	56	47	76
Cobalt	8.0	9.5	11	12	13	12	--
Copper	13	14	14	15	17	15	49.98
Iron, %	1.9	2.0	2.2	2.2	2.5	2.2	--
Lead	18	19	21	22	26	22	47.82
Lithium	24	26	27	28	34	27	--
Manganese	340	460	530	620	710	600	--
Mercury	<.01	<.01	<.01	<.01	<.01	<.01	.23
Molybdenum	<1	<1	1	1	1	1	--
Nickel	16	18	20	20	23	19	23.77
Nitrogen, %	.08	.09	.10	.10	.10	.10	--
Phosporus	430	460	490	520	590	480	--
Selenium	.1	.2	.2	.2	.3	.2	
Silver	<.5	<.5	<.5	<.5	<.5	<.5	.44
Strontium	130	140	150	160	180	140	--
Sulfur	.02	.02	.02	.03	.03	.02	--
Thallium	<50	<50	<50	<50	<50	<50	--
Titanium, %	.36	.37	.38	.38	.39	.36	--
Uranium	<50	<50	<50	<50	<50	<50	--
Vanadium	61	66	68	70	76	66	--
Zinc	59	65	69	72	80	66	140.48

to dry-weight sediment concentrations. Sediment-quality guidelines are presented as the concentration of a compound or trace element that would produce toxic effects in sediment-inhabiting organisms with a specified probability – for example, 25-percent (T25) and 50-percent (T50) probabilities of toxicity (table 10).

USEPA notes that T25 and T50 guidelines are for use as screening tools for possible hazardous levels of chemicals and are not intended as regulatory criteria (U.S. Environmental Protection Agency, 2004). This cautionary statement is made because, although biological-effects correlation identifies level-of-concern concentrations associated with the likelihood of adverse organism response, the procedure may not demonstrate that a particular chemical or trace element is solely responsible. In fact, biological-effects correlation may not indicate direct cause-and-effect relations because sampling

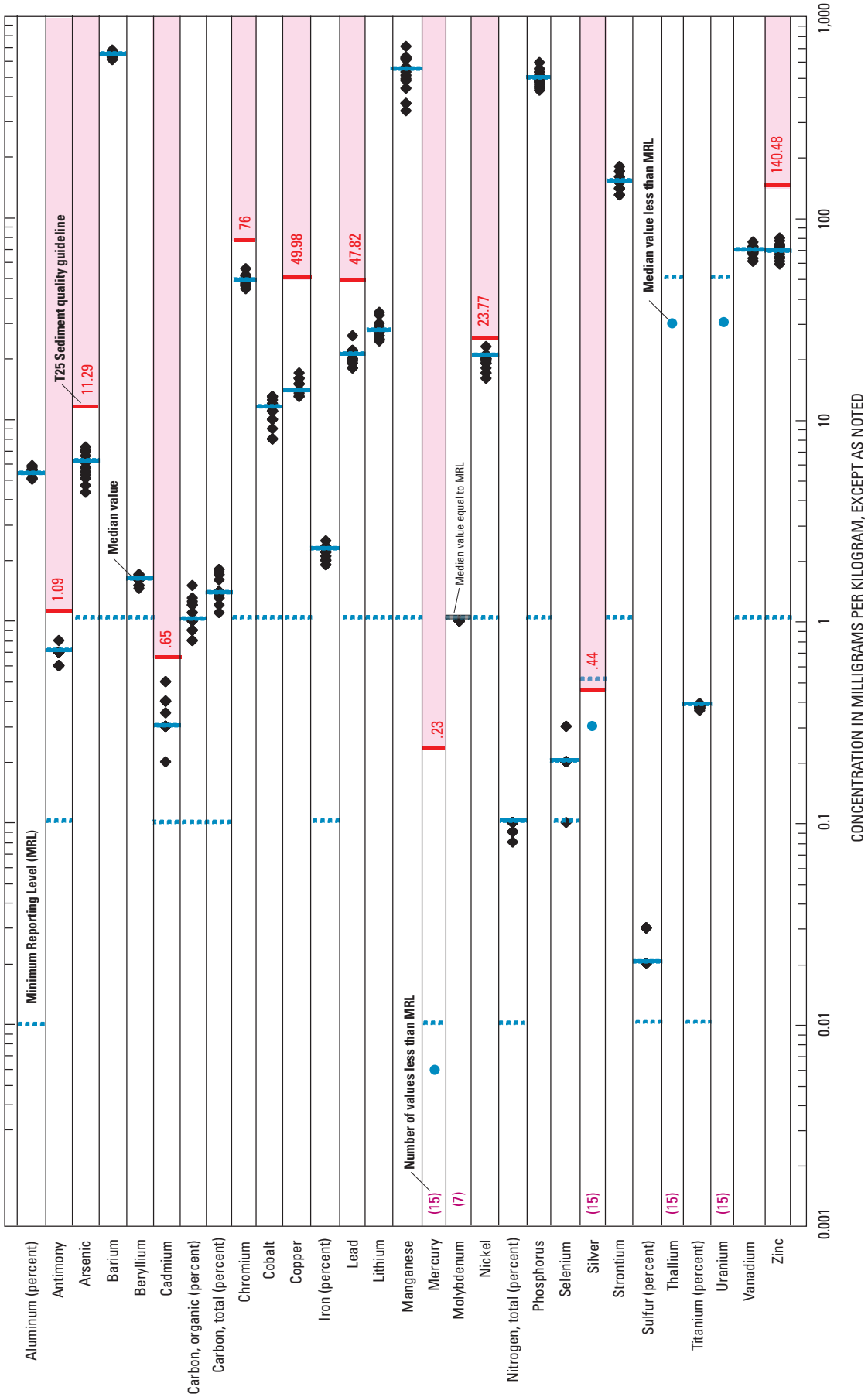


Figure 7. Method reporting limits, sample concentrations and median values in the less-than-0.063-millimeter fraction of streambed sediment for selected trace elements and carbon from 15 sites at Fort Riley, 2007, and 25-percent probability sediment-quality guidelines for toxicity in benthic organisms (U.S Environmental Protection Agency, 2004).

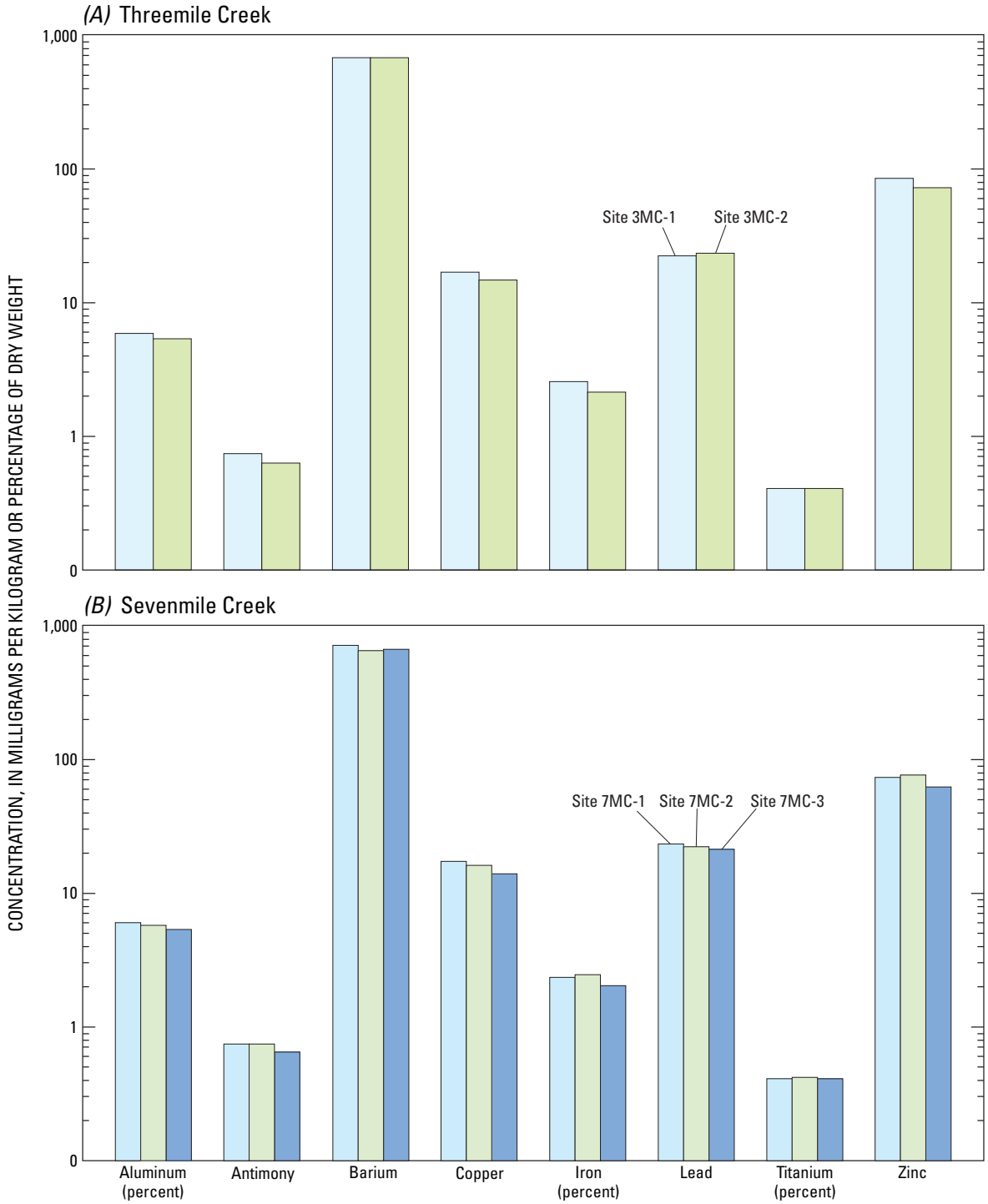


Figure 8. Comparison of concentrations of selected trace elements in the less-than-0.063-millimeter fraction of streambed sediment from sampling sites on Threemile and Sevenmile Creeks, Fort Riley, 2007.

sites may contain a mixture of chemicals or trace elements that contribute to the toxic effects to some degree. Therefore, for any given site, these guidelines may be over-or underprotective.

Although sediment-quality guidelines have not been established for any of the energetic compounds examined in the study described in this report, guidelines have been established for several SVOCs and trace elements (table 10). Maximum concentrations of these SVOCs and trace elements determined among all 16 streambed-sampling sites (fig. 1) at or near Fort Riley were compared to the T25 and T50 sediment-quality guidelines. None of the maximum concentrations reported as uncensored values in table 10 exceeded either sediment-quality guideline, and, in fact, only one constituent

Table 10. Maximum concentrations and recommended sediment-quality guidelines (U.S. Environmental Protection Agency, 2004) for selected semi-volatile organic compounds and trace elements analyzed in streambed sediment from 16 sampling sites at or near Fort Riley, Kansas, 2007.

[T25, concentration with a 25-percent probability of toxic effects; T50, concentration with a 50-percent probability of toxic effects; <, less than; E, estimated concentration; ?, not known because method reporting limit is large relative to guideline value]

Sediment constituent	Maximum concentration or largest non-detected value	T25 guidelines		T50 guidelines	
		Guideline value	Number of sites exceeding guideline	Guideline value	Number of sites exceeding guideline
Semi-volatile organic compounds, in micrograms per kilogram					
1,1'-Biphenyl	<1,570	30	?	140	?
9H-Fluorene	<157	40	?	260	0
Acenaphthene	<157	40	?	270	0
Acenaphthylene	<157	40	?	420	0
Anthracene	<157	80	?	800	0
Benzo[a]anthracene	<157	140	?	1,210	0
Benzo[a]pyrene	E54.3	160	0	1,340	0
Benzo[b]fluoranthene	165	320	0	3,030	0
Benzo[g,h,i]perylene	<157	150	?	1,280	0
Benzo[k]fluoranthene	<157	160	0	1,400	0
Chrysene	<157	190	0	1,730	0
Dibenzo[a,h]anthracene	<157	40	?	260	0
Fluoranthene	E107	290	0	2,860	0
Indeno[1,2,3-cd]pyrene	<157	160	0	1,230	0
Phenanthrene	<157	150	?	1,120	0
Pyrene	E114	290	0	2,410	0
Trace elements, in milligrams per kilogram					
Antimony	.8	1.09	0	4.41	0
Arsenic	7.3	11.29	0	32.61	0
Cadmium	.5	.65	0	2.49	0
Chromium	56	76	0	233.27	0
Copper	17	49.98	0	157.13	0
Lead	26	47.82	0	161.06	0
Mercury	<.01	.23	0	.87	0
Nickel	23	23.77	0	80.07	0
Silver	<.5	.44	?	2.45	0
Zinc	80	140.48	0	383.81	0

(nickel) was even relatively close to the most stringent (smallest concentration) T25 guideline. This diverges from the results obtained in the U.S. Army (2007) study where the trace elements antimony, arsenic, cadmium, lead, and nickel exceeded the T25 guideline in some instances.

Some ambiguity exists in the comparison of streambed-sediment concentrations of some SVOCs and a trace element to sediment-quality guidelines because of relatively large MRLs. The MRLs for the SVOCs 1,1'-biphenyl, 9H-fluorene, acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[g,h,i]perylene, dibenzo[a,h]anthracene, and indeno[1,2,3-cd]pyrene, and the trace element silver were larger than the most stringent guideline for each compound (T25; table 10). Analytical methods and associated MRLs were fixed by the USACE contract laboratory for energetic compounds and SVOCs. The inability of the analytical methods to report nondetection concentrations at or smaller than guideline values for these compounds means it is unclear whether concentrations of these particular compounds exceed guideline values in these instances. With the exception of 1,1'-biphenyl, however, the MRLs were less than the T50 guideline. The maximum concentration comparisons to sediment-quality guidelines do not indicate a large probability of toxic effects to aquatic organisms from detected concentrations of SVOCs or trace elements in streambed sediment at or near Fort Riley.

Assessment of Stream-Water Quality

Energetic compounds, SVOCs, and trace elements may be transported in runoff from areas of dispersal in particulate form, adsorbed to suspended sediment, or in the dissolved phase. These constituents, subsequently, may reach streams and become contaminants in stream water. Analyses of unfiltered stream-water samples provide information about the extent and magnitude of constituent occurrence and potential watershed source. Stream-water samples were collected from five sites during the investigation described in this report and were analyzed for selected physical properties, energetic compounds, SVOCs, and trace elements. Results of these analyses were tabulated (table 16 in the "Supplemental Information" section at the back of this report), summarized, and assessed. Assessment of these data included the extent and magnitude of constituent occurrence and the potential for constituent concentrations to adversely affect aquatic life relative to surface-water-quality criteria. Results of the manually collected runoff sample (1320 hours) and split replicate sample (1325 hours) collected at site 7MC-2 on June 2, 2008, were averaged prior to statistical summary or assessments described in this report. Because manually collected EWI samples were available for site 7MC-2 on June 2, 2008, data from the automatically collected, concurrent replicate sample (1335 hours) for this date (table 16) were not used in statistical summaries or assessments.

Statistical Summary and Spatial Variability

Stream-water samples were collected throughout a wide range of streamflow conditions. Base-flow samples (stable, low streamflow) were collected at sites HC-1, 3MC-1, and 7MC-2 (fig. 1) at instantaneous discharges ranging from 0.62 (site HC-1) to 6.4 ft^3/s (site 7MC-2) (table 16). Runoff samples were collected at sites RC-1, FC-1, and HC-1 during a falling stream stage with discharges that ranged from 24.9 (site FC-1) to 1,030 ft^3/s (site HC-1). Of the two runoff samples collected at site 3MC-1, one was during a falling stage (163 ft^3/s), and the other was during a rising stage (53.1 ft^3/s). Runoff samples collected at site 7MC-2 were collected during rising, peak, and falling stages with discharges that ranged from 4.6 to 966 ft^3/s. This discharge range for sample collection at site 7MC-2 roughly corresponds to the total range in recorded discharge at this site (0.32 to 1,100 ft^3/s) during stream-water sample collection from June 20, 2007, through June 2, 2008 *(http://nwis.waterdata.usgs.gov/ks/nwis/measurements/?site_no=390857096430600)*.

Perchlorate was the only energetic compound detected in stream-water samples collected during the study described in this report. Perchlorate was detected in 19 of 20 stream-water samples in concentrations that ranged from an estimated 0.057 µg/L (site 7MC-2) to an estimated 0.236 µg/L (site FC-1) (table 16) with a median concentration of an estimated 0.114 µg/L, which is substantially less than the 15-µg/L IHA. This range of concentrations is similar to that found in stream water during the U.S. Army (2007) study (0.069 to 0.194 µg/L). Also, the nondetection of other energetic compounds in stream water in the U.S. Army (2007) study is in general agreement with the nondetection of selected energetic compounds (other than perchlorate) in the study described in this report.

Perchlorate reacts vigorously when used as a component of rocket propellant, however, it is actually quite chemically stable under many conditions (Espenson, 2003). The chemical stability of perchlorate is attested to by its detection in the environment in various samples. In the late 19th century, perchlorate was identified in samples of high-nitrate caliche deposits in Chile (Dasgupta and others, 2006). These deposits are used as a fertilizer called "Chilean nitrate fertilizer" (CNF). Use of CNF on agricultural land represents a source of perchlorate input to the environment that is separate from munitions use. Historically, CNF has been used extensively in the United States, although its use in recent decades has decreased substantially (Dasgupta and others, 2006).

More recently, small concentrations of perchlorate have been detected in natural water, especially in groundwater. Often, the presence of perchlorate in water is linked to its production, handling, and use as a propellant, but detections of the compound in samples from relatively pristine areas have led to the investigation of naturally occurring perchlorate. Naturally occurring perchlorate is thought to originate from atmospheric formation of the compound especially during lightning storms. Parker and others (2008) reported detectable concentrations of perchlorate in a majority of rainfall samples from pristine sites in the conterminous United States, with a range of detected values between an estimated 0.07 and 24.4 µg/L and the maximum concentration detected in a sample from a site in rural Colorado. The authors also noted large spatial and temporal variability in perchlorate concentrations in rainfall.

Parker and others (2008) also investigated naturally occurring perchlorate concentrations in groundwater in the conterminous United States. They estimated that a median background concentration of perchlorate is detectable but not quantifiable in groundwater at a concentration between 0.04 and 0.12 µg/L. Concentrations generally were larger in semi-arid regions including the Great Plains. Perchlorate in water from the nine wells sampled in Kansas for the Parker and others (2008) study had a median concentration of 0.665 µg/L.

Backus and others (2005) studied surface-water occurrence of perchlorate in the Canadian Great Lakes Basin. Samples were collected from Lake Erie, Lake Huron, and 12 streams. Perchlorate was not found in samples from the lakes but was detected in samples from six of the streams with concentrations that ranged from 0.16 to 0.33 µg/L. Backus and others (2005) attributed the presence of perchlorate in the stream water to agricultural activity in the watershed.

Perchlorate occurs in stream water at sites receiving drainage from munitions firing points and impact areas at Fort Riley. However, a more thorough analysis of stream-water data is required to identify potential sources of perchlorate.

The concentrations of perchlorate in stream water were relatively small (median concentration was an estimated 0.114 µg/L), which is similar to the median concentration of perchlorate detected in groundwater (0.166 µg/L) during the U.S. Army (2007) study. Thus, it is possible that perchlorate concentrations measured in stream water in the study described herein were derived, at least in part, from the groundwater that provides base flow for streams.

In general, positive relations between water-quality constituent concentrations and stream discharge (as one increases, so does the other) probably indicate a land-surface origin for the constituent mass (transported from the land surface in runoff). On the other hand, negative relations may indicate a primarily groundwater origin for the constituents. The relation between concentration and discharge provides a means for evaluating the relative importance of stream-water constituent sources, particularly sources of perchlorate.

Three stream-water sampling sites (3MC-1, HC-1, 7MC-2) had multiple samples including base-flow and runoff samples. Within-site differences of perchlorate concentrations were not very large; maximum concentrations were no more than about three times larger than minimum concentrations (table 16), but an examination of these differences is worthwhile. At sites HC-1 and 7MC-2 maximum perchlorate concentrations corresponded to base-flow conditions. The base-flow sample at site HC-1 had a discharge of 0.62 ft^3/s, and the perchlorate concentration was 0.216 µg/L. The runoff sample at site HC-1 with a maximum discharge of 1,030 ft^3/s had a nondetectable (less than 0.2 µg/L) perchlorate concentration, the only nondetection of the compound in stream-water samples. At site 7MC-2 the base-flow discharge was 6.4 ft^3/s with a maximum perchlorate concentration of an estimated 0.180 µg/L. The series of runoff samples collected from site 7MC-2 on June 2, 2008, provides a reasonable illustration of

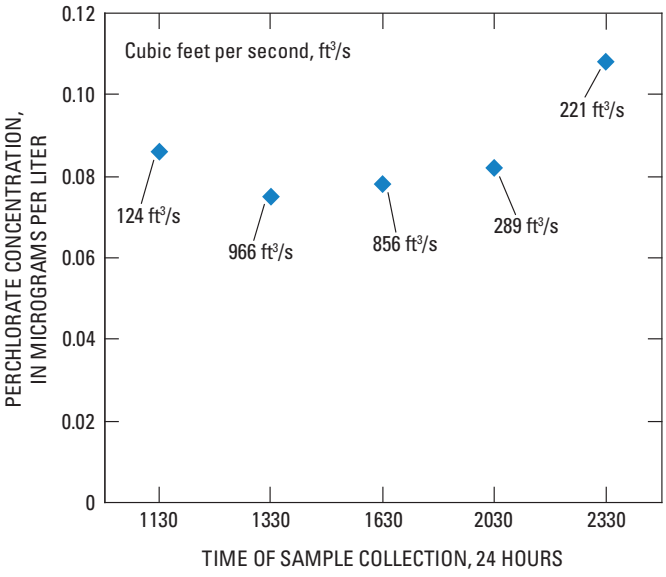


Figure 9. Time series of estimated stream-water perchlorate concentrations at sampling site 7MC-2, Fort Riley, collected during runoff on June 2, 2008, with discharge values noted.

the negative relation between perchlorate concentrations and discharge observed at this site. Figure 9 shows the time series of perchlorate concentrations in samples collected during runoff on June 2, 2008, with corresponding discharge values noted (replicate samples are not shown).

The first sample (1130 hours) was collected with a discharge of 124 ft^3/s and a perchlorate concentration of an estimated 0.086 µg/L. A small decrease in perchlorate concentration (estimated 0.075 µg/L) occurred when the discharge reached a maximum of 966 ft^3/s at 1320 hours. The perchlorate concentration rebounded and reached an estimated 0.108 µg/L at 2330 hours when discharge had decreased to 221 ft^3/s. The relation is even more apparent if the correction factor of 1.3 times the measured concentration of constituents in the automatically collected samples (see section on "Quality Assurance"; table 7) is applied to the measured concentrations of perchlorate in these samples; however, only estimated values are shown in figure 9. Site 3MC-1 was the only site where base-flow conditions did not correspond to maximum within-site perchlorate concentrations. The maximum perchlorate concentration at site 3MC-1 was an estimated 0.176 µg/L with the maximum discharge of 163 ft^3/s; the minimum perchlorate concentration was an estimated 0.085 µg/L with the minimum (base-flow) discharge of 2.0 ft^3/s. The positive relation between perchlorate concentration and discharge at site 3MC-1 may indicate a land-surface source of perchlorate at Threemile Creek. However, a firm conclusion cannot be drawn because only three samples were collected from the site, and the collection dates were spaced widely–June 20, 2007; May 27, 2008; June 2, 2008. In contrast, the negative relations observed at site HC-1 and especially at site 7MC-2 give an indication that perchlorate concentrations are more strongly connected to groundwater influx at these sites. The fact that all base-flow stream-water samples contained measurable perchlorate and the negative relations in perchlorate concentration in relation to discharge at two of the sites points to a relatively substantial groundwater contribution of perchlorate in stream water. Because the median concentration of perchlorate in stream water measured during this study is similar to the median concentration measured in groundwater at the periphery of the IAC during the U.S. Army (2007) study and because these concentrations are within the range of naturally occurring groundwater perchlorate concentrations reported by Parker and others (2008), it is likely that the stream-water perchlorate concentrations measured during the study described herein result, at least in part, from natural sources.

Additionally, the watersheds for sites RC-1 and FC-1 contain only firing points (Figures 1 and 6) and these are for artillery whose propellants generally do not contain perchlorate, not for rockets whose propellants do contain perchlorate (Richard Shields, U.S. Army Corps of Engineers, written communication, 2009). Site FC-1, in particular, only has historic (1981) firing points. The one stream-water sample taken from site FC-1 had the highest (estimated 0.236 µg/L) (table 16) measured perchlorate concentration. Perchlorate concentrations for site RC-1 and especially site FC-1 cannot, therefore,

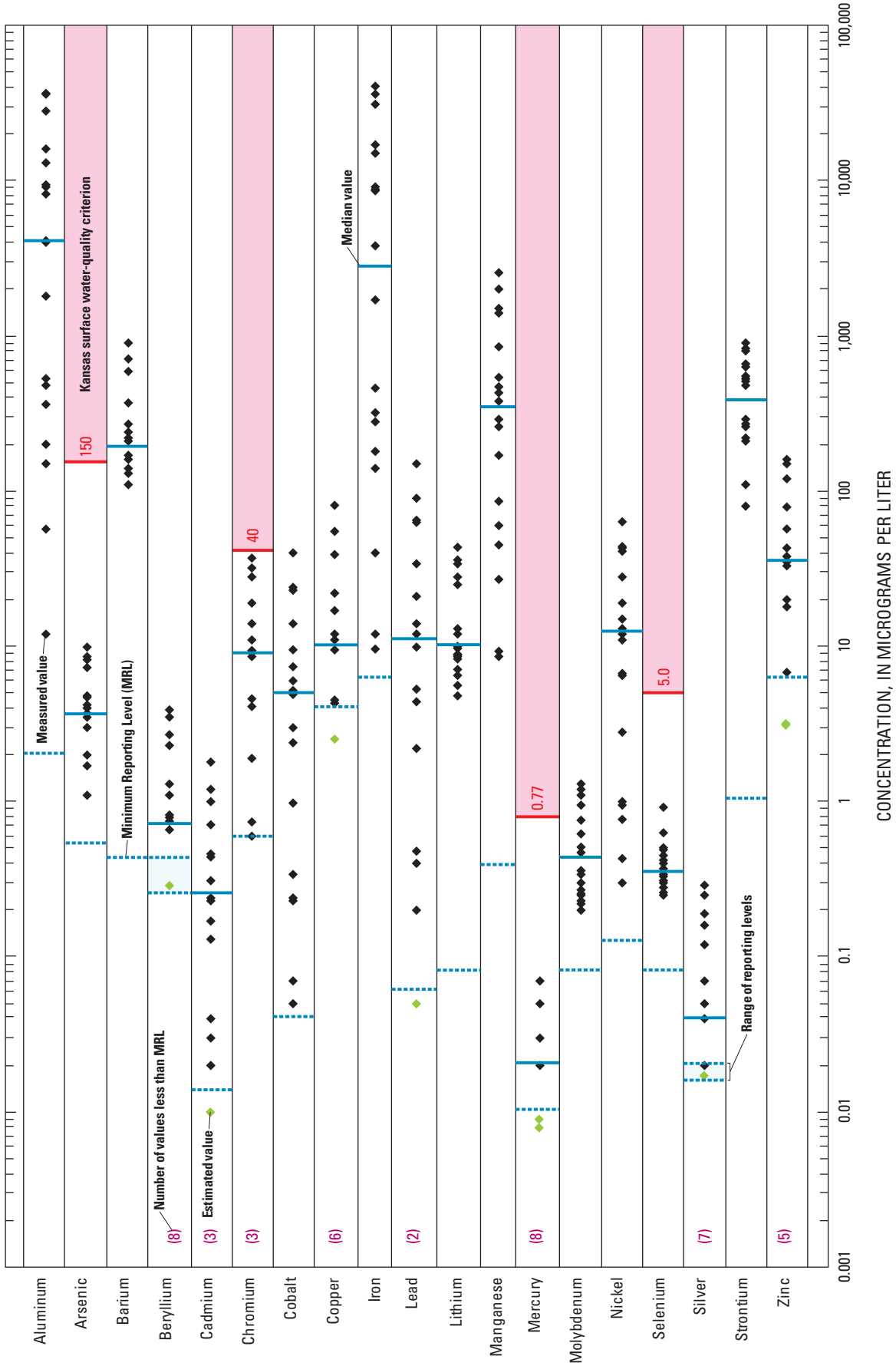


Figure 10. Method reporting limits, sample concentrations and median values, and surface-water-quality criteria (Kansas Department of Health and Environment, 2005) for selected trace elements in stream water from sampling sites at Fort Riley, 2007–08.

Table 11. Statistical summary of trace element concentrations in stream-water samples from five sampling sites at Fort Riley, Kansas, 2007–08.

[Concentrations may represent an average of primary and replicate samples presented in table 16. Concentrations are in micrograms per liter. <, less than]

Trace element	Summary statistic					
	Number of samples	Minimum	Percentile			Maximum
			25	50 (median)	75	
Aluminum	18	12	390	4,000	12,000	36,000
Arsenic	18	1.1	2.0	3.6	4.8	9.9
Barium	18	110	160	190	260	900
Beryllium	18	<.26	.32	.70	1.2	3.9
Cadmium	18	.01	.03	.24	.65	1.8
Chromium	18	<.6	1.0	8.8	18	38
Cobalt	18	.05	.50	5.0	13	40
Copper	18	2.5	<4.0	9.5	21	81
Iron	18	9.6	200	2,800	14,000	40,000
Lead	18	.05	.91	11	31	150
Lithium	18	4.8	8.4	9.8	22	44
Manganese	18	8.6	66	340	770	2,600
Mercury	18	.008	<.010	.02	.04	.07
Molybdenum	18	.20	.26	.42	.90	1.3
Nickel	18	.30	1.4	12	26	64
Selenium	18	.25	.30	.36	.45	.92
Silver	18	<.016	.018	.04	.11	.29
Strontium	18	80	230	380	610	900
Zinc	18	3.1	6.2	34	74	160

be reasonably attributed to firing-range activities, and provide further evidence of a naturally occurring perchlorate source at Fort Riley.

The weight of the evidence regarding perchlorate in stream water suggests that occurrence of the compound in water from selected streams at Fort Riley arises from natural sources, although a contribution from firing-range activities is also certainly possible. Therefore a definitive identification of the source of perchlorate is difficult. The fact that perchlorate was not detected in any streambed-sediment samples during this study but was found in nearly all stream-water samples can be attributed, in part, to the fact that perchlorate is a highly soluble compound and has a negative log K_{ow} value (table 1). Thus, perchlorate would be expected to favor dissolution in water rather than adsorption to streambed sediment.

SVOCs generally were not detected in stream-water samples except for two compounds. Bis(2-ethylhexyl) phthalate was detected in one sample from site FC-1 at an estimated concentration of 1.18 µg/L and in three samples from site 7MC-2 (fig. 1) at estimated concentrations of 1.70, 2.46, and 1.56 µg/L. Di-n-butyl phthalate was found in one sample from site 7MC-2 at an estimated concentration of 1.25 µg/L. Both of these phthalate compounds are plasticizers and have many commercial and industrial uses, and their occurrence in water can result from (1) leaching of plastics such as tubes, dishes, containers, and paper; (2) from a microcontaminant in laboratory chemicals, food, and detergents; (3) from the applications of paints, coatings, and adhesives; and (4) from evaporates of inks and insecticides. Additionally, di-n-butyl phthalate is a component in the fuel matrix of double-base rocket propellant (Verschueren, 1996). The detection of di-n-butyl phthalate in one sample from site 7MC-2 does provide some speculation that munitions use at Fort Riley may be responsible for the occurrence of this constituent; however, because of its non-pervasive occurrence, the fact that the only SVOCs detected in stream-water samples were related phthalate compounds with similar commercial and industrial sources, and because the concentrations detected were small, there is no definitive evidence that the detection of di-n-butyl phthalate is from munitions use.

Variability in concentrations of trace elements in all stream-water samples collected from the five sampling sites (fig. 1) was large (table 11; fig. 10) relative to the narrow range determined for concentrations in streambed sediment. Maximum concentrations were more than three orders of magnitude larger than minimum concentrations for several trace elements. Aluminum, iron, manganese, and strontium had some

Table 12. Maximum concentrations and associated water-quality criteria for selected constituents analyzed in stream water collected from five sampling sites at Fort Riley, Kansas, 2007–08.

[KDHE, Kansas Department of Health and the Environment; USEPA, U.S. Environmental Protection Agency; IHA, Interim Health Advisory; E, estimated concentration; <, less than; --, criterion not available or not applicable; ?, not known because detection value is large relative to most stringent criterion value]

Constituent	Number of samples	Maximum concentration or largest non-detected value	Water-quality criteria source, type, or value			Number of samples exceeding most stringent criterion
			KDHE[1]		USEPA[2]	
			Acute	Chronic	IHA	
Energetic compounds, in micrograms per liter						
2,4-Dinitrotoluene	18	<0.87	330	230	--	0
Nitrobenzene	18	<.87	27,000	--	--	0
Perchlorate	18	E.236	--	--	15	0
Semi-volatile organic compounds, in micrograms per liter						
1,2-Dichlorobenzene	18	<13.3	1,120	763	--	0
1,3-Dichlorobenzene	18	<13.3	1,120	763	--	0
2,4-Dichlorophenol	11	<13.3	2,020	365	--	0
2,4,5-Trichlorophenol	11	<13.3	100	63	--	0
2,4,6-Trichlorophenol	11	<13.3	--	970	--	0
2,4-Dimethylphenol	11	<13.3	1,300	530	--	0
2-Chlorophenol	12	<13.3	4,380	2,000	--	0
4-Chloro-3-methylphenol	11	<13.3	30	--	--	0
Acenaphthene	18	<11.9	1,700	520	--	0
Atrazine	5	<13.3	170	3.0	--	?
Bis(2-chloroethoxy)methane	18	<13.3	11,000	--	--	0
Bis(2-chloroethyl) ether	18	<13.3	238,000	--	--	0
Bis(2-chloroisopropyl) ether	18	<13.3	238,000	--	--	0
Bis(2-ethylhexyl) phthalate	18	E2.46	400	360	--	0
Dimethyl phthalate	18	<13.3	940	3.0	--	?
Di-n-butyl phthalate	18	E1.25	940	3.0	--	0
Fluoranthene	18	<11.9	3,980	--	--	0
Hexachlorobutadiene	18	<13.3	90	9.3	--	?
Hexachlorocyclopentadiene	18	<13.3	7.0	5.2	--	?
Hexachloroethane	18	<13.3	980	540	--	0
Isosphorone	18	<13.3	117,000	--	--	0
Naphthalene	18	<11.9	2,300	620	--	0
Pentachlorophenol[3]	11	<13.3	11	7.0	--	?
Phenanthrene	18	<11.9	30	6.3	--	?
Phenol	11	<13.3	10,200	2,560	--	0
Trace elements, in micrograms per liter						
Arsenic	18	9.9	340	150	--	0
Chromium	18	38	--	40	--	0
Mercury	18	.07	1.4	0.77	--	0
Selenium	18	.92	20	5.0	--	0

[1] Kansas Department of Health and Environment (2005), aquatic-life criteria.

[2] U.S. Environmental Protection Agency (2009a).

[3] Values are pH dependent, and were calculated using the minimum field pH measured in this study according to Kansas Department of Health and Environment (2005) criteria.

of the widest concentration ranges and the largest median concentrations of all selected trace elements.

The number of samples collected at stream-water sampling sites was not sufficient to assess between-site statistical differences in concentrations. However, within-site variation in trace element concentrations among stream-water samples was large at sites HC-1, 3MC-1, and 7MC-2 (fig. 1) (table 16), and generally, the largest concentrations for each trace element were associated with runoff samples. Exceptions included barium, lithium, molybdenum, and strontium where the base-flow sample had the largest concentration among all samples for at least one of the three sites with both base-flow and runoff samples. As noted in the discussion of perchlorate detections, positive relations between water-quality constituent concentrations and discharge probably indicate a land-surface origin for the constituent mass (runoff). Conversely, negative relations may indicate a primarily groundwater origin for the constituent such as might be the case for barium, lithium, molybdenum, and strontium.

The wide range in concentrations of some trace elements in stream water is not necessarily an indication of anthropogenic (human-related) sourcing or, more specifically, the result of munitions use at Fort Riley. Total concentrations (determined on unfiltered water) for many constituents may increase as discharge increases because of increased suspended-sediment load and the associated mineral compounds in runoff. Mineral-associated trace elements include aluminum, iron, and manganese (Hem, 1992). The assessment of the relation to water-quality criteria described in the next section provides a more informative evaluation of contaminant occurrence in stream water.

Relation to Water-Quality Criteria

Perchlorate was the only energetic compound detected in stream-water samples; however, the maximum concentration determined at any sampling site was substantially less than the U.S. Environmental Protection (2009b) IHA of 15 µg/L (table 12). In addition, several SVOCs have established aquatic-life criteria (Kansas Department of Health and Environment, 2005) (table 12). Of these SVOCs, only bis(2-ethylhexyl) phthalate and di-n-butyl phthalate were detected but at concentrations less than 50 percent of the most stringent criteria.

Some ambiguity exists in the comparison of stream-water concentrations of some SVOCs to water-quality criteria because of relatively large MRLs. The MRLs for atrazine, dimethyl phthalate, hexachlorobutadiene, hexachlorocyclopentadiene, pentachlorophenol, and phenanthrene were larger than the most stringent criterion for each compound (chronic criterion; table 12). As noted in the discussion of streambed-sediment quality criteria, analytical methods and associated MRLs were fixed by the USACE contract laboratory for energetic compounds and SVOCs. The inability of the analytical methods to report nondetection concentrations at or smaller than criteria values for these compounds means it is unclear whether concentrations of these particular SVOCs exceeded criteria values in these instances. With the exception of hexachlorocyclopentadiene and pentachlorophenol, however, the MRLs were substantially less than the acute criteria.

The concentrations of the trace elements arsenic, chromium, mercury, and selenium determined in stream-water samples were all less than KDHE aquatic-life criteria (Kansas Department of Health and Environment, 2005; table 12), confirming the results of the U.S. Army (2007) study. KDHE also has established aquatic-life criteria for cadmium, copper, lead, nickel, silver, and zinc (Kansas Department of Health and Environment, 2005). However, these criteria are water-hardness dependent, and hardness values could not be calculated from the data set obtained during the study described in this report because calcium and magnesium concentrations were determined on unfiltered stream-water samples. Analytical results, therefore, would include the calcium and magnesium incorporated in mineral matrix, which could be a substantial part of reported concentrations especially for runoff samples with large suspended-sediment loads.

Analytical results of stream-water samples provided little evidence of contamination by energetic compounds, SVOCs, or trace elements from munitions use at Fort Riley. The pervasive occurrence of perchlorate in stream-water samples was the only indication of a possible munitions-use signature on stream-water quality. However, perchlorate was found in small concentrations and has possible natural sources. The implication of these results is that stream-water contamination arising from firing-range activities, if it exists, is so small as to be nondetectable with current (2008) analytical methods or is not distinguishable from background concentrations for constituents that also are naturally occurring. Overall, the munitions-related constituents analyzed in this report in streambed sediment or stream water when detected were at concentrations that were less than regulatory criteria.

Summary

Many military installations throughout the United States have live-fire training ranges, including Fort Riley, Kansas, home of the First Infantry Division. The use of live-fire training ranges can result in the environmental dispersal of residues of energetic compounds, semi-volatile organic compounds (SVOCs), and trace elements that are components of munitions as explosives and propellants or part of the explosive casing.

The occurrence and distribution of energetic compounds, SVOCs, and trace elements on soils in and around munitions firing points and impact areas have been well documented at military installations throughout the United States. Energetic compounds, SVOCs, and trace elements can be mobilized into streams during runoff (adsorbed to soil particles or dissolved in water) or as a component of groundwater discharged to adjacent streams during base flow.

This report provides an assessment of the occurrence and distribution of energetic compounds, SVOCs, and trace elements in streambed sediments and stream water from streams draining munitions firing points and impact areas on the Fort Riley Military Reservation in northeast Kansas. Streambed sediment was collected from 16 sampling sites located at or near Fort Riley. Samples of stream water also were collected during base-flow and runoff conditions at 5 of the 16 sites. Streambed sediment and stream-water samples were analyzed for as many as 17 energetic compounds, 65 SVOCs, and 27 trace elements. The occurrence and distribution of energetic compounds, SVOCs, and trace elements are discussed in relation to applicable State and Federal sediment- and water-quality guidelines.

None of the energetic compounds or SVOCs analyzed in streambed sediment were detected in samples from selected stream sites located within the Fort Riley Military Reservation. The only detections of any of these compounds were for four SVOCs detected at concentrations near or less than the analytical method minimum reporting levels. All of the SVOC detections were in the sample collected at a reference site located just outside of the northern boundary of Fort Riley. These results are in general agreement with the nondetection of energetic compounds in streambed sediment during a previous study of Fort Riley by the U.S. Army. The implications of these nondetections for energetic compounds and SVOCs are that either the compounds are not being transported from dispersal areas (munitions firing points and impact areas) or, if they are, that current (2008) analytical methods are not sensitive enough to detect the small concentrations that may be transported adsorbed to suspended sediment and subsequently deposited on streambeds.

Generally, the range in concentrations for most trace elements among the 15 streambed-sediment sampling sites located on the Fort Riley Military Reservation was narrow and not too dissimilar from concentrations determined in streambed sediment from the off-reservation reference site. These results provide little evidence for contamination relative to live-firing exercises. Additionally, none of the trace element maximum concentrations exceeded USEPA sediment-quality guidelines. This diverges from the results obtained in an earlier U.S. Army study where, in some instances, the trace elements antimony, arsenic, cadmium, lead, and nickel exceeded the applicable 25-percent probability sediment-quality guidelines established by USEPA.

Data from selected streambed sampling sites at Fort Riley are not indicative of trace elements contaminantion of streambed sediment at least in regards to movement from dispersal areas. This conclusion may indicate that (1) trace elements associated with military munitions may not be of sufficient mass to significantly increase background concentrations in streambed sediment of local streams, (2) trace elements become adsorbed to soil particles not readily transported from dispersal areas, (3) actual munitions dispersal areas (areas directly affected by detonations) may be small relative to the overall size and associated drainage area of the munitions firing points and impact areas at Fort Riley, or (4) some combination of the first three indications.

Perchlorate was the only energetic compound detected in stream-water samples collected during the study described in this report. Perchlorate was detected in 19 of 20 stream-water samples with a median concentration of an estimated 0.114 micrograms per liter (µg/L) and a maximum concentration of an estimated 0.236 µg/L, which was substantially less than the USEPA Interim Health Advisory criterion (15 µg/L).

The stream-water sample data suggests a perchlorate source tied to shallow groundwater. The median concentration (an estimated 0.114 µg/L) of perchlorate in stream water measured during this study is similar to the median concentration (0.166 µg/L) measured in groundwater at the periphery of the Impact Area complex during the earlier U.S. Army study and these concentrations are within the range of naturally occurring perchlorate concentrations reported in groundwater from pristine sites in the conterminous United States in a previous study. Perchlorate was detected in stream water from sites RC-1 and FC-1, where firing-range activities cannot reasonably contribute to occurrence of the compound. The weight of the evidence suggests that occurrence of perchlorate in water from selected streams at Fort Riley arises from natural sources, although a contribution from firing-range activities is also certainly possible. Therefore a definitive identification of the source of perchlorate is difficult.

The concentrations of perchlorate in stream water determined during the study described in this report had a range similar to the earlier U.S. Army study (0.069 to 0.194 µg/L). Also, the nondetection of other energetic compounds in the U.S. Army study is in general agreement with the nondetection of selected energetic compounds (other than perchlorate) in the study described herein.

SVOCs were not detected in stream-water samples except for bis(2-ethylhexyl) phthalate (4 samples), and di-n-butyl phthalate (1 sample), which were detected at small, estimated (less than 2.5 µg/L) concentrations and were less than the most stringent KDHE aquatic-life criteria. Of these, only di-n-butyl phthalate is used as a munitions component, although it has many other commercial and industrial uses. The detection of di-n-butyl phthalate in one sample does lead to some speculation that munitions use at Fort Riley may be responsible for the occurrence of this compound; however, because of its nonpervasive occurrence, the only SVOCs detected in stream-water samples are related phthalate compounds with similar commercial and industrial sources, and because of the small concentrations detected, there is no definitive evidence that the detection of di-n-butyl phthalate is from munitions use.

The concentrations of trace elements arsenic, chromium, mercury, and selenium detected in stream-water samples were all less than KDHE aquatic-life criteria, which confirms the results of the earlier U.S. Army study. Analytical results of stream-water samples provided little evidence of contamination by energetic compounds, SVOCs, or trace elements from munitions use at Fort Riley. The pervasive occurrence of perchlorate in stream-water samples was the only indication

of a possible munitions-use signature on stream-water quality. However, perchlorate was found in small concentrations and has possible natural sources. The implication of these results is that potential stream-water contamination arising from range activities, if it exists, is so small as to be nondetectable with current (2008) analytical methods or is not distinguishable from background concentrations for constituents that also are naturally occurring.

In brief, this study did not identify concentrations of energetic compounds, SVOCs, or trace elements that indicated contamination of bed sediment in streams draining live-firing ranges at Fort Riley. Stream-water samples did contain small concentrations (within regulatory criteria) of the energetic compound perchlorate in most samples and the SVOCs bis(2-ethylhexyl) phthalate and di-n-butyl phthalate in a few samples. Concentrations of trace elements in stream water were within regulatory criteria. The results of this study are in general agreement with the earlier U.S. Army study with the exception that the exceedance of sediment-quality guidelines for some trace elements in the earlier study was not found in this study. Overall, the munitions-related constituents analyzed in this report in streambed sediment or stream water when detected were at concentrations that were less than regulatory criteria.

References Cited

Backus, S.M., Klawuun, P., Brown, S., D'sa, I., Sharp, S., Surette, C., and Williams, D.J., 2005, Determination of perchlorate in selected surface waters in the Great Lakes basin by HPLC/MS/MS: Chemosphere, v. 61, p. 834–843.

Chapman, S.S., Omerik, S.M., Freeouf, J.A., Huggins, D.G., McCauley, J.R., Freeman, C.C., Steinauer, G., Angelo, R.T., and Schlepp, R.L., 2001, Ecoregions of Nebraska and Kansas (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey, 1 sheet, map scale 1:1,950,000.

Childress, C.J.O.; Foreman, W.T.; Connor, B.F.; Maloney, T.J., 1999, New reporting procedures based on long-term method detection levels and some considerations for interpretations of water-quality data provided by the U.S. Geological Survey National Water Quality Laboratory: U.S. Geological Survey Open-File Report 99–193, 19 p.

Clark, S.F., Chalmers, A., Mack, T.J., and Denner, J.C., 2005, Hydrogeologic framework and water quality of the Vermont Army National Guard Ethan Allen Firing Range, northern Vermont, October 2002 through December 2003: U.S. Geological Survey Scientific Investigations Report 2005–5159, 48 p., information available on Web, accessed June 13, 2008, at *http://pubs.usgs.gov/sir/2005/5159/SIR2005–5159_report.pdf.*

Craig, J.R., Rimstidt, J.D., Bonnaffon, C.A., Collins, T.K., and Scanlon, P.F., 1999, Surface water transport of lead at a shooting range: Bulletin of Environmental Contamination and Toxicology, v. 63, no. 3, p. 312–319.

Dasgupta, K.D., Dyke, J.V., Kirk, A.B., and Jackson, W.A., 2006, Perchlorate in the United States— analysis of relative source contributions to the food chain: Environmental Science and Technology, v. 40, p. 6,608–6,614.

Dobak, W.A., 1998, Fort Riley and its neighbors—military money and economic growth, 1853–1895: Norman, Oklahoma, University of Oklahoma Press, 241 p.

Espenson, J.H., 2003, The problem and perversity of perchlorate, *in* Urbansky, E.T., ed., Perchlorate in the environment: New York, Academic/Plenum Publishers, p. 1–8.

Fenneman, N.M., and Johnson, D.G., 1946, Physical divisions of the United States [map]: U.S. Geological Survey, 1 sheet, scale 1:7,000,000.

Fishman, M.J., 1993, Methods of analysis by the U.S. Geological Survey National Water-Quality Laboratory—determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p.

Garbarino, J.R., and Damrau, D.L., 2001, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—determination of organic plus inorganic mercury in filtered and unfiltered natural water with cold vapor-atomic fluorescence spectrometry: U.S. Geological Survey Water-Resources Investigations Report 01–4132, 16 p., information available on the Web, accessed June 6, 2008, at *http://nwql.usgs.gov/Public/pubs/WRIR01–4132.pdf.*

Garbarino, J.R., and Struzeski, T.M., 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—determination of elements in whole-water digests using inductively coupled plasma-optical emission spectrometry and inductively coupled plasma-mass spectrometry: U.S. Geological Survey Open-File Report 98–165, 101 p., information available on the Web, accessed June 6, 2008, at *http://nwql.usgs.gov/Public/pubs/OFR98–165.pdf.*

Global Security, 2008, Depleted uranium [DU]: Information available on the Web, accessed July 28, 2008, at *http://www.globalsecurity.org/military/systems/munitions/du.htm.*

Grosbois, C.A., Horowitz, A.J., Smith, J.J., and Elrick, K.A., 2001, The effect of mining and related activities on the sediment-trace element geochemistry of Lake Coeur d'Alene, Idaho, USA, part III. Downstream effects—the Spokane River basin: Hydrological Processes, v. 15, p. 855–875.

Hem, J.D., 1992, Study and interpretation of the chemical characteristics of natural water (3rd ed.): U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Hewitt, 1997, Detecting metallic primary explosives with a portable x-ray fluorescence spectrometer: U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 97–8, 9 p.

Horowitz, A.J., 1991, A primer on sediment-trace element chemistry: Chelsea, Michigan, Lewis Publishers, 136 p.

Horowitz, A.J., Elrick, K.A., and Hooper, R.P., 1989, The prediction of aquatic sediment-associated trace element concentrations using selected geochemical factors: Hydrological Processes, v. 3, p. 347–364, information available on the Web, accessed June 5, 2008, at *http://www3.interscience.wiley.com/cgi-bin/fulltext/112736667/PDFSTART.*

Jantz, D.R., Harner, R.F., Rowland, H.T., and Gier, D.A., 1975, Soil survey of Riley County and part of Geary County, Kansas: U.S. Department of Agriculture, Soil Conservation Service, 71 p.

Jenkins, T.F., Thiboutot, Sonia, Ampelman, Guy, Hewitt, A.D., Walsh, M.E., Ranney, T.A., Ramsey, C.A., Grant, C.L., Collins, C.M., Brochu, Sylvie, Bigl, S.R., and Pennington, J.C., 2005, Identity and distribution of resides of energetic compounds at military life-fire training ranges: U.S. Army Corps of Engineers, Engineer Research and Development Center Report ERDC TR–05–10, 64 p.

Jewett, J.M., 1941, The geology of Riley and Geary Counties, Kansas: Kansas Geological Survey, Bulletin 39, 164 p.

Kansas Department of Health and Environment, 2005, Kansas surface water quality standards: Topeka, Kansas, Bureau of Water, information available on the Web, accessed July 3, 2008, at *http://www.kdheks.gov/water/download/28_16_28b_g.pdf.*

Kennedy, E.J., 1983, Computation of continuous records of streamflow: U.S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. A13, 53 p.

Lane, S.L., Flanagan, Sarah, and Wilde, F.D., 2003, Selection of equipment for water sampling (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A2, information available on the Web, accessed September 29, 2008, at *http://pubs.water.usgs.gov/twri9A2/.*

Larson, S.L., Martin, W.A., Escalon, B.L., and Thompson, Michelle, 2008, Dissolution, sorption, and kinetics involved in systems containing explosives, water, and soil: Environmental Science and Technology, v. 42, p. 796–792.

McConnell, J.B., Stamey, T.C., Persinger, H.H., and McFadden, K.W., 2000, Trace elements and semi-volatile organic compounds in bed sediments from streams and impoundments at Fort Gordon, Georgia: U.S. Geological Survey Open-File Report 00–87, 39 p.

National Climatic Data Center 2002, Climatology of the United States No. 81, monthly station normals of temperature, precipitation, and heating and cooling degree days 1971–2000, 14, Kansas: Asheville, North Carolina, National Oceanic and Atmospheric Administration, 37 p., information available on the Web, accessed May 2, 2008, at *http://cdo.ncdc.noaa.gov/climatenormals/clim81/KSnorm.pdf.*

National Climatic Data Center, 2008, NNDC climate data online, information available on the Web, accessed September 18, 2008, at *http://cdo.ncdc.noaa.gov/cgi-bin/cdo/cdostnsearch.pl.*

National Imagery and Mapping Agency, 1981, Fort Riley installation map: Bethesda, Maryland, 1 sheet, map scale 1:50,000.

National Imagery and Mapping Agency, 1997, Fort Riley installation map, 6th Edition: Bethesda, Maryland, 1 sheet, map scale 1:50,000.

National Library of Medicine, 2008, Hazardous Substance Data Bank, information available on the Web, accessed August 11, 2008, at, *http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB.*

Parker, D.R., Seyfferth, A.L., and Reese, B.K., 2008, Perchlorate in groundwater—a synoptic survey of "pristine" sites in the coterminous United States: Environmental Science and Technology, v. 42, p. 1,465–1,471.

Pennington, J.C., Jenkins, T.F., Brannon, J.M., Thiboutot, Sonia, DeLaney, J.E., Lynch, John, and Clausen, J.L., 2001, Distribution and fate of energetics on DOD test and training ranges, *in* Proceedings of the 2001 annual meeting of the Geological Society of America, Boston, Massachusetts, November 1–10, 2001: Geological Society of America, v. 22, no. 6, p. 118.

Phelan, D.J., Olsen, L.D., Cashel, M.L., Tegeler, J.L., and Marchand, E.H., 1998, Assessment of soil, surface-water, and ground-water contamination at selected sites at J-Field, Aberdeen Proving Ground, Maryland: U.S. Geological Survey Water-Resources Investigations Report, 98–4037, 76 p.

Rantz, S.E., and others, 1982, Measurement and computation of streamflow—measurement of stage and discharge: U.S. Geological Survey Water-Supply Paper 2175, vol. 1, 284 p.

Savard, Kathleen, Berthelot, Yann, Auroy, Aurelie, Spear, P.A., Trottier, Bertin, and Robidoux, P.Y., 2007, Effects of HMX-lead mixtures on reproduction of the earthworm Eisenia Andrei: Archives of Environmental Contamination and Toxicology, v. 53, p. 351–358.

Shelton, L.R., and Capel, P.D., 1994, Guidelines for collecting and processing samples of streambed sediment for analyses of trace elements and organic contaminants for the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 94–458, 20 p.

U.S. Army, 1984, Fort Riley—its historic past: Department of the Army, 37 p.

U.S. Army, 2007, Final training range site characterization and risk evaluation No. 38–EH–030J–05, regional range study—Fort Riley, Kansas: U.S. Army, 116 p.

U.S. Department of Defense, 2002, Strategic Environmental Research and Development Program and the Environmental Science and Technology Program, Partners in Environmental Technology information bulletin, no. 12, 7 p., information available on the Web, accessed December 8, 2009, at *http://www.serdpestcp.org/shared/information_bulletins/2002_Spring.pdf.*

U.S. Environmental Protection Agency, 2004, The incidence and severity of sediment contamination in surface waters of the United States, national sediment quality survey (2nd ed.): U.S. Environmental Protection Agency Report EPA–823–R–04–007, various pagination, information available on the Web, accessed June, 10, 2008, at *http://www.epa.gov/waterscience/cs/report/2004/nsqs2ed-complete.pdf.*

U.S. Environmental Protection Agency, 2006, 2006 Edition of the drinking water standards and health advisories: Washington, D.C., EPA 822-R-06-013, summer 2006, information available on the Web, accessed July 14, 2008, at *http://www.epa.gov/waterscience/criteria/drinking/dwstandards.pdf.*

U.S. Environmental Protection Agency, 2007, Test methods for evaluating solid waste, physical/chemical methods, EPA publication SW-846: Washington D.C., information available on the Web, accessed January 12, 2009, at *http://www.epa.gov/epawaste/hazard/testmethods/sw846/index.htm.*

U.S. Environmental Protection Agency, 2009a, Emerging contaminant—perchlorate: Federal Facilities Restoration and Reuse Office, EPA 505-F-09-005, September 2009, information available on the Web, accessed October 13, 2009, at *http://www.clu-in.org/download/contaminantfocus/epa505f09005.pdf.*

U.S. Environmental Protection Agency, 2009b, Interim drinking water health advisory for perchlorate, information available on the Web, accessed August 25, 2009, at *http://www.epa.gov/OGWDW/contaminants/unregulated/pdfs/healthadvisory_perchlorate_interim.pdf.*

U.S. Geological Survey, 2006, Collection of water samples (ver. 2.0): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A4, information available on the Web, accessed September 29, 2008, at *http://pubs.water.usgs.gov/twri9A4/.*

Verschueren, Karel, 1996, Handbook of environmental data on organic chemicals: New York, John Wiley and Sons, Inc., 2,064 p.

Wilde, F.D., Radtke, D.B., Gibs, Jacob, and Iwatsubo, R.T., eds., April 2004, Processing of water samples (ver. 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A5, information available on the Web, accessed September 29, 2008, at *http://pubs.water.usgs.gov/twri9A5/.*

Supplemental Information

Table 13. Energetic and semi-volatile organic compounds analyzed in the less-than-2.0-millimeter fraction and carbon and trace elements analyzed in the less-than-0.063-millimeter fraction of streambed sediment collected from 16 sampling sites at or near Fort Riley, Kansas, 2007.

[Some method reporting limits are interim limits and limits expressed as a range include one or more interim reporting limits. %, percentage of dry weight]

Constituent	Minimum reporting level	Constituent	Minimum reporting level
Energetic compounds, in micrograms per kilogram			
1,3-Dinitrobenzene	150	1,3,5-Trinitrobenzene	150
2,4-Dinitrotoluene	150	2,6-Dinitrotoluene	150
2-Amino-4,6-dinitrotoluene	150	4-Amino-2,6-dinitrotoluene	150
2-Nitrotoluene	150	3-Nitrotoluene	150
4-Nitrotoluene	150	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	150
Nitrobenzene	150	Nitroglycerin	1,000
Pentaerythritol tetranitrate	500	Perchlorate	2.71–3.17
1,3,5-Hexahydro-1,3,5-trinitrotriazine (RDX)	150	Tetryl	150
		2,4,6-Trinitrotoluene (TNT)	150
Semi-volatile organic compounds, in micrograms per kilogram			
1,1’-Biphenyl	1,360–1,570	1,2,4-Trichlorobenzene	1,360–1,570
1,2-Dichlorobenzene	1,360–1,570	1,3-Dichlorobenzene	1,360–1,570
1,4-Dichlorobenzene	1,360–1,570	2,4-Dichlorophenol	1,360–1,570
2,4,5-Trichlorophenol	1,360–1,570	2,4,6-Trichlorophenol	1,360–1,570
2,4-Dimethylphenol	1,360–1,570	2,4-Dinitrophenol	2,710–3,140
2-Chloronaphthalene	136–157	2-Chlorophenol	1,360–1,570
2-Methyl-4,6-dinitrophenol	1,360–1,570	2-Methylnaphthalene	136–157
2-Nitroaniline	1,360–1,570	2-Nitrophenol	1,360–1,570
3,3’-Dichlorobenzidine	1,360–1,570	3-Nitroaniline	1,360–1,570
4-Bromophenyl phenyl ether	1,360–1,570	4-Chloro-3-methylphenol	1,360–1,570
4-Chloroaniline	1,360–1,570	4-Chlorophenyl phenyl ether	1,360–1,570
4-Nitroaniline	1,360–1,570	4-Nitrophenol	1,360–1,570
9H-Fluorene	136–157	Acenaphthene	136–157
Acenaphthylene	136–157	alpha-Terpineol	1,360–1,570
Anthracene	136–157	Atrazine	1,360–1,570
Benzaldehyde	1,360–1,570	Benzo[a]anthracene	136–157
Benzo[a]pyrene	136–157	Benzo[b]fluoranthene	136–157
Benzo[g,h,i]perylene	136–157	Benzo[k]fluoranthene	136–157
Benzyl n-butyl phthalate	1,360–1,570	Bis(2-chloroethoxy)methane	1,360–1,570
Bis(2-chloroethyl) ether	1,360–1,570	Bis(2-chloroisopropyl) ether	1,360–1,570

Table 13. Energetic and semi-volatile organic compounds analyzed in the less-than-2.0-millimeter fraction and carbon and trace elements analyzed in the less-than-0.063-millimeter fraction of streambed sediment collected from 16 sampling sites at or near Fort Riley, Kansas, 2007.—Continued

[Some method reporting limits are interim limits and limits expressed as a range include one or more interim reporting limits. %, percentage of dry weight]

Constituent	Minimum reporting level	Constituent	Minimum reporting level
Semi-volatile organic compounds, in micrograms per kilogram—Continued			
Bis(2-ethylhexyl) phthalate	678–785	Carbazole	136–157
Chrysene	136–157	Dibenzo[a,h]anthracene	136–157
Dibenzofuran	1,360–1,570	Diethyl phthalate	1,360–1,570
Dimethyl phthalate	1,360–1,570	Di-n-butyl phthalate	1,360–1,570
Di-n-octyl phthalate	1,360–1,570	Diphenylamine	1,360–1,570
Fluoranthene	136–157	Hexachlorobenzene	1,360–1,570
Hexachlorobutadiene	1,360–1,570	Hexachlorocyclopentadiene	1,360–1,570
Hexachloroethane	1,360–1,570	Indeno[1,2,3-cd]pyrene	136–157
Isophorone	1,360–1,570	m-Cresol plus p-Cresol	1,360–1,570
Naphthalene	136–157	N-Nitrosodi-n-propylamine	1,360–1,570
o-Cresol	1,360–1,570	Pentachlorophenol	1,360–1,570
Phenanthrene	136–157	Phenol	1,360–1,570
Pyrene	136–157		
Carbon and trace elements, in milligrams per kilogram unless otherwise noted			
Aluminum, %	.01	Antimony	.1
Arsenic	1	Barium	1
Beryllium	1	Cadmium	.1
Carbon, organic, total, %	.01	Carbon, total, %	.01
Chromium	1	Cobalt	1
Copper	1	Iron, %	.01
Lead	1	Lithium	1
Manganese	1	Mercury	.01
Molybdenum	1	Nickel	1
Nitrogen, %	.01	Phosphorus	1
Selenium	.1	Silver	.5
Strontium	1	Sulfur, total, %	.01
Thallium	50	Titanium, %	.01
Uranium	50	Vanadium	1
Zinc	1		

Table 14. Water-quality constituents analyzed in stream water collected from five sampling sites at Fort Riley, Kansas, 2007–08.

[FNU, formazin nephelometric units; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mV, millivolts, relative to standard hydrogen electrode; --, not applicable. Some reporting limits are interim limits and limits expressed as a range include one or more interim reporting limits]

Constituent	Minimum reporting level	Constituent	Minimum reporting level
Physical properties and dissolved oxygen			
Specific conductance (µS/cm)	2.6	pH (standard units)	0.01
Water temperature (°C)	.1	Turbidity (FNU)	.10
Dissolved oxygen (mg/L)	.01	Redox potential (mV)	--
Energetic compounds, in micrograms per liter			
1,3-Dinitrobenzene	0.325–0.87	1,3,5-Trinitrobenzene	0.325–0.87
2,4-Dinitrotoluene	0.487–0.87	2,6-Dinitrotoluene	0.487−0.87
2-Amino-4,6-dinitrotoluene	0.487–0.87	4-Amino-2,6-dinitrotoluene	0.487−0.87
2-Nitrotoluene	0.487−0.87	3-Nitrotoluene	0.325–0.87
4-Nitrotoluene	0.487–0.87	Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	0.487–0.87
Nitrobenzene	0.325–0.87	Nitroglycerin	1.95−5.48
Pentaerythritol tetranitrate (PETN)	1.95–5.43	Perchlorate	.20
1,3,5-Hexahydro-1,3,5-trinitrotriazine (RDX)	0.487–0.87	Tetryl	0.4–1.46
		2,4,6-Trinitrotoluene (TNT)	0.487–0.87
Semi-volatile organic compounds, in micrograms per liter			
1,1’-Biphenyl	10.8–13.3	1,2,4-Trichlorobenzene	10.2–13.3
1,2-Dichlorobenzene	10.2–13.3	1,3-Dichlorobenzene	10.2–13.3
1,4-Dichlorobenzene	10.2–13.3	2,4-Dichlorophenol	10.2–13.3
2,4,5-Trichlorophenol	10.2–13.3	2,4,6-Trichlorophenol	10.2–13.3
2,4-Dimethylphenol	10.2–13.3	2,4-Dinitrophenol	10.2–26.7
2-Chloronaphthalene	1.08−11.9	2-Chlorophenol	10.2–13.3
2-Methyl-4,6-dinitrophenol	10.2–13.3	2-Methylnaphthalene	1.08–11.9
2-Nitroaniline	10.2–13.3	2-Nitrophenol	10.2–13.3
3,3’-Dichlorobenzidine	10.2–13.3	3-Nitroaniline	10.2–13.3
4-Bromophenyl phenyl ether	10.2–13.3	4-Chloro-3-methylphenol	10.2–13.3
4-Chloroaniline	10.2–13.3	4-Chlorophenyl phenyl ether	10.2–13.3
4-Nitroaniline	10.2–13.3	4-Nitrophenol	10.2–13.3
9H-Fluorene	1.08–11.9	Acenaphthene	1.08–11.9
Acenaphthylene	1.08–11.9	Anthracene	1.08–11.9
Atrazine	10.8−13.3	Benzaldehyde	10.8–13.3
Benzo[a]anthracene	1.08–11.9	Benzo[a]pyrene	1.08–11.9
Benzo[b]fluoranthene	1.08–11.9	Benzo[g,h,i]perylene	1.08–11.9
Benzo[k]fluoranthene	1.08–11.9	Benzyl n-butyl phthalate	10.2−13.3

Table 14. Water-quality constituents analyzed in stream water collected from five sampling sites at Fort Riley, Kansas, 2007–08.—Continued

[FNU, formazin nephelometric units; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; mV, millivolts, relative to standard hydrogen electrode; --, not applicable. Some reporting limits are interim limits and limits expressed as a range include one or more interim reporting limits]

Constituent	Minimum reporting level	Constituent	Minimum reporting level
Semi-volatile organic compounds, in micrograms per liter—Continued			
Bis(2-chloroethoxy)methane	10.2–13.3	Bis(2-chloroethyl) ether	10.2–13.3
Bis(2-chloroisopropyl) ether	10.2–13.3	Bis(2-ethylhexyl) phthalate	10.2–13.3
Carbazole	1.08–11.9	Chrysene	1.08–11.9
Dibenzo[a,h]anthracene	1.08–11.9	Dibenzofuran	10.2–13.3
Diethyl phthalate	10.2–13.3	Dimethyl phthalate	10.2–13.3
Di-n-butyl phthalate	10.2–13.3	Di-n-octyl phthalate	10.2–13.3
Diphenylamine	10.2–13.3	Fluoranthene	1.08–11.9
Hexachlorobenzene	10.2–13.3	Hexachlorobutadiene	10.2–13.3
Hexachlorocyclopentadiene	10.2–13.3	Hexachloroethane	10.2–13.3
Indeno[1,2,3-cd]pyrene	1.08–11.9	Isophorone	10.2–13.3
m-Cresol plus p-Cresol	10.8–23.3	Naphthalene	1.08–11.9
N-Nitrosodi-n-propylamine	10.2–13.3	o-Cresol	10.2–13.3
Pentachlorophenol	10.2–13.3	Phenanthrene	1.08–11.9
Phenol	10.2–13.3	Pyrene	1.08–11.9
Selected trace elements and major cations, in micrograms per liter unless otherwise noted			
Aluminum	2.0	Arsenic	.60
Barium	.40	Beryllium	0.26–0.40
Cadmium	.014	Calcium (mg/L)	.04
Chromium	.60	Cobalt	.04
Copper	4.0	Iron	6.0
Lead	.06	Lithium	.08
Magnesium (mg/L)	.004	Manganese	.40
Mercury	.010	Molybdenum	.08
Nickel	.12	Potassium (mg/L)	.16
Selenium	.08	Silver	0.016–0.020
Sodium (mg/L)	.12	Strontium	1.0
Zinc	6.0		

Table 15. Results of analyses for energetic compounds, semi-volatile organic compounds, carbon, and selected trace elements in streambed sediment collected from sampling sites at or near Fort Riley, Kansas, 2007.

[P, environmental (primary) sample; SE-R, sequential-replicate sample; SP-R, split-replicate sample; CO-R, concurrent-replicate sample; RS, reference site; <, less than; %, percentage of dry weight; E, estimated; shading indicates detections of semi-volatile organic compounds]

Date, time, or constituent	Map index identifier (fig. 1)																		
	RC-1	FC-1	7MC-1	MC-1	DC-1		MCT-1	3MC-1		HC-1	7MC-2	LAC-1	WC-1	3MC-2	7MC-3		DBC-1	WCC-1	TC-1 (RS)
					P	SE-R		P	SP-R						P	CO-R			
Date (month/day/year)	06/12/07	06/12/07	06/12/07	06/13/07	06/13/07	06/13/07	06/13/07	06/20/07	06/20/07	06/20/07	06/20/07	06/25/07	06/25/07	06/25/07	06/26/07	06/26/07	06/26/07	06/26/07	06/13/07
Time (24-hour)	1200	1345	1515	1115	1230	1235	1400	1000	1005	1300	1430	1000	1130	1330	0900	0905	1045	1200	1530
Energetic compounds, in micrograms per kilogram																			
1,3-Dinitrobenzene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
1,3,5-Trinitrobenzene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
2,4-Dinitrotoluene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
2,6-Dinitrotoluene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
2-Amino-4,6-dinitrotoluene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
4-Amino-2,6-dinitrotoluene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
2-Nitrotoluene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
3-Nitrotoluene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
4-Nitrotoluene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
HMX	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
Nitrobenzene	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
Nitroglycerin	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000	<1,000
Pentaerythritol tetranitrate	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500
Perchlorate	<2.92	<3.04	<3.06	<2.91	<3.05	<3.17	<2.95	<2.92	<3.01	<3.14	<2.84	<2.71	<3.06	<2.81	<2.96	<2.95	<3.14	<3.14	<3.02
RDX	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
Tetryl	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
TNT	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150	<150
Semi-volatile organic compounds, in micrograms per kilogram																			
1,1'-Biphenyl	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
1,2,4-Trichlorobenzene	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
1,2-Dichlorobenzene	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
1,3-Dichlorobenzene	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
1,4-Dichlorobenzene	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
2,4-Dichlorophenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
2,4,5-Trichlorophenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530

Table 15. Results of analyses for energetic compounds, semi-volatile organic compounds, carbon, and selected trace elements in streambed sediment collected from sampling sites at or near Fort Riley, Kansas, 2007. —Continued

[P, environmental (primary) sample; SE-R, sequential-replicate sample; SP-R, split-replicate sample; CO-R, concurrent-replicate sample; RS, reference site; <, less than; %, percentage of dry weight; E, estimated; shading indicates detections of semi-volatile organic compounds]

Date, time, or constituent	Map index identifier (fig. 1)																		
	RC-1	FC-1	7MC-1	MC-1	DC-1		MCT-1	3MC-1		HC-1	7MC-2	LAC-1	WC-1	3MC-2	7MC-3		DBC-1	WCC-1	TC-1 (RS)
					P	SE-R		P	SP-R						P	CO-R			
Semi-volatile organic compounds, in micrograms per kilogram—Continued																			
2,4,6-Trichlorophenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
2,4-Dimethylphenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
2,4-Dinitrophenol	<3,030	<2,980	<3,110	<2,860	<3,080	<3,000	<2,950	<2,920	<3,010	<3,140	<2,840	<2,710	<3,060	<2,810	<2,960	<2,950	<3,140	<3,140	<3,070
2-Chloronaphthalene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
2-Chlorophenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
2-Methyl-4,6-dinitrophenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
2-Methylnaphthalene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
2-Nitroaniline	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
2-Nitrophenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
3,3'-Dichlorobenzidine	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
3-Nitroaniline	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
4-Bromophenyl phenyl ether	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
4-Chloro-3-methylphenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
4-Chloroaniline	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
4-Chlorophenyl phenyl ether	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
4-Nitroaniline	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
4-Nitrophenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
9H-Fluorene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Acenaphthene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Acenaphthylene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
alpha-Terpineol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Anthracene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Atrazine	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Benzaldehyde	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Benzo[a]anthracene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153

Table 15. Results of analyses for energetic compounds, semi-volatile organic compounds, carbon, and selected trace elements in streambed sediment collected from sampling sites at or near Fort Riley, Kansas, 2007. —Continued

[P, environmental (primary) sample; SE-R, sequential-replicate sample; SP-R, split-replicate sample; CO-R, concurrent-replicate sample; RS, reference site; <, less than; %, percentage of dry weight; E, estimated; shading indicates detections of semi-volatile organic compounds]

Date, time, or constituent	Map index identifier (fig. 1)																		
	RC-1	FC-1	7MC-1	MC-1	DC-1		MCT-1	3MC-1		HC-1	7MC-2	LAC-1	WC-1	3MC-2	7MC-3		DBC-1	WCC-1	TC-1 (RS)
					P	SE-R		P	SP-R						P	CO-R			
Semi-volatile organic compounds, in micrograms per kilogram—Continued																			
Benzo[a]pyrene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	E54.3
Benzo[b]fluoranthene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	165
Benzo[g,h,i]perylene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Benzo[k]fluoranthene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Benzyl n-butyl phthalate	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Bis(2-chloroethoxy) methane	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Bis(2-chloroethyl) ether	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Bis(2-chloroisopropyl) ether	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Bis(2-ethylhexyl) phthalate	<757	<745	<778	<714	<771	<751	<737	<731	<754	<784	<710	<678	<765	<702	<740	<737	<785	<784	<767
Carbazole	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Chrysene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Dibenzo[a,h]anthracene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Dibenzofuran	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Diethyl phthalate	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Dimethyl phthalate	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Di-n-butyl phthalate	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Di-n-octyl phthalate	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Diphenylamine	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Fluoranthene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	E107
Hexachlorobenzene	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Hexachlorobutadiene	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Hexachlorocyclopentadiene	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Hexachloroethane	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Indeno[1,2,3-cd]pyrene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Isophorone	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530

Table 15. Results of analyses for energetic compounds, semi-volatile organic compounds, carbon, and selected trace elements in streambed sediment collected from sampling sites at or near Fort Riley, Kansas, 2007. —Continued

[P, environmental (primary) sample; SE-R, sequential-replicate sample; SP-R, split-replicate sample; CO-R, concurrent-replicate sample; RS, reference site; <, less than; %, percentage of dry weight; E, estimated; shading indicates detections of semi-volatile organic compounds]

Date, time, or constituent	Map index identifier (fig. 1)																		
	RC-1	FC-1	7MC-1	MC-1	DC-1		MCT-1	3MC-1		HC-1	7MC-2	LAC-1	WC-1	3MC-2	7MC-3		DBC-1	WCC-1	TC-1 (RS)
					P	SE-R		P	SP-R						P	CO-R			
Semi-volatile organic compounds, in micrograms per kilogram—Continued																			
m-Cresol plus p-Cresol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Naphthalene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
N-Nitrosodi-n-propylamine	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
o-Cresol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Pentachlorophenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Phenanthrene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	<153
Phenol	<1,510	<1,490	<1,560	<1,430	<1,540	<1,500	<1,470	<1,460	<1,510	<1,570	<1,420	<1,360	<1,530	<1,400	<1,480	<1,470	<1,570	<1,570	<1,530
Pyrene	<151	<149	<156	<143	<154	<150	<147	<146	<151	<157	<142	<136	<153	<140	<148	<147	<157	<157	E114
Carbon and selected trace elements, in milligrams per kilogram unless otherwise indicated																			
Sediment <0.063 mm (%)	59	71	56	53	70	67	72	59	59	71	44	58	60	60	77	78	65	68	76
Aluminum (%)	5.5	5.5	5.6	5.5	5.8	5.5	5.8	5.6	5.7	5.9	5.4	5.5	5.4	5.1	5.0	5.1	5.6	5.1	5.5
Antimony	.8	.7	.7	.6	.7	.7	.7	.7	.7	.7	.7	.6	.7	.6	.6	.6	.7	.6	.7
Arsenic	5.5	7.0	7.0	5.3	6.2	6.1	6.9	5.6	5.9	7.3	6.1	6.6	6.3	4.7	4.3	4.4	5.8	5.1	6.6
Barium	660	630	660	670	670	660	650	640	650	630	610	610	640	640	620	630	680	650	650
Beryllium	1.6	1.6	1.6	1.6	1.7	1.6	1.7	1.6	1.6	1.7	1.6	1.6	1.6	1.5	1.4	1.5	1.6	1.5	1.6
Cadmium	.5	.5	.3	.4	.4	.4	.4	.4	.3	.4	.3	.3	.3	.3	.3	.3	.2	.3	.4
Carbon, organic, total, %	1.1	.9	1.2	.9	1.2	1.2	.8	1.3	1.2	1.3	1.0	1.0	.9	1.5	1.1	1.1	.8	1.0	1.0
Carbon, total, %	1.3	1.4	1.4	1.4	1.6	1.8	1.2	1.8	1.7	1.8	1.6	1.8	1.4	1.7	1.3	1.4	1.1	1.3	1.6
Chromium	49	49	50	46	48	48	52	51	52	56	52	49	48	46	45	44	47	47	47
Cobalt	10	12	11	13	13	12	11	11	11	11	11	10	13	8	8	8	8	9	12
Copper	14	14	16	14	14	13	15	16	16	17	15	14	14	14	13	13	15	13	15
Iron, %	2.0	2.2	2.2	2.1	2.3	2.1	2.3	2.3	2.4	2.5	2.3	2.2	2.2	2.0	1.9	1.9	2.1	1.9	2.2
Lead	26	21	22	22	22	22	19	21	21	20	21	19	20	22	19	20	18	18	22
Lithium	26	28	26	27	27	25	28	29	29	34	30	33	27	25	24	25	25	25	27
Manganese	340	710	560	530	590	530	620	480	500	620	610	510	630	480	360	380	370	440	600
Mercury	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01	<.01
Molybdenum	<1	1	1	<1	1	<1	1	<1	1	1	<1	<1	<1	<1	1	<1	1	<1	1
Nickel	19	21	19	20	20	19	21	20	20	23	20	20	19	18	16	16	17	17	19

Table 15. Results of analyses for energetic compounds, semi-volatile organic compounds, carbon, and selected trace elements in streambed sediment collected from sampling sites at or near Fort Riley, Kansas, 2007. —Continued

[P, environmental (primary) sample; SE-R, sequential-replicate sample; SP-R, split-replicate sample; CO-R, concurrent-replicate sample; RS, reference site; <, less than; %, percentage of dry weight; E, estimated; shading indicates detections of semi-volatile organic compounds]

Date, time, or constituent	Map index identifier (fig. 1)																		
	RC-1	FC-1	7MC-1	MC-1	DC-1		MCT-1	3MC-1		HC-1	7MC-2	LAC-1	WC-1	3MC-2	7MC-3		DBC-1	WCC-1	TC-1 (RS)
					P	SE-R		P	SP-R						P	CO-R			
Carbon and selected trace elements, in milligrams per kilogram unless otherwise indicated—Continued																			
Nitrogen, %	0.10	0.09	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.10	0.08	0.09	0.10
Phosphorus	440	490	460	490	530	530	470	520	530	550	510	480	450	590	470	480	430	490	480
Selenium	.3	.1	.2	.2	.2	.2	.2	.2	.2	.3	.2	.2	.2	.2	.2	.2	.2	.2	.2
Silver	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5	<.5
Strontium	150	160	130	150	140	140	130	170	170	140	170	140	130	180	150	150	160	150	140
Sulfur, %	.02	.02	.02	.03	.02	.02	.02	.03	.03	.02	.03	.02	.02	.03	.02	.02	.02	.03	.02
Thallium	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Titanium, %	.38	.36	.38	.37	.38	.38	.38	.37	.38	.38	.39	.37	.37	.38	.38	.37	.38	.37	.36
Uranium	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50	<50
Vanadium	67	67	72	66	72	68	72	69	70	76	68	68	68	61	61	61	71	63	66
Zinc	63	73	69	64	71	65	69	79	80	77	72	69	66	69	58	60	74	61	66

Table 16. Results of analyses for physical properties, energetic compounds, semi-volatile organic compounds, and selected trace elements and major cations in stream water collected from sampling sites at Fort Riley, Kansas, 2007–08.

[RO, manually collected runoff sample; B, manually collected base-flow sample; A, automatically collected sample; S, manually collected split- replicate sample; C, manually collected concurrent- replicate sample; FNU, formazin nephelometric units; --, not determined; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; ft^3/s, cubic feet per second; <, less than; E, estimated; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene; E, estimated concentration; shading indicates detections of perchlorate or semi-volatile organic compounds]

Date, time, sample type, property, or constituent	Map index identifier (fig. 1)							
	RC-1	FC-1	3MC-1			HC-1		
Date (month/day/year)	05/27/08	05/27/08	06/20/07	07/04/07	05/26/08	06/20/07	05/27/08	06/02/08
Time (24-hour)	0815	1000	0930	2040	1215	1230	1030	1400
Sample type	RO	RO	B	RO	RO	B	RO	RO
Physical properties and dissolved oxygen								
Stream stage	falling	falling	steady	falling	rising	steady	falling	falling
Instantaneous discharge (ft^3/s)	48.0	24.9	2.0	163	53.1	.62	30.2	1,030
Specific conductance, field (µS/cm)	141	170	672	156	331	627	358	101
Specific conductance, laboratory (µS/cm)	141	167	687	170	481	643	367	144
pH, field (standard units)	7.53	7.67	7.64	8.01	7.87	7.60	7.76	7.57
pH, laboratory (standard units)	7.70	7.66	7.70	7.44	7.77	7.72	7.94	7.66
Water temperature (°C)	17.8	18.4	19.0	22.6	17.8	19.0	16.9	10.0
Turbidity (FNU)	--	--	1.0	300	1,000	0.10	190	--
Dissolved oxygen (mg/L)	8.9	9.0	--	7.5	7.4	--	7.6	10
Energetic compounds, in micrograms per liter								
1,3-Dinitrobenzene	<.741	<.625	<.325	<.325	<.408	<.325	<.4	<.8
1,3,5-Trinitrobenzene	<.741	<.625	<.325	<.325	<.408	<.325	<.4	<.8
2,4-Dinitrotoluene	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
2,6-Dinitrotoluene	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
2-Amino-4,6-dinitrotoluene	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
4-Amino-2,6-dinitrotoluene	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
2-Nitrotoluene	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
3-Nitrotoluene	<.741	<.625	<.325	<.325	<.408	<.325	<.4	<.8
4-Nitrotoluene	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
HMX	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
Nitrobenzene	<.741	<.625	<.325	<.325	<.408	<.325	<.4	<.8
Nitroglycerin	<4.67	<3.94	<1.95	<1.95	<2.57	<1.95	<2.52	<5.04
Pentaerythritol tetranitrate	<4.63	<3.91	<1.95	<1.95	<2.55	<1.95	<2.5	<5
Perchlorate	E.126	E.236	E.085	E.176	E.093	.216	E.117	<.2
RDX	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
Tetryl	<.741	<.625	<1.46	<1.46	<.408	<1.46	<.4	<.8
TNT	<.741	<.625	<.487	<.487	<.408	<.487	<.4	<.8
Semi-volatile organic compounds, in micrograms per liter								
1,1'-Biphenyl	--	--	<10.9	<13.3	--	<11.4	--	--
1,2,4-Trichlorobenzene	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
1,2-Dichlorobenzene	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
1,3-Dichlorobenzene	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
1,4-Dichlorobenzene	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4

Table 16. Results of analyses for physical properties, energetic compounds, semi-volatile organic compounds, and selected trace elements and major cations in stream water collected from sampling sites at Fort Riley, Kansas, 2007–08.—Continued

[RO, manually collected runoff sample; B, manually collected base-flow sample; A, automatically collected sample; S, manually collected split- replicate sample; C, manually collected concurrent- replicate sample; FNU, formazin nephelometric units; --, not determined; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; ft^3/s, cubic feet per second; <, less than; E, estimated; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene; E, estimated concentration; shading indicates detections of perchlorate or semi-volatile organic compounds]

Date, time, sample type, property, or constituent	Map index identifier (fig. 1)							
	RC-1	FC-1	3MC-1			HC-1		
Date (month/day/year)	05/27/08	05/27/08	06/20/07	07/04/07	05/26/08	06/20/07	05/27/08	06/02/08
Time (24-hour)	0815	1000	0930	2040	1215	1230	1030	1400
Sample type	RO	RO	B	RO	RO	B	RO	RO
Semi-volatile organic compounds, in micrograms per liter—Continued								
2,4-Dichlorophenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
2,4,5-Trichlorophenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
2,4,6-Trichlorophenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
2,4-Dimethylphenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
2,4-Dinitrophenol	--	--	<21.7	<26.7	--	<22.7	--	<11.4
2-Chloronaphthalene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
2-Chlorophenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
2-Methyl-4,6-dinitrophenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
2-Methylnaphthalene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
2-Nitroaniline	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
2-Nitrophenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
3,3'-Dichlorobenzidine	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
3-Nitroaniline	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
4-Bromophenyl phenyl ether	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
4-Chloro-3-methylphenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
4-Chloroaniline	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
4-Chlorophenyl phenyl ether	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
4-Nitroaniline	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
4-Nitrophenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
9H-Fluorene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Acenaphthene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Acenaphthylene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Anthracene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Atrazine	--	--	<10.9	<13.3	--	<11.4	--	--
Benzaldehyde	--	--	<10.9	<13.3	--	<11.4	--	--
Benzo[a]anthracene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Benzo[a]pyrene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Benzo[b]fluoranthene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Benzo[g,h,i]perylene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Benzo[k]fluoranthene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Benzyl n-butyl phthalate	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Bis(2-chloroethoxy)methane	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Bis(2-chloroethyl) ether	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Bis(2-chloroisopropyl) ether	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Bis(2-ethylhexyl) phthalate	<10.5	E1.18	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4

Table 16. Results of analyses for physical properties, energetic compounds, semi-volatile organic compounds, and selected trace elements and major cations in stream water collected from sampling sites at Fort Riley, Kansas, 2007–08.—Continued

[RO, manually collected runoff sample; B, manually collected base-flow sample; A, automatically collected sample; S, manually collected split- replicate sample; C, manually collected concurrent- replicate sample; FNU, formazin nephelometric units; --, not determined; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; ft^3/s, cubic feet per second; <, less than; E, estimated; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene; E, estimated concentration; shading indicates detections of perchlorate or semi-volatile organic compounds]

Date, time, sample type, property, or constituent	Map index identifier (fig. 1)							
	RC-1	FC-1	3MC-1			HC-1		
Date (month/day/year)	05/27/08	05/27/08	06/20/07	07/04/07	05/26/08	06/20/07	05/27/08	06/02/08
Time (24-hour)	0815	1000	0930	2040	1215	1230	1030	1400
Sample type	RO	RO	B	RO	RO	B	RO	RO
Semi-volatile organic compounds, in micrograms per liter—Continued								
Carbazole	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Chrysene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Dibenzo[a,h]anthracene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Dibenzofuran	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Diethyl phthalate	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Dimethyl phthalate	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Di-n-butyl phthalate	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Di-n-octyl phthalate	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Diphenylamine	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Fluoranthene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Hexachlorobenzene	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Hexachlorobutadiene	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Hexachlorocyclopentadiene	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Hexachloroethane	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
Indeno[1,2,3-cd]pyrene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Isophorone	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
m-Cresol plus p-Cresol	--	--	<10.9	<13.3	--	<11.4	--	<22.7
Naphthalene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
N-Nitrosodi-n-propylamine	<10.5	<10.5	<10.9	<13.3	<10.3	<11.4	<11.2	<11.4
o-Cresol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
Pentachlorophenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
Phenanthrene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Phenol	--	--	<10.9	<13.3	--	<11.4	--	<11.4
Pyrene	<10.5	<10.5	<1.09	<1.33	<10.3	<1.14	<11.2	<11.4
Selected trace elements and major cations, in micrograms per liter unless otherwise indicated								
Aluminum	9,100	4,100	150	9,400	4,000	12	1,800	36,000
Arsenic	3.5	3.0	2.0	4.0	3.0	1.1	1.7	8.6
Barium	170	110	220	210	160	160	130	710
Beryllium	.75	E.29	<.26	.79	<.40	<.26	<.40	3.5
Cadmium	.24	.13	.02	.44	.17	E.01	.04	1.2
Calcium (mg/L)	27	24	94	38	73	110	62	68
Chromium	9.4	4.1	<.60	9.1	4.6	<.60	1.9	32
Cobalt	4.9	2.4	.23	6.0	3.0	.05	.98	24
Copper	9.5	4.5	<4.0	9.5	4.3	<4.0	E2.5	81
Iron	8,600	3,800	180	9,100	9.6	12	1,700	36,000
Lead	9.9	4.4	0.20	12	5.3	<.06	2.2	150

Table 16. Results of analyses for physical properties, energetic compounds, semi-volatile organic compounds, and selected trace elements and major cations in stream water collected from sampling sites at Fort Riley, Kansas, 2007–08.—Continued

[RO, manually collected runoff sample; B, manually collected base-flow sample; A, automatically collected sample; S, manually collected split- replicate sample; C, manually collected concurrent- replicate sample; FNU, formazin nephelometric units; --, not determined; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; ft^3/s, cubic feet per second; <, less than; E, estimated; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene; E, estimated concentration; shading indicates detections of perchlorate or semi-volatile organic compounds]

Date, time, sample type, property, or constituent	Map index identifier (fig. 1)							
	RC-1	FC-1	3MC-1			HC-1		
Date (month/day/year)	05/27/08	05/27/08	06/20/07	07/04/07	05/26/08	06/20/07	05/27/08	06/02/08
Time (24-hour)	0815	1000	0930	2040	1215	1230	1030	1400
Sample type	RO	RO	B	RO	RO	B	RO	RO
Selected trace elements and major cations, in micrograms per liter unless otherwise indicated—Continued								
Lithium	10	5.6	6.5	12	8.9	7.1	4.8	34
Magnesium (mg/L)	5.1	5.7	22	7.2	15	19	9.4	15
Manganese	260	170	86	470	380	9.3	60	1,500
Mercury	.02	E.009	<.010	.02	E.008	<.010	<.010	.07
Molybdenum	.27	.51	1.3	.47	.76	1.2	.62	.20
Nickel	12	6.5	.77	13	6.7	.30	2.8	44
Potassium (mg/L)	6.2	6.0	2.2	5.2	3.3	1.7	4.2	13
Selenium	.28	.25	.31	.34	.26	.63	.30	.40
Silver	.04	.02	<.016	.05	E.017	<.016	<.02	.25
Sodium (mg/L)	2.2	4.1	19	4.1	18	7.0	4.4	1.4
Strontium	80	110	900	210	630	550	290	220
Zinc	33	18	<6.0	43	20	<6.0	6.8	150

Table 16. Results of analyses for physical properties, energetic compounds, semi-volatile organic compounds, and selected trace elements and major cations in stream water collected from sampling sites at Fort Riley, Kansas, 2007–08.—Continued

[RO, manually collected runoff sample; B, manually collected base-flow sample; A, automatically collected sample; S, manually collected split- replicate sample; C, manually collected concurrent- replicate sample; FNU, formazin nephelometric units; --, not determined; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; ft³/s, cubic feet per second; <, less than; E, estimated; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene; E, estimated concentration; shading indicates detections of perchlorate or semi-volatile organic compounds]

Date, time, sample type, property, or constituent	Map index identifier (fig. 1)											
	7MC-2											
Date (month/day/year)	06/20/07	07/31/07	05/26/08	05/26/08	05/27/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08
Time (24-hour)	1400	1150	1045	2140	0810	1130	1320	1325	1335	1630	2030	2330
Sample type	B	RO	RO	A	RO	A	RO	RO-S	RO-A-C	RO	A	A
Physical properties and dissolved oxygen												
Stream stage	steady	falling	peak	rising	falling	rising	rising	rising	rising	rising	falling	falling
Instantaneous discharge (ft³/s)	6.4	4.6	5.3	148	151	124	966	966	966	856	289	221
Specific conductance, field (µS/cm)	675	555	610	272	244	--	155	155	155	107	185	266
Specific conductance, laboratory (µS/cm)	686	560	631	282	241	352	218	215	223	179	191	263
pH, field (standard units)	7.99	7.83	7.95	7.95	7.81	--	7.93	7.93	7.93	7.94	7.20	7.24
pH, laboratory (standard units)	8.01	7.97	8.15	7.57	7.59	7.68	7.65	7.63	7.65	7.50	7.54	7.56
Dissolved oxygen (mg/L)	--	8.0	6.5	--	7.6	--	8.4	8.4	8.4	8.3	--	--
Turbidity (FNU)	0.80	15	8.1	--	320	--	1,500	1,500	1,500	12	--	--
Stream stage	steady	falling	peak	rising	falling	rising	rising	rising	rising	rising	falling	falling
Energetic compounds, in micrograms per liter												
1,3-Dinitrobenzene	<.325	<.325	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
1,3,5-Trinitrobenzene	<.325	<.325	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
2,4-Dinitrotoluene	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
2,6-Dinitrotoluene	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
2-Amino-4,6-dinitrotoluene	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
4-Amino-2,6-dinitrotoluene	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
2-Nitrotoluene	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
3-Nitrotoluene	<.325	<.325	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
4-Nitrotoluene	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
HMX	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
Nitrobenzene	<.325	<.325	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
Nitroglycerin	<1.95	<1.95	<2.68	<5.48	<3.5	<3.53	<4.02	<4.5	<4.06	<2.7	<4.34	<2.66
Pentaerythritol tetranitrate	<1.95	<1.95	<2.66	<5.43	<3.47	<3.5	<3.99	<4.46	<4.03	<2.68	<4.31	<2.64
Perchlorate	E.180	E.139	E.130	E.112	E.135	E.086	E.075	E.072	E.057	E.078	E.082	E.108
RDX	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
Tetryl	<1.46	<1.46	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
TNT	<.487	<.487	<.426	<.87	<.556	<.561	<.638	<.714	<.645	<.429	<.69	<.423
Semi-volatile organic compounds, in micrograms per liter												
1,1'-Biphenyl	<10.9	<10.8	--	--	--	--	--	--	--	--	--	--
1,2,4-Trichlorobenzene	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
1,2-Dichlorobenzene	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
1,3-Dichlorobenzene	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
1,4-Dichlorobenzene	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6

Table 16. Results of analyses for physical properties, energetic compounds, semi-volatile organic compounds, and selected trace elements and major cations in stream water collected from sampling sites at Fort Riley, Kansas, 2007–08.—Continued

[RO, manually collected runoff sample; B, manually collected base-flow sample; A, automatically collected sample; S, manually collected split- replicate sample; C, manually collected concurrent- replicate sample; FNU, formazin nephelometric units; --, not determined; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; ft^3/s, cubic feet per second; <, less than; E, estimated; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene; E, estimated concentration; shading indicates detections of perchlorate or semi-volatile organic compounds]

Date, time, sample type, property, or constituent	Map index identifier (fig. 1)											
	7MC-2											
Date (month/day/year)	06/20/07	07/31/07	05/26/08	05/26/08	05/27/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08
Time (24-hour)	1400	1150	1045	2140	0810	1130	1320	1325	1335	1630	2030	2330
Sample type	B	RO	RO	A	RO	A	RO	RO-S	RO-A-C	RO	A	A
Semi-volatile organic compounds, in micrograms per liter—Continued												
2,4-Dichlorophenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2,4,5-Trichlorophenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2,4,6-Trichlorophenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2,4-Dimethylphenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2,4-Dinitrophenol	<21.7	<21.5	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2-Chloronaphthalene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2-Chlorophenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2-Methyl-4,6-dinitrophenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2-Methylnaphthalene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2-Nitroaniline	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
2-Nitrophenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
3,3'-Dichlorobenzidine	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
3-Nitroaniline	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
4-Bromophenyl phenyl ether	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
4-Chloro-3-methylphenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
4-Chloroaniline	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
4-Chlorophenyl phenyl ether	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
4-Nitroaniline	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
4-Nitrophenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
9H-Fluorene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Acenaphthene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Acenaphthylene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Anthracene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Atrazine	<10.9	<10.8	--	--	--	--	--	--	--	--	--	--
Benzaldehyde	<10.9	<10.8	--	--	--	--	--	--	--	--	--	--
Benzo[a]anthracene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Benzo[a]pyrene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Benzo[b]fluoranthene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Benzo[g,h,i]perylene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Benzo[k]fluoranthene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Benzyl n-butyl phthalate	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Bis(2-chloroethoxy)methane	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Bis(2-chloroethyl) ether	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Bis(2-chloroisopropyl) ether	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Bis(2-ethylhexyl) phthalate	<10.9	<10.8	E1.7	E2.46	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	E1.56

Table 16. Results of analyses for physical properties, energetic compounds, semi-volatile organic compounds, and selected trace elements and major cations in stream water collected from sampling sites at Fort Riley, Kansas, 2007–08.—Continued

[RO, manually collected runoff sample; B, manually collected base-flow sample; A, automatically collected sample; S, manually collected split- replicate sample; C, manually collected concurrent- replicate sample; FNU, formazin nephelometric units; --, not determined; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; ft³/s, cubic feet per second; <, less than; E, estimated; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene; E, estimated concentration; shading indicates detections of perchlorate or semi-volatile organic compounds]

Date, time, sample type,	Map index identifier (fig. 1)											
	7MC-2											
Date (month/day/year)	06/20/07	07/31/07	05/26/08	05/26/08	05/27/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08
Time (24-hour)	1400	1150	1045	2140	0810	1130	1320	1325	1335	1630	2030	2330
Sample type	B	RO	RO	A	RO	A	RO	RO-S	RO-A-C	RO	A	A
Semi-volatile organic compounds, in micrograms per liter—Continued												
Carbazole	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Chrysene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Dibenzo[a,h]anthracene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Dibenzofuran	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Diethyl phthalate	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Dimethyl phthalate	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Di-n-butyl phthalate	<10.9	<10.8	<11.2	E1.25	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Di-n-octyl phthalate	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Diphenylamine	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Fluoranthene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Hexachlorobenzene	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Hexachlorobutadiene	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Hexachlorocyclopen-tadiene	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Hexachloroethane	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Indeno[1,2,3-cd]pyrene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Isophorone	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
m-Cresol plus p-Cresol	<10.9	<10.8	--	--	--	<22	<21.1	<21.1	<20.4	<23.3	<20.8	<23.3
Naphthalene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
N-Nitrosodi-n-propyl-amine	<10.9	<10.8	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
o-Cresol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Pentachlorophenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Phenanthrene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Phenol	<10.9	<10.8	--	--	--	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Pyrene	<1.09	<1.08	<11.2	<11.9	<11.8	<11	<10.5	<10.5	<10.2	<11.6	<10.4	<11.6
Selected trace elements and major cations, in micrograms per liter unless otherwise indicated												
Aluminum	57	530	360	200	480	16,000	37,000	36,000	29,000	28,000	13,000	8,200
Arsenic	1.7	1.7	2.0	7.3	4.2	4.8	9.9	9.9	7.8	8.2	4.7	3.7
Barium	170	140	160	110	240	370	900	900	670	590	270	210
Beryllium	<.26	<.26	<.40	2.3	.82	1.3	3.9	3.9	2.9	2.7	1.1	.66
Cadmium	E.01	.03	<.014	1.0	.31	.71	1.8	1.8	1.3	1.0	.46	.23
Calcium, mg/L	110	84	99	110	49	98	130	140	89	74	43	50
Chromium	<.60	.74	.60	28	11	19	38	36	30	28	14	8.6
Cobalt	.07	.34	.24	23	7.4	14	40	40	27	23	9.5	5.2
Copper	<4.0	<4.0	<4.0	39	12	22	55	55	43	39	17	11
Iron	40	460	320	140	280	17,000	41,000	40,000	32,000	31,000	15,000	8,800
Lead	E.05	.48	.40	65	14	34	90	90	59	63	21	12

Table 16. Results of analyses for physical properties, energetic compounds, semi-volatile organic compounds, and selected trace elements and major cations in stream water collected from sampling sites at Fort Riley, Kansas, 2007–08.—Continued

[RO, manually collected runoff sample; B, manually collected base-flow sample; A, automatically collected sample; S, manually collected split- replicate sample; C, manually collected concurrent- replicate sample; FNU, formazin nephelometric units; --, not determined; mg/L, milligrams per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 °C; ft^3/s, cubic feet per second; <, less than; E, estimated; HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine; RDX, 1,3,5-hexahydro-1,3,5-trinitrotriazine; TNT, 2,4,6-trinitrotoluene; E, estimated concentration; shading indicates detections of perchlorate or semi-volatile organic compounds]

Date, time, sample type, property, or constituent	Map index identifier (fig. 1)											
	7MC-2											
Date (month/day/year)	06/20/07	07/31/07	05/26/08	05/26/08	05/27/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08	06/02/08
Time (24-hour)	1400	1150	1045	2140	0810	1130	1320	1325	1335	1630	2030	2330
Sample type	B	RO	RO	A	RO	A	RO	RO-S	RO-A-C	RO	A	A
Selected trace elements and major cations, in micrograms per liter unless otherwise indicated—Continued												
Lithium	8.3	8.8	8.6	36	12	25	44	43	33	28	13	9.7
Magnesium, mg/L	23	19	21	19	9.7	18	22	23	18	14	9	9.8
Manganese	8.6	27	45	2,000	430	850	2,500	2,600	1,800	1,400	540	290
Mercury	<.010	<.010	<.010	.05	.02	.03	.07	.07	.05	.05	.05	.02
Molybdenum	1.2	.95	1.4	.22	.34	.30	.26	.25	.23	.23	.25	.36
Nickel	.43	1.0	.95	43	15	28	64	63	48	41	19	11
Potassium, mg/L	1.9	2.2	2.1	8.9	6.1	6.4	11	11	9.3	11	7.5	6.4
Selenium	.92	.45	.42	.45	.34	.49	.55	.46	.40	.33	.26	.37
Silver	<.016	<.016	<.02	.16	.05	.12	.29	.29	.22	.19	.07	.04
Sodium, mg/L	10	7.1	9.6	4.0	3.6	5.2	4.0	4.0	4.1	2.0	2.6	3.9
Strontium	830	660	800	510	270	480	530	530	420	260	220	290
Zinc	<6.0	E3.2	E3.1	120	38	79	160	160	130	120	57	35

Table 17. Results of chemical analyses of standard-reference soil/sediment samples and comparison to most probable values.

[Shading indicates values outside of published limits for each soil-quality constituent or ± 10 percent of the most probable value, whichever is greater. MPV, most probable value; mg/kg, milligrams per kilogram; NIST, National Institute of Standards and Technology; --, not determined; (nc), not certified; USGS, U.S. Geological Survey; <, less than; ?, actual value in question]

Sample source	Sample code		Aluminum		Antimony		Arsenic		Barium		Beryllium		Cadmium	
			Concentration (percentage of dry weight)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV
NIST	2709	MPV	7.50±0.6	--	7.9±0.6	--	17.7±0.8	--	968±40	--	--	--	0.4	--
			7.5	0	7.5	-5.1	18	1.7	990	2.3	5.8	--	.4	0
NIST	2711 MT. soil	MPV	6.53±0.9	--	19.4±1.8	--	105±8	--	726±38	--	--	--	41.70±0.25	--
			6.4	-2.0	17	-12.4	99	-5.7	730	.6	2.2	--	40	-4.1
NIST	1646a	MPV	2.30±0.2	--	.3	--	6.23±0.21	--	210	--	<1	--	.2	--
			2.3	0	.3	0	6.0	-3.7	220	4.8	.9	--	.2	0
USGS	MAG-1	MPV	8.66±.16	--	0.96±0.10	--	9.2±1.2	--	479±41	--	3.2±0.4	--	.2±.1	--
			8.5	-1.8	.9	-6.2	8.9	-3.3	520	8.6	3.1	-3.1	.1	-50.0
USGS	STM-1	MPV	9.73±0.12	--	1.66±0.15	--	4.6±0.6	--	560±60	--	9.6±0.6	--	.27±0.05	--
			9.7	-.3	1.5	-9.6	4.8	4.3	610	8.9	9.7	1.0	.2	-25.9
USGS	SDO-1	MPV	6.49±0.14	--	4.1-4.8	--	68.5±8.6	--	397±38	--	3.3±0.6	--	--	--
			6.4	-1.4	4.2	--	68	-.7	330	-16.9	3.2	-3.0	<.1	--
USGS	SGR-1	MPV	3.45±0.11	--	3.4±0.5	--	67±5	--	290±40	--	1.06±0.16	--	.93±0.05	--
			3.5	1.4	3.0	-11.8	62	-7.5	310	6.9	1.1	3.8	1.0	7.5
USGS	SCO-1	MPV	7.23±0.11	--	2.5±0.1	--	12.4±1.4	--	570±30	--	1.84±0.20	--	.14	--
			7.1	-1.8	2.3	-8.0	12	-3.2	600	5.3	1.8	-2.2	.1	-28.6
USGS	GSP-2	MPV	7.88±0.11	--	--	--	--	--	1,340±44	--	1.5±0.2	--	--	--
			7.8	-1.0	.3	--	1.2	--	1,400	4.5	1.5	0	<.1	--

Table 17. Results of chemical analyses of standard-reference soil/sediment samples and comparison to most probable values.—Continued

[Shading indicates values outside of published limits for each soil-quality constituent or ± 10 percent of the most probable value, whichever is greater. MPV, most probable value; mg/kg, milligrams per kilogram; NIST, National Institute of Standards and Technology; --, not determined; (nc), not certified; USGS, U.S. Geological Survey; <, less than; ?, actual value in question]

Sample source	Sample code		Carbon, organic, total		Carbon, total		Chromium		Cobalt		Copper		Iron	
			Concentration (percentage of dry weight)	Percentage different from MPV	Concentration (percent dry weight)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (percent dry weight)	Percentage different from MPV
NIST	2709	MPV	--	--	1.2(nc)	--	130±4	--	13.4±0.7	--	34.6±0.7	--	3.5±0.11	--
			1.1	--	1.1	-8.3	120	-7.7	14	4.5	33	-4.6	3.5	0
NIST	2711 MT. soil	MPV	--	--	2	--	47	--	10	--	114±2	--	2.89±0.06	--
			1.8	--	1.8	-10.0	45	-4.3	10	0	110	-3.5	2.8	-3.1
NIST	1646a	MPV	--	--	--	--	41±2	--	5	--	10±0.34	--	2.00±0.04	--
			.6	--	.6	--	40	-2.4	4.8	-4.0	9.4	-6.0	2.0	0
USGS	MAG-1	MPV	--	--	2.15±0.40	--	97±8	--	20.4±1.6	--	30±3	--	4.75±0.21	--
			2.3	--	2.3	7.0	95	-2.1	22	7.8	27	-10.0	4.9	3.2
USGS	STM-1	MPV	--	--	.01	--	4.3±2.6	--	0.90±0.15	--	4.6±2.0	--	3.65±0.07	--
			<.1	--	<.1	--	3	-39.5	<1	--	4	-13.0	3.6	-1.4
USGS	SDO-1	MPV	--	--	9.95±0.44	--	66.4±7.6	--	46.8±6.3	--	60.2±9.6	--	6.53±0.15	--
			9.4	--	9.4	-5.5	69	3.9	49	4.7	61	1.3	6.4	-2.0
USGS	SGR-1	MPV	24.8	--	28	--	30±3	--	11.8±1.5	--	66±9	--	2.12±0.10	--
			27	8.9	27	-3.6	33	10.0	12	1.7	67	1.5	2.1	-.9
USGS	SCO-1	MPV	--	--	0.81±0.12	--	68±5	--	10.5±0.8	--	28.7±1.9	--	3.59±0.13	--
			1.0	--	1.0	23.5	63	-7.4	11	4.8	26	-9.4	3.5	-2.5
USGS	GSP-2	MPV	--	--	--	--	20±6	--	7±1	--	43±4	--	3.43±0.11	--
			<.1	--	.07	--	17	-15.0	7.1	1.4	45	4.7	3.3	-3.8

Table 17. Results of chemical analyses of standard-reference soil/sediment samples and comparison to most probable values.—Continued

[Shading indicates values outside of published limits for each soil-quality constituent or ± 10 percent of the most probable value, whichever is greater. MPV, most probable value; mg/kg, milligrams per kilogram; NIST, National Institute of Standards and Technology; --, not determined; (nc), not certified; USGS, U.S. Geological Survey; <, less than; ?, actual value in question]

Sample source	Sample code		Lead		Lithium		Manganese		Mercury		Molybdenum		Nickel	
			Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV
NIST	2709	MPV	18.9±0.5	--	--	--	538±17	--	1.40±.08	--	2.0(nc)	--	88±5	--
			19		53	--	530	-1.5	1.30	-7.1	1.9	-5.0	83	-5.7
NIST	2711 MT. soil	MPV	1,162±31	--	--	--	638±28	--	6.25±0.19	--	1.6	--	20.6±1.1	--
			1,100	-5.3	26	--	610	-4.4	6.50	4.0	1.2	-25.0	19	-7.8
NIST	1646a	MPV	12±1	--	17	--	234±3	--	.04	--	1.8	--	23	--
			12	0	17	0	230	-1.7	.06	50.0	1.5	-16.7	21	-8.7
USGS	MAG-1	MPV	24±3	--	79±4	--	760±70	--	.018	--	1.6±0.6	--	53±8	--
			26	8.3	77	-2.5	710	-6.6	.05	177.8	.8	-50.0	48	-9.4
USGS	STM-1	MPV	17.7±1.8	--	32±8	--	1,700±120	--	.015	--	5.2±0.9	--	3.0±1.6	--
			16	-9.6	38	18.8	1,600	-5.9	<.01	--	5.0	-3.8	2	-33.3
USGS	SDO-1	MPV	27.9±5.2	--	28.6±5.5	--	325±39	--	0.19±0.08	--	134±21	--	99.5±9.9	--
			26	-6.8	31	8.4	310	-4.6	.14	-26.3	150	11.9	92	-7.5
USGS	SGR-1	MPV	38±4	--	147±26	--	267±34	--	.313	--	35.1±0.9	--	29±5	--
			42	10.5	130	-11.6	230	-13.9	.28	-10.5	33	-6.0	28	-3.4
USGS	SCO-1	MPV	31±3	--	45±3	--	408±30	--	.052	--	1.37±0.16	--	27±4	--
			30	-3.2	44	-2.2	380	-6.9	.096	84.6	.94	-31.4	24	-11.1
USGS	GSP-2	MPV	42±3	--	36±1	--	320±20	--	--	--	2.1±0.6	--	17±2	--
			42	0.0	35	-2.8	300	-6.3	.02	--	2.2	4.8	15	-11.8

Table 17. Results of chemical analyses of standard-reference soil/sediment samples and comparison to most probable values.—Continued

[Shading indicates values outside of published limits for each soil-quality constituent or ± 10 percent of the most probable value, whichever is greater. MPV, most probable value; mg/kg, milligrams per kilogram; NIST, National Institute of Standards and Technology; --, not determined; USGS, (nc), not certified; U.S. Geological Survey; <, less than; ?, actual value in question]

Sample source	Sample code		Nitrogen		Phosphorus		Selenium		Silver		Strontium		Sulfur	
			Concentration (percentage of dry weight)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (mg/kg)	Percentage different from MPV	Concentration (percent dry weight)	Percentage different from MPV
NIST	2709	MPV	--	--	620±50	--	1.57±0.08	--	0.41±0.03	--	231±2	--	0.089±0.002	--
			0.10	--	630	1.6	1.5	-4.5	.5	22.0	240	3.9	.081	-9.0
NIST	2711 MT. soil	MPV	--	--	860±70	--	1.52±0.14	--	4.63±0.39	--	245.3±0.7	--	.042±.001	--
			.10	--	810	-5.8	1.4	-7.9	4.6	-.6	240	-2.2	.037	-11.9
NIST	1646a	MPV	--	--	270±10	--	0.19±0.03	--	<.3	--	68	--	0.35±0.004	--
			.06	--	280	3.7	.3	57.9	<.5	--	70	2.9	.33	-5.7
USGS	MAG-1	MPV	--	--	710±90	--	1.16±0.12	--	.08	--	146±15	--	0.39±0.07	--
			.30	--	700	-1.4	1.0	-13.8	<.5	--	140	-4.1	.34	-12.8
USGS	STM-1	MPV	--	--	690±60	--	0.008±0.002	--	.08	--	700±30	--	--	--
			<.1	--	680	-1.4	<.1	--	<.5	--	670	-4.3	<.01	--
USGS	SDO-1	MPV	0.35±0.04	--	480±31	--	1.9–6.8	--	0.1–0.2	--	75.1±11	--	5.35±0.44	--
			.39	11.4	470	-2.1	1.8	--	<.5	--	80	6.5	4.90	-8.4
USGS	SGR-1	MPV	--	--	1,430±290	--	3.5±.28	--	0.01–0.20	--	420±30	--	1.53±0.11	--
			.90	--	1,200	-16.1	3.9	11.4	<.5	--	390	-7.1	1.40	-8.5
USGS	SCO-1	MPV	--	--	900±90	--	0.89±0.06	--	.13	--	174±16	--	0.063±0.009	--
			.06	--	860	-4.4	.9	1.1	<.5	--	170	-2.3	.061	-3.2
USGS	GSP-2	MPV	--	--	1,300±100	--	--	--	--	--	240±10	--	--	--
			<.1	--	1,200	-7.7	.05	--	<.5	--	250	4.2	.044	--

Table 17. Results of chemical analyses of standard-reference soil/sediment samples and comparison to most probable values.—Continued

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Sample source	Sample code		Thallium		Titanium		Uranium		Vanadium		Zinc	
			Concentration (mg/kg)	Percent-age different from MPV	Concentration (percentage of dry weight)	Percent-age different from MPV	Concentration (mg/kg)	Percent-age different from MPV	Concentration (mg/kg)	Percent agedif-ferent from MPV	Concentration (mg/kg)	Percent-age different from MPV
NIST	2709	MPV	0.74±0.05	--	.342±.024	--	3	--	112±5	--	106±3	--
			<50	--	.35	2.3	<50	--	110	-1.8	110	3.8
NIST	2711 MT. soil	MPV	2.47±0.15	--	0.306±0.023	--	2.6	--	81.6±2.9	--	350.4±4.8	--
			<50	--	.29	-5.2	<50	--	79	-3.2	360	2.7
NIST	1646a	MPV	<.5	--	0.46±0.02	--	2	--	45±1	--	49±2	--
			<50	--	.46	0	<50	--	43	-4.4	49	0
USGS	MAG-1	MPV	0.590±?	--	0.450±0.040	--	2.7±0.3	--	140±6	--	130±6	--
			<50	--	.43	-4.4	<50	--	130	-7.1	140	7.7
USGS	STM-1	MPV	0.260±0.050	--	0.081±0.007	--	9.06±0.13	--	8.7±5.2	--	235±22	--
			<50	--	.083	2.5	<50	--	4	-54.0	260	10.6
USGS	SDO-1	MPV	8.3?	--	0.426±0.019	--	48.8±6.5	--	160±21	--	64.1±6.9	--
			<50	--	.42	-1.4	50	2.5	160	0	71	10.8
USGS	SGR-1	MPV	0.330±?	--	0.152±0.015	--	5.4±0.4	--	128±6	--	74±9	--
			<50	--	.15	-1.3	<50	--	120	-6.3	81	9.5
USGS	SCO-1	MPV	0.72±0.13	--	0.376±0.039	--	3.0±0.2	--	131±13	--	103±8	--
			<50	--	.35	-6.9	<50	--	120	-8.4	110	6.8
USGS	GSP-2	MPV	1.1	--	0.40±0.01	--	2.4	--	52±4	--	120±10	--
			<50	--	.40	0	<50	--	51	-1.9	130	8.3

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