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Soil- and Groundwater-Quality Data for Petroleum Hydrocarbon Compounds within Fuels Area C, Ellsworth Air Force Base, South Dakota, 2014

Data Series 939

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

Front cover. Background: B-1B Lancer aircraft preparing for takeoff from Ellsworth Air Force Base, South Dakota. Photograph by John F. Stamm, U.S. Geological Survey (USGS). Foreground left: USGS hydrologist describing the split soil core for 20 to 25 feet from well EAFB FAC MW14_07, Fuels Area C. Photograph by David A. Bender. Foreground right: USGS hydrologist taking field measurements during groundwater sampling at EAFB FAC MW14_02, Fuels Area C. Photograph by David A. Bender.

Back cover. Clockwise from upper left: Drilling rig setup and drilling well EAFB FAC MW14_04 on Fuels Area C, Ellsworth Air Force Base, South Dakota. Photograph by John F. Stamm. USGS hydrologist using a photoionization detector on a split soil core from 15 to 20 feet for well EAFB FAC MW14_06, Fuels Area C. Photograph by John F. Stamm. Groundwater sampling setup at EAFB FAC MW14_04, Fuels Area C. Photograph by Brian C. Engle. USGS hydrologist preparing to collect groundwater samples at EAFB FAC MW14_06, Fuels Area C. Photograph by David A. Bender.

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SALLY JEWELL, Secretary

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
ounce, fluid (fl. oz)	0.02957	liter (L)
	Energy	
electron volt (eV)	$1.602x10^{-19}$	joules (J)

International System of Units to Inch/Pound

Multiply	By	To obtain
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
	Volume	
milliliter (mL)	0.03381	ounce, fluid (fl. oz)

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

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as $°C = (°F - 32) / 1.8$.

Datum

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

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

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

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in air are given in parts per million (ppm).

Concentrations of chemical constituents in soil are given in milligrams per kilogram (mg/kg).

Concentrations of chemical constituents in water are given in micrograms per liter (µg/L).

Abbreviations

<	less than
>	greater than
ARSD	Administrative Rules of South Dakota
BTEX	benzene, toluene, ethylbenzene, and total xylenes
C_3	three-carbon organic compound
C_4	four-carbon organic compound
C_{12}	12-carbon organic compound
C_{25}	25-carbon organic compound
DRO	diesel-range organic compound
E	estimated
EAFB	Ellsworth Air Force Base
GNSS	global navigation satellite system
GRO	gasoline-range organic compound
JP-8	jet propellant-8
NWIS	National Water Information System
OPUS	Online Positioning User Service
PID	photoionization detector
QC	quality control
RTK	real-time kinematic
SD DENR	South Dakota Department of Environment and Natural Resources
SOP	standard operating procedure
TPH	total petroleum hydrocarbon
USGS	U.S. Geological Survey
UST	underground storage tank
YSI	Yellow Springs International

Soil- and Groundwater-Quality Data for Petroleum Hydrocarbon Compounds within Fuels Area C, Ellsworth Air Force Base, South Dakota, 2014

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Abstract

Ellsworth Air Force Base is an Air Combat Command located approximately 10 miles northeast of Rapid City, South Dakota. Ellsworth Air Force Base occupies about 6,000 acres within Meade and Pennington Counties, and includes runways, airfield operations, industrial areas, housing, and recreational facilities. Fuels Area C within Ellsworth Air Force Base is a fuels storage area that is used to support the mission of the base. In fall of 2013, the U.S. Geological Survey began a study in cooperation with the U.S. Air Force, Ellsworth Air Force Base, to estimate groundwater-flow direction, select locations for permanent monitoring wells, and install and sample monitoring wells for petroleum hydrocarbon compounds within Fuels Area C. Nine monitoring wells were installed for the study within Fuels Area C during November 4–7, 2014. Soil core samples were collected during installation of eight of the monitoring wells and analyzed for benzene, toluene, ethylbenzene, total xylenes, naphthalene, *m*- and *p*-xylene, *o*-xylene, and gasoline- and diesel-range organic compounds. Groundwater samples were collected from seven of the nine wells (two of the monitoring wells did not contain enough water to sample or were dry) during November 19–21, 2014, and analyzed for select physical properties, benzene, toluene, ethylbenzene, total xylenes, naphthalene, *m*- and *p*-xylene, *o*-xylene, and gasoline- and diesel-range organic compounds. This report describes the nine monitoring well locations and presents the soil- and groundwater-quality data collected in 2014 for this study.

Introduction

Ellsworth Air Force Base (EAFB) is an Air Combat Command that is located approximately 10 miles (mi) northeast of Rapid City, South Dakota. The EAFB occupies about 6,000 acres within Meade and Pennington Counties, and includes runways, airfield operations, industrial areas, housing, and recreational facilities. The EAFB supports about 3,500 active military personnel with an overall population of about 9,000 that includes military, family members, and civilian employees (Powers, 2013).

The EAFB is home to the 28th Bomb Wing, which delivers decisive combat power for global response from missions of the B-1B Lancer aircraft. To meet aircraft flight energy demands, equipment and facilities are used to transport and store total petroleum hydrocarbons (TPHs) as gasoline fuels, total TPHs as diesel fuels, and additional compounds associated with jet propulsion fuels.

Fuels Area C within EAFB is a fuels storage area that is used to support the mission of the base. Fuels Area C is located near the southern boundary of EAFB immediately west of Ellsworth Street (fig. 1). The site consists of about 79 acres and is predominantly barren of housing and ornamental landscapes. A water course is located east of Fuels Area C, with Gateway Lake to the northeast of Fuels Area C (U.S. Air Force, 2011). Industrial buildings are located to the northwest of Fuels Area C.

Historically, fuel was delivered by tanker truck and by rail-line tankers to Fuels Area C for storage; currently (2014), fuel is delivered by pipeline to underground storage tanks (USTs) within Fuels Area C (Jens Christensen, Environmental Restoration Program Manager, Ellsworth Air Force Base, oral commun., 2015). Two 840,000-gallon USTs within Fuels Area C currently (2014) contain aviation turbine fuel Jet A. Historically, Fuels Area C has been used to hold and transfer other jet fuels (jet propellant-8 [JP-8], JP-4, and so forth), diesel fuel, aviation gasoline, and vehicle gasoline (Tetra Tech, Inc., written commun., 2008). In addition to the current USTs, a battery of aboveground storage tanks was located within the northwest part of Fuels Area C, and a single aboveground storage tank was located near the central part of the area. The aboveground fuel storage tanks were removed in June 2001 (Tetra Tech, Inc., written commun., 2008).

Large volumes of aviation turbine fuels operationally are moved through Fuels Area C on a regular basis. The movement and storage of large quantities of fuels, potential spills, releases from USTs, and releases from former aboveground storage tanks within Fuels Area C may be mechanisms of point-source contamination that could pose a threat to water quality (Boulding and Ginn, 2003). Historical petroleum

Figure 1. General location of Fuels Area C, Ellsworth Air Force Base, South Dakota (modified from U.S. Air Force, 2011).

releases have occurred within Fuels Area C and are documented on the South Dakota Environmental Events Database (South Dakota Department of Environment and Natural Resources, 2015a).

The UST program is primarily implemented by States and Territories (U.S. Environmental Protection Agency, 2013a). The State of South Dakota has an approved UST program lead by the South Dakota Department of Environment and Natural Resources (SD DENR), which is responsible for the UST program enforcement at EAFB. The SD DENR sets the standards for performance criteria that (1) are no less stringent than Federal standards, (2) contain provisions for adequate enforcement, and (3) regulate at least the same USTs that are regulated by Federal standards (U.S. Environmental Protection Agency, 2013a).

Findings from previous soil samples and groundwater samples within Fuels Area C indicate that leakage of JP-8 is potentially associated with two existing USTs. The JP-8 is a complex mix of petroleum hydrocarbons and hundreds of additional compounds that may vary in composition (Custance and others, 1992). Compounds of potential human-health concern associated with JP-8 include TPHs as gasoline; TPHs as diesel; benzene, toluene, ethylbenzene, and total xylenes (BTEX); and naphthalene.

The TPHs as gasoline fuel consist of carbon chains that range from four-carbon organic compounds (C_4) to 12-carbon organic compounds (C_{12}); however, TPHs as diesel tend to be heavier and potentially more persistent than TPHs as gasoline fuel because of the additive kerosene and the utilized hydrocarbons that range from three-carbon organic compounds (C_3) to 25-carbon organic compounds (C_{25}) (Custance and others, 1992). The TPH compounds tend to be more persistent in groundwater than in surface water, and readily partition into equilibrium between water and soil. Individual BTEX compounds are relatively light, volatile, mobile, and water soluble (Srijata and Roy, 2011). When exposed to oxygen and sunlight, most of the BTEX compounds degrade rapidly to other compounds.

Humans may be exposed to the petroleum hydrocarbons constituents by inhalation, direct contact, and (or) drinking water (U.S. Department of Health and Human Services, 1999). Concerns regarding chemicals within JP-8 include (1) movement of contaminants from the EAFB Fuels Area C by groundwater flow or surface-water runoff, or both; (2) current EAFB personnel engaged in mowing open areas who are exposed to surface soil; (3) construction workers engaged in repairing damaged underground water mains or excavating basements for onsite building; (4) adults living onsite who walk on surface soil; and (5) and aquatic life in Gateway Lake (Jens Christensen, Environmental Restoration Program Manager, Ellsworth Air Force Base, oral commun., 2013) (fig. 1).

Exposures to high levels of BTEX compounds can result in central nervous system depression, skin and sensory irritation, and negative effects on the respiratory system. Compounds could also affect the kidney, liver, and blood systems (U.S. Environmental Protection Agency, 2013b). Benzene is known to cause cancer, based on evidence in both people and laboratory animals. Sufficient evidence indicates that benzene is a human carcinogen (U.S. Environmental Protection Agency, 2013b). Furthermore, workers who have been exposed to high concentrations of benzene in the occupational setting were determined to have a greater occurrence of leukemia (U.S. Environmental Protection Agency, 2013c). A person is most likely to be exposed to these high concentrations through occupational and prolonged exposure (U.S. Department of Health and Human Services, 1999).

Documentation of historical contamination plumes indicates a general easterly flow of groundwater from EAFB (U.S. Environmental Protection Agency, 2013d). Tetra Tech, Inc., was retained by EAFB during 2008−11 to sample soil and groundwater to assess potential petroleum hydrocarbon leakage from former and existing underground and aboveground storage tanks within Fuels Area C. Compounds reported in these studies included BTEX compounds, naphthalene, TPH as gasoline, and TPHs as diesel (Tetra Tech, Inc., written commun., 2008, 2011).

Lithology is an important factor affecting the movement of contaminants in groundwater (National Academy of Sciences, 2000). The geology of EAFB consists of about 860 feet (ft) of bedrock Pierre Shale that is overlain by surficial deposits that predominately consist of alluvium (McGregor and Cattermole, 1973; Rahn and Glick, 2000). Based on descriptions of soil borings from previous studies within Fuels Area C (South Dakota Department of Environment and Natural Resources, 2015b), the alluvium consists of deposits of sand, silt, clay, and gravel that range in depth from about 10 to 40 ft. In addition, the alluvial materials within this relatively small area may be highly variable. The topographic relief shown in figure 2 indicates a land-surface slope to the southeast.

In fall of 2013, the U.S. Geological Survey (USGS) South Dakota Water Science Center began a study in cooperation with the U.S. Air Force, EAFB, to estimate groundwater-flow direction, select locations for permanent monitoring wells, and install and sample monitoring wells for petroleum hydrocarbon compounds within Fuels Area C. Nine monitoring well locations were selected in 2014 based on a review of the previous soil and groundwater monitoring results (Tetra Tech, Inc., written commun., 2008, 2011), a review of the local lithology, and consultation with SD DENR and EAFB environmental staff in September 2014. Nine monitoring wells were installed within Fuels Area C during November 4–7, 2014. Soil core samples were collected during installation of the monitoring wells and analyzed for BTEX, naphthalene, *m*- and *p*-xylene, *o*-xylene, gasoline-range organic compounds (GROs) and diesel-range organic compounds (DROs). Groundwater samples were collected from seven of the nine wells (two of the monitoring wells did not contain enough water to sample or were dry) during November 19–21, 2014, and analyzed for select physical properties, BTEX, naphthalene, *m*- and *p*-xylene, *o*-xylene, GROs, and DROs.

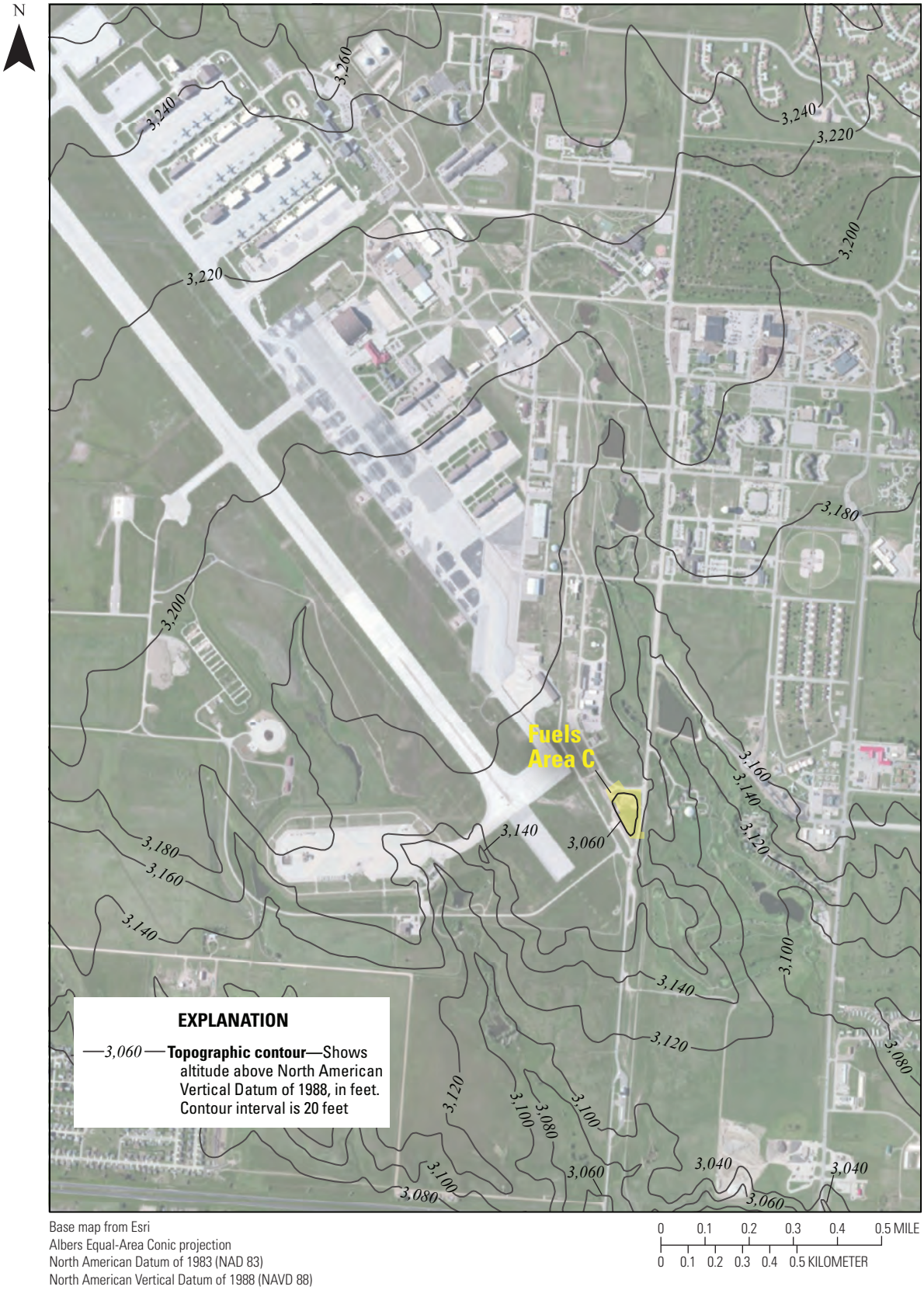

Figure 2. Land-surface topography of and in the vicinity of Fuels Area C, Ellsworth Air Force Base, South Dakota.

Purpose and Scope

The purposes of this report are to describe the location of nine monitoring wells installed during November 4–7, 2014, in Fuels Area C of EAFB and to present the soil- and groundwater-quality data collected in 2014. Soil cores were extracted at each of these nine wells and assessed using a photoionization detector (PID) that measures volatile organic compounds and other gases. Soil samples were collected from the location within each soil core that showed the highest PID values and analyzed for BTEX, naphthalene, *m*- and *p*-xylene, *o*-xylene, DROs; and GROs. Groundwater samples were collected during November 19–21, 2014, and analyzed for field properties (temperature, pH, dissolved oxygen, and specific conductance) and BTEX, naphthalene, *m*- and *p*-xylene, *o*-xylene, DROs, and GROs. The static water level at time of sampling also is presented for each monitoring well.

Methods

Locations for nine permanent monitoring wells to better describe groundwater-flow direction and to sample for petroleum hydrocarbon compounds within Fuels Area C were selected based on a review of the previous soil and groundwater monitoring results (Tetra Tech, Inc., written commun., 2008, 2011), a review of the local lithology, and consultation with SD DENR and EAFB environmental staff in September 2014. The monitoring wells were installed during November 4–7, 2014. This section of the report describes the real-time kinematic (RTK) survey used to determine the locations and altitudes of the monitoring wells and other features, the installation of the monitoring wells, the collection and analysis of soil- and groundwater-quality samples, and quality assurance and quality control (QA/QC).

Real-Time Kinematic Survey

The RTK survey method uses a stationary "base" global navigation satellite system (GNSS) receiver, which transmits real-time differential correction signals to one or more mobile "rover" receivers used to collect data at objective points. Data collected at each point included latitude and longitude, and land-surface elevation. The RTK surveys were used to locate selected features, such as fence lines, electrical lines and boxes, stormwater lines, and fuel pipelines within Fuels Area C before installation of monitoring wells. The locations of existing monitoring wells also were identified. The RTK survey was then used to mark the selected locations of the drilling sites for the monitoring wells installed in 2014.

An established benchmark with published coordinates (Name: I90 066.2, PID: PU2524) from the National Geodetic Survey Data Explorer (National Oceanic and Atmospheric Administration, 2014) was used for the GNSS RTK base occupations. Static occupation files from the base location were processed using the Online Positioning User Service (OPUS; National Geodetic Survey, 2014). The coordinates of each objective point were then adjusted based on the OPUS solution for the coordinates of the base. Horizontal accuracy of the GNSS equipment being used in RTK mode is specified by the manufacturer as 0.3937 inch (10 millimeters [mm]) plus 1 part per million times the baseline length (Topcon Positioning Systems, Inc., 2007). The maximum baseline length to the northwest corner of Fuels Area C was about 1.1 mile. The resulting horizontal error for a 1.1-mile baseline is about 0.46 inch. Vertical errors specified by the GNSS manufacturer used in RTK mode are 0.5906 inch (15 mm) plus 1 part per million times the baseline length (Topcon Positioning Systems, Inc., 2007). The resulting vertical error for a 1.1-mile baseline is about 0.66 inch. The GNSS surveying methods used to support this study met or exceeded the quality descriptions for a Level IV GNSS survey (Rydlund and Densmore, 2012).

Installation of Wells

The nine permanent monitoring wells were drilled and installed during November 4–7, 2014, by American Technical Services, Inc., in accordance with the well construction standards of the South Dakota Department of Environment and Natural Resources (2003a). The drilling method for the monitoring wells consisted of a hollow-stem auger with an 8-inch outside diameter and a 4.25-inch inside diameter with 5-ft sections. Each well was completed flush to grade with a protective steel manhole cover (fig. 3).

Figure 3. Flush-to-grade manhole cover for monitoring wells installed in Fuels Area C, Ellsworth Air Force Base, South Dakota, 2014.

Soil Sampling

During the augering of the monitoring wells, soil cores were retrieved in 5-ft sections, split, and visually assessed on a specified table for sediment descriptions, which were entered in a designated soil-sampling log. Subsurface soil sampling followed guidelines from South Dakota Department of Environment and Natural Resources (2003b), which cover the collection of surface and subsurface soil samples that are thought to be contaminated.

Each soil core was screened by use of a MiniRAE 3000 (RAE Systems, Inc., San Jose, California) PID equipped with a 10.6 electron volt (eV) ultraviolet lamp to evaluate the presence or absence of total volatile organic compounds (fig. 4). Generally, one soil sample was collected from each monitoring well site from the location in the core with the highest PID reading. In most cases, where a measurable field reading using the PID was not obtained, soil from the interval just above the groundwater interface was selected for analyses. Soil samples were collected using stainless steel spoons and were immediately placed in 4-ounce jars and chilled. Soil samples were collected in the field, appropriately preserved, labeled, logged, and placed in a cooler with ice to be maintained at 4 degrees Celsius (°C). The containers were shipped with adequate packing and cooling to ensure that samples arrived intact at the laboratory and within established temperature range. Soil samples were sent to RTI Laboratories, Inc., in Livonia, Michigan, and analyzed for BTEX, naphthalene, *m*- and *p*-xylene, *o*-xylene, DROs, and GROs using the analytical methods noted in table 1.

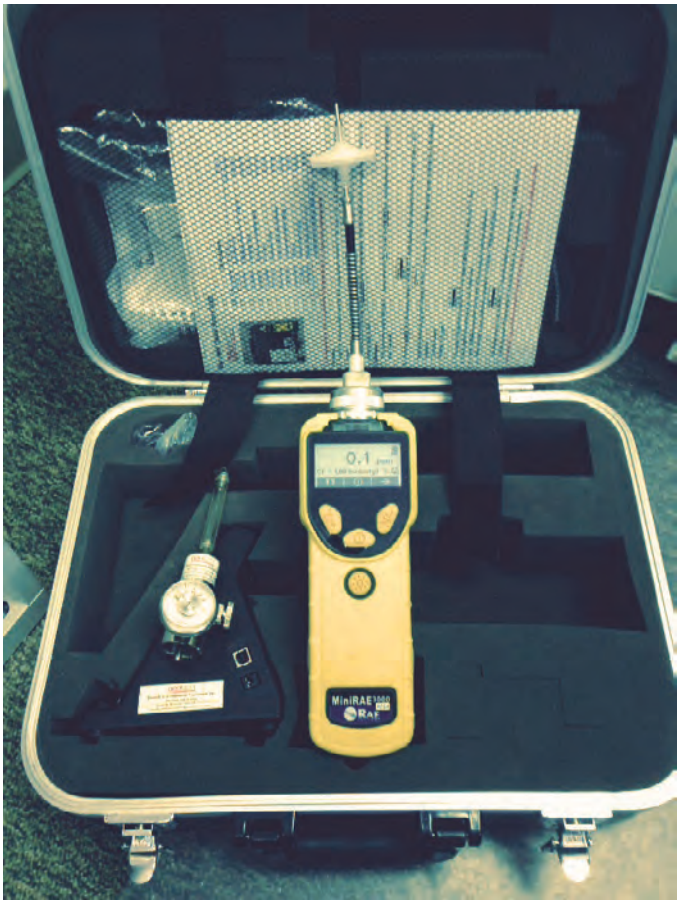

Figure 4. Photoionization detector (PID) meter.

Table 1. Methods used for analyses by RTI Laboratories, Inc., of soil samples and groundwater samples collected at Fuels Area C, Ellsworth Air Force Base, South Dakota.

[BTEX, benzene, toluene, ethylbenzene, total xylenes; g, gram; mL, milliliter; VOA, volatile organic analysis; oz, ounce; HCl, hydrochloric acid]

Laboratory method	Compound	Containers
	Soil	
8260B[1]	BTEX, naphthalene, *m*- and *p*-xylene, and *o*-xylene	10 g = 40-mL VOA preserved with 10 mL of methanol.
8015B[2] GRO	Gasoline range organics	10 g = 40-mL VOA preserved with 10 mL of methanol.
8015B[2] DRO	Diesel range organics	4 oz = 4-oz wide mouth glass jar, unpreserved.
	Groundwater	
8260B[1]	BTEX, naphthalene, *m*- and *p*-xylene, and *o*-xylene	three 40-mL VOA vials with HCl preservation.
8015B[2] GRO	Gasoline range organics	two 40-mL VOA vials with HCl preservation.
8015B[2] DRO	Diesel range organics	1-liter amber glass container, unpreserved.

[1]U.S. Environmental Protection Agency (1996a).

[2]U.S. Environmental Protection Agency (1996b).

Groundwater Sampling

Groundwater samples were collected from each monitoring well about 2 weeks after well completion and development, during November 19–21, 2014. The collection of groundwater samples followed USGS protocols for sampling organic compounds from monitoring wells (U.S. Geological Survey, variously dated).Water levels were measured at each site during sample collection following USGS protocols for the collection of water-level measurements (Cunningham and Schalk, 2011). Water samples were collected using a submersible pump after evacuating the casing with three well-casing volumes. Sample vials were directly filled following USGS sampling protocols. Each sample was labeled according to the laboratory specifications. The submersible pump, Teflon® tubing, and other field sampling equipment were thoroughly cleaned using collection protocols for organic samples (U.S. Geological Survey, variously dated) before sampling individual wells to prevent cross contamination of water samples. Selected physical properties (water and air temperature, barometric pressure, specific conductance, dissolved oxygen, and pH) were collected during the groundwater sampling using a Yellow Springs International (YSI) 6920 multi-parameter sonde (YSI Incorporated, Yellow Springs, Ohio) with an optical dissolved oxygen probe with a flow through cell connected to the groundwater pump sample line. Groundwater samples were collected in the field, appropriately preserved, labeled, logged, and placed in a cooler with ice to be maintained at 4 °C. The containers were shipped with adequate packing and cooling to ensure that samples arrived intact at the laboratory and within established temperature range. Groundwater samples were sent to RTI Laboratories, Inc., in Livonia, Mich., and analyzed for BTEX, naphthalene, *m*- and *p*-xylene, *o*-xylene, DROs, and GROs using the analytical methods noted in table 1.

Quality Assurance and Quality Control

Two field QA/QC groundwater samples (a field equipment blank and a replicate environmental sample) were collected in the field to help ensure that data meet data-quality acceptability limits. These two QA/QC samples represented about 10 percent of the groundwater environmental samples, which is consistent with QA/QC protocols of the USGS South Dakota Water Science Center for routine sample collection. In addition, one trip blank sample was included with the sample containers shipment from the laboratory. The trip blank accompanied the sample bottles from the laboratory to the field and on the return of samples from the field to the laboratory.

Monitoring Well Data

Selected well information was collected for the monitoring wells and entered into the USGS National Water Information System (NWIS) database. This information included location (latitude, longitude, altitude) and well construction information after drilling (table 2). A map of the locations of the monitoring wells installed in 2014 within Fuels Area C is shown in figure 5. During the well drilling, soil cores were collected from a range extending from the surface to the bottom of the well. The soil cores were described and logged. The well completion reports for the monitoring wells are included in the SD DENR Well Completion Reports database (South Dakota Department of Environment and Natural Resources, 2015b). The monitoring well completion report links for the nine monitoring wells are available in table 2.

Soil-Quality Data

The analytical results of the soil-quality samples collected from eight of the nine monitoring wells are presented in table 3. A soil sample was not collected from monitoring well EAFB FAC MW14-02 because a PID reading was not detected throughout the depth of the soil core. Benzene and toluene concentrations were not detected (indicated by a less than symbol [<] in front of a value) in the eight monitoring wells with soil samples. Ethylbenzene concentrations ranged from not detected to 3.0 milligrams per kilogram (mg/kg), total xylenes concentrations ranged from not detected to 1.1 mg/kg, naphthalene concentrations ranged from not detected to 7.6 mg/kg, *m*- and *p*-xylene concentrations ranged from not detected to 0.92 mg/kg, *o*-xylene concentrations ranged from not detected to 0.16 mg/kg, GRO concentrations ranged from 20 to 5,200 mg/kg, and DRO concentrations ranged from 1.4 to 3,600 mg/kg.

All eight monitoring wells with soil samples had quantifiable concentrations of GROs in the soil. Concentrations in soil samples were compared to State of South Dakota Tier 1 action levels (State of South Dakota, 1996), which are levels that may pose a risk to human health or the environment, and if reached or exceeded, require further assessment or corrective action. Soil samples from monitoring wells EAFB FAC MW14-01, EAFB FAC MW14-05, and EAFB FAC MW14-09 had soil concentrations larger than the Tier 1 action levels for GROs, and the soil sample from monitoring well EAFB FAC MW14-07 had a GRO concentration greater than one-half the Tier 1 action level for GROs. All eight monitoring wells with soil samples had quantifiable concentrations in the soil of DROs. Monitoring well EAFB FAC MW14-01 had a soil DRO concentration larger than the Tier 1 action level for DROs, and monitoring well EAFB FAC MW14-05 had a DRO concentration greater than one-half the Tier 1 action level for DROs.

Table 2. Summary of information for monitoring wells drilled in November 4–7, 2014, within Fuels Area C, Ellsworth Air Force Base, South Dakota.

[DMS, degrees, minutes, decimal seconds; NAVD 88, North American Vertical Datum of 1988; SD DENR, Department of Environment and Natural Resources]

Station identification number	Local name	Site name	Latitude (DMS)	Longitude (DMS)	Altitude of land surface, in feet above NAVD 88	Well depth, in feet below land surface	SD DENR well completion reports[1]
440754103045401	2N 9E18 CAAD 1	EAFB FAC MW14-01	44 07 54.67	103 04 54.68	3,157.81	35	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070887.pdf
440754103045001	2N 9E18 DBBC 1	EAFB FAC MW14-02	44 07 54.72	103 04 50.64	3,153.87	45	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070885.pdf
440753103045501	2N 9E18 CAAD 2	EAFB FAC MW14-03	44 07 53.16	103 04 55.38	3,160.76	20	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070886.pdf
440753103045201	2N 9E18 CAAD 3	EAFB FAC MW14-04	44 07 53.83	103 04 52.44	3,154.86	35	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070884.pdf
440751103045301	2N 9E18 CADA 1	EAFB FAC MW14-05	44 07 51.32	103 04 53.55	3,158.46	15	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070883.pdf
440753103045202	2N 9E18 CAAD 4	EAFB FAC MW14-06	44 07 53.12	103 04 52.15	3,155.18	35	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070882.pdf
440753103045001	2N 9E18 DBBC 2	EAFB FAC MW14-07	44 07 53.22	103 04 50.70	3,150.92	40	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070881.pdf
440751103045101	2N 9E18 CADA 2	EAFB FAC MW14-08	44 07 51.35	103 04 51.89	3,157.15	15	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070880.pdf
440752103045001	2N 9E18 DBBC 3	EAFB FAC MW14-09	44 07 52.80	103 04 50.64	3,151.25	30	http://denr.sd.gov/wrimage/WellCompletionReports/images75k/00070879.pdf

[1]South Dakota Department of Environment and Natural Resources (2015b).

Figure 5. Locations of the monitoring wells installed within Fuels Area C, Ellsworth Air Force Base, South Dakota, 2014.

Table 3. Summary of field and laboratory analyses for soil samples collected during the installation of nine monitoring wells during November 4–7, 2014, within Fuels Area C, Ellsworth Air Force Base, South Dakota.

[5-digit number above the analyte name is the U.S. Geological Survey parameter code; NA, not available; <, not detected at laboratory reporting level; --, no data; >, greater than; E, compound present but concentration estimated less than the laboratory reporting level]

Station identification number	Local name	Site name	Sample date	Sample time	Depth of sample (feet below land surface)	46311	NA	Concentration in soil (milligrams per kilogram)								
								30096	30099	30098	30140	30171	NA	NA	62228	62227
						Moisture content, soil, dry weight (percent)	Photoionization detector reading (parts per million)	Benzene	Toluene	Ethylbenzene	Total xylenes	Naphthalene	*m*- and *p*-Xylene	*o*-Xylene	Gasoline-range organic compounds	Diesel-range organic compounds
						NA	NA	[1]0.2	[1]15	[1]10	[1]300	[1]25	NA	NA	[1]500	[1]500
440754103045401	2N 9E18 CAAD 1	EAFB FAC MW14-01	11/06/2014	1000	18.8–19.3	11	370	<0.036	<0.060	3.00	1.1	2.1	0.92	0.160	[2]***5,200***	[2]***3,600***
440754103045001	2N 9E18 DBBC 1	EAFB FAC MW14-02	11/05/2014	1400	No sample	--	0.0	--	--	--	--	--	--	--	--	--
440753103045501	2N 9E18 CAAD 2	EAFB FAC MW14-03	11/04/2014	0930	19.5–20.0	26	0.0	<0.052	<0.087	<0.087	<0.26	<0.43	<0.17	<0.087	44	1.8
440753103045201	2N 9E18 CAAD 3	EAFB FAC MW14-04	11/06/2014	1450	24.3–24.7	22	0.0	<0.047	<0.079	<0.079	<0.24	<0.40	<0.16	<0.079	26	1.7
440751103045301	2N 9E18 CADA 1	EAFB FAC MW14-05	11/04/2014	1110	13.9–14.3	27	>15,000	<0.054	<0.091	<0.091	<0.27	7.6	<0.18	<0.091	[2]***580***	440
440753103045202	2N 9E18 CAAD 4	EAFB FAC MW14-06	11/07/2014	1040	23.5–23.9	20	0.10	<0.047	<0.078	<0.078	<0.23	<0.39	<0.16	<0.078	20	1.4
440753103045001	2N 9E18 DBBC 2	EAFB FAC MW14-07	11/05/2014	1130	21.1–21.8	17	260	<0.043	<0.071	0.280	E0.18	E0.05	0.15	E0.026	370	4.6
440751103045101	2N 9E18 CADA 2	EAFB FAC MW14-08	11/04/2014	1230	7.9–8.4	18	23.0	<0.044	<0.074	<0.074	<0.22	E0.14	<0.15	<0.074	68	5.7
440752103045001	2N 9E18 DBBC 3	EAFB FAC MW14-09	11/04/2014	1600	18.6–19.0	26	1,100	<0.055	<0.092	<0.092	<0.28	E0.03	<0.18	<0.092	[2]***1,800***	3.2

[1]Number designates the State of South Dakota (1996) Tier 1 action level for the compound.

[2]Bolded italic numbers indicate that the sample concentration exceeded State of South Dakota (1996) Tier 1 action level.

Soil samples from monitoring wells EAFB FAC MW14-03 and EAFB FAC MW14-04 did not have quantifiable concentrations of any of the BTEX compounds or naphthalene. The remaining six monitoring wells with soil samples had quantifiable concentrations of one or more of the BTEX compounds and naphthalene but the concentrations were much smaller than the Tier 1 action levels.

Groundwater-Quality Data

Water-quality data from seven of the nine monitoring wells are shown in tables 4 and 5. Two of the monitoring wells (EAFB FAC MW14-05 and EAFB FAC MW14-08) did not contain enough water to sample or were dry. Selected physical properties of the groundwater, including water temperature, specific conductance, dissolved oxygen, and pH, were measured in the field during sampling (table 4). Analytical results for the laboratory analyses of organic compounds are presented in table 5, along with the analytical results for a replicate sample for QA/QC purposes collected at monitoring well EAFB FAC MW14-01, a field blank sample collected at monitoring well EAFB FAC MW14-09, and a trip blank sample associated with these samples.

Benzene was not detected in any groundwater samples. Toluene concentrations ranged from not detected to an estimated (E) 0.2 µg/L, ethylbenzene concentrations ranged from not detected to 64 micrograms per liter (µg/L), total xylenes concentrations ranged from not detected to 30 µg/L, naphthalene concentrations ranged from not detected to 33 µg/L, *m*- and *p*-xylene concentrations ranged from not detected to 27 µg/L, *o*-xylene concentrations ranged from not detected to 2.4 µg/L, GRO concentrations ranged from 45 to 3,600 µg/L, and DRO concentrations ranged from not detected to 2,400 µg/L.

Groundwater samples from monitoring wells EAFB FAC MW14-03 and EAFB FAC MW14-06 did not have quantifiable concentrations of any of the BTEX compounds or naphthalene. The remaining five monitoring wells with groundwater samples had quantifiable concentrations of one or more of the BTEX compounds and naphthalene. All the monitoring wells with groundwater samples had quantifiable concentrations of GROs and DROs. The largest concentrations of GROs were found in the samples from monitoring wells EAFB FAC MW14-01 and EAFB FAC MW14-07. None of the concentrations of organic compounds exceeded associated U.S. Environmental Protection Agency Maximum Contaminant Levels (U.S. Environmental Protection Agency, 2013b).

The field blank collected at monitoring well EAFB FAC MW14-09, after the groundwater sample collection and field decontamination, had no quantifiable concentrations for any of the measured analytes except for a small quantifiable concentration of 45 µg/L for GROs. Two of the sampled wells, EAFB FAC MW14-03 and EAFB FAC MW14-06, had similar GRO concentrations to the field blank sample, but were collected on previous days with field decontamination after each well.

The replicate groundwater sample collected at monitoring well EAFB FAC MW14-01 had much larger concentrations than the primary groundwater sample for all measured constituents except benzene and toluene. The analytical results for the replicate sample collected at monitoring well EAFB FAC MW14-01 were similar to analytical results for the groundwater sample collected at monitoring well EAFB MW14-07; constituents that had quantifiable concentrations in the replicate sample collected at monitoring well EAFB FAC MW14-01 also had quantifiable concentrations in the groundwater sample collected at monitoring well EAFB MW14-07. Conversely, constituents that were not quantifiable in the replicate sample collected at monitoring well EAFB FAC MW14-01 also were not quantifiable in the groundwater sample collected at monitoring well EAFB MW14-07. The differences between the primary and replicate samples at monitoring well EAFB FAC MW14-01 were checked to make sure the collection, shipment, and analysis protocols were followed (for example, sample bottles were not mislabeled, analytical request forms were not mislabeled, and analyses of the samples were not switched for other samples). Further investigation of the variability within the monitoring wells is needed in future sampling.

Table 4. Summary of selected physical properties of groundwater samples collected from monitoring wells during November 19–21, 2014, within Fuels Area C, Ellsworth Air Force Base, South Dakota.

[5-digit number above the physical property name is the U.S. Geological Survey parameter code; mm Hg, millimeters of mercury; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; --, no data; >, greater than]

Station identification number	Local name	Site name	Sample date	Sample time	Static water level (feet below measuring point)	Depth of sample (feet below measuring point)	Sample type	Physical properties of groundwater					
								00010	00020	00025	00095	00300	00400
								Temperature, water (degrees Celsius)	Temperature, air (degrees Celsius)	Barometric pressure (mm Hg)	Specific conductance, water, unfiltered (µS/cm at 25 degrees Celsius)	Dissolved oxygen (mg/L)	pH, water, unfiltered (standard pH units)
440754103045401	2N 9E18 CAAD 1	EAFB FAC MW14-01	11/21/2014	1230	13.7	25.0	Groundwater	13.0	14.5	674	2,610	0.7	7.0
440754103045401	2N 9E18 CAAD 1	EAFB FAC MW14-01	11/21/2014	1235	--	--	Groundwater replicate	--	--	--	--	--	--
440754103045001	2N 9E18 DBBC 1	EAFB FAC MW14-02	11/19/2014	1000	21.1	40.0	Groundwater	8.7	0.0	679	3,770	7.5	7.2
440753103045501	2N 9E18 CAAD 2	EAFB FAC MW14-03	11/20/2014	1150	15.5	19.7	Groundwater	9.8	3.5	676	3,770	6.6	7.1
440753103045201	2N 9E18 CAAD 3	EAFB FAC MW14-04	11/19/2014	1440	13.2	35.0	Groundwater	10.4	-1.5	677	1,960	0.2	7.2
440751103045301	2N 9E18 CADA 1	EAFB FAC MW14-05	11/20/2014	1300	>15.0	--	No sample, dry well	--	3.5	676	--	--	--
440753103045202	2N 9E18 CAAD 4	EAFB FAC MW14-06	11/20/2014	1000	13.8	35.0	Groundwater	9.7	-5.5	676	3,550	0.1	6.9
440753103045001	2N 9E18 DBBC 2	EAFB FAC MW14-07	11/19/2014	1230	19.5	35.0	Groundwater	11.3	5.0	678	2,240	7.0	7.4
440751103045101	2N 9E18 CADA 2	EAFB FAC MW14-08	11/20/2014	1300	>15.0	--	No sample, dry well	--	3.5	676	--	--	--
440752103045001	2N 9E18 DBBC 3	EAFB FAC MW14-09	11/21/2014	0940	10.9	26.0	Groundwater	11.5	7.0	674	3,590	0.2	7.1

Table 5. Summary of laboratory analyses of groundwater samples collected from monitoring wells during November 19–21, 2014, within Fuels Area C, Ellsworth Air Force Base, South Dakota.

[5-digit number above the analyte name is the U.S. Geological Survey parameter code; NA, not available; <, not detected at laboratory reporting level; E, compound present but concentration estimated less than the laboratory reporting level; --, no data; >, greater than]

Station identification number	Local name	Site name	Sample date	Sample time	Static water level, feet below measuring point	Depth of sample, feet below measuring point	Sample type	Concentration in groundwater (micrograms per liter)								
								34030	34010	34371	81551	34696	85795	77135	49892	04585
								Benzene	Toluene	Ethylbenzene	Total xylenes	Naphthalene	*m*- and *p*-Xylene	*o*-Xylene	Gasoline-range organic compounds	Diesel-range organic compounds
								[1]5	[1]1,000	[1]700	[1]10,000	NA	NA	NA	NA	NA
440754103045401	2N 9E18 CAAD 1	EAFB FAC MW14-01	11/21/2014	1230	13.7	25.0	Groundwater	<1.0	<1.0	5.0	1.0	<1.0	E0.7	E0.5	1,200	150
440754103045401	2N 9E18 CAAD 1	EAFB FAC MW14-01	11/21/2014	1235	--	--	Groundwater replicate	<1.0	<1.0	56	26	29	24	2.1	3,600	2,000
440754103045001	2N 9E18 DBBC 1	EAFB FAC MW14-02	11/19/2014	1000	21.1	40.0	Groundwater	<1.0	<1.0	<1.0	<3.0	E0.5	<2.0	<1.0	80	80
440753103045501	2N 9E18 CAAD 2	EAFB FAC MW14-03	11/20/2014	1150	15.5	19.7	Groundwater	<1.0	<1.0	<1.0	<3.0	<1.0	<2.0	<1.0	45	41
440753103045201	2N 9E18 CAAD 3	EAFB FAC MW14-04	11/19/2014	1440	13.2	35.0	Groundwater	<1.0	E0.2	<1.0	<3.0	<1.0	<2.0	<1.0	53	300
440751103045301	2N 9E18 CADA 1	EAFB FAC MW14-05	11/20/2014	1300	>15.0	--	No sample, dry well	--	--	--	--	--	--	--	--	--
440753103045202	2N 9E18 CAAD 4	EAFB FAC MW14-06	11/20/2014	1000	13.8	35.0	Groundwater	<1.0	<1.0	<1.0	<3.0	<1.0	<2.0	<1.0	45	75
440753103045001	2N 9E18 DBBC 2	EAFB FAC MW14-07	11/19/2014	1230	19.5	35.0	Groundwater	<1.0	<1.0	64	30	33	27	2.4	2,600	2,400
440751103045101	2N 9E18 CADA 2	EAFB FAC MW14-08	11/20/2014	1300	>15.0	--	No sample, dry well	--	--	--	--	--	--	--	--	--
440752103045001	2N 9E18 DBBC 3	EAFB FAC MW14-09	11/21/2014	0940	10.9	26.0	Groundwater	<1.0	<1.0	<1.0	<3.0	E0.6	<2.0	<1.0	470	49
440752103045001	2N 9E18 DBBC 3	EAFB FAC MW14-09	11/21/2014	1040	--	--	Field blank	<1.0	<1.0	<1.0	<3.0	<1.0	<2.0	<1.0	45	<220
Trip blank	--	--	11/21/2014	1200	--	--	Trip blank	<1.0	<1.0	<1.0	<3.0	<1.0	<2.0	<1.0	--	--

[1]Number designates the U.S. Environmental Protection Agency (2013b) Maximum Contaminant Level for the compound.

References Cited

Boulding, J.R., and Ginn, J.S., 2003, Practical handbook of soil, vadose zone, and ground-water contamination—Assessment, prevention, and remediation (2d ed.): Boca Raton, Florida, CRC Press, 664 p.

Cunningham, W.L., and Schalk, C.W., comps., 2011, Groundwater technical procedures of the U.S. Geological Survey, GWPD 4—Measuring water levels by use of an electric tape: U.S. Geological Survey Techniques and Methods, book 1, chap. A1, 6 p., accessed October 20, 2014, at http://pubs.usgs.gov/tm/1a1/pdf/tm1-a1.pdf.

Custance, S.R., McCaw, P.A., Kopf, A.C., and Sullivan, M.J., 1992, Environmental fate of chemical mixtures—Crude oil, JP-5, mineral spirits, and diesel fuel: Journal of Soil Contamination, v. 1, no. 4, p. 379–386.

McGregor, E.E., and Cattermole, J.M., 1973, Geologic map of the Rapid City NW quadrangle, Meade and Pennington Counties, South Dakota: U.S. Geological Survey Geologic Quadrangle 1093, 1 map. [Also available at http://pubs.er.usgs.gov/publication/gq1093.]

National Academy of Sciences, 2000, Seeing into the earth—Noninvasive characterization of the shallow subsurface for environmental and engineering applications: Washington, D.C., The National Academies Press, 148 p.

National Geodetic Survey, 2014, OPUS—Online Positioning User Service: accessed June 26, 2014, at http://www.ngs.noaa.gov/OPUS/about.jsp#about.

National Oceanic and Atmospheric Administration, 2014, National Geodetic Survey data explorer: accessed June 26, 2014, at http://www.ngs.noaa.gov/NGSDataExplorer/.

Powers, Rod, 2013, Installation overview—Ellsworth Air Force Base, South Dakota: accessed September 8, 2013, at http://usmilitary.about.com/od/airforcebaseprofiles/ss/Ellsworth_4.htm.

Rahn, P.H., and Glick, M.J., 2000, Waste disposal potential in Cretaceous shale in western South Dakota, *in* Strobel, M.L., Davis, A.D., Sawyer, J.F., Rahn, P.H., Webb, C.J., and Naus, C.A., eds., Hydrology of the Black Hills: Rapid City, South Dakota, Proceedings of the 1999 Black Hills Hydrology Conference, p. 184–192.

Rydlund, P.H., Jr., and Densmore, B.K., 2012, Methods of practice and guidelines for using survey-grade global navigation satellite systems (GNSS) to establish vertical datum in the United States Geological Survey: U.S. Geological Survey Techniques and Methods, book 11, chap. D1, 102 p. with appendixes, accessed April 17, 2014, at http://pubs.usgs.gov/tm/11d1/.

South Dakota Department of Environment and Natural Resources, 2003a, Standard Operating Procedure (SOP) Three—Monitoring well design and installation, *in* Release investigation and corrective action requirements: accessed August 12, 2013, at http://denr.sd.gov/des/gw/Spills/handbook/Hand_Book.aspx.

South Dakota Department of Environment and Natural Resources, 2003b, Standard Operating Procedure (SOP) Two—Surface and subsurface soil sampling, *in* Release investigation and corrective action requirements: accessed August 12, 2013, at http://denr.sd.gov/des/gw/Spills/handbook/Hand_Book.aspx.

South Dakota Department of Environment and Natural Resources, 2015a, South Dakota environmental events database: accessed January 5, 2015, at http://denr.sd.gov/des/gw/spills/spilldata.aspx.

South Dakota Department of Environment and Natural Resources, 2015b, South Dakota environmental water well completion reports database: accessed January 5, 2015, at http://denr.sd.gov/des/wr/dblogsall.aspx.

Srijata, Mitra, and Roy, Pranab, 2011, BTEX—A serious groundwater contaminant: Research Journal of Environmental Sciences, v. 5, p. 394–398.

State of South Dakota, 1996, Remediation criteria for petroleum-contaminated soils (ARSD 74:56:05): accessed February 25, 2015, at http://legis.sd.gov/Rules/DisplayRule.aspx?Rule=74:56:05.

Topcon Positioning Systems, Inc., 2007, HiPer Ga/Gb operator's manual: Topcon Positioning Systems, Inc., [variously paged].

U.S. Air Force, 2011, Draft Environmental Assessment addressing activities associated with development of a regional wastewater treatment plant Ellsworth Air Force Base, South Dakota (draft document): accessed October 22, 2014, at http://www.ellsworth.af.mil/shared/media/document/AFD-110421-078.pdf.

U.S. Department of Health and Human Services, 1999, Toxicological profile for total petroleum hydrocarbons (TPH): U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances and Disease Registry, 315 p., accessed October 22, 2014, at http://www.atsdr.cdc.gov/ToxProfiles/tp123.pdf.

U.S. Environmental Protection Agency, 1996a, Method 8260B, Volatile organic compounds by gas chromatography/mass spectrometry: accessed August 5, 2013, at http://www.epa.gov/osw/hazard/testmethods/sw846/pdfs/8260b.pdf.

U.S. Environmental Protection Agency, 1996b, Total petroleum hydrocarbons (TPH) as gasoline and diesel—SW-846 Method 8015B, revision 2, December: accessed August 16, 2013, at http://www.epa.gov/region9/qa/pdfs/8015.pdf.

U.S. Environmental Protection Agency, 2013a, Underground storage tanks: accessed July 22, 2013, at http://www.epa.gov/oust/fsstates.htm.

U.S. Environmental Protection Agency, 2013b, Drinking water contaminants: accessed July 24, 2013, at http://water.epa.gov/drink/contaminants/.

U.S. Environmental Protection Agency, 2013c, Benzene: accessed October 23, 2013, at http://www.epa.gov/ttnatw01/hlthef/benzene.html.

U.S. Environmental Protection Agency, 2013d, Region 8, Ellsworth Air Force Base: accessed October 24, 2013, at http://www2.epa.gov/region8/ellsworth-air-force-base.

U.S. Geological Survey, variously dated, The national field manual for the collection of water-quality data (version 7): U.S. Geological Survey Techniques and Methods, book 9, chaps. A1–A9, [variously paged], accessed August 13, 2014, at http://water.usgs.gov/owq/FieldManual/.

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