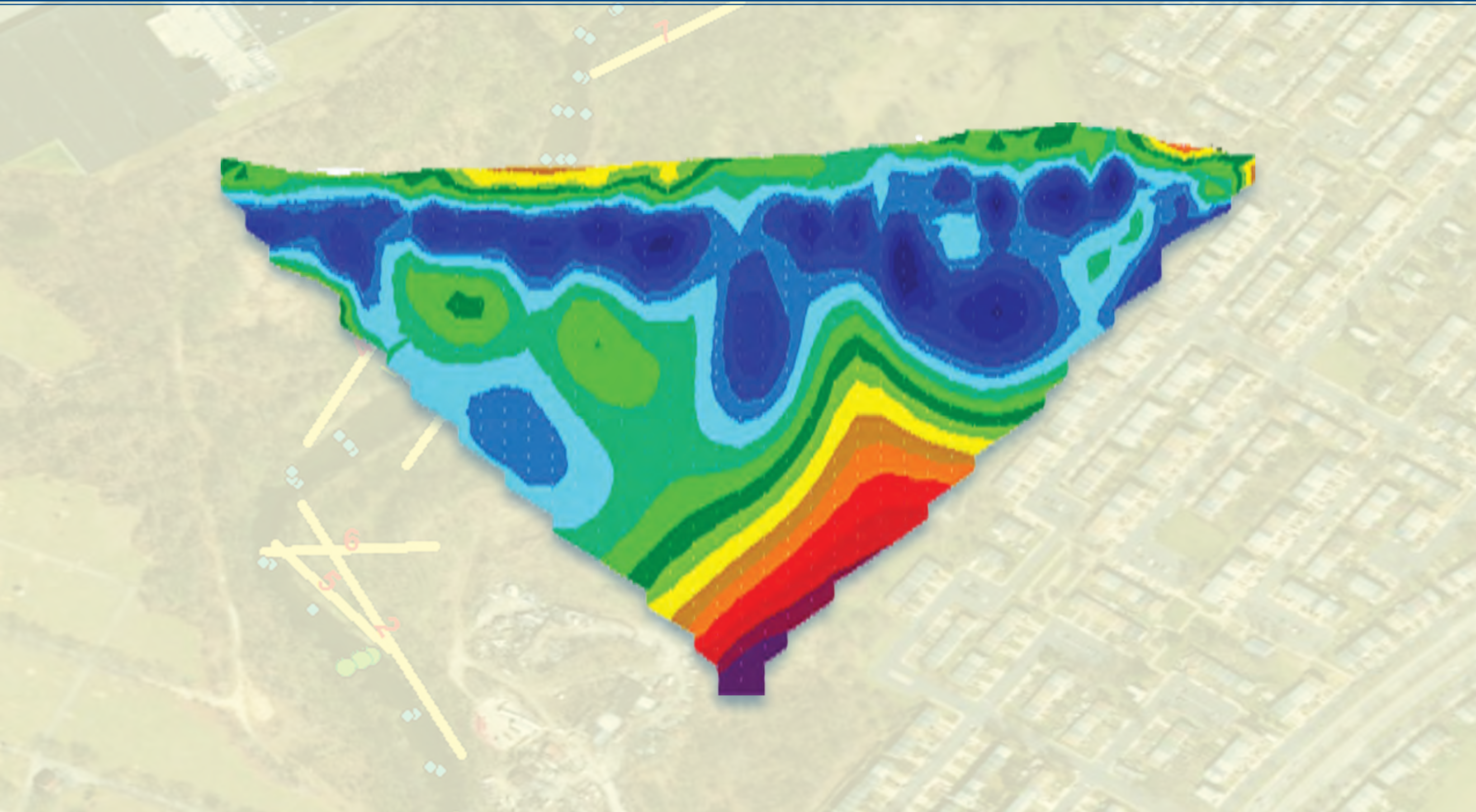
Prepared in cooperation with the
U.S. Environmental Protection Agency

Surface Geophysics and Porewater Evaluation at the Lower Darby Creek Area Superfund Site, Philadelphia, Pennsylvania, 2013



Data Series 927

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

Cover. Background aerial photograph of Lower Darby Creek Area Superfund Site, Philadelphia, Pennsylvania, 2013, from the U.S. Department of Agriculture (USDA) National Agricultural Imagery Program (NAIP), and direct-current resistivity results from line 2. Refer to figures 1 and 3.

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U.S. Department of the Interior
SALLY JEWELL, Secretary

U.S. Geological Survey
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Conversion Factors

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Volume	
cubic meter (m^3)	6.290	barrel (petroleum, 1 barrel = 42 gal)
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
cubic meter (m^3)	264.2	gallon (gal)
cubic decimeter (dm^3)	0.2642	gallon (gal)
cubic meter (m^3)	0.0002642	million gallons (Mgal)
cubic centimeter (cm^3)	0.06102	cubic inch (in^3)
cubic decimeter ($dm^{3)}$	61.02	cubic inch (in^3)
liter (L)	61.02	cubic inch (in^3)
cubic decimeter (dm^3)	0.03531	cubic foot (ft^3)
cubic meter (m^3)	35.31	cubic foot (ft^3)
cubic meter (m^3)	1.308	cubic yard (yd^3)
cubic kilometer (km^3)	0.2399	cubic mile (mi^3)
cubic meter (m^3)	0.0008107	acre-foot (acre-ft)
cubic hectometer (hm^3)	810.7	acre-foot (acre-ft)

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

$$°F = (1.8 \times °C) + 32$$

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

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By Charles W. Walker, James R. Degnan, Michael J. Brayton, Roberto M. Cruz, and Michelle M. Lorah

Abstract

In cooperation with the U.S. Environmental Protection Agency (EPA), Region 3, the U.S. Geological Survey (USGS) is participating in an ongoing study to aid in the identification of subsurface heterogeneities that may act as preferential pathways for contaminant transport in and around the Lower Darby Creek Area (LDCA) Superfund Site, Philadelphia Pa. Lower Darby Creek, which flows into the Delaware River, borders the western part of the former landfill site. In 2013, the USGS conducted surface geophysics measurements and stream porewater sampling to provide additional data for EPA's site characterization. This report contains data collected from field measurements of direct current (DC) resistivity, frequency-domain electromagnetic (FDEM) surveys, and stream porewater specific conductance (SC).

Introduction

The U.S. Geological Survey (USGS), in cooperation with the U.S. Environmental Protection Agency (EPA), Region 3, is participating in an ongoing site characterization of the Lower Darby Creek Area (LDCA) Superfund Site, formerly known as the Clearview Landfill (fig. 1). Previously, evaluation of landfill impacts on groundwater, nearby surface water and sediment were conducted at the Clearview Landfill as part of the initial Remedial Investigation (RI) (TetraTech NUS, Inc., 2010). A variety of contaminants of concern were identified during the initial RI, including 1,4-dioxane and arsenic, which warranted additional investigations of groundwater impacts and subsequent risks. A large part of the Clearview Landfill is located adjacent to Darby and Cobbs Creeks and as such, there is the potential for contaminated groundwater in the shallow Coastal Plain aquifer to impact sediment and surface water. Potential site-related contaminants also have been detected in the bedrock aquifer. Historical photographs indicate the presence of channels and (or) canals intersecting with Lower Darby Creek at the site. Although most of these channels have been buried with fill, they still have the potential for transporting contaminated groundwater to Lower Darby Creek.

Site Description

Located near the Philadelphia International Airport, Philadelphia, Pa., the Clearview Landfill was in operation (without permit) from the 1950s to the 1970s, continuing to receive waste for many years despite a court order to cease activity in 1973. The size of the landfill grew to approximately 65 acres by 1973 with wastes up to 22 meters (m) above the original ground surface at the center and about 6 m above the ground surface at edge of the landfill. The elevation of the landfill is over 24 m above mean sea level, giving it the largest relief of any nearby land surface. There are no records of waste types that were received at Clearview Landfill; however, a 1965 aerial photo shows junked vehicles, debris, and a pit of dark standing liquid at the site (TetraTech NUS, Inc., 2010).

The LDCA Superfund Site is situated on unconsolidated Coastal Plain sediments (Quaternary Trenton Gravel) overlying bedrock of the Precambrian Age Wissahickon Formation. The depth to bedrock is at or below mean sea level. Monitoring wells have been installed at the site in the shallow aquifer. A groundwater mound is known to exist under the landfill, resulting in radial flow away from the landfill and towards Darby Creek (TetraTech NUS, Inc., 2010). The landfill (fig. 1) is adjacent to the lower part of Darby Creek, and Cobbs Creek converges with Darby Creek to the north of the landfill (fig. 1). To the south, Darby Creek is joined by Hermesprota Creek near the John Heinz National Wildlife Refuge (NWR) at Tinicum, which in turn drains into the Delaware River approximately 5.5 kilometers downstream of LDCA. The lower part of Darby Creek, along the landfill, experiences tidal fluctuations of approximately 1 m. (TetraTech NUS, Inc., 2010).

Figure 1. Locations of geophysical-survey lines and porewater sampling points, Lower Darby Creek Area Superfund Site, Philadelphia, Pennsylvania.

Purpose and Scope

The purpose of this report is to provide data to aid EPA in their evaluation of the contamination caused by former activity at the Clearview Landfill. The report includes data collected from eight direct current (DC) resistivity surveys, frequency-domain electromagnetic (FDEM) surveys, and a stream porewater survey of specific conductance (SC) within Lower Darby Creek. The data from these surveys are intended to provide additional data for EPA's site characterization.

Methods

Surface Geophysical Data Collection and Analysis

DC resistivity surveys measure the electrical resistivity of subsurface materials. This type of survey can be a valuable tool to help characterize subsurface heterogeneities that may be important for understanding contaminant transport. For example, under ambient groundwater-quality conditions, clay typically has a lower resistivity response than sand, which will be less resistive than gravel. Saturated sand or gravel will be less resistive than unsaturated sand or gravel (Zohdy and others, 1974; Kearey and Brooks, 1991). If the porewater of a sand or gravel is altered by conductive groundwater (often due to the presence of contaminants), gravel may appear less resistive than clay because of elevated SC of the water.

The methodology for the DC-resistivity surveys conducted for this report is adapted from Degnan and Brayton (2010) and Degnan and Harte (2013). DC is induced in the ground using two current electrodes, while the voltage is measured across two potential electrodes. Apparent resistivity is calculated from the resistance value measured and geometric factors, which are based on electrode spacing and array type (arrangement of current and potential electrodes in relation to each other). Dipole-dipole and Schlumberger array (Zohdy and others, 1974) survey configurations were used, and reverse dipole-dipole and reciprocal Schlumberger surveys served as quality-assurance surveys for this study. Some data points were removed because of large errors in parts of the survey lines located near buried landfill debris, where current application or potential measurement was difficult. Schlumberger, reciprocal Schlumberger, reverse, and forward dipole-survey data were combined and inverted together five times and are presented in this report. DC-resistivity data were processed using RES2DINV version 3.55 (Loke, 1999) to produce inverted resistivity sections from the apparent resistivity data. Data are inverted to convert apparent values that are averages corresponding to a half-sphere depth into estimates of values at a specific depth; however, results are slightly less reliable at the ends of survey lines. Survey locations were chosen based on length of line possible without interference from buried conductive features (such as metal pipes). The location of each point in the survey was recorded with a Trimble GPS unit and the local elevation was measured with a hand level using established reference elevations from nearby wells.

FDEM surveys, performed with the Geophex GEM-2 Plus, a portable multifrequency electromagnetic sensor, were used to indirectly measure bulk electrical conductivity of the subsurface to a depth of approximately 20 m (Degnan and Harte, 2013). Before and after each survey, a common base station was measured to evaluate the shift in instrument response with time. Data collection and processing methods used in this study were similar to those described in Abraham and others (2006). Total conductivity measurements were calculated using WinGEM version 3, 0, 0, 14 (Geophex, Ltd., 2007).

Stream Porewater Specific Conductance Measurements

The SC of porewater beneath Lower Darby Creek was measured using a 1.8-m-long portable piezometer coupled with a flow-through conductivity probe (fig. 2). The piezometer was constructed of a 1.2-centimeter (cm) stainless steel pipe with a 1- by 2-cm screened opening at the bottom of the probe. The top of the screened opening was sealed with epoxy, except for a piece of 0.3-cm inside diameter tubing. The tubing was connected to a Campbell Scientific CS547A water conductivity and temperature probe, located at the top of the piezometer. The CS547A was operated with a Campbell Scientific CR1000 Datalogger. Measurements were taken by drawing, with a 60-milliliter (mL) syringe, 120 mL of porewater through the tubing and probe to ensure the equipment had been thoroughly rinsed. After rinsing, an additional 60 mL of porewater was drawn through the tubing and probe to take a measurement. In addition to temperature and SC, sample depth and GPS location also were recorded. Measurements of SC were made in the surface water and in the porewater approximately 60 cm below land surface (bls) and 120 cm bls. Land surface was considered to be the creek bottom. Surface-water measurements were taken during the survey with a WTW Tetracon 350 conductivity probe and meter. Periodically, throughout the study, comparisons were made between the two probes, and there were no significant differences between the two probes ($n = 21$, $p = 0.98$), using a paired sample T-test. The calibration of each meter also was checked on a daily basis.

Field Data Collection Summary

During the week of March 24, 2013, a total of eight DC resistivity lines were measured (fig. 1). FDEM surveys were conducted during the week of March 3, 2013. The first part of the Lower Darby Creek porewater SC survey was

Figure 2. Conductivity probe used to measure the specific conductance of porewater beneath Lower Darby Creek. [Photograph by Charles W. Walker, U.S. Geological Survey.]

conducted during the last week of July 2013. The survey was conducted during low tide conditions, which typically allowed for approximately 4 hours of stream access each day. After evaluation of the initial data, additional measurements were conducted on August 23 and 26, 2013. During the week of September 8, 2013, USGS assisted EPA with the collection of porewater samples for laboratory analyses in Lower Darby Creek to further delineate the extent of contamination (data not included in this report) (fig. 1).

Results

Direct Current Resistivity

Data collected for eight DC resistivity lines are presented in figure 3. The locations of each line are shown in figure 1. Individual point data are included in Appendix 1. In addition to measures of resistivity, relative elevation, and transect position of each point (given as distance from the first electrode), Appendix 1 also contains the geographic coordinates for the electrodes in each transect. Resistivity values, presented in Appendix 1, are calculated for the midpoint between two electrodes, starting from the second electrode in the array. The point placement within the transects, represented as X in Appendix 1, considers the surface topography of the transect, and therefore may not be exactly 5 m apart.

Frequency-Domain Electromagnetic Surveys

Data collected for the FDEM surveys are provided in Appendix 2. A total of 77,172 data points were collected, both on land and in the stream. The minimum bulk conductivity value observed at the site was 0.36 millisiemens per meter (mS/m), whereas the maximum bulk electrical conductivity of the subsurface observed was 229 mS/m. Latitude and longitude are also included for each measurement in Appendix 2.

Stream Porewater Specific Conductance Measurements

Data collected for the Lower Darby Creek porewater SC survey are presented in Appendix 3. The minimum SC of the surface water was 315 microsiemens per centimeter (µS/cm) and the maximum was 618 µS/cm. The minimum SC at the nominal 60-cm-bls depth interval was 189 µS/cm, whereas the maximum was 7,000 µS/cm. The SC at the nominal 120-cm-bls depth ranged from a minimum of 538 µS/cm to a maximum of 8,010 µS/cm. The temperature of the surface water was recorded intermittently, with a minimum temperature of 21.3 degrees Celsius (°C) and a maximum temperature of 25.6 °C. At 60 cm bls, the temperature ranged from 19.8 °C to 25.2 °C. The maximum temperature measured at 120 cm bls was 23.4 °C, and the minimum temperature measured was 18.4 °C. Although the results presented above are based on the approximate depths of measurement, actual depths are provided in Appendix 3.

Based on the results of the SC survey, 17 of the 100 SC survey sites were sampled for additional laboratory analyses provided by EPA (fig. 1). The site identification numbers and location information for each of the sites that had additional samples taken for laboratory analyses are provided in Appendix 3.

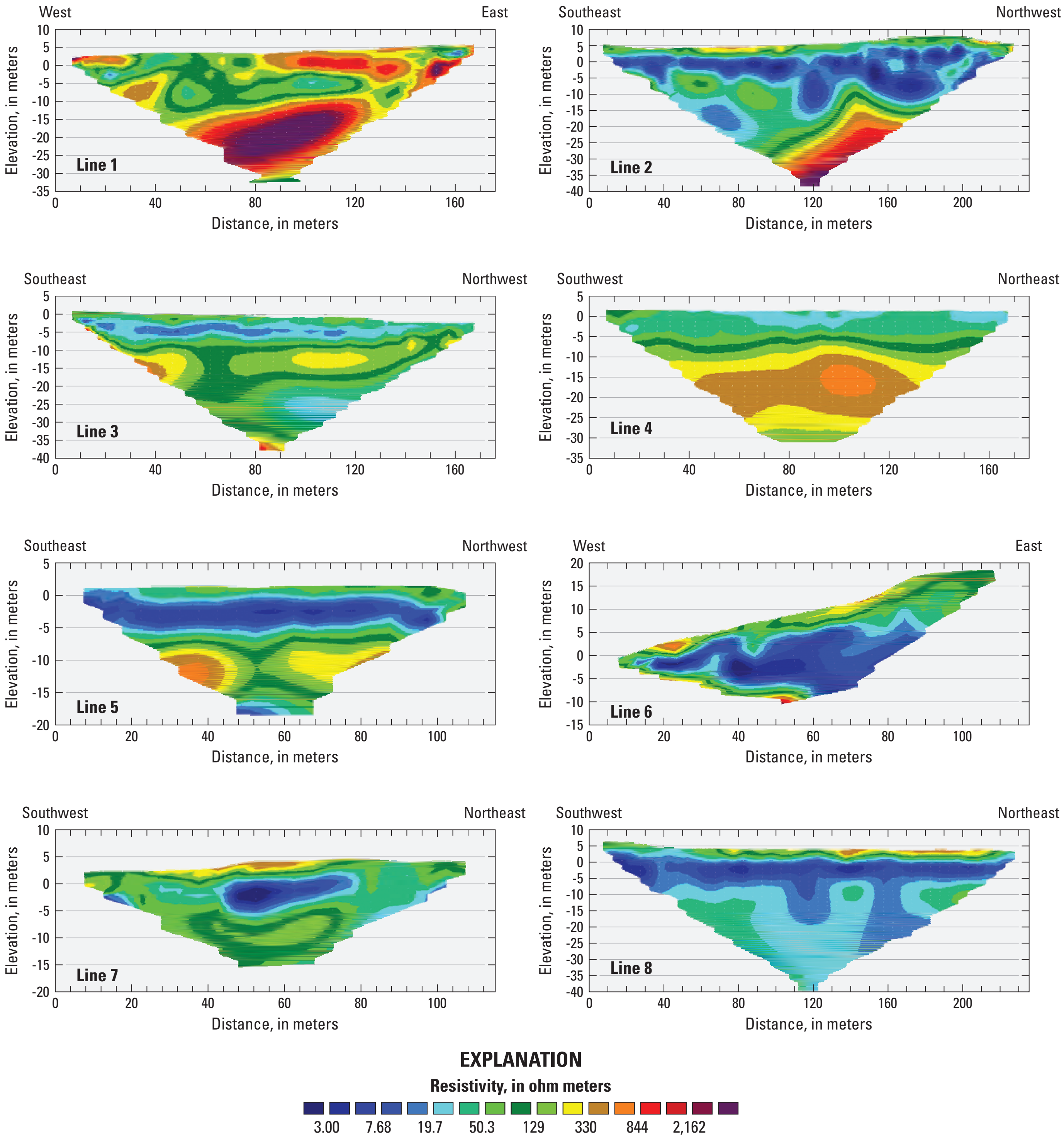

Figure 3. Cross sections showing direct-current resistivity results from lines 1–8, Lower Darby Creek Area Superfund Site, Philadelphia, Pennsylvania.

References Cited

Abraham, Jared, Deszcz-Pan, Maria, Fitterman, David, and Burton, Bethany, 2006, Use of a handheld broadband FDEM induction system for deriving resistivity depth images, *in* Symposium on the Application of Geophysics to Engineering and Environmental Problems, 19, Las Vegas, Nevada, February 10–14, 2002, Proceedings: Denver, Colo., Environmental and Engineering Geophysical Society CD-ROM, p. 1,782–1,799.

Degnan, J.R., and Brayton, M.J., 2010, Preliminary investigation of paleochannels and groundwater specific conductance using direct-current resistivity and surface-wave seismic geophysical surveys at the Standard Chlorine of Delaware, Inc., Superfund Site, Delaware City, Delaware, 2008: U.S. Geological Survey Open-File Report 2010–1058, 27 p., accessed December 8, 2014, at http://pubs.usgs.gov/of/2010/1058/.

Degnan, J.R., and Harte, P.T., 2013, Hydrogeologic framework, arsenic distribution, and groundwater geochemistry of glacial-sediment aquifer at the Auburn Road Landfill Superfund Site, Londonderry, New Hampshire: U.S. Geological Survey Scientific Investigations Report 2013–5123, 58 p., accessed December 8, 2014, at http://pubs.usgs.gov/sir/2013/5123/.

Geophex, Ltd., 2007, WinGEM2 software: Geophex, Ltd., accessed October 16, 2014, at http://www.geophex.com/.

Kearey, Philip, and Brooks, Michael, 1991, An introduction to geophysical exploration (2d ed.): Cambridge, Mass., Blackwell Scientific Publications, 254 p.

Loke, M.H., 1999, Electrical imaging surveys for environmental and engineering studies—A practical guide to 2-D and 3-D Surveys: Penang, Malaysia, 57 p., accessed May 12, 2014, at http://www.abem.se/support/downloads/case-studies/practical-guide-to-2d-3d-surveys.

Tetra Tech NUS, Inc., 2010, Remedial Investigation report for Lower Darby Creek area site, Clearview Landfill Operable Unit 1 (OU-1): EPA Contract Number EP-S3-07-04, 139 p.

Zohdy, A.A.R., Eaton, G.P., and Mabey, D.R., 1974, Application of surface geophysics to ground-water investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, book 2, chap. D1, 86 p., accessed March 16, 2015, at http://pubs.usgs.gov/twri/twri2-d1/index.html.

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