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Hydrogeology and Shallow Groundwater Quality in the Tidal Anacostia River Watershed, Washington, D.C.

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

Cover: Aerial view, looking southwest, of tidal Anacostia River, Washington, D.C. Photograph by Daniel Macy, April 5, 2009.

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DAVID BERNHARDT, Secretary

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

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Conversion Factors and Datums

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

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

$$°F = (1.8 \times °C) + 32$$

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.

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness ($[ft^3/d]/ft^2)ft$. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

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

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

Abbreviations

DOEE	District Department of Energy & Environment
MCL	maximum contaminant level
msl	mean sea level
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PVC	polyvinyl chloride
RBC	risk-based concentration
SVOC	semi-volatile organic compound
USGS	U.S. Geological Survey
VOC	volatile organic compound

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Abstract

Groundwater hydrology and geochemistry within the tidal Anacostia River watershed of Washington, D.C. are related to natural and human influences. The U.S. Geological Survey, in cooperation with the District Department of Energy & Environment, began investigating the hydrogeology and groundwater quality of the watershed in 2002. Lithologic coring, groundwater-level and tidal monitoring, and water-quality sampling have been conducted to improve understanding of the groundwater-flow system, geochemistry, water quality, and the likely interaction between groundwater and the tidal Anacostia River. The flow and interaction of shallow groundwater with the tidal Anacostia River and other area streams are affected by diversions, pumping, land reclamation, and other human activities in this highly urbanized watershed.

The tidal Anacostia River watershed is underlain by a wedge of unconsolidated sediments that is part of the Atlantic Coastal Plain Physiographic Province. These sediments form a system of confined and unconfined aquifers. The coarse sediments of the Potomac Group sand-dominated lithofacies form the Patuxent aquifer. The Patuxent aquifer crops out and subcrops in the northwestern part of the study area, but is confined to the southeast by the overlying Potomac Group clay-dominated lithofacies. Overlying the Potomac Group is a series of interbedded sands and clays that form an unconfined surficial aquifer system. Regional correlation in the unconfined surficial aquifer system is complicated by local heterogeneity in aquifer sediments. Local perched and semi-confined conditions occur in some areas.

Recharge of the confined Patuxent aquifer occurs primarily in the outcrop and subcrop area, although some recharge may also occur through overlying confining units. Recharge to the unconfined surficial aquifer system occurs through infiltration of precipitation and possible artificial recharge from structures such as underground water or sewer pipes. In the Patuxent aquifer, hydraulic gradients indicate downward movement in the outcrop area, whereas hydraulic heads beneath the Anacostia River are higher than land surface, indicating an upward hydraulic gradient. In the unconfined surficial aquifer system, groundwater generally flows from upland recharge areas towards discharge areas near the Anacostia River and its tributaries. Groundwater from the confined part of the Patuxent aquifer also may discharge to the Anacostia River in locations where the overlying clay-dominated lithofacies of the Potomac Group is absent as a result of past geologic and (or) alluvial processes.

Geochemistry and groundwater quality are affected by hydrologic conditions as well as anthropogenic influences. Local variability in groundwater quality reflects local variability in hydrogeologic conditions and sources of chemicals. Groundwater ranges from anoxic and iron- or calcium-bicarbonate type, to oxic with elevated nitrate. The occurrence and distribution of pesticides, volatile organic compounds, and other selected chemical compounds in groundwater reflect the multitude of sources common to urban areas, as well as variable hydrogeologic and geochemical conditions that affect their fate and transport in the environment. Overall, concentrations of only a few of the over 200 chemical constituents included in laboratory analyses exceeded regulatory standards or guidance values. These include tetrachloroethene and arsenic, which were each detected one time in different wells. There were also several detections of iron and manganese that exceeded regulatory standards or guidance values that are associated with reducing conditions in aquifer sediments.

Introduction

A wide variety of chemical compounds are used for various purposes in urban areas including Washington, D.C. These chemical compounds include pesticides, volatile organic compounds (VOCs), fertilizers, metals, pharmaceuticals, and deicing chemicals. Although agriculture accounts for more than 75 percent of pesticide usage in the United States, more than 200 million pounds of pesticides are used annually for industrial, commercial, government, or residential (home and garden) applications (Kiely and others, 2004). VOCs are also commonly found in urban areas; commercial, industrial, or residential products containing VOCs include cosmetics, deodorants, polishes, adhesives, cleaning products, paints, solvents, and fuels (Moran and others, 2002). The District Department of Energy & Environment (DOEE) is responsible for protecting the water resources of Washington, D.C., and understanding the occurrence or lack thereof of these compounds is essential to the management of these resources.

Urban influences on groundwater and surface-water quality have been documented in many areas over the past several decades. Koterba and others (2010) found that in Washington, D.C., the presence of pesticides in groundwater was related to land use and hydrogeologic factors, such as depth of a well, the permeability of subsurface sediment, and the chemistry of groundwater. Similarly, a survey of urban areas across the United States during 1992 to 2001 found that pesticides were detected at relatively low levels (rarely greater than 0.1 microgram per liter (μg/L) in more than 90 percent of stream samples and more than 50 percent of groundwater samples (Gilliom and others, 2006). Urban streams and (or) groundwater commonly contain insecticides and herbicides commonly used in urban settings (such as prometon and simazine), as well as herbicides more common in agricultural areas (such as atrazine and metolachlor) (Capel and others, 1999; Reiser, 1999; Hickman, 2004; Gilliom and others, 2006). VOCs also have been detected in groundwater in urban areas (Zogorski and others, 2006), such as Long Island, New York (Eckhardt and Stackelberg, 1995) and the suburbs of Detroit, Michigan (Thomas, 2000). They are more commonly detected in urban areas than in areas with other land uses (Zogorski and others, 2006). Nitrate (Eckhardt and Stackelberg, 1995), metals (Velinsky and others, 1994), pharmaceuticals and hormonal compounds (Kolpin and others, 2002), and salt from septic discharges or highway deicing (Thomas, 2000) also have been detected in urban streams and (or) groundwater. Because many anthropogenic compounds are used for similar applications or in similar areas, they often co-occur in mixtures of multiple compounds in streams and groundwater, rather than individually (Thomas, 2000; Squillace and others, 2002; Gilliom and others, 2006). The possible health effects of these mixtures have not been studied extensively and are largely unknown (Gilliom and others, 2006).

Groundwater provides the majority of flow in many streams, and may carry a significant load of chemical compounds to surface waters. Many anthropogenic compounds are applied directly to the land surface; others may reach the land surface or streams through atmospheric deposition, leaks, or spills. In Washington, D.C., particularly soluble and persistent compounds may become dissolved in water and carried into and through the groundwater system to discharge areas in streams, estuaries, or other receiving waters, such as the Anacostia or Potomac Rivers. The relative importance of groundwater, overland runoff, and other transport processes to particular streams is affected by hydrogeologic conditions and resulting groundwater-flow systems that develop in their watersheds. Groundwater may be particularly important in well-drained watersheds underlain by relatively permeable geologic materials, for example, but less so in areas with relatively impermeable sediments or bedrock. Groundwater contributes nutrients and pesticides to streams on the Delmarva Peninsula (Denver and others, 2004; Ator and others, 2005), including an estimated 40 percent of nitrogen loads from the Peninsula to Chesapeake Bay (Bachman and Phillips, 1996). Contributions of nutrients from groundwater have also been reported for streams in the upper Potomac River Basin (Miller and others, 1997). Groundwater flow is slow, however, and years to several decades are often required for water to move completely through a shallow aquifer from recharge areas to discharge areas (Dunkle and others, 1993; Focazio and others, 1998).

Purpose and Scope

The geology, hydrology, and groundwater quality within the heavily urbanized tidal Anacostia River watershed in Washington, D.C. are described and discussed in this report. Physical characteristics of the Coastal Plain sediments, and the occurrence, flow, and chemistry of groundwater in the area are discussed, with a particular emphasis on the uppermost surficial sediments that are most likely contributing groundwater to the Anacostia River and other local surface waters. Interpretations and conclusions are based on data collected from 2002 through 2008 as part of a cooperative study between the U.S. Geological Survey (USGS) and the DOEE, Water-Quality Division, as well as similar information from previous studies. Hydrogeologic investigations were conducted in the watershed as a first step toward (1) evaluating the hydrologic connection between the Anacostia River and adjacent shallow groundwater, (2) assessing shallow groundwater quality and possible effects on water quality in the Anacostia River, and (3) establishing a groundwater monitoring network for the District of Columbia.

The Tidal Anacostia River Watershed

The Anacostia River is a tributary to the tidal Potomac River in central Maryland and Washington, D.C. (fig. 1). The head of tide on the Anacostia River is located upstream from the District of Columbia near Bladensburg, Maryland (Velinsky and others, 1994); the river is entirely freshwater tidal within the study area. The specific conductance of the freshwater tidal Anacostia River ranges from 300 to 500 microsiemens per centimeter (μS/cm), and the pH ranges from 6 to 8 (District Department of the Environment, 2010). In the winter, the specific conductance occasionally increases to 1,000 to 5,000 μS/cm as a result of road salting. The approximately 26-square-mile (mi^2) tidal Anacostia River watershed includes most of eastern Washington, D.C., and lies entirely within the Atlantic Coastal Plain Physiographic Province (Fenneman and Johnson, 1946). The watershed is almost exclusively (greater than 80 percent) urban, including mixed residential, commercial, and industrial areas. In addition to potential sources of anthropogenic compounds, urban development over the last 200 years has brought considerable hydrologic alteration to the watershed, including dredging of the Anacostia River, filling of tributaries and riparian areas, construction of impervious surfaces, sewers, pipelines, and tunnels, and dewatering for construction purposes (Williams, 1977; D.C. Water Resources Research Center, 1992).

Water quality and sediment chemistry in the Anacostia River reflect urban influences in the watershed. In addition to direct runoff over the land surface during and following precipitation, the river also receives direct discharge from numerous storm sewers and combined sewers, which contribute contaminants such as trace metals (Velinsky and others, 1994) and chlordane (Wade and others, 1994). Other potentially toxic materials that have been detected in Anacostia River sediment include polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) (Behm and others, 2003). PAHs may cause tumors in brown bullheads in the river, and PCBs and chlordane have contributed to fish consumption advisories in the Anacostia River since 1987 (Behm and others, 2003).

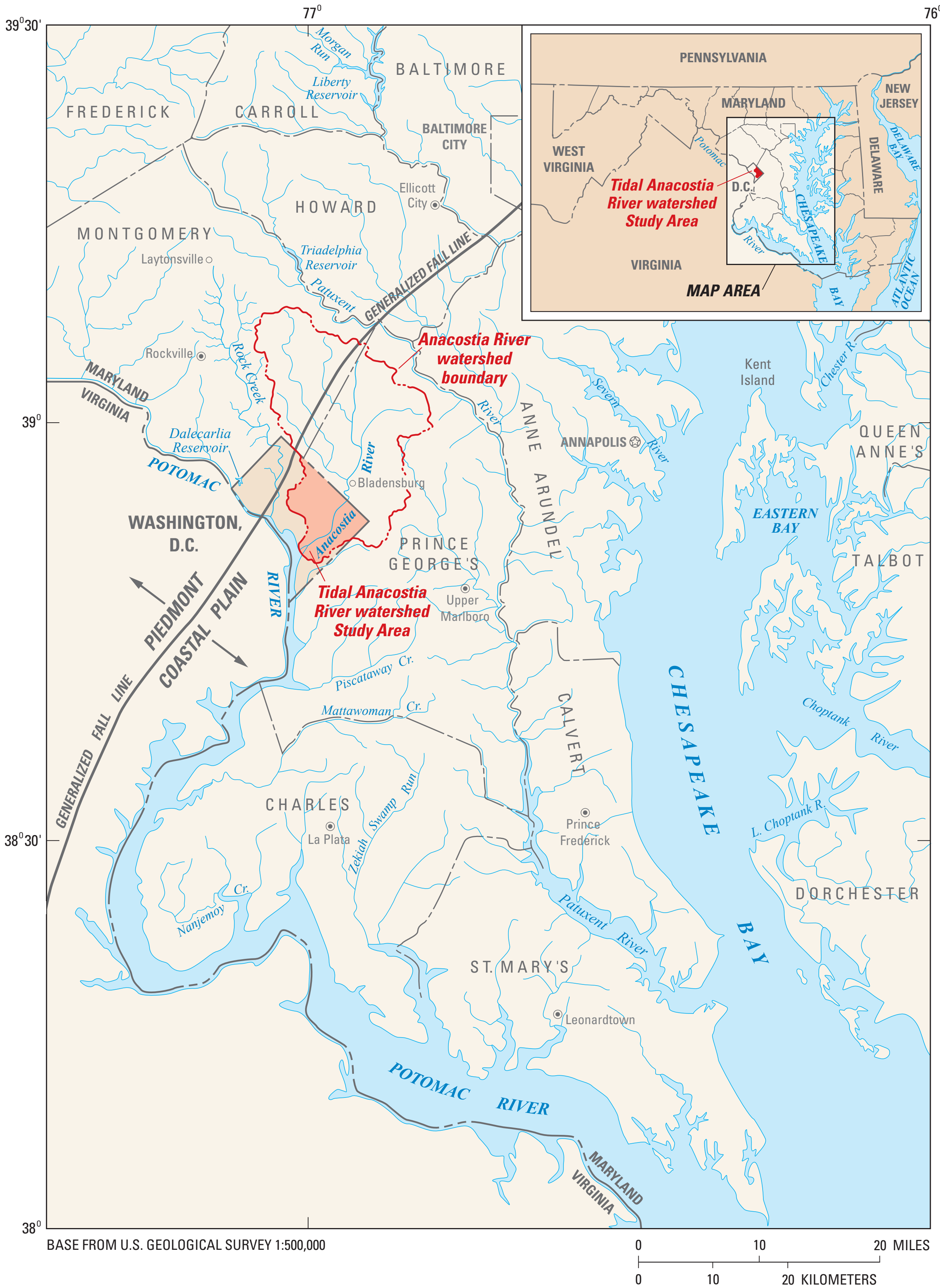

Figure 1. Location of the tidal Anacostia River watershed within Washington, D.C. (modified from Tenbus, 2003, and Anderson and others, 2002).

Methods

Available information was compiled, and new data were collected to describe the hydrogeologic framework and shallow groundwater quality within the Coastal Plain sediments of the tidal Anacostia River watershed. The hydrogeologic framework of the Coastal Plain sediments in the area was inferred from previous interpretations and newly available borehole data. Groundwater flow and quality were similarly interpreted from results of previous studies and data collected during this study. Data on the occurrence, distribution, and chemistry of groundwater in the study area were collected to support an interpretation of groundwater quality and its potential impacts on the Anacostia River.

Coring and Geologic Interpretation

Geologic cores were collected and analyzed to supplement existing information on the Coastal Plain geologic framework in the study area (fig. 2, tables 1, 2, Appendix 1). Coring was primarily conducted to characterize relatively shallow sediments (within approximately 40 feet [ft] of land surface); these sediments are most relevant to the flow and quality of shallow groundwater that is most likely affected by anthropogenic chemicals and may be discharging to local surface waters. Shallow sediments are also particularly variable in texture and composition, and this information is therefore difficult to extrapolate over wide areas.

Shallow cores were collected within the tidal Anacostia River watershed study area in 2002, 2005, and 2008 (tables 1, 2). Coring was conducted at selected sites within and near the tidal Anacostia River in July 2002 (Miller and Klohe, 2003; Tenbus, 2003). Cores were collected along the river near the New York Avenue crossing (WE Bb 4 on fig. 2), at Kenilworth Aquatic Gardens (WE Cb 6 on fig. 2), and in Anacostia Park (WE Ca 29 on fig. 2). Additional cores were collected in the river on a tidal flat about 1,700 ft north of Benning Road (WE Ca 30 on fig. 2), and in Beaverdam Creek, about 150 ft above its confluence with the Anacostia River (WE Cb 7 on fig. 2). Cores were collected using a vibracore drill rig mounted on a truck or (for the offshore sites) a hovercraft. Coring was conducted to refusal (typically about 30 to 40 ft below land surface), and cores were collected in 5-ft increments (Miller and Klohe, 2003; Tenbus, 2003). Additional cores were collected within the watershed at 13 locations in July and August 2005 (AC Aa 2, AC Ab 3, WE Ba 9, WE Ba 10, WE Ca 33, WE Ca 34, WE Ca 38, WE Cb 11, WE Cb 12, WE Cc 3, WE Bc 8, WW Bc 9, and WW Cc 37 on fig. 2) and at two locations (AC Aa 6 and AC Aa 7 on fig. 2) in May 2008 using a truck-mounted hollow-stem auger or Geoprobe. In cooperation with the DOEE and the D.C. Clean Rivers Project, a borehole was extended 10 ft into competent bedrock in 2009 (AX Ac 2, table 2, Appendix 1) to determine the depth to bedrock.

Geologic cores were reviewed and analyzed to document and interpret the nature and variability of near-surface sediments in the study area, and to support interpretation of shallow groundwater flow and quality. All cores collected for this project were briefly described onsite during the drilling process, and more thoroughly described (particularly for color and grain size) later at the USGS Water Science Center in Baltimore, Maryland (Tenbus, 2003) (Appendix 1). Additional cores collected primarily along the Anacostia River in 2007 by the District of Columbia Water and Sewer Authority were also reviewed and interpreted by USGS. Because of the variable nature of shallow sediments (land surface to approximately 40 ft below land surface) in the study area, shallow cores were used primarily to interpret local conditions, and were not correlated throughout the study area (Tenbus, 2003), but descriptions are provided in Appendix 1. Deeper cores (greater than 40 ft deep) were correlated throughout the study area. Sediment from selected cores was also analyzed for selected chemical constituents, including nutrients, metals, pesticides, PCBs, and VOCs (Miller and Klohe, 2003).

Cross-sectional data from various sources were also incorporated into the geologic interpretations. Cross sections are from various sources primarily located at existing bridge locations. Cross-sectional data from the South Capitol Street Bridge geotechnical report (Appendix 5, MACTEC Engineering and Consulting, Inc., 2005), the 11th Street Bridge cross section, and D.C. Metro crossings were incorporated into the interpretation.

Well and Tide Gage Construction

A network of 27 shallow monitoring wells and 1 tidal gage was established to support hydrologic measurements and water-quality sampling (table 1). Ten existing wells (AC Aa 1, AX Ac 1, WE Ca 31, WE Ca 32, WE Ca 35, WE Ca 36, WE Ca 37, WE Cb 8, WE Cb 9, and WE Cb 10) were included in the monitoring network (fig. 2, table 1); these wells were installed by various other groups, but were included as part of the monitoring network on the basis of location, geologic setting, access, and available well-construction and other ancillary information. Seventeen additional wells (AC Aa 2, AC Aa 6, AC Aa 7, WE Ba 9, WE Ba 10, WE Bb 3, WE Bb 4, WE Ca 29, WE Ca 33, WE Ca 34, WE Cb 5, WE Cb 6, WE Cb 11, WE Cb 12, WE Cc 3, WW Bc 8, and WW Bc 9) were constructed in boreholes resulting from geologic coring to supplement information available at the 10 existing wells listed above. In addition, a tide gage (USGS station number 01651750) was constructed on the Anacostia River.

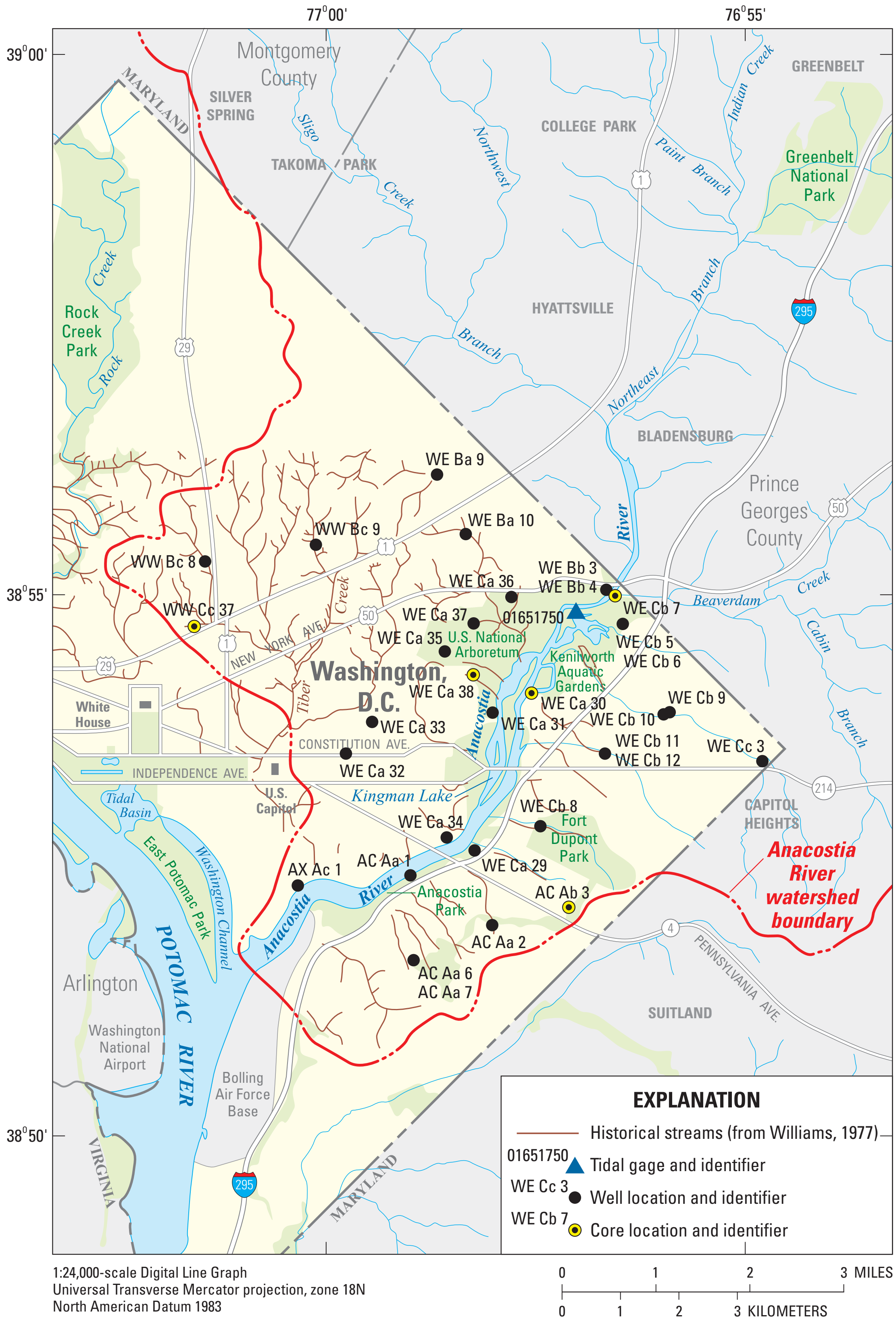

Figure 2. Location of monitoring wells, selected cores, and historical streams in the tidal Anacostia River watershed study area, Washington, D.C.

Table 1. Summary of monitoring locations and associated instrumentation in the tidal Anacostia River watershed, Washington, D.C.

[USGS, U.S. Geological Survey; DDOE, District Department of Energy and Environment; ft bls, feet below land surface; GE, geologic or lithologic core; WL, water level; AT, aquifer test; QW, water quality; X, data are available; Co, continuous data are available; P, periodic data are available]

Site name	Site number (USGS)	Site number (DDOE)	Site type	Aquifer	Depth (ft bls)	Screened interval (ft bls)	Data available			
							GE	WL	AT	QW
AC Aa 1	385225076590101	DCMW001-03	well	alluvium	30	25–30		P	X	P
AC Aa 2	385157076580301	DCMW010-05	well	Potomac Group	16	11–16	X[1]	P		
AC Aa 6	385138076585901	DCMW001-08	well	alluvium	18.5	12.5–18.5		P		
AC Aa 7	385138076585902	DCMW002-08	well	Potomac Group	60	49.5–59.5		P		
AX Ac 1	385219077002201	DCMW006-04	well	alluvium	20	7.5–20		P		
WE Ba 9	385606076584101	DCMW012-05	well	Potomac Group	18	8–18	X[1]	P		P
WE Ba 10	385534076582101	DCMW007-05	well	Potomac Group	17	7–17	X[1]	P		P
WE Bb 3	385504076563801	DCMW001-02	well	alluvium	25	15–25	X[2]	Co, P		Co, P
WE Bb 4	385504076563802	DCMW004-02	well	alluvium	32	22–32	X[2]	Co, P		Co, P
WE Ca 29	385238076581501	DCMW005-02	well	alluvium	48.5	38.5–48.5	X[2]	P		P
WE Ca 31	385355076575901	DCMW002-03	well	alluvium	14.7	unknown		P		
WE Ca 32	385332076594701	DCMW001-04	well	terrace deposits	29	19–29	X[3]	P	X	P
WE Ca 33	385349076592801	DCMW006-05	well	terrace deposits	38	28–38	X[1]	P		P
WE Ca 34	385245076583501	DCMW005-05	well	alluvium and terrace deposits	43	13–33	X[1]	P		P
WE Ca 35	385429076583601	DCMW004-04	well	Potomac Group	250	190–210, 220–250		P		
WE Ca 36	385500076574801	DCMW003-04	well	Potomac Group	232	105–170, 200–230		P		
WE Ca 37	385446076581001	DCMW005-04	well	Potomac Group	25.2	unknown		P		
WE Cb 5	385443076562801	DCMW002-02	well	terrace deposits	22.6	12.6–22.6	X[2]	Co, P		Co, P
WE Cb 6	385443076562802	DCMW003-02	well	terrace deposits	46.3	36.3–46.3	X[2]	Co, P		Co, P
WE Cb 8	385252076572801	DCMW002-04	well	Potomac Group	265	255–265	X[3]	Co, P	X	Co, P
WE Cb 9	385355076555501	DCMW001-05	well	terrace deposits	18.5	8.5–18.5	X[4]	P		
WE Cb 10	385354076555901	DCMW002-05	well	terrace deposits	18	8–18	X[4]	P		
WE Cb 11	385332076564101	DCMW003-05	well	alluvium	21	16–21	X[1]	P		P
WE Cb 12	385332076564102	DCMW004-05	well	Potomac Group	39	29–39	X_1	Co, P		P
WE Cc 3	385327076544801	DCMW008-05	well	Potomac Group	23	13–23	X[1]	P		P
WW Bc 8	385519077012601	DCMW009-05	well	Potomac Group	32	22–32	X[1]	P		P
WW Bc 9	385527077000701	DCMW011-05	well	Potomac Group	36	26–36	X[1]	P		P
Anacostia River Aquatic Gardens at Washington, D.C.	01651750		tide gage					Co		

[1] See Appendix 1.

[2] Tenbus, 2003.

[3] D.C. Water Resources Research Center, 1993a.

[4] D.C. Water Resources Research Center, 1993b.

Table 2. Summary of selected lithologic description locations in and near the tidal Anacostia River watershed, Washington, D.C.

[°, ′, ″, degrees, minutes, seconds; ft, feet; USGS, U.S. Geological Survey; DC WASA LTCP, District of Columbia Water and Sewer Authority long-term control plan project]

Site name	Altitude of land surface (ft)	Latitude	Longitude	Total depth of hole (ft)	Geophysical logs available	Reference
AC Aa 2	125.59	38° 51′ 57.4″	76° 58′ 03.3″	24		USGS boring, described by C. Klohe on March 6, 2006
AC Ab 3	205	38° 52′ 07.1″	76° 57′ 07.6″	36		USGS boring, described by C. Klohe on March 13, 2006
Arena Stage	14	38° 52′ 37.01″	77° 01′ 12.97″	183	Yes	Somes, 2003
AX Ac 2, BPS-42	10.16	38° 52′ 28.39″	77° 00′ 11.91″	326	Yes	DC Clean Rivers Project boring, Anthony Harding, DC Clean Rivers Project, written commun., August 12, 2011
DC 2	19.26	38° 54′ 35.01″	76° 56′ 16.97″	400		Otton, 1955
DC Aquatic Resource Center PW-2	16	38° 52′ 42.01″	76° 58′ 09.96″	398	Yes	HSI Geotrans, 1998
MW-2	82.35	38° 54′ 23.00″	77° 00′ 44.97″	47		DCWRRC, 1993a
PG Cc 13	209.65	38° 58′ 30.00″	76°59′ 43.97″	134		Cooke and others, 1952
PG Cd 9	135.4	38° 56′ 00.01″	76° 51′ 57.97″	160		Cooke and others, 1952
PG Dc 1	290	38° 51′ 19″	76° 56′ 05″	365		Cooke and others, 1952
PG Dc 3	290	38° 50′ 24″	76° 56′ 32″	388		Cooke and others, 1952
PG Dc 4	250	38° 50′ 47″	76° 57′ 10″	620		Cooke and others, 1952
PG Eb 1	14.3	38° 48′ 42.00″	77° 00′ 21.97″	603		Cooke and others, 1952
SAS-001	8.4	38° 52′ 20.87″	77° 00′ 15.49″	250		DC WASA LTCP boring described by Camp Dresser & McKee Inc.—Hack Mott Mcdonald, James Shaughnessy, written commun., February 2008
SAS-002	13	38° 52′ 09.39″	77° 00′ 06.12″	156		DC WASA LTCP boring described by C. Dieter on September 11, 2007
SAS-006	12.3	38° 53′ 01.39″	76° 58′ 16.65″	182		DC WASA LTCP boring described by C. Dieter on February 21, 2008
SAS-101	14.9	38° 51′ 55.99″	76° 59′ 36.20″	191		DC WASA LTCP boring described by C. Dieter on February 7, 2008
SAS-102	12	38° 51′ 51.81″	77º 00’ 03.53”	195		DC WASA LTCP boring described by C. Dieter on February 7, 2008
SAS-103	10	38° 52′ 28.78″	77° 00′ 13.38″	152.5		DC WASA LTCP boring described by C. Dieter on September 11, 2007
SAS-104	6.3	38° 52′ 40.83″	76° 58′ 42.99″	175		DC WASA LTCP boring described by C. Dieter on September 13, 2007
SAS-106	13	38° 53′ 46.70″	76° 58′ 06.63″	166		DC WASA LTCP boring described by C. Dieter on February 8, 2008
SAS-107	30.4	38° 53′ 59.57″	76° 58′ 09.18″	166		DC WASA LTCP boring described by C. Dieter on February 14, 2008
SAS-108	69.4	38° 54′ 39.10″	76° 59′ 08.82″	172		DC WASA LTCP boring described by C. Dieter on September 19, 2007
SAS-109	4	38° 52′ 16.50″	76° 59′ 15.31″	177		DC WASA LTCP boring described by C. Dieter on September 12, 2007
SAS-110	7.2	38° 52′ 31.87″	76° 58′ 37.78″	177		DC WASA LTCP boring described by C. Dieter on September 19, 2007
SAS-111	13	38° 52′ 49.82″	76° 58′ 08.50″	185		DC WASA LTCP boring described by C. Dieter on September 20, 2007
SAS-112	10.3	38° 53′ 15.36″	76° 58′ 11.37″	175		DC WASA LTCP boring described by C. Dieter on February 8, 2008

Table 2. Summary of selected lithologic description locations in and near the tidal Anacostia River watershed, Washington, D.C.—Continued

[°, ′, ″, degrees, minutes, seconds; ft, feet; USGS, U.S. Geological Survey; DC WASA LTCP, District of Columbia Water and Sewer Authority long-term control plan project]

Site name	Altitude of land surface (ft)	Latitude	Longitude	Total depth of hole (ft)	Geophysical logs available	Reference
SAS-201	20.2	38° 49′ 07.93″	77° 01′ 05.78″	216		DC WASA LTCP boring described by C. Dieter on February 15, 2008
SAS-202	157.7	38° 49′ 47.03″	77° 00′ 52.12″	336		DC WASA LTCP boring described by C. Dieter on February 15, 2008
SAS-203	33.2	38° 51′ 29.30″	77° 00′ 10.46″	206		DC WASA LTCP boring described by C. Dieter on September 12, 2007
SAS-204	158	38° 50′ 55.03″	77° 00′ 20.65″	329		DC WASA LTCP boring described by C. Dieter on February 14, 2008
USNA PW-3	14	38° 54′ 34.00″	76° 57′ 32.97″	306	Yes	Schnabel Engineering Associates, 1995
WE Ba 9	81.26	38° 56′ 06.5″	76° 58′ 41.4″	24		USGS boring, described by C. Klohe on March 10 2006
WE Ba 10	74.43	38° 55′ 34.4″	76° 58′ 21.4″	20		USGS boring, described by C. Klohe on March 7, 2006
WE Ca 6	80	38° 53′ 30.00″	76° 59′ 46.98″	340		Hansen, 1968
WE Ca 30	3	38° 54′ 05.8″	76° 57′ 34.2″	30.5		Tenbus, 2003
WE Ca 32, MW-4	80	38° 53′ 32.00″	76° 59′ 46.98″	42		DCWRRC, 1993a
WE Ca 33	67.75	38° 53′ 49.8″	76° 59′ 28.3″	40		USGS boring, described by C. Klohe on August 5, 2005
WE Ca 34	19.61	38° 52′ 45.6″	76° 58′ 35.1″	45.5		USGS boring, described by C. Klohe on August,10 2005
WE Ca 35, USNA PW-2	149.6	38° 54’ 29.20”	76° 58’ 36.00”	265		A.C. Schultes of Maryland, Inc, Job #2616
WE Ca 38	45	38° 54′ 16.07″	76° 58′ 15.54″	24		USGS boring, described by C. Klohe on March 13, 2006
WE Cb 7	4	38° 54′ 59.5″	76° 56′ 34.0″	27.9		Tenbus, 2003
WE Cb 8, MW-1	61	38° 52′ 52.00″	76° 57′ 27.97″	277		DCWRRC, 1993a
WE Cb 9, MW-B1	45.52	38° 53′ 55.00″	76° 55′ 54.97″	19		DCWRRC, 1993b
WE Cb 11	59.99	38° 53′ 32.1″	76° 56′ 41.2″	24		USGS boring, described by C. Klohe on March 13, 2006
WE Cb 12	60.59	38° 53′ 32.1″	76° 56′ 41.2″	81		USGS boring, described by C. Klohe on March 10 2006
WE Cc 3	88.7	38° 53′ 27.0″	76° 54′ 48.5″	24		USGS boring, described by C. Klohe on March 2, 2006
WW Bc 8	123.39	38° 59′ 19.3″	77° 01′ 26.9″	32		USGS boring, described by C. Klohe on March 1, 2006
WW Bc 9	133.6	38° 55′ 27.8″	77° 00′ 07.7″	36		USGS boring, described by C. Klohe on March 7, 2006
WW Cc 26	65	38° 54′ 10.00″	77° 01′ 53.97″	85		Hansen, 1968
WW Cc 37	84	38° 54′ 43.41″	77° 01′ 34.66″	36		USGS boring, described by R. Starsoneck on August 11, 2005

Seventeen monitoring wells were constructed and developed at selected coring locations. Five of these wells (WE Bb 3, WE Bb 4, WE Cb 5, WE Cb 6, and WE Ca 29) were constructed at onshore coring locations near the Anacostia River in July 2002 (Miller and Klohe, 2003; Tenbus, 2003) (fig. 2, table 1). A truck-mounted solid-stem auger was used to deepen some core holes beyond the depth attainable through vibracoring. The 12 remaining wells were installed at selected locations throughout the watershed in August 2005 (AC Aa 2, WE Ba 9, WE Ba 10, WE Ca 33, WE Ca 34, WE Cb 11, WE Cb 12, WE Cc 3, WW Bc 8, and WW Bc 9) and May 2008 (AC Aa 6 and AC Aa 7) using a hollow-stem auger or a truck-mounted Geoprobe. Wells were constructed of 1- or 2-inch (in.)-diameter threaded polyvinyl chloride (PVC) casing and slotted screen. Sand was used to fill the annulus between the well screen and core hole, and bentonite was used to grout the annulus above the screen interval to a concrete plug at the surface. Wells were generally screened within the uppermost water-bearing zone at each location; some wells are nested at different depths at the same location (WE Bb 3 and WE Bb4, WE Cb 5 and WE Cb 6, WE Cb 11 and WE Cb 12, and AC Aa 6 and AC Aa 7). All wells were developed through mechanical surging and pumping to remove fine material from the screen and sand pack. Development continued until water clarity increased, turbidity decreased, and water temperature and specific conductance stabilized.

A tide gage was constructed on a seawall along the Anacostia River near the Kenilworth Aquatic Gardens (fig. 2, table 1, USGS station 01651750) in May 2004. A perforated horizontal steel pipe extends from the seawall approximately 8 ft into the river. The pipe is attached to the base of a vertical steel pipe at the seawall, which is in turn attached to an instrument enclosure at its top.

Hydrologic Measurements

Measurements were made to estimate groundwater-flow gradients and variability, and hydrologic properties of Coastal Plain sediment in the study area. Groundwater levels were measured periodically or continuously in selected monitoring wells. In addition, aquifer tests were conducted to estimate hydrologic properties of selected Coastal Plain aquifers, and tidal fluctuations in the Anacostia River were recorded at the installed tide gage.

Groundwater levels were measured to estimate groundwater-flow gradients, and document seasonal or temporal variability in groundwater levels in the tidal Anacostia River watershed study area. Groundwater levels were recorded continuously at 30-minute intervals in selected wells by In-Situ sondes from 2003 through 2007 (table 1, Appendix 2). Sondes were typically installed within the screened interval of the well. Monthly to quarterly servicing of the sondes included cleaning, battery replacement, and calibration checks against manual water-level measurements. Sondes were reset to match the manual water-level measurements if the values were more than 0.02 ft different. Manual water-level measurements were also made periodically (typically monthly to quarterly) in additional monitoring wells using an electric water-level tape or chalked steel tape (table 1, Appendix 3).

Tidal variations in water level in the Anacostia River were recorded continuously from June 2004 to October 2017 at the tide gage that was installed near Kenilworth Aquatic Gardens. Instantaneous measurement data (6-minute interval) from 2004 through 2007 are available in Appendixes 4*A* through 4*D*. Instantaneous data from 2008 through 2017, and daily data from 2004 through 2017, are available through the USGS National Water Information System database (U.S. Geological Survey, 2017). A data logger in the instrument shelter recorded varying water levels reflected in a float and counter-weight system installed in the vertical pipe. Water levels were recorded every 6 minutes at 0, 6, 12, 18, 24, 30, 36, 42, 48, and 54 minutes past the hour for consistency with National Oceanic and Atmospheric Administration gages, and transmitted via satellite to USGS databases. Data were reviewed periodically, and the tide gage was visited periodically for calibration checks and equipment servicing.

Aquifer tests (slug tests) (Butler, 1998) were conducted to estimate the hydraulic properties of aquifer sediments within which selected wells are screened (table 3). Multiple tests (such as rising head, falling head, and slugs of different volumes) were generally conducted at each well, and analytical methods for resulting data were selected on the basis of individual hydrogeologic conditions (Cooper and others, 1967; Bouwer and Rice, 1976; Greene and Shapiro, 1995). Most wells do not penetrate the entire thickness of aquifer sediments, and estimated hydraulic properties may therefore only apply to screened intervals. Only later-time data were used in the interpretation of slug tests at well WE Ca 32, on the assumption that the quick initial responses observed in water levels during the tests were reflective of properties of the well filter pack rather than aquifer sediments (Butler, 1998). Multiple unsuccessful slug tests at wells WE Ca 31, WE Ca 33, and WE Ca 34 may be indicative of low-permeability sediments surrounding the well screen or a partially clogged well screen (even after multiple attempts to redevelop the wells).

Water-Quality Sampling

Water samples collected periodically from selected wells were analyzed for chemical constituents indicative of natural and human influences on groundwater quality. In addition, selected parameters were recorded continuously in some wells to document temporal and seasonal variation in groundwater quality (table 1).

Table 3. Summary and results of aquifer slug tests on selected wells.

[T, transmissivity; K, horizontal hydraulic conductivity; ft/d, foot per day; ft^2/d, foot squared per day]

Site name	Aquifer (type)	Analysis method	Estimated aquifer properties		
			T (ft^2/d)	K (ft/d)	Storage
AC Aa 1	surficial aquifer system (unconfined)	Cooper and others, 1967; Greene and Shapiro, 1995	100	20	2.138E−4
WE Ca 32	terrace deposits (unconfined)	Bouwer and Rice, 1976	100	6	
WE Cb 8	Patuxent Aquifer (confined)	Cooper and others, 1967; Greene and Shapiro, 1995	200	20	2.545E−8

Samples were collected from September through December 2005 from 17 monitoring wells in three geologic settings (Klohe and Debrewer, 2007); 5 of these wells had previously been sampled in August 2002 (WE Bb 3, WE Bb 4, WE Cb 5, WE Cb 6, and WE Ca 29) (Miller and Klohe, 2003). Wells were purged (generally a minimum of three well volumes) until pH, temperature, dissolved oxygen, turbidity, and specific conductance stabilized prior to sampling. Samples were collected with a peristaltic or stainless-steel submersible pump. Subsamples intended for analysis of dissolved constituents were passed through a 0.45- micrometer (µm) cellulose-nitrate filter (for inorganics) or a 0.70-µm baked glass-fiber filter (for organics). Selected preservatives were added, as necessary, and samples were chilled and shipped overnight to the USGS National Water Quality Laboratory, in Denver, Colorado, or Severn Trent Laboratory, in Arvada, Colorado. for analysis. Samples were analyzed for selected major ions, trace elements, nutrients, pesticides and pesticide degradants, VOCs, semi-volatile organic compounds (SVOCs), phenols, PCBs, and oil and grease (Miller and Klohe, 2003; Klohe and Debrewer, 2007).

Selected water-quality parameters were recorded continuously in a limited number of monitoring wells. In-Situ TROLL 9000 multi-parameter sondes installed in selected monitoring wells (WE Bb 3, WE Bb 4, WE Cb 5, WE Cb 6, WE Cb 8, and WE Cb 12) recorded specific conductance, pH, reduction/oxidation (redox) potential, temperature, dissolved oxygen, and barometric pressure, as well as water levels, at 30-minute intervals from June 2003 through 2006. Periodic calibration checks were done using a multipoint approach for pH and conductance, and dissolved-oxygen calibration was done using an air calibration chamber in water. Occasional missing records resulted from faulty probes, fouling, or unusual conditions (such as flooding from Tropical Storm Isabel).

Geologic Framework

The Anacostia River watershed within Washington, D.C. is underlain by unconsolidated sediments of the Atlantic Coastal Plain Physiographic Province (Fenneman and Johnson, 1946). These sediments form a wedge that thickens from 0 ft at the Fall Line (the unconformity between the Piedmont and Coastal Plain Physiographic Provinces) to more than 1,400 ft in the southeastern part of the Washington, D.C. metropolitan area (Reed and Obermeier, 1982), and lie unconformably on the sloping surface of much older crystalline rocks of the Piedmont Province (figs. 3, 4*A–D*). Unconsolidated sediments of the Atlantic Coastal Plain vary laterally and vertically in color, texture, and permeability, reflecting a complex history of erosional and depositional processes over millions of years. The oldest Atlantic Coastal Plain deposits are fluvial sediments of the Cretaceous Potomac Group. These are overlain in places by younger marine deposits and by surficial upland gravels and alluvial and terrace deposits (table 4).

The Potomac Group

The oldest Coastal Plain sediments in the study area are Cretaceous fluvial deposits of the Potomac Group (Southworth and Denenny, 2006), including a sand-dominated lithofacies (previously referred to as the “Patuxent Formation,” and hereinafter referred to as the “Potomac Group sand-dominated lithofacies”) and an overlying clay-dominated lithofacies (previously referred to as the “Arundel” and “Patapsco Formations,” and hereinafter referred to as the “Potomac Group clay-dominated lithofacies”) (Mathews, 1933; Cooke and others, 1952; Johnston, 1964; Vroblesky and Fleck, 1991) (figs. 3, 4 *A–D*, table 4). The Potomac Group sand-dominated lithofacies includes some pebbles and multicolored clay and rests unconformably upon the basal Piedmont rocks. In Washington, D.C., the depth to the Piedmont rocks from land surface varies: 85 ft at WW Cc 26 (Hansen, 1968), 182 ft at Arena Stage (Somes, 2003), 306 ft at USNA PW-3 (Schnabel Engineering Associates, 1995), 316 ft at AX Ac 2 (Appendix 1), 328 ft at WE Ca 6 (Hansen, 1968), 377 ft at DC2 (Otton, 1955), and 398 ft at DC Aquatic Resource Center PW-2, (HSI Geotrans, Inc., 1998). The Potomac Group clay-dominated lithofacies includes some sand, but is mostly massive, mottled, silty clay (Southworth and Denenny, 2006).

Geology mapped from 2001–2004
Mapping based on 1:24,000-scale Digital Line Graph base map data
Projection: Universal Transverse Mercator, zone 18N
Datum: North American Datum 1983

0 1 2 3 MILES
0 1 2 3 KILOMETERS

Figure 3. Generalized geology of the tidal Anacostia River watershed, selected lithologic description locations, and cross-section locations, Washington, D.C. (modified from Southworth and Denenny, 2006).

GEOLOGIC MAP UNITS

QUATERNARY AND CENOZOIC SURFICIAL MATERIALS

dgf	Disturbed ground and artificial fill
Qa	Alluvium (Holocene)
Qt	Terrace deposits, low level (Holocene and Pleistocene)
Qc	Colluvium (Holocene and Pleistocene)
Ql	Landslide (Holocene and Pleistocene)
Qte	Low-level fluvial and estuarine deposits (Pleistocene)
Qfe	Upper-level fluvial and estuarine deposits (Pleistocene)
Qtt	Terrace deposits, upper level (Pleistocene and Tertiary)

TERTIARY COASTAL PLAIN DEPOSITS

Tt	Terrace deposits (Tertiary)
Ttu	Highest level upland terrace deposits (Tertiary)
Tc	Calvert Formation (middle Miocene)
Ta	Aquia Formation (upper Paleocene)
TKb	Brightseat Formation and Monmouth Group, undivided (lower Paleocene and upper Cretaceous)

CRETACEOUS COASTAL PLAIN DEPOSITS

Kpc	Potomac Group clay-dominated lithofacies
Kps	Potomac Group sand-dominated lithofacies

Figure 3. Generalized geology of the tidal Anacostia River watershed, selected lithologic description locations, and cross-section locations, Washington, D.C. (modified from Southworth and Denenny, 2006).—Continued

The lower part of the clay facies (previously referred to as the "Arundel Formation") is almost entirely dark-colored clay, with some iron-carbonate nodules and lignitized woody material. The uppermost Potomac Group deposits in the area (previously referred to as the "Patapsco Formation") include a basal clay layer (commonly maroon in color) and an upper layer of mixed texture (sand and clay). Although the Potomac Group varies considerably in texture, collectively, it is primarily fine-grained. More than 70 percent of one 946-ft vertical section through the Potomac Group just east of the study area in Prince George's County, Maryland is composed primarily of clay (Cooke and others, 1952). It is important to note that the Potomac Group sand-dominated lithofacies and the Potomac Group clay-dominated lithofacies are each on the order of tens of feet in thickness. Therefore, although the Potomac Group sand-dominated lithofacies includes some clay and the Potomac Group clay-dominated lithofacies contains some sand, individual layers (less than 10 ft thick) of sand or clay should not be identified as the Potomac Group sand-dominated lithofacies or Potomac Group clay-dominated lithofacies, respectively.

The Potomac Group crops out and subcrops in a broad band that trends through the study area from northeast to southwest, and dips to the southeast beneath younger Tertiary and Quaternary deposits (Johnston, 1964; Southworth and Denenny, 2006; figs. 3, 4*A*–*D*). In general, the clay facies separates the underlying Potomac Group sand-dominated lithofacies deposits from overlying younger sediments. The contact between the Potomac Group sand-dominated and clay-dominated lithofacies crops out in the northwestern part of the study area, but subcrops beneath younger Quaternary deposits to the south. Although the uppermost part of the Potomac Group clay-dominated lithofacies includes sediments of variable texture, the transition from finer-grained deposits to coarser-grained deposits crops out or subcrops southeast of the Anacostia River, and the Potomac Group clay contains predominantly fine-grained sediments within the study area (figs. 3, 4*A*–*D*).

Potomac Group sediments may be missing from the geologic column in parts of the tidal Anacostia River watershed, particularly near the Anacostia River. Sediments of the Potomac Group deposited during the Cretaceous Period have been subsequently removed by erosion due to down-cutting of the Potomac and Anacostia Rivers during periods of relatively low sea level. Coring revealed particularly thick (greater than 100 ft) alluvial and estuarine sequences around the lower Anacostia River near its mouth (fig. 4*C*, for example, cores SAS-001 and SAS-103). The river may have eroded completely through the Potomac Group clay-dominated lithofacies to the underlying sand-dominated lithofacies in this area. Further coring would be necessary to determine the lateral extent of missing clay-dominated lithofacies (figs. 4*C*, 4*D*, 5, Appendix 1). Another location where data indicate that the clay-dominated lithofacies is missing is beneath the northwestern bank of the Anacostia River near the South Capitol Street Bridge (Appendix 5). Data from this bridge crossing generally indicate the existence of the clay-dominated lithofacies from approximately –25 ft down to greater than –75 ft relative to mean sea level (msl) on the southeastern bank of the Anacostia River. The clay-dominated lithofacies thins and pinches out near the southeastern bank of the Anacostia River. Beneath the center of the current Anacostia River channel, a Quaternary paleochannel fill includes a clay-dominated lithofacies approximately 10 to 40 ft thick (at –90 to –120 ft relative to msl). The cross section also shows that from the center of the channel to the northwest bank, the lithology is primarily clayey sand, indicating that the clay-dominated lithofacies is missing beneath part of the Anacostia River. However, borings in the northwest part of the cross section are fairly shallow (50 to 75 ft below land surface), limiting the interpretation of the presence or absence of the clay-dominated lithofacies. Because of the highly variable nature of fluvial depositional environments of the Potomac Group, as well as subsequent complex paleochannel erosional and alluvial and estuarine erosional and depositional environments, additional data would be necessary to determine the extent and location of areas where the clay-dominated lithofacies is not present. In such areas, the sand-dominated lithofacies would be in direct connection with shallower sand deposits (terrace or alluvial deposits).

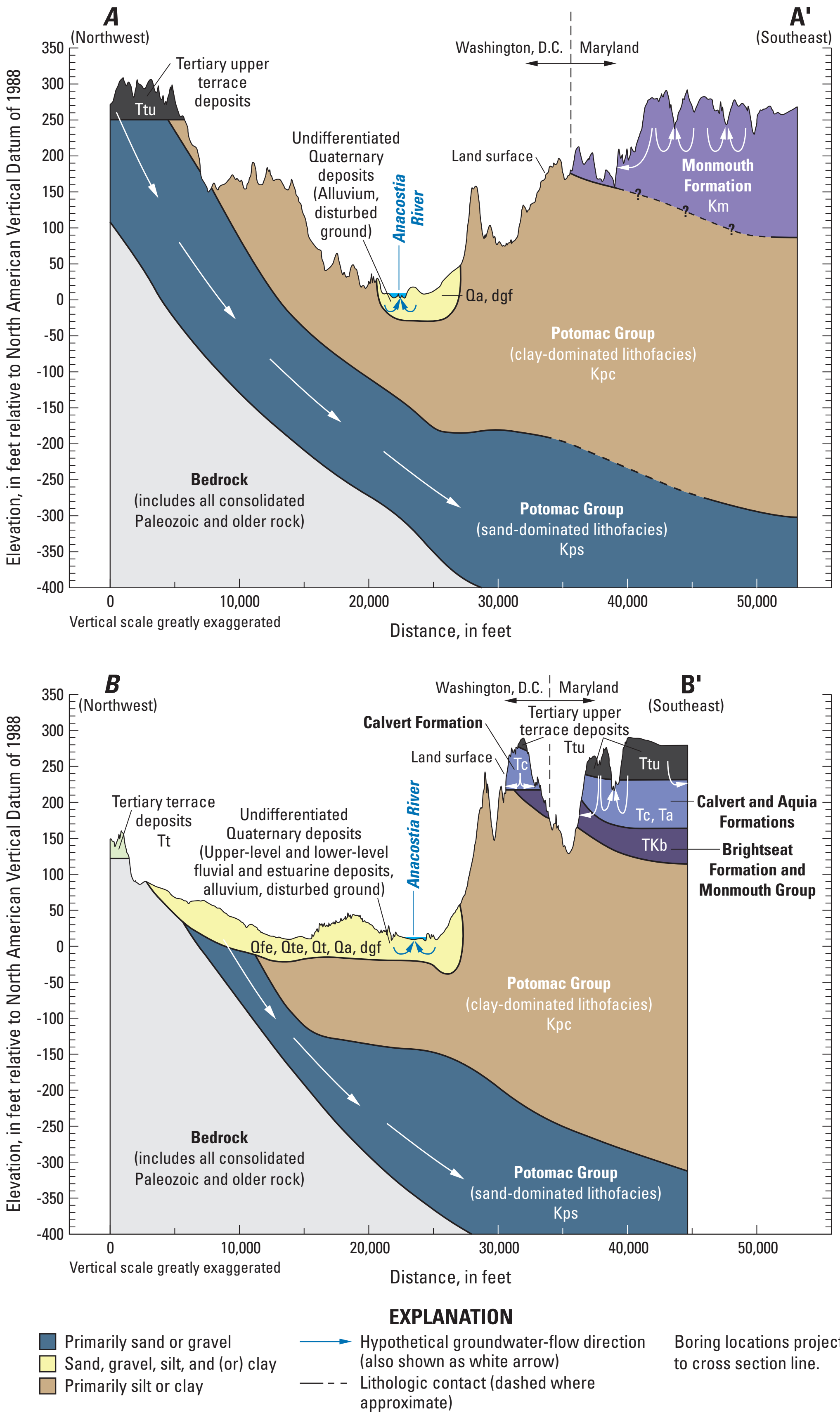

Figure 4*A–B*. Generalized geologic cross sections A-A′ and B-B′, showing hypothetical groundwater-flow directions in the tidal Anacostia River watershed, Washington, D.C. Refer to figure 3 for location of cross sections and geologic units.

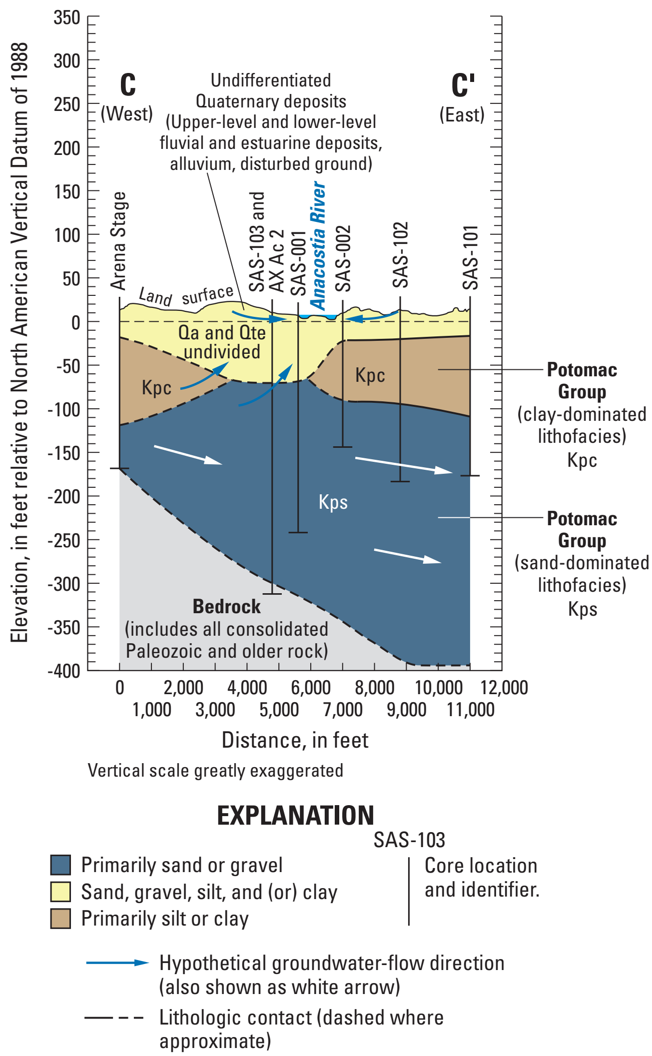

Figure 4*C*. Generalized geologic cross section C–C′ showing hypothetical groundwater-flow directions in the tidal Anacostia River watershed, Washington, D.C. Refer to figure 3 for location of cross sections and geologic units.

Upper Cretaceous and Tertiary Deposits

The Potomac Group is overlain in parts of the study area and vicinity by marine and estuarine deposits of the Monmouth Group, Brightseat Formation, Aquia Formation, Marlboro Clay, and Nanjemoy and Calvert Formations (table 4; Cooke and others, 1952). These deposits are limited to uplands south of the Anacostia River in the extreme southeastern part of the study area (Johnston, 1964; Southworth and Denenny, 2006; figs. 3, 4*C*, 4*D*). The Monmouth Group is composed primarily of fine glauconitic or mica-rich sand, with a thin (2-ft) basal gravel bed just above its contact with the underlying Potomac Group (Cooke and others, 1952). The Aquia Formation includes green glauconitic sand, similar to that of the underlying Monmouth Formation. The Nanjemoy Formation also contains glauconitic sand, overlying the pink Marlboro Clay. Miocene-age Chesapeake Group sediments in the vicinity of the study area are predominantly dark gray to light gray clay (Cooke and others, 1952).

Upper Tertiary and Younger Deposits

The uppermost and youngest geologic units in the study area include coarse upland sediments, and more recent alluvial and terrace deposits along modern stream channels. Coarse deposits (primarily gravel and sand) occur as erosional remnants in relatively isolated uplands (Cooke and others, 1952; Johnston, 1964; Southworth and Denenny, 2006; figs. 3, 4*B*, table 4). The Anacostia River Valley and much of downtown Washington, D.C. near the confluence of the Anacostia and Potomac Rivers are underlain by Pleistocene fluvial and estuarine terrace deposits and more recent alluvium (Cooke and others, 1952; Johnston, 1964; Southworth and Denenny, 2006). Terrace deposits include fining-upward sequences of sediment (including gravel, sand, silt, and clay) formed as the ancient river valleys were flooded by rising sea levels. Holocene alluvium (primarily clay, sand, and gravel, usually only a few feet thick) occurs beneath the modern Anacostia River flood plain and channel (Johnston, 1964; Southworth and Denenny, 2006).

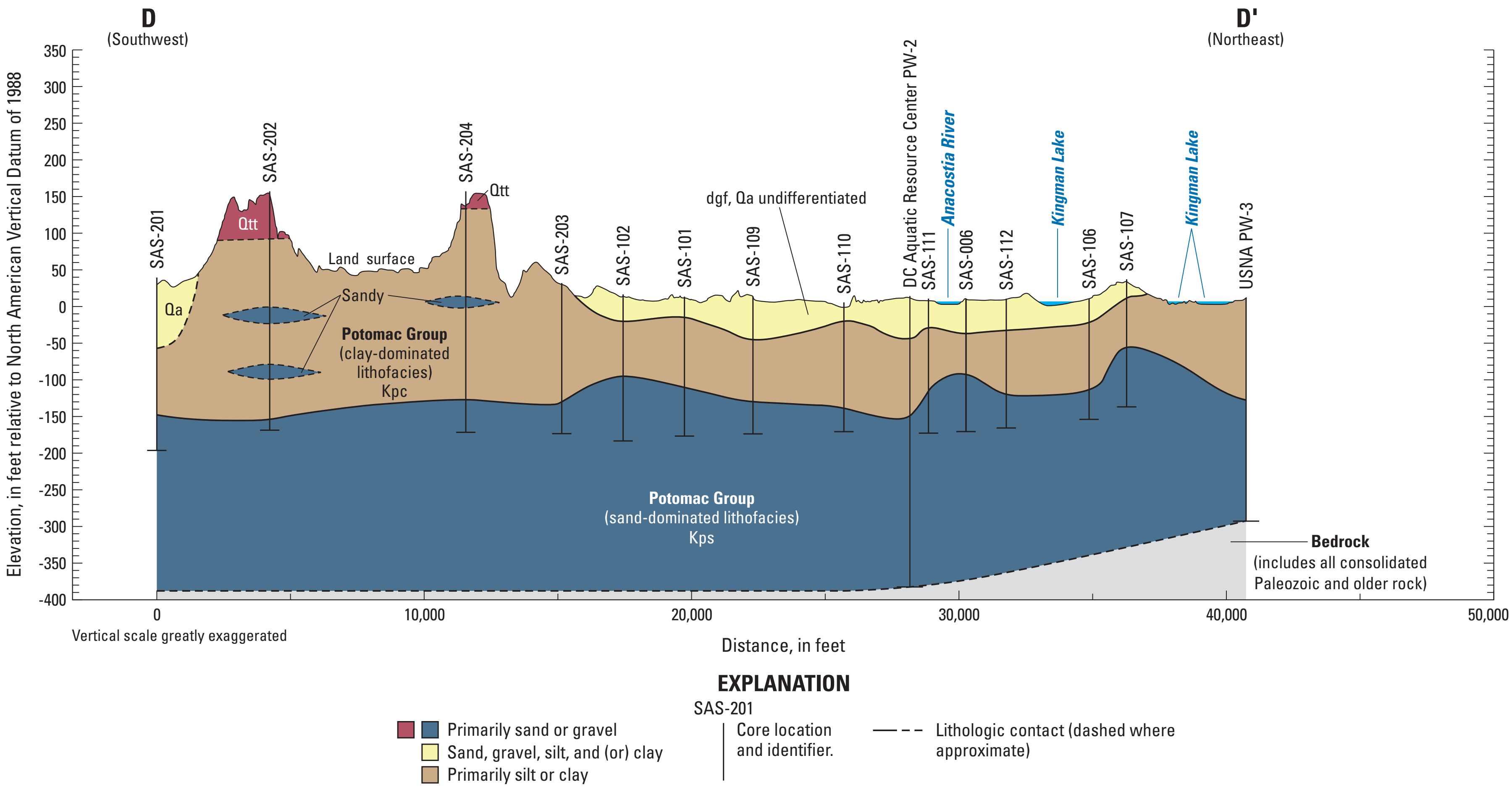

Figure 4*D*. Generalized geologic cross section D–D′ through the Coastal Plain sediments in the tidal Anacostia River watershed, Washington, D.C. Refer to figure 3 for location of cross section and geologic units. Hypothetical flow directions are not shown on this section because they are primarily perpendicular to this cross section.

Table 4. Summary of Coastal Plain geologic and hydrogeologic units in the tidal Anacostia River watershed, Washington, D.C. and surrounding area.

<table>
<tr><th>Age</th><th colspan="2">Geologic units[1]
(see figs. 3 and 4)</th><th colspan="2">Previous geologic units[2]</th><th>Description[1,2]</th><th>Hydrogeologic units[3]</th></tr>
<tr><td rowspan="4">**Quaternary**</td><td colspan="2" rowspan="3">Disturbed ground, artificial fill, alluvium, terrace deposits, fluvial and estuarine deposits</td><td colspan="2">Alluvium</td><td>Variable sediments in modern stream channels and flood plains.</td><td rowspan="3">Surficial aquifer system</td></tr>
<tr><td colspan="2">Pamlico Formation</td><td>Fining upward sequence of gravel, sand, and silt.</td></tr>
<tr><td colspan="2">Wicomico Formation</td><td>Fining upward sequence of coarse gravel, overlain by finer sand and silt.</td></tr>
<tr><td colspan="2">Terrace deposits</td><td colspan="2">Sunderland Formation</td><td>Fining upward sequence of coarse gravel, sand, silt, and clay.</td><td rowspan="2">Terrace deposits of the surficial aquifer system</td></tr>
<tr><td rowspan="6">**Tertiary**</td><td colspan="2">Upland terrace deposits</td><td>Brandywine Gravel</td><td>Bryn Mawr Gravel</td><td>Coarse pebbles, with some sand and silt. Bryn Mawr is red in color, whereas Brandywine is pink or yellow.</td></tr>
<tr><td colspan="2">Calvert Formation, Chesapeake Group</td><td colspan="2">Chesapeake Group</td><td>Primarily gray clay, sand, and silt.</td><td rowspan="6">Permeable sands, where unconfined are part of the surficial aquifer system</td></tr>
<tr><td colspan="2">Nanjemoy Formation</td><td rowspan="3">Pamunkey Group</td><td rowspan="2">Nanjemoy Formation</td><td rowspan="2">Gray and green glauconitic sand, overlying a pink plastic clay (the Marlboro Clay member).</td></tr>
<tr><td colspan="2">Marlboro Clay</td></tr>
<tr><td colspan="2">Aquia Formation</td><td>Aquia Formation</td><td>Sand, including glauconite, cemented in places by lime.</td></tr>
<tr><td colspan="2" rowspan="2">Brightseat Formation and Monmouth Group, undivided</td><td colspan="2">Brightseat Formation</td><td rowspan="2">Green and gray clayey sand and very fine glauconitic and micaceous green sand, with 2 feet of gravel, rounded pebbles, and coarse pink quartz sand at the base.</td></tr>
<tr><td rowspan="4">**Cretaceous**</td><td colspan="2">Monmouth Formation</td></tr>
<tr><td rowspan="3">Potomac Group</td><td rowspan="2">Clay-dominated lithofacies</td><td rowspan="3">Potomac Group</td><td>Patapsco Formation</td><td>Commonly maroon clay at the base. Upper part is light colored, with variable sand and clay.</td><td rowspan="2">Potomac Group clay-dominated lithofacies (confining to semi-confining unit)</td></tr>
<tr><td>Arundel Formation</td><td>Primarily dark dense clay, with iron carbonate and hydrous iron oxide nodules.</td></tr>
<tr><td>Sand-dominated lithofacies</td><td>Patuxent Formation</td><td>Mainly medium to coarse sand, with pebbles, gravel, and lenses of white or multicolored clay.</td><td>Patuxent aquifer</td></tr>
</table>

[1]Modified from Southworth and Denenny, 2006.

[2]Cooke and others, 1952; Johnston, 1964; Vroblesky and Fleck, 1991.

[3]This column contains hydrogeologic units used in this report.

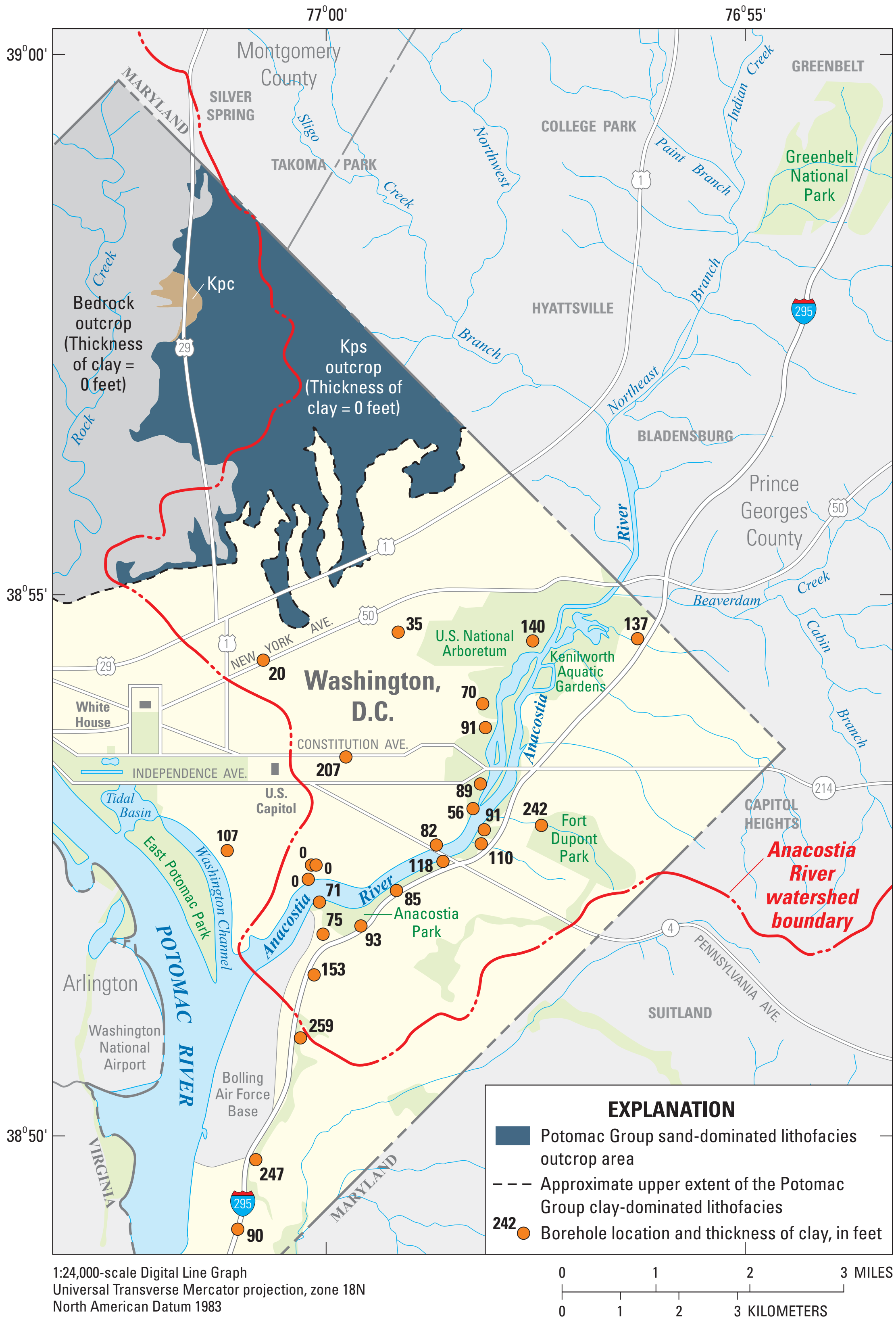

Figure 5. Distribution of the clay-dominated lithofacies of the Potomac Group (Kpc) within the tidal Anacostia River watershed, Washington, D.C. (Outcrop area of the Kps is modified from Southworth and Denenny, 2006.)

The modern land surface in the study area reflects anthropogenic influences, as well as modern sea level. Streambed sediments in the Anacostia River in the study area are predominantly fine-grained clay and mud with abundant organic matter, as might be expected in a tidal estuary, although zones of coarser sands and gravels do occur (Velinsky and others, 1994; Washington Metropolitan Area Transit Authority, 1981). In addition, the modern river and its watershed reflect anthropogenic influences typical of urban areas (Behm and others, 2003). Natural sediments are overlain in many areas by artificial fill (Southworth and Denenny, 2006; fig. 3). The river and its streambed and riparian areas, in particular, have been altered by dredging and land reclamation; much of the modern riverfront is underlain by fill overlying buried marsh deposits (Williams, 1977).

Hydrology

The occurrence, distribution, and movement of groundwater in the Coastal Plain sediments in the study area are controlled primarily by topography, the texture and permeability (hydraulic characteristics) of geologic materials (particularly the abundance of relatively impermeable clay and silt), and human activities and alterations at or near the land surface. Groundwater in the study area occurs under both confined and unconfined conditions (Johnston, 1964). Confined groundwater occurs in the Patuxent aquifer, where it is overlain by the clay-dominated lithofacies of the Potomac Group. Groundwater in primarily permeable overlying deposits also may be locally confined in places beneath lenses or other zones of finer material. Under natural conditions, unconfined groundwater would occur in relatively permeable surficial deposits in many parts of the study area, and generally flow from upland recharge areas in the northwest and southeast toward discharge areas in and near the Anacostia River and its tributaries. The occurrence and movement of unconfined groundwater has been altered considerably, however, by dewatering, storm sewers, and other urban influences. Groundwater discharges to the Anacostia River and other streams in Washington, D.C., but the amount of groundwater discharge may be limited in areas by fine-grained riverbed sediment.

Confined Aquifer

Permeable sediments of the Potomac Group sand-dominated lithofacies form a productive aquifer in the study area referred to in this report as the Patuxent aquifer, which represents an important source of water supply in southern Maryland to the south and east of Washington, D.C. (Vroblesky and Fleck, 1991; Andreasen, 2007; Drummond, 2007). Johnston (1964) reported an average yield of 80 gallons per minute (gal/min) for wells in these sediments in the vicinity of Washington, D.C.; transmissivity of the aquifer in the area is between 1,000 and 2,000 feet squared per day (ft^2/d) (Papadopulos and others, 1974; Schnabel Engineering Associates, 1995), considerably higher than estimates for surficial aquifer sediments (table 3). The Patuxent aquifer is confined beneath the clay-dominated lithofacies of the Potomac Group in the southeastern part of the study area, but unconfined or semi-confined where it crops out or subcrops along the Fall Line to the northwest, and (possibly) in other areas if the Potomac Group clay-dominated lithofacies is missing (figs. 3, 4*A–D*, 5). Recharge to the confined Patuxent aquifer likely occurs primarily in the outcrop and subcrop areas, although some water may reach the aquifer as leakage through the relatively impermeable overlying sediments (Fleck and Vroblesky, 1996). Hydraulic heads in the confined Patuxent aquifer in the vicinity of the U.S. National Arboretum (observed in wells WE Ca 35 and WE Ca 36, approximately 30 and 36 ft relative to North American Vertical Datum of 1988 [NAVD 88], respectively) are lower than in the surficial unconfined aquifer (WE Ca 37, approximately 46 ft NAVD 88) (table 1, Appendix 3), indicating a downward gradient for groundwater flow to the Patuxent aquifer, at least in this area. Conversely, hydraulic heads in the Patuxent aquifer are higher than land surface (up to 10 ft in places) in the vicinity of the Anacostia River in some areas (Schnabel Engineering Associates, 1995; HSI Geotrans Inc., 1998), indicating an upward hydraulic gradient and potential groundwater discharge to the river.

Surficial Aquifer System

The surficial aquifer system in the study area includes all sediments, that primarily are permeable, at or near the land surface in the watershed (Matheson and others, 1994). These include the permeable sediments of the Patuxent aquifer, where not confined beneath the Potomac Group clay-dominated lithofacies, as well as permeable overlying upland gravels and Quaternary alluvium and terrace deposits. Permeable sediments of the Brightseat Formation, Monmouth Group, and Aquia, Nanjemoy, or Calvert Formations may also form part of the surficial aquifer where they outcrop in the southeastern part of the study area. Groundwater likely occurs under primarily unconfined conditions within these sediments on the watershed scale, and groundwater-flow patterns may be approximated by the orientation of the regional water table (Matheson and others, 1994). These deposits vary considerably in texture both laterally and vertically in most areas, however, and local groundwater-flow patterns are therefore likely to be similarly complex. Groundwater within the surficial aquifer system may be perched in some areas, for example, or locally confined beneath impermeable sediments in others. Shallow groundwater flow in the heavily urbanized study area also is significantly affected by human alterations and activities at or near the land surface (D.C. Water Resources Research Center, 1992; Matheson and others, 1994), although such influences are too localized to be mapped at the regional scale.

Natural recharge to the surficial aquifer system occurs as vertical infiltration of precipitation to the water table throughout the study area. Annual precipitation in the Washington, D.C. area ranges from 27 to 60 in., with average annual precipitation of approximately 40 in. (National Oceanographic and Atmospheric Administration, 2013): approximately 25 percent of this provides recharge to the unconfined surficial aquifer system (Cooke and others, 1952; D.C. Water Resources Research Center, 1992). Shallow groundwater is warmest in the winter (December through February) and coolest in the late spring to early summer (May through July) (fig. 6, Appendix 2), indicating a lag time between infiltration of recharge from the land surface through the unsaturated zone to the water table.

The depth to the water table varies daily, seasonally, and (or) annually within the study area, but generally occurs within 15 to 25 ft of land surface. Near the Anacostia River, the depth to water is approximately 11 ft below land surface at WE Bb 3, and about 8 ft below land surface at WE Ca 29. Further from the Anacostia River, water levels in well WE Ca 32 are approximately 22 ft below land surface. Water levels in shallow wells close to the Anacostia River, such as WE Bb 3, vary daily due to tidal fluctuations and precipitation. Other wells show seasonal fluctuations as a result of variations in precipitation and evapotranspiration (fig. 7, Appendixes 2 and 3) (D.C. Water Resources Research Center, 1992). Annual and decadal variations in the water table range from 1 to 10 ft for the period of record for monitoring wells listed/shown in Appendix 3. Once below the water table, groundwater flows laterally and vertically downgradient from recharge areas to discharge areas such as local streams. Most parts of the watershed that are underlain by relatively permeable sediments are likely recharge areas for the surficial unconfined aquifer; where measured, vertical flow gradients are generally downward (see, for example, fig. 7, Appendix 2).

Groundwater flow in the surficial unconfined aquifer system in the study area generally follows topographic gradients from recharge areas in uplands to discharge areas in local streams and the Anacostia River Valley. Topographic controls on unconfined groundwater flow are reflected in the regional water table shown in figure 8. Regional groundwater-flow patterns in the surficial aquifer system are similar to those observed in the early 1990s. Water levels measured in 2006 (fig. 8) are similar to those reported by Matheson and others (1994), and water-level records from shallow wells in nearby Arlington, Virginia and Prince George's County, Maryland (U.S. Geological Survey, 2009) show considerable inter-annual variability since 1980, but minimal long-term trends. Groundwater in the surficial aquifer generally flows from uplands in the northwestern and southeastern parts of the study area toward a major regional discharge area in the lowlands of the Anacostia River Valley and downtown Washington, D.C., near the confluence of the Anacostia and Potomac Rivers. Northwest of the Anacostia River, groundwater flows radially from the upland near the U.S. Soldiers Home; south toward downtown and the Potomac River, east toward the Northwest Branch of the Anacostia River in Prince George's County, Maryland, and east to the tidal Anacostia River in Washington, D.C. (fig. 8) (Matheson and others, 1994). Although the study area is defined by the tidal Anacostia River watershed within Washington, D.C., groundwater flows across the surface watershed boundaries. For example, between the U.S. Capitol building and the White House, groundwater flows from within the Anacostia River watershed to the Potomac River watershed.

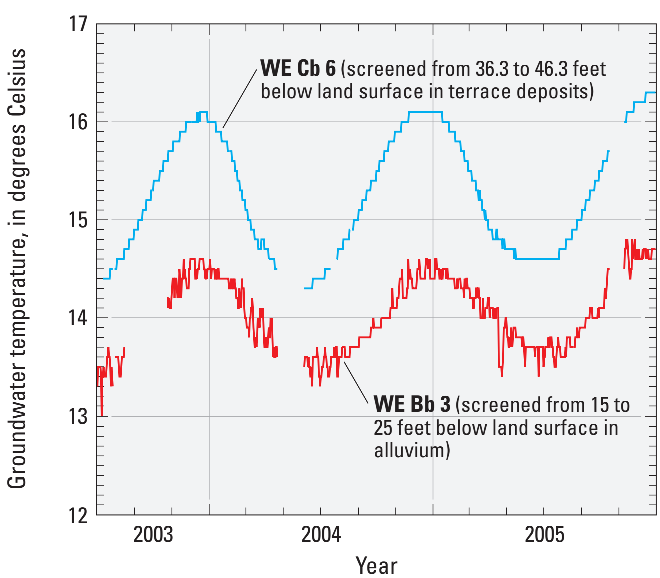

Figure 6. Groundwater temperature over time measured in selected shallow wells near the Anacostia River.

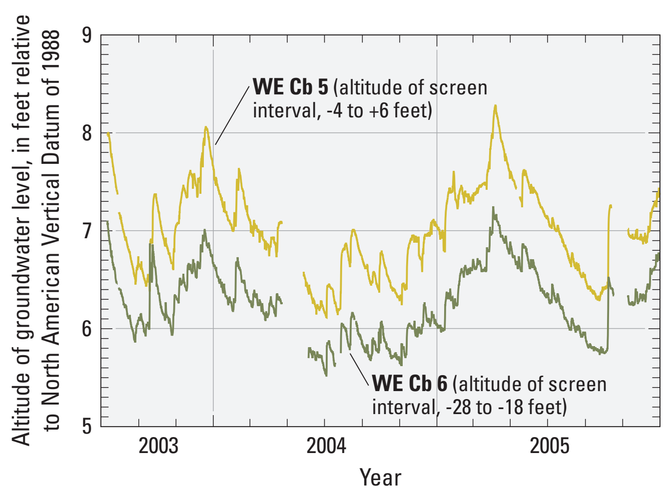

Figure 7. Groundwater levels over time at the same location but different depths within the terrace deposits.

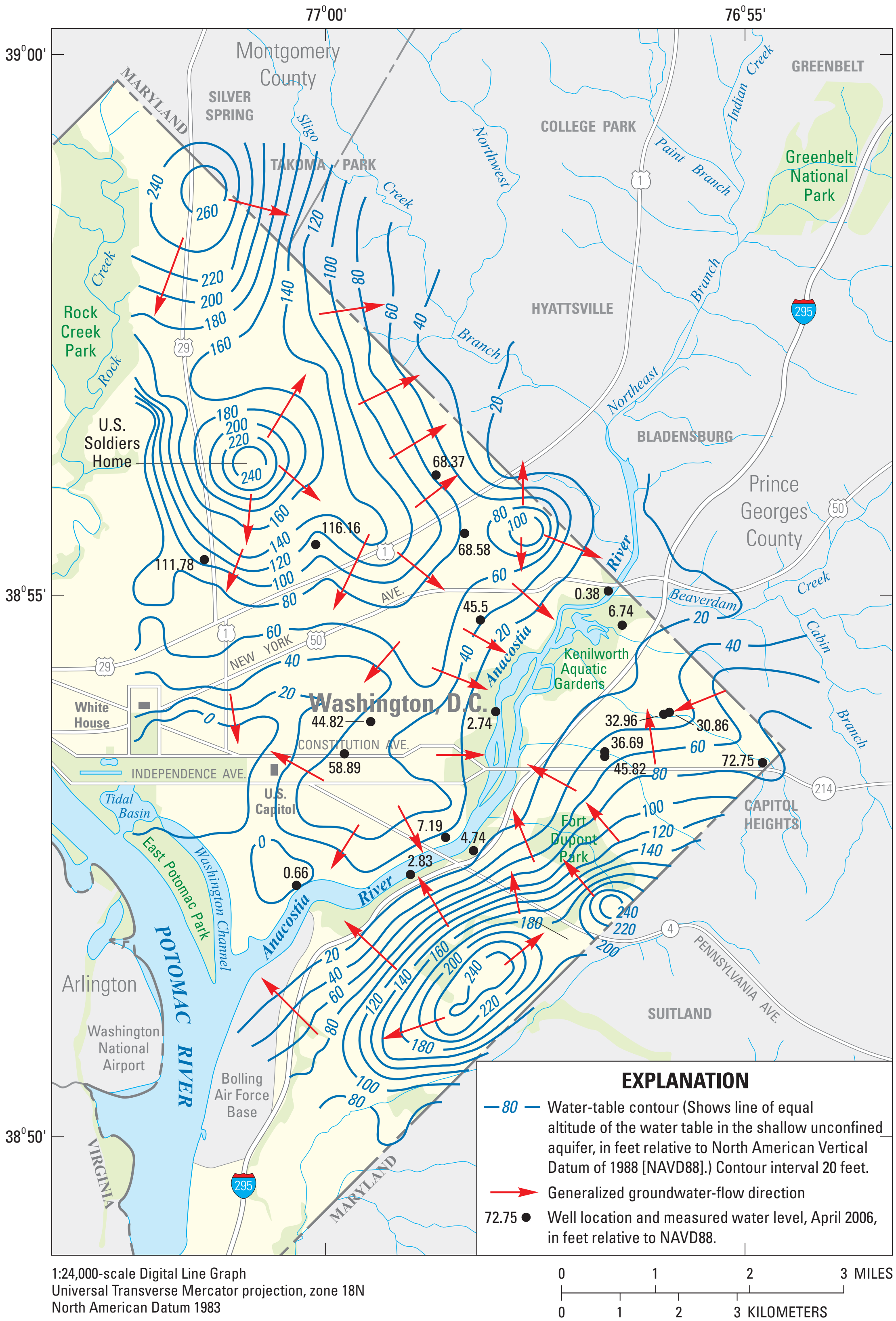

Figure 8. Estimated orientation of the regional water table, and generalized groundwater-flow directions in the surficial aquifer, tidal Anacostia River watershed, Washington, D.C., and vicinity (modified from Matheson and others, 1994, on the basis of groundwater-level measurements, April 2006).

General groundwater occurrence, distribution, and flow patterns in the surficial aquifer apparent from the orientation of the regional water table are likely complicated locally by variable hydrogeologic conditions. Groundwater may be unconfined in surficial aquifers at the regional scale, but locally confined in places by overlying clay lenses or other zones of relatively impermeable sediments. Flow patterns also are affected by local variability in sediments that is difficult to map regionally. Lateral groundwater flow is likely focused in relatively permeable sediments (such as sand or gravel); flow through less permeable silt or clay is often more vertical and much slower. Also, perched groundwater above the regional water table may occur in permeable sediments overlying relatively impermeable clay lenses or other deposits (D.C. Water Resources Research Center, 1992).

Groundwater flow in the surficial aquifer system of the study area is also significantly affected by human activities and alterations common to urban areas (D.C. Water Resources Research Center, 1992; Matheson and others, 1994). The water table in parts of the study area is artificially lowered for construction or to prevent seepage and flooding of basements, tunnels, or other buried infrastructure. Conversely, groundwater levels around some buildings must be artificially raised to prevent deterioration of wooden foundation pilings (D.C. Water Resources Research Center, 1992). This manipulation of the water table alters local flow gradients, and dewatering may also cause irreversible sediment compaction and land subsidence. Many natural streams in the watershed have been completely filled for development (fig. 2), creating high-permeability zones of preferential groundwater flow. The former course of Tiber Creek (fig. 2), for example, remains apparent as a zone of focused groundwater flow in the regional water table (fig. 8) (Matheson and others, 1994). Pipelines, sewers, tunnels, and other buried infrastructure may also divert local groundwater flow and serve as discharge zones (Matheson and others, 1994).

Groundwater–Surface-Water Interaction

Streams and tidal estuaries (such as the tidal Anacostia River) are discharge areas for most groundwater in the lower Anacostia River watershed study area. As in most humid areas, groundwater levels in the study area are generally higher than water levels in adjacent streams, indicating groundwater discharge to streams (Fleck and Vroblesky, 1996) (fig. 8, Appendix 2). Although local groundwater-flow directions may be altered by human activities (such as dewatering) in some areas, groundwater in the surficial aquifer generally flows from upland recharge areas to discharge areas in streams and other surface waters (fig. 8). Unlike in upland recharge areas where vertical gradients reflect downward recharge to the surficial aquifer (fig.7, Appendix 2,), vertical gradients are lower or upward in discharge areas near the Anacostia River, and groundwater may flow more laterally (fig. 9) or upward beneath the river. Sediments in the surficial aquifer are coarse and permeable in some areas near the river (Appendix 1), and variations in groundwater levels in discharge areas near the Anacostia River are controlled mainly by the tidal fluctuations in the river (fig. 9), rather than seasonally variable infiltration rates as in upland recharge areas (fig. 7, Appendix 2).

Groundwater discharge to the Anacostia River and tributaries may occur over broad areas of the streambed, but is likely focused in areas of particularly permeable sediments. Direct groundwater seepage to the Anacostia River has been documented (Chadwick and others, 2001; Matrix Environmental and Geotechnical Services, 2003), and tidal fluctuations in groundwater levels near tidal waters (fig. 9) may indicate a connection between groundwater and surface waters in the study area. Such connections are enhanced by storm sewers, which may serve as direct conduits for shallow groundwater movement to streams and estuaries. The District of Columbia Water and Sewer Authority (Greeley and Hansen, 2009, table ES-2) estimated that from May 2003 to May 2004 in Washington, D.C., 58 million gallons per day (Mgal/d) of groundwater infiltrated into sewers, and 16 Mgal/d of groundwater were pumped from sumps into sewers. This estimated 74 Mgal/d of groundwater ultimately discharged to surface waters during the 1-year period. Greeley and Hansen (2009, table ES-2) also estimated that 47, 52, or 64 Mgal/d of groundwater (infiltration and pumpage) flows into sewers during dry, average, and wet years, respectively.

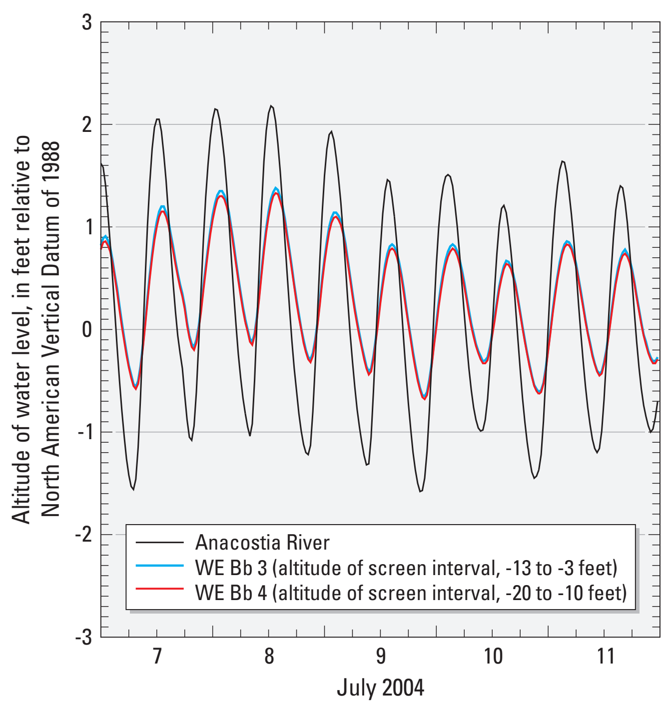

Figure 9. Tidal fluctuations in water levels in the Anacostia River (U.S. Geological Survey station number 01651750) and in nearby shallow groundwater wells WE Bb 3 and WE Bb 4, July 2004.

Locally in some places, the hydraulic heads in the confined Patuxent aquifer are higher than the level of the Anacostia River (up to 20–30 ft) (Matheson and others, 1994; Schnabel Engineering Associates, 1995; HSI Geotrans Inc., 1998). Discharge from the Patuxent aquifer to the Anacostia River is probably limited by the intervening clays of the Potomac Group (Schnabel Engineering Associates, 1995), but could be occurring in areas, such as at borings AX Ac 2, SAS-001, and SAS-103, where the clayey sediments are missing as a result of erosion or other natural geological processes.

Geochemistry and Groundwater Quality

Groundwater in the tidal Anacostia River watershed is affected by natural hydrogeologic conditions and a variety of chemicals from different urban sources. Surficial sediments in the study area are highly variable, ranging from sand with little organic matter in fluvial terrace deposits and Potomac Group sand subcrop areas, to organic-rich silt and clay in alluvium near the river (fig. 3). Factors such as the amount of sand, silt, clay, or organic matter in soils and aquifer sediments influence natural water chemistry and the redox state of the aquifer, as well as the ease with which contaminants may enter and travel through groundwater. Under natural conditions in shallow Coastal Plain sediments, dissolved ions in groundwater are derived from precipitation and natural mineral sources (such as silicates and carbonates), and groundwater is typically dilute (Hamilton and others, 1993). Nitrate concentrations are generally less than 0.4 milligram per liter (mg/L) and chloride concentrations are generally less than 6 mg/L (Hamilton and others, 1993). Human sources of chemical contaminants in urban areas include road salting (Williams and others, 1999), fertilizer and pesticide applications, and leaks from sewer lines, industrial activities, and chemical storage and transport facilities. Sources of chemical contamination may be diffuse and widespread, such as infiltration of water near roads, or they may occur in localized plumes from spills and leaks.

Reduction/oxidation processes affect shallow groundwater quality in Washington, D.C. Where soils and surficial aquifer sediments are sandy with little organic matter, groundwater is typically unconfined, oxic (dissolved oxygen greater than 1 mg/L), and contains low concentrations of iron and manganese. Such aquifers are particularly vulnerable to surficial contamination, because groundwater moves easily through the permeable sediments, and sorption sites for solutes are limited. Also, some organic contaminants are more persistent in oxic groundwater than in areas with little dissolved oxygen (Zogorski and others, 2006). In addition to organic contaminants, groundwater in sandy unconfined aquifers often contains elevated concentrations of nitrate and chloride from leaky sewers, fertilizers, or road salt (Williams and others, 1999).

Groundwater in areas with fine-grained organic-rich soil and sediments is less vulnerable to contamination from surficial sources. Infiltration in such areas is limited by the low-permeability materials. Also, sorption sites for chemicals on clay and organic particles are more common, and water moves more slowly, allowing more time for sorption or biological degradation of many contaminants. Groundwater in such fine-grained sediments generally contains little dissolved oxygen (less than 1 mg/L). In these anoxic conditions, dissolved nitrogen generally occurs in ammonia or organic forms and any nitrate present is reduced to nitrogen gas. Conversely, concentrations of iron and manganese, which occur naturally in aquifer sediments and are more soluble and therefore mobile under reducing conditions, are commonly elevated in anoxic groundwater. Denver and others (2014, p. 29) provide a description of redox processes that occur in groundwater systems. The occurrence of nitrate and iron together in a water sample may indicate mixing of groundwater from zones of different redox conditions as iron will only dissolve in oxic groundwater where pH is particularly low (Hem, 1992). Arsenic and other metals are also more mobile in groundwater under anoxic conditions. Therefore, metals, such as arsenic, can occur naturally in the aquifer materials and become mobilized by redox processes, or they can be the result of anthropogenic sources.

Major-Ion Geochemistry

Groundwater in sampled wells in the study area is chemically variable, but predominantly anoxic, and an iron- or calcium-bicarbonate type (Klohe and Debrewer, 2007) (fig. 10). Groundwater samples were collected from 17 wells screened in three geologic settings: Holocene alluvium (including overlying dredge spoils) along the Anacostia River and tributaries (6 wells); Upper Tertiary and younger terrace deposits (4 wells); and unconfined and confined parts of the Potomac Group (7 wells) (table 1). The predominantly anoxic conditions in groundwater are shown by the common occurrence of iron and manganese at high concentrations, and concentrations of nitrate that are below detection. Iron concentrations exceeded 15,000 mg/L in most of the groundwater samples from the Holocene alluvium (table 5), and are above the District of Columbia groundwater standard of 300 µg/L (District of Columbia, 1993). Low concentrations of sulfate in groundwater within the alluvium indicate that much of the groundwater with high iron concentrations has been chemically altered by sulfate reduction. Under such anoxic conditions, dissolved oxygen should be below detection in groundwater. The occurrence of detectable dissolved oxygen in samples from the alluvium where anoxic conditions are indicated may be the result of mixing of water from anoxic and oxic zones in the aquifer, or from the introduction of air during sampling (table 5).

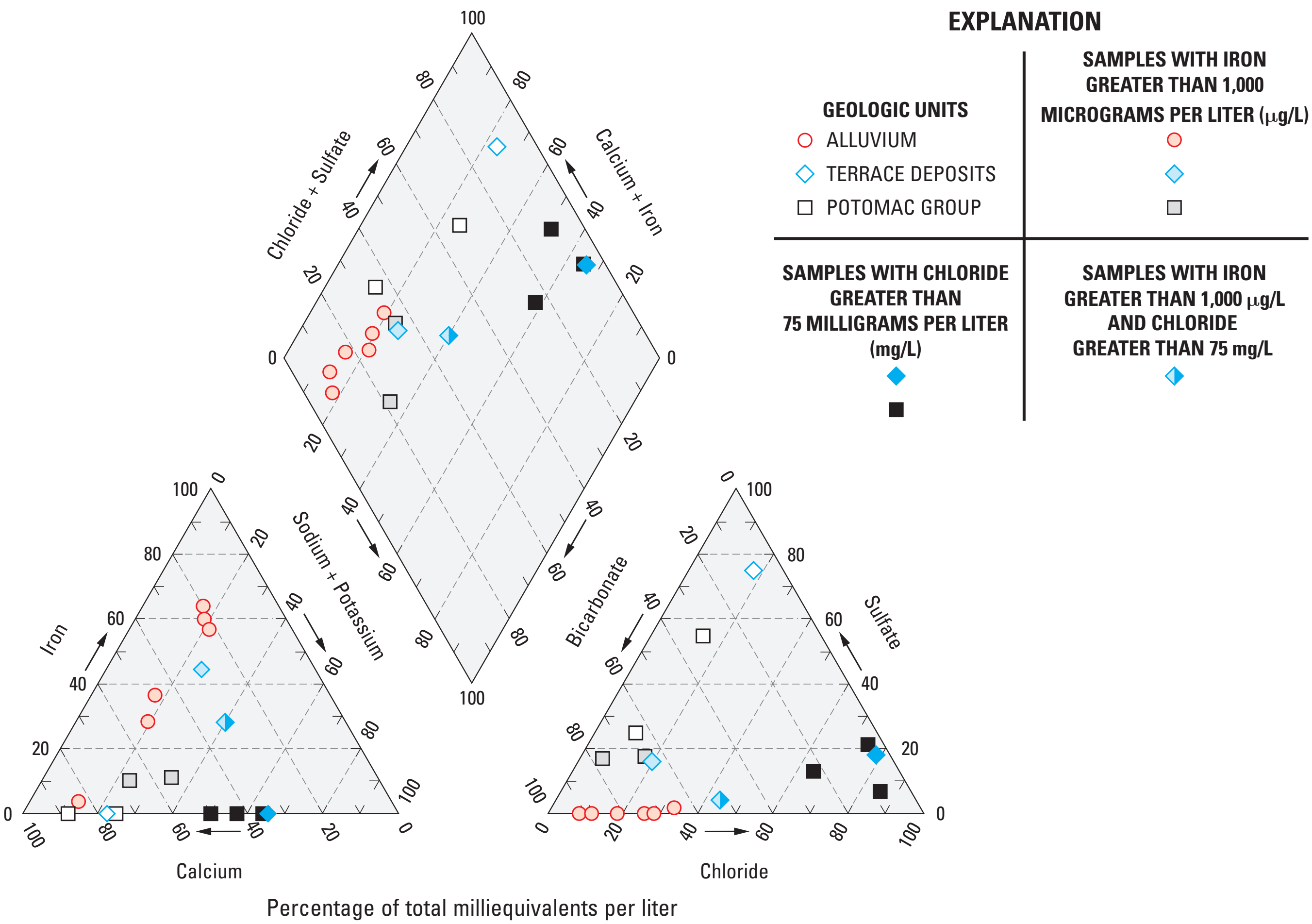

Figure 10. General water chemistry by geologic unit for groundwater samples collected from the Anacostia River watershed in Washington, D.C., September–December 2005. Percentages of particular ions increase in the direction of the arrow on each axis (modified from Klohe and Debrewer, 2007).

Groundwater from terrace deposits and the Potomac Group is more commonly oxic and more vulnerable to contamination from surficial sources than groundwater in the alluvium. Nitrate concentrations above 1 mg/L indicate the presence of human nitrogen sources; nitrate was above the District of Columbia groundwater standard of 10 mg/L in well WW Bc 8 (11.2 mg/L) (table 5). Concentrations of chloride in five samples (from wells WE Ca 32, WE Ca 33, WE Cc 3, WW Bc 8, and WW Bc 9) exceeded 75 mg/L (fig. 10, table 5), indicating significant infiltration of salty water, such as from road salting (Williams and others, 1999). Chloride in well WE Ca 32 (257 mg/L) was above the District of Columbia groundwater standard of 250 mg/L. Iron concentrations were generally low in these oxic groundwater samples, although other samples with dissolved oxygen below detection had elevated concentrations of iron and manganese (generally found in anoxic groundwater) (table 5). Concentrations of both nitrate and iron were relatively high in well WE Cc 3, indicating a mixture of water from oxic and anoxic zones in the aquifer (table 5). Some oxic groundwater also contains manganese at concentrations above the District of Columbia groundwater standard (table 5). Although high concentrations of manganese are more common in anoxic water, manganese is more stable than iron in oxic water and may occur at high concentrations (Hem, 1992).

Human Impacts on Groundwater Quality

Anthropogenic influences on groundwater quality in the tidal Anacostia River watershed are apparent from the occurrence and distribution of selected inorganic and organic ions and compounds. Chloride and nitrate occur naturally in the environment, but elevated concentrations observed in some areas of the watershed are indicative of human sources, such as fertilizer applications, leaking sewer lines, or road salt. Many organic compounds (such as pesticides and VOCs) have no natural sources, and their occurrence in groundwater is clearly related to potential human sources typical of the heavily urbanized watershed.

Table 5. Summary of selected water-quality constituents in groundwater in different geologic settings in the Anacostia River watershed within Washington, D.C., 2005.

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter, µg/L, micrograms per liter; N, nitrogen; --, not measured; <, less than; E, estimated]

Well number	Specific conductance (µS/cm)	pH	Dissolved oxygen (mg/L)	Chloride mg/L	Iron (µg/L)	Manganese (µg/L)	Nitrate (mg/L as N)	Ammonia (mg/L as N)	Phosphorus (mg/L)	Sulfate (mg/L)	Arsenic (µg/L)
Alluvium											
AC Aa 1	291	6.7	3.1	9.39	22,500	63.1	< 0.06	3.81	0.43	< 2	39.9
WE Bb 3	363	5.9	1	23	54,400	2,330	< 0.06	4.38	0.49	< 2	0.38
WE Bb 4	279	6	1.6	24.2	36,900	1,600	< 0.06	1.76	0.43	< 2	0.4
WE Ca 29	179	6	1.1	17.8	23,900	141	< 0.06	0.54	0.18	< 2	3.1
WE Ca 34	696	7.3	< 1	27.6	7,930	643	< 0.06	3.27	0.2	E.1	2.1
WE Cb 11	355	6.2	--	37	17,200	5,890	< 0.06	0.15	< 0.04	2.7	0.79
Terrace deposits											
WE Ca 32	1,100	5.6	5.8	257	13	2.8	7.74	< 0.10	< 0.04	79.7	0.43
WE Ca 33	710	6.7	< 1	108	37,800	6,830	< 0.06	< 0.04	< 0.20	14.1	5.8
WE Cb 5	286	5.3	4.5	11.9	E3	19.3	5.41	0.12	< 0.04	76.7	E.06
WE Cb 6	87	6.2	< 1	5.58	5,210	92	< 0.06	0.18	0.13	6.4	3.4
Potomac Group											
WE Ba 9	649	6.2	< 1	24.2	< 6	554	1.36	0.4	< 0.04	91.1	E0.1
WE Ba 10	261	5.4	< 1	11.4	< 6	176	1.15	E0.07	< 0.04	61.1	E.06
WE Cb 8	151	6.8	--	2.91	3,070	189	< 0.06	E0.08	0.29	11.8	E0.11
WE Cb 12	164	5.8	< 1	9.14	3,060	1,400	< 0.06	0.15	< 0.04	12.5	0.3
WE Cc 3	854	5.9	2	170	815	255	3.03	0.16	< 0.04	46.7	0.12
WW Bc 8	482	5	1.7	97.4	8	480	11.2	0.56	< 0.04	11.4	0.28
WW Bc 9	371	4.8	--	77.3	7	296	2.92	E0.07	< 0.04	30.6	0.2

Organic contaminants, including VOCs and SVOCs, diesel-range and gasoline-range organics, and pesticides and their degradants, were detected in shallow groundwater in the study area. Although only a few of the more than 200 anthropogenic organic compounds for which samples were analyzed were detected in groundwater, at least 1 such compound was detectable in samples from 15 of the 17 wells (table 6) (Klohe and Debrewer, 2007). The most commonly detected compounds were solvents, pesticides, and pesticide degradants (tables 6, 7). Concentrations of detected compounds were compared to District of Columbia groundwater standards, U.S. Environmental Protection Agency Maximum Contaminant Levels (MCLs) and Risk-Based Concentrations (RBCs) (Klohe and Debrewer, 2007). Concentrations were generally well below established standards and many were detected below their laboratory reporting levels. One exception is tetrachloroethene, which was measured at 68 µg/L in water from well WW Bc 8; the District of Columbia groundwater standard is 5 µg/L for this compound. Several of the detected pesticide and degradant compounds (dieldrin, heptachlor epoxide, p,p’-DDE, and chlordane) have been banned since at least the 1980s (Klohe and Debrewer, 2007); their presence in groundwater is related to their persistence in the environment and the slow traveltime of groundwater.

The distribution of organic contaminants in groundwater is related to the local hydrogeologic setting and natural aquifer geochemistry, as well as the distribution of potential sources. The frequency of detection and variability in types of organic contaminants were generally greater in wells located in areas with high density residential, commercial, or municipal development (particularly in wells WE Ca 32, WE Ca 33, and WW Bc 8), for example, than in settings like neighborhoods and municipal parks, where most of the other sampled wells are located (table 6).

Table 6. Distribution of organic compounds by type in groundwater samples from different geologic settings in the Anacostia River watershed within Washington, D.C., 2005.

[Shading indicates compounds were detected; number indicates number of individual compounds, where reported.]

Well number	Gasoline hydrocarbons	Gasoline oxygenates	Solvents	Pesticides or degradates	Phenols	Phthalates	Diesel range organics	Gasoline range organics	Oil and grease
Alluvium									
AC Aa 1									
WE Bb 3			1	1					
WE Bb 4			1						
WE Ca 29			1						
WE Ca 34									
WE Cb 11									
Terrace deposits									
WE Ca 32			1	7					
WE Ca 33	3	2	1	1					
WE Cb 5		1	1						
WE Cb 6									
Potomac Group									
WE Ba 9				1					
WE Ba 10									
WE Cb 8				1					
WE Cb 12			1						
WE Cc 3				2					
WW Bc 8			6						
WW Bc 9			1	3					

Potomac Group

Groundwater in the Potomac Group occurs in the sand-dominated lithofacies (Patuxent aquifer), as well as relatively coarse sediments in the overlying Potomac Group clay-dominated lithofacies. Where these sediments crop out in parts of the study area (figs. 3, 4*A*, 4*B*), groundwater is vulnerable to contamination from the land surface or from near-surface leaks and spills. Nitrate and chloride concentrations in five of the seven Potomac Group wells indicate oxic groundwater and human impacts, such as fertilizer applications, leaky sewers, or road salting (table 5). Organic contaminants were present in groundwater in all but one of these wells (WE Ba 10) (table 6), which contained only slightly elevated concentrations of nitrate and chloride (table 5). Most of the observed concentrations of organic contaminants were relatively low, and sources are apparently diffuse and at or near the land surface. Water from well WW Bc 8 was particularly contaminated with solvents and hydrocarbon compounds that may be associated with an unidentified leak in an underground tank.

Organic contaminants also were present in samples from selected Potomac Group wells with relatively high iron concentrations and, therefore, anoxic groundwater (tables 5, 6). Concentrations of both nitrate (indicative of oxic aquifer conditions) and iron (indicative of anoxic conditions) were relatively high in samples from well WE Cc 3 (table 5), indicating that this well may be screened across two geochemical environments in the aquifer. The particularly high chloride concentration in water from this well indicates infiltration from road surfaces. Water from well WE Cb 8, which is 265 ft deep and screened in the confined part of the Patuxent aquifer, showed characteristics of natural groundwater quality (table 5), but also had a very low concentration of a pesticide used for weed control (metsulfuron methyl). This contamination may be related to a broken well cap that allowed water from the surface to enter the well.

Table 7. Summary of organic compounds detected in groundwater samples from 17 wells in the Anacostia River watershed within Washington, D.C., September–December 2005 (modified from tables 7 and 8 in Klohe and Debrewer, 2007).

[1, indicates number of compounds detected; *, indicates one or more detections below reporting level; CEAT, 2-cloro-6-ethylamino-*s*-triazine; CIAT, 2-chloro-4-isopropylamino-6-amino-*s*-triazine; OIET, 2-Hydroxy-4-isopropylamino-6-ethylamino-*s*-triazine]

Volatile organic compounds	Semivolatile organic compounds
1,2,Dichloroethane (1*)	bis(2-Ethylhexyl) phthalate (1*)
Dichloromethane (4*)	Phenols, total recoverable (2*)
Isopropylbenzene (1)	**Pesticides and degradates**
methyl *tert*-butyl ether (2*)	Atrazine (1)
n-Butylbenzene (1)	Bromacil (1*)
sec-Butylbenzene (1)	CEAT (1*)
tert-Butylbenzene (1*)	CIAT (2*)
Tetrachloroethene (1)	Dieldrin (2)
Toluene (1*)	Heptachlor epoxide (2)
Trichloroethene (1)	Imidacloprid (1)
Trichloromethane (5*)	Metsulfuron (1)
Diesel-range/ gasoline-range organics	OIET (1*)
Diesel-range organics (6*)	p,p'-DDE (1)
Gasoline-range organics (5*)	Chlordane, technical mix (1)
Oil and Grease (2*)	Tebuthiuron (1)

Terrace Deposits

The terrace deposits include fining-upward sequences of gravel, sand, silt, and clay and form the land surface over much of Washington, D.C. in the Anacostia River Valley (fig. 3). Much of the area covered by sandy deposits near the land surface is vulnerable to contamination. Water quality in these deposits is quite variable, ranging from apparently uncontaminated (in well WE Cb 6) to highly contaminated (in wells WE Ca 32 and WE Ca 33) (tables 5, 6). This variability is related to the heterogeneous hydrogeologic conditions in these deposits, as well as the variability in urban sources of contamination. Groundwater in well WE Cb 6 is confined, and the low specific conductance and chloride concentrations indicate minimal (if any) anthropogenic impacts (table 5). In contrast, specific conductance and chloride concentrations were considerably higher in groundwater from wells WE Ca 32 and WE Ca 33. Groundwater from well WE Ca 32 also contained nitrate and sulfate at relatively high concentrations, indicative of possible sewage contamination, as well as a variety of pesticides (mostly insecticides), and hydrocarbon-related organic compounds. Contaminants in well WE Ca 33 were generally petroleum-related compounds indicative of a leak or spill. Water from well WE Ca 33 was anoxic (with a relatively high dissolved-iron concentration), possibly due to degradation of petroleum-related compounds and related consumption of dissolved oxygen and nitrate in the water.

Alluvium

Alluvial sediments (and fine-grained fill dredged from the river channel and placed over buried marsh deposits) are located beneath and adjacent to the Anacostia River and its tributaries (fig. 3). These sediments typically contain abundant organic matter, and groundwater is therefore generally anoxic, with very high concentrations of dissolved iron and little detectable sulfate or nitrate (table 5). Concentrations of ammonia, organic nitrogen, and arsenic also are generally higher in groundwater in the alluvium than in most samples from other hydrogeologic settings; these compounds could be derived from natural sources such as buried marshes. The highest arsenic concentration, 39.9 µg/L, was measured in groundwater from well AC Aa 1 near Poplar Point, where arsenic contamination in soil has been documented (Ridolfi Inc., 2005). Chloride concentrations were slightly elevated in samples from all six alluvium wells, but not as high as might be expected from significant infiltrations of salty road runoff (table 5). Organic chemicals detected in these samples could be indicative of above- or below-ground releases, although the relatively fine-grained, organic-rich alluvium is not particularly conducive to contaminant transport. As a result, concentrations and detection frequencies of organic contaminants were generally lower in water samples from these areas (areas labeled as Qa on fig. 3) than in many samples from other parts of the study area, and may be indicative of diffuse sources (table 6). Because of the proximity of the wells screened in the alluvium to the Anacostia River (fig. 2) and the predominant hydraulic gradient of the water table toward the river (fig. 8), however, dissolved chemicals in alluvial sediments may be particularly relevant to surface-water quality.

Comparison of Groundwater Quality in 2002 and 2005

Data presented in Miller and Klohe (2003) and Klohe and Debrewer (2007) indicate that groundwater quality in sampled wells has changed minimally over recent years, as would be expected in light of the typically slow movement of groundwater. Temporal comparisons are complicated by variable sample collection and analysis methods. Specific conductance and pH, however, varied by only 2 to 15 percent between 2002 and 2005 in samples from five wells for which data are available. Similarly, concentrations of phosphorus and ammonia plus organic nitrogen in samples from these wells in 2002 were generally within 0.3 mg/L of those measured in 2005. Concentrations of selected dissolved trace metals (measured in filtered samples) in 2005 were generally less than or equal to the whole-water concentrations (measured in unfiltered samples) in 2002. Trichloromethane (chloroform) was the only anthropogenic organic compound detected above a common level in the same well in 2002 and 2005; concentrations in well WE Cb 5 were 5.7 and 0.95 µg/L (estimated) in 2002 and 2005, respectively.

Summary and Conclusions

Hydrology and groundwater quality in the tidal Anacostia River watershed in Washington, D.C. are affected by multiple natural and human influences. Although sources of some ions or compounds to the land surface or groundwater may be natural, other compounds (such as pesticides and volatile organic compounds, or VOCs) are exclusively anthropogenic, and may be derived from many different human activities in the heavily urbanized watershed. The distribution of these compounds in groundwater and streams in the study area is related to spatially variable hydrogeologic and geochemical conditions that control their movement and persistence in the environment, as well as the distribution and magnitude of sources. Hydrologic, geochemical, and geologic data were collected over a multi-year period and interpreted along with similar existing information to improve understanding of the hydrogeology and groundwater quality in the tidal Anacostia River watershed.

The tidal Anacostia River watershed is underlain by a wedge of heterogeneous unconsolidated sediment that forms a series of aquifers and confining units overlying a sloping bedrock surface. The Patuxent aquifer, the oldest and lowermost unconsolidated unit, crops out and subcrops in the northwestern part of the study area along the Fall Line and dips to the southeast. This aquifer is confined to the southeast by the overlying Potomac Group clay-dominated lithofacies (where present), which is relatively thick and likely isolates the confined Patuxent aquifer from the Anacostia River. Above the Potomac Group sediments are younger Upper Cretaceous and Tertiary marine deposits, coarse upland deposits, and alluvial and terrace deposits. Surficial and near-surface sediments are particularly variable and difficult to correlate at the watershed scale, and surficial geology has been further complicated by more than 200 years of human alterations such as dredging and filling. Permeable surficial sediments form an extensive surficial aquifer system, although locally variable hydrologic and geochemical conditions in the system reflect the locally variable geology. The interbedded permeable and less permeable sediments in the surficial aquifer, for example, may cause local perched aquifers or semi-confined conditions.

Water levels and groundwater flow in the surficial aquifer system are controlled primarily by topography and the permeability of the sediments. Recharge to the surficial aquifer system occurs through infiltration of precipitation, as well as possible artificial sources such as underground water or sewer pipes. Unconfined groundwater generally flows from upland recharge areas in the northwest and southeast toward discharge areas in and near the Anacostia River and its tributaries. Discharge to the Anacostia River may be limited in areas by fine-grained riverbed sediment. Recharge to the Patuxent aquifer occurs primarily in the outcrop and subcrop areas, or as leakage from the less permeable overlying clays. Beneath the Anacostia River, the hydraulic heads in the confined Patuxent aquifer are higher than land surface, and discharge from this aquifer to the Anacostia River probably occurs where sediments of the Potomac Group clay-dominated lithofacies are absent.

Chemical data collected from 17 wells were analyzed for selected major ions, trace elements, nutrients, pesticides and pesticide degradants, VOCs and semi-volatile organic compounds, phenols, polychlorinated biphenyls, and oil and grease. Of over 200 chemicals included in these analyses, only 28 anthropogenic organic compounds were detected in groundwater from 15 of the 17 sampled wells, and over half of these compounds were only detected once. Only one organic compound in one sample, tetrachloroethene, was detected at a concentration above an existing health standard. Arsenic was detected at generally low levels; however, the concentration in one sample exceeded the U.S. Environmental Protection Agency Maximum Contaminant Level of 10 micrograms per liter. In addition, concentrations of iron and manganese were detected in many wells at levels above regulatory criteria due to reducing conditions in aquifer sediments.

The distribution of groundwater chemistry and contaminants in groundwater of the Anacostia River watershed is related to local hydrogeology and natural aquifer geochemistry, as well as land use and the associated distribution of potential sources. Nitrate and chloride concentrations in some areas likely exceed natural levels, and anthropogenic organic compounds were widely detected in shallow groundwater (particularly in the terrace deposits and Potomac Group). Groundwater in unconfined parts of the Potomac Group is primarily oxic, and concentrations of nitrate and chloride are indicative of infiltration of fertilizers, highway runoff, or water from leaky sewers. Organic contaminants were widely detected in these wells at relatively low concentrations, indicating diffuse sources. Samples from wells screened in terrace deposits were characterized by highly variable chemical concentrations as a result of diverse hydrogeologic conditions and potential variability in urban sources of contamination. Some samples contained high concentrations of nitrate and sulfate, a variety of pesticide compounds, or hydrocarbon-related compounds, whereas others showed minimal anthropogenic impacts. Groundwater in alluvial deposits along the Anacostia River and its tributaries is generally anoxic with very high concentrations of dissolved iron and little detectable sulfate or nitrate. Concentrations of ammonia, organic nitrogen and arsenic were generally higher than those in groundwater from the Potomac Group or terrace deposits, and may be derived from natural sources. Detection frequencies and concentrations of organic contaminants were generally lower in groundwater from alluvial deposits than in groundwater from other groups, likely reflecting the fine-grained nature of sediments in recharge areas and diffuse sources of contaminants.

Groundwater-flow rates and traveltimes must be considered when interpreting groundwater quality and geochemistry. One or more decades are generally required for the movement of groundwater from the water table to local discharge areas in the Atlantic Coastal Plain, although traveltimes may be significantly altered by dewatering, leaking sewer lines, or other human influences. Groundwater in confined aquifers is generally much older than groundwater in unconfined aquifers. Groundwater quality reflects human sources of compounds in the recharge areas during the time of recharge, which may change drastically over time. Several compounds that have not been used in many years remain detectable in groundwater of the tidal Anacostia River watershed, including dieldrin, heptachlor epoxide, p,p’-DDE, and chlordane. Many years may be required for the effects of watershed management practices, such as low-impact development, to be reflected throughout the aquifer system.

The transport of chemical compounds from human sources from the land surface, through groundwater, to the Anacostia River and other local streams is likely in the tidal Anacostia River watershed. Many anthropogenic compounds are soluble in water and have been detected in shallow groundwater of the study area. Groundwater flow is typically very slow under natural conditions, but may be accelerated by human alterations of local hydrology. The Anacostia River is the ultimate destination for most shallow groundwater in the study area, although the transport of dissolved constituents may be impeded by changing geochemical conditions. Groundwater seepage has been observed through bed sediments in the tidal Anacostia River. Interaction between the Anacostia River and the confined Patuxent aquifer is likely where intervening finer sediments of the Potomac Group clay-dominated lithofacies have been removed by erosion or other processes, and infiltration of river water into the aquifer may occur if hydraulic heads in the confined aquifer drop below the level of water in the river.

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Appendix 1. Selected Lithologic Core Descriptions in and near the Anacostia River Watershed

EXPLANATION

Geologic map units	Lithologic descriptions
dgf	Disturbed ground and artificial fill
Qa	Alluvium (Holocene)
Qt	Terrace deposits, low level (Holocene and Pleistocene)
Qte	Low-level fluvial and estuarine deposits (Pleistocene)
Qfe	Upper-level fluvial and estuarine deposits (Pleistocene)
Qtt	Terrace deposits, upper level (Pleistocene and Tertiary)
Tt	Terrace deposits (Tertiary)
Ttu	Highest level upland terrace deposits (Tertiary)
Tc	Calvert Formation (middle Miocene)
Ta	Aquia Formation (upper Paleocene)
TKb	Brightseat Formation and Monmouth Group, undivided (lower Paleocene and upper Cretaceous)
Km	Monmouth Formation
Kpc	Potomac Group clay-dominated lithofacies
Kps	Potomac Group sand-dominated lithofacies
bedrock	All consolidated Paleozoic and older rock

[Please note that this appendix presents lithologic descriptions from many different references, as noted in the header information, and descriptions by USGS personnel not previously published. Descriptions from cited references were not modified, except as noted; therefore descriptions presented in this appendix are not necessarily consistent with regards to terminology, punctuation, etc. Designations of tops and bottoms of geologic map units shown in this appendix were determined by the authors, with the exception of DC2, PG Cc 13, PG Cd 9, PG Dc 1, PG Dc 3, PG Dc 4, PG Eb 1, WE Ca 6, and WW Cc 26.]

Appendix 1. Lithologic descriptions.

Site name: AC Aa 2 (described by C. Klohe on March 6, 2006)

Altitude: 125.59 feet **Total depth:** 24 feet

Latitude / Longitude: 38° 51′ 57.4″ N / 76° 58′ 03.3″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Soil, and fill (dark gray gravel, light brown to yellow-orange sandy silt. (2.3 feet of recovery)	0.0	4.0	4.0
TKb	Light brown to yellow-orange silty sand. Brown, silty, fine-grained sand with gravels, woody organic material, and light gray clay. (2 feet of core recovery)	4.0	8.0	4.0
	Brown, silty, fine-grained sand. Black fine- to medium-grained sand and medium dark gray clayey sand. Root visible in core. Very high organic content. 1.5-inch diameter stone at bottom of core. (2 feet of recovery)	8.0	12.0	4.0
	Black, organic rich (wood pieces), silty sand. Light gray clayey sand. Light gray clay. Light gray clay with very thin layers of black organic material (leaves?). Layer of 0.4-inch diameter pebbles. Layer of light gray to medium gray clay. (2 feet of recovery)	12.0	16.0	4.0
Kpc	No recovery.	16.0	20.0	4.0
	Light gray clay mottled with maroon and yellow-orange clay. Some organic matter and some medium- to coarse-grained dark minerals.	20.0	21.0	1.0
	Light gray silty clay mottled with yellow-orange silty clay. medium- to coarse-grained dark minerals.	21.0	22.0	1.0
	Light gray to yellow-orange silt with some thin layers of very fine-grained sand.	22.0	23.0	1.0
	Light gray clay mottled with maroon-red clay.	23.0	24.0	1.0

Appendix 1. Lithologic descriptions.—Continued

Site name: AC Ab 3 (described by C. Klohe on March 13, 2006)

Altitude: 205 feet **Total depth:** 36 feet

Latitude / Longitude: 38° 52′ 07.1″ N / 76° 57′ 07.6″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Light gray and yellow-orange clay with poorly sorted, angular gravels. Some zones with poorly sorted coarse sand	0	3.5	3.5
	Medium brown silt with organic matter	3.5	4.0	0.5
TKb	Medium brown-gray silty clay with organic matter and gravels	4.0	5.5	1.5
	Light yellow-orange and tan clayey silt with poorly sorted, well rounded to subrounded gravel (0.12- to 0.75-inch diameter)	5.5	8.0	2.5
	Light brown, pooly sorted clayey coarse sand and gravel. Angular to well-rounded quartzite gravels (0.12- to 1.25-inch diameter)	8.0	9.5	1.5
	Light gray, poorly sorted coarse sand and gravel (subrounded)	9.5	11.5	2.0
	Light brown-gray clayey silt with poorly sorted gravel (0.12- to 0.75-inch diameter)	11.5	13.5	2.0
Kpc	Light gray clay	13.5	15.0	1.5
	Reddish-maroon and light gray mottled clay	15.0	20.0	5.0
	Light gray and reddish-brown mottled clay. Organic matter at 21.5 feet.	20.0	32.0	12.0
	Gray clay	32.0	36.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: Arena Stage (from Somes, 2003)

Altitude: 14 feet **Total depth:** 183 feet

Latitude / Longitude: 38° 52′ 37.01″ N / 77° 01′ 12.97″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Top soil	0.0	1.0	1.0
	Brown sandy clay with fill	1.0	6.0	5.0
Qte	Brown clay with some fine sand	6.0	14.0	8.0
	Hard layer of stones and pea gravel (slow)	14.0	32.0	18.0
Kpc	Orange and white and gray clay	32.0	59.0	27.0
	Medium to coarse sand	59.0	74.0	15.0
	Gray and red clay (slow)	74.0	115.0	41.0
	Fine to medium sand with some clay	115.0	124.0	9.0
	Red and gray clay (slow)	124.0	139.0	15.0
Kps	Fine to coarse sand with some clay	139.0	182.0	43.0
bedrock	Hard layer	182.0	183.0	1.0

Appendix 1. Lithologic descriptions.—Continued

Site name: AX Ac 2 (BPS-42), (Anthony Harding, DC Clean Rivers Project, written commun., 2011)

Altitude: 10.16 feet **Total depth:** 326 feet

Latitude / Longitude: 38° 52′ 28.39″ N / 77° 00′ 11.91″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	(Fill) Sampled as moist, brown to dark brown, fine to coarse, Silty Sand With Gravel, estimated 15–25% fines, estimated 15–25% gravel, subangular to subrounded gravel, contains brick fragments, upper 0.5 feet contains asphalt and concrete	0	8	8
	(FILL) Sampled as wet, dark grayish brown, soft, low to medium plasticity, Sandy Lean Clay, estimated 15–25% fine to coarse sand, estimated 5–10% fine gravel	8	11	3
	(FILL) Sampled as wet, dark grayish brown, medium plasticity, Lean Clay, estimated 5–10% fine to coarse gravel and cobbles (1-inch to 3-inch diameter), angular to subangular, contains wood debris	11	21	10
Qte	Moist, very dark grayish brown and very dark brown, ORGANIC SILT WITH SAND, estimated 15–25% fine to medium sand, moderate organic odor, numerous organics, contains wood fibers, approximately 1-inch to 3-inch peat layers from 21 feet to 25 feet. Pleistocene marsh deposits from pollen analysis, Christopher Bernhardt, written commun. At 25.0 feet changes to estimated 30–40% fines	21	30	9
	Wet, dark grayish brown, fine to coarse, WELL GRADED GRAVEL, subrounded gravel	30	39.5	9.5
	Moist, dark grayish brown, low plasticity, LEAN CLAY WITH SAND, estimated 15–25% fine sand, 4-inch cobble encountered at 42 feet	39.5	42	2.5

Appendix 1. Lithologic descriptions.—Continued

Site name: AX Ac 2 (BPS-42), (Anthony Harding, DC Clean Rivers Project, written commun., 2011)

Altitude: 10.16 feet **Total depth:** 326 feet

Latitude / Longitude: 38° 52′ 28.39″ N / 77° 00′ 11.91″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qte	Wet, dark gray, fine to medium, POORLY GRADED SAND, estimated < 5% fine sand. At 43.7 feet contains 3-inch layer of silt with wood fibers	42	44.5	2.5
	Wet, dark gray, fine to medium, POORLY GRADED SAND WITH GRAVEL, estimated 30–45% gravel, estimated < 5% fines, subrounded gravel, contains 6-inch layer of moist to wet, light gray to dark gray, fine to medium POORLY GRADED SAND WITH SILT, estimated 5–10% fines	44.5	52	7.5
	Moist, very stiff, reddish brown and olive brown, high plasticity, FAT CLAY, estimated < 5% fine sand	52	54	2
	Moist, dark yellowish brown and light gray, low plasticity, fine to medium, SILTY SAND, estimated 15–25% fines	54	57	3
	Moist, dark yellowish brown and light gray, fine to medium, POORLY GRADED SAND WITH SILT, estimated 5–10% fines	57	61	4
	Moist, gray, medium plasticity, SANDY LEAN CLAY, estimated 30–45% fine to medium sand, estimated < 5% dark gray-black lignite, lignite is soft/smears	61	62	1
	Moist to wet, gray, fine to medium, POORLY GRADED SAND WITH CLAY, estimated 5–10% fines	62	67.5	5.5
	Moist, very stiff, gray and olive brown, medium plasticity, SANDY FAT CLAY, estimated 30–45% fine sand. At 73.0 feet changes to estimated 30–45% lignite, contains approximately 4-inch layer of crisp lignite	67.5	75	7.5
Kps	Moist to wet, gray, fine to medium, CLAYEY SAND, estimated 15–25% fines	75	76	1
	Wet, gray, fine to medium, POORLY GRADED SAND, estimated < 5% fines	76	77.5	1.5
	Moist to wet, gray, fine to medium, CLAYEY SAND, estimated 15–25% fines	77.5	80	2.5
	Wet, light gray, fine to medium, CLAYEY SAND, estimated 15–25% fines, estimated < 5% fine gravel. At 92.5 feet contains 6-inch layer of SANDY CLAY	80	95	15
	Moist, very stiff, light gray, high plasticity, FAT CLAY, estimated 5–10% fine sand	95	98	3
	Moist, light gray and olive brown, fine to medium, CLAYEY SAND, estimated 15 –25% fines	98	100	2
	Wet, light gray, fine to medium, POORLY GRADED SAND WITH SILT, estimated 5–10% fines, contains 12-inch layer of moist, light gray, fine to medium, CLAYEY SAND at 104	100	105	5
	Moist, very stiff, dark gray, high plasticity, FAT CLAY, estimated < 5% fine sand. At 106.0 feet fine sand lamination present from 106 feet to 109.5 feet	105	109.5	4.5
	Moist, dark gray and light gray, high plasticity, SANDY FAT CLAY, estimated 30–45% fine to medium sand (present in layers/laminations, interbedded with clay), contains 6-inch layers of POORLY GRADED SAND WITH CLAY and POORLY GRADED SAND at 113 feet and 113.5 feet	109.5	114	4.5
	Moist, gray to very dark gray, fine to medium, POORLY GRADED SAND WITH SILT, estimated 5–10 % fines, estimated 30–45% lignite, crisp lignite	114	116.5	2.5
	Moist, dark gray, fine, SILTY SAND, estimated 30–45% fines, low plasticity, laminated	116.5	115.5	1
	Moist, dark gray, medium plasticity, LEAN CLAY WITH SAND, estimated 15–25% fine sand. Patuxent Formation from pollen analysis, Raymond Christopher, written commun.	117.5	125.5	8

Appendix 1. Lithologic descriptions.—Continued

Site name: AX Ac 2 (BPS-42), (Anthony Harding, DC Clean Rivers Project, written commun., 2011)

Altitude: 10.16 feet **Total depth:** 326 feet

Latitude / Longitude: 38° 52′ 28.39″ N / 77° 00′ 11.91″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Moist to wet, dark gray, fine to medium, POORLY GRADED SAND WITH CLAY, estimated 5–10% fines	125.5	130.5	5
	Moist, hard, dark gray, high plasticity, FAT CLAY, estimated < 5% fine sand	130.5	133.5	3
	Moist to wet, dark gray, fine to medium, CLAYEY SAND, contains 6-inch and 15-inch layers of moist, dark gray fine to medium, POORLY GRADED SAND at 135 feet, 136 feet, and 138 feet, contains 4-inch and 6-inch layers of FAT CLAY at 136.2 feet and 137 feet, contains lignite from 148 feet to 139 feet. Contains 2-inch layer of crisp lignite at 139 feet.	133.5	140	6.5
	Wet, loose, dark gray, fine to medium, POORLY GRADED SAND, estimated < 5% fines	140	141	1
	Moist to wet, dark greenish gray, fine to medium, CLAYEY SAND, estimated 15–25% fines, FAT CLAY lenses present	141	142	1
	Moist, hard, dark greenish gray, high plasticity, FAT CLAY, estimated < 5% fine to coarse sand	142	144	2
	Wet, light gray to gray, POORLY GRADED SAND WITH CLAY, estimated 5–10% fines	144	148	4
	Moist, gray to dark gray, fine to coarse, CLAYEY SAND WITH GRAVEL, estimated 15–25% fines, estimated 15–25% fine to coarse gravel, subrounded gravel, contains 2-inch lens of crisp lignite at 148 feet	148	149	1
	Moist, hard, gray to dark gray, high plasticity, FAT CLAY, estimated < 5% fine sand	149	150	1
	Wet, gray, fine to medium, POORLY GRADED SAND, estimated < 5% fines	150	150.8	0.8
	Moist, hard, dark gray, medium plasticity, LEAN CLAY, estimated 5–10% fine sand, estimated < 5% lignite, contains fine sand as 2-inch to 3-inch layers	150.8	156.5	5.7
	Wet, light gray, fine to medium, POORLY GRADED SAND WITH CLAY, estimated 5–10% fines	156.5	160	3.5
	Moist, hard, gray with mottles of olive brown, high plasticity, FAT CLAY, estimated < 5% fine sand, mottles are multi colored with gray, olive brown, and reddish brown. At 162.0 feet changes to hard, dark reddish brown with mottles of olive brown. At 170.0 feet changes to stiff. At 175.0 feet changes to hard, dark reddish brown with mottles of light bluish gray.	160	177	17
	Moist, hard, light bluish gray, high plasticity, SANDY FAT CLAY, estimated 30–45% fine sand	177	179	2
	Moist, hard, dark reddish brown and light bluish gray, high plasticity, FAT CLAY, estimated < 5% fine sand. At 180.0 feet changes to stiff, light bluish gray. At 181.0 feet changes to hard, dark reddish brown and light bluish gray. At 182.5 feet changes to dark reddish brown and olive brown, contains mottles of light bluish gray. At 191.0 feet changes to light bluish gray and dark reddish brown, contains mottles of pale red and olive brown	179	192.5	13.5
	Moist, hard, bluish gray with mottles of dark reddish brown, SANDY FAT CLAY, estimated 30–45% fine sand	192.5	197.5	5
	Moist, bluish gray, CLAYEY SAND, estimated 30–45% fines	197.5	206	8.5
	Moist, bluish gray, fine to medium, SILTY SAND, estimated 15–25% fines	206	213.5	7.5

Appendix 1. Lithologic descriptions.—Continued

Site name: AX Ac 2 (BPS-42), (Anthony Harding, DC Clean Rivers Project, written commun., 2011)

Altitude: 10.16 feet **Total depth:** 326 feet

Latitude / Longitude: 38º 52′ 28.39″ N / 77º 00′ 11.91″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Moist, hard, bluish gray with mottles of reddish brown, medium plasticity, FAT CLAY, estimated 5–10% fine sand. At 220.0 feet changes to light bluish gray and dark reddish brown, estimated < 5% fine sand. At 222.0 feet contains thin (< 0.1 feet) fine to medium gravel lenses at 222 feet and 226 feet	213.5	227	13.5
	Moist, light bluish gray, medium plasticity, SANDY LEAN CLAY, estimated 30–45% fine sand	227	230	3
	Moist to wet, light bluish gray, fine to medium, CLAYEY SAND, estimated 15–25% fines	230	237	7
	Moist, hard, dark greenish gray, low plasticity, LEAN CLAY, estimated 5–10% fine sand. At 244.5 feet changes to dark greenish gray with mottles of olive brown	237	249	12
	Wet to moist, medium stiff to stiff, dark grayish brown, medium plasticity, SANDY SILT, estimated 5–10% fine sand	249	251	2
	Moist, hard, dark gray, medium plasticity, LEAN CLAY	251	258	7
	Moist, dense, light bluish gray, fine to medium, CLAYEY SAND, estimated 30–45% fines	258	260	2
	Wet, dark gray, fine to coarse, WELL GRADED SAND WITH CLAY, estimated 5–10% fine gravel, estimated 5–10% fines, subrounded gravel	260	262	2
	Moist, bluish gray, fine to medium, SILTY SAND, estimated 15–25% fines, contains 2-inch crisp, dense lignite at 265 feet	262	265.5	3.5
	Moist, hard, bluish gray, medium plasticity, LEAN CLAY, estimated 5–10% fine sand. At 276.0 feet contains 6-inch layer of moist dark gray, fine to medium, CLAYEY SAND at 276 feet to 276.5 feet	265.5	277	11.5
	Moist to wet, bluish gray, fine to coarse, WELL GRADED SAND WITH CLAY, estimated 5–10% fines, estimated 5–10% fine to coarse gravel, rounded to subrounded gravel	277	279	2
	Moist to wet, bluish gray, fine to coarse, POORLY GRADED SAND WITH SILT AND GRAVEL, estimated 5–10% fines, estimated 15–25% fine gravel, subrounded gravel, weak cementation	279	280.8	1.8
	Moist, hard, bluish gray, high plasticity, FAT CLAY, estimated < 5% fine sand, very thinly bedded to very thinly laminated	280.8	284	3.2
	Moist, loose, bluish gray, fine to coarse, SILTY SAND, estimated 15–25% fines, contains 2-inch layer of FAT CLAY at 284.8 feet	284	286	2
	Moist, loose, bluish gray, fine to coarse, SILTY GRAVEL WITH SAND, estimated 15–25% fines, estimated 15–25% fine to coarse sand, rounded to subrounded gravel, strong cementation	286	286.7	0.7
	Moist, hard, bluish gray, high plasticity, FAT CLAY, estimated < 5% sand, very thinly bedded to very thinly laminated	286.7	289.5	2.8
	Moist to wet, loose, bluish gray, fine to coarse, WELL GRADED SAND, estimated < 5% gravel, estimated < 5% fines	289.5	295	5.5
	Moist, loose, bluish gray, fine to coarse, WELL GRADED SAND WITH GRAVEL, estimated 30–45% gravel, rounded to subrounded gravel	295	296	1

Appendix 1. Lithologic descriptions.—Continued

Site name: AX Ac 2 (BPS-42), (Anthony Harding, DC Clean Rivers Project, written commun., 2011)

Altitude: 10.16 feet **Total depth:** 326 feet

Latitude / Longitude: 38° 52′ 28.39″ N / 77° 00′ 11.91″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Moist, medium dense, bluish gray and greenish gray, fine to coarse, WELL GRADED GRAVEL WITH SAND, estimated 30–45% sand, rounded to subrounded gravel, weak to strong cementation	296	300	4
	Wet, greenish gray, fine to coarse, SILTY GRAVEL, estimated 15–25% fines, estimated 15–25% fine to coarse sand, rounded to subrounded gravel	300	302	2
	Moist, very stiff, greenish gray, medium plasticity, ELASTIC SILT WITH GRAVEL, contains rounded to subrounded gravel, moderate cementation	302	303.5	1.5
bedrock	Weathered bedrock (D. Powers, USGS, written commun., 2012)	303.5	316	12.5
	Metatonalite (J.W. Horton, USGS, written commun., 2012)	316	326	10

Appendix 1. Lithologic descriptions.—Continued

Site name: DC2 (from Otton, 1955)

Altitude: 19.26 feet **Total depth:** 400 feet

Latitude / Longitude: 38° 54′ 35.01″ N / 76° 56′ 16.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa	Clay, finely micaceous, silty, tan and red; pebbly	0.0	13.0	13.0
	Clay, gray, streaked with red and tan clay	13.0	24.0	11.0
	Gravel, fine, slightly clayey, consists of rounded and subangular pebbles of gray, white and pink chert	24.0	33.0	9.0
Kpc	Clay, silty, finely micaceous, red; contains inclusions of gray-green silty clay	33.0	53.0	20.0
	Clay, sandy, micaceous, gray and red; sample contains a few subrounded gravel pebbles	53.0	70.0	17.0
	Clay, gray, sandy, with inclusions of red clay	70.0	80.0	10.0
	Clay, red and pink, with inclusions of white clay; a few siderite spherules	80.0	123.0	43.0
	Clay, red and pink, with inclusions of white clay; a few siderite spherules	123.0	131.0	8.0
	Clay, red and pink, with inclusions of white clay; a few siderite spherules; one fragment black, vesicular, carbonaceous material	131.0	170.0	39.0
Kps	Sand, clean, coarse, well sorted, subangular; consists largely of gray and white quartz grains; few lumps of iron oxide	170.0	182.0	12.0
	Gravel, consisting of round pebbles of chert and red and gray clay (sample 60 percent clay pebbles and fragments)	182.0	195.0	13.0
	Sand, coarse, clean, gray; contains some quartz pebbles of gravel size	195.0	225.0	30.0
	Gravel, consisting of round pebbles of chert and red and gray clay (sample 60 percent clay pebbles and fragments)	225.0	230.0	5.0
	Sand, medium to coarse grained, gray and white, slightly feldspathic	230.0	242.0	12.0
	Sand, red, coarse (composed of quartz and reworked red clay granules); one piece of lignite	242.0	257.0	15.0

Appendix 1. Lithologic descriptions.—Continued

Site name: DC2 (from Otton, 1955)

Altitude: 19.26 feet **Total depth:** 400 feet

Latitude / Longitude: 38° 54′ 35.01″ N / 76° 56′ 16.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Sand, red-gray, fine to medium (quartz sand with associated red clays granules); few pellets lignitic material	257.0	271.0	14.0
	Sand, gray-white, medium grained, angular; some pyrite and marcasite; few pieces of lignite	271.0	295.0	24.0
	Clay, silty, red, with associated fine gravel	295.0	318.0	23.0
	Sand, medium to coarse grained, clean, gray; contains associated red clay inclusions	318.0	340.0	22.0
	Clay, red and gray; consists of rounded clay lumps and some rounded quartz or chert pebbles	340.0	345.0	5.0
	Sand, medium grained, subrounded, clean, gray; a few pieces of marcasite	345.0	354.0	9.0
	Gravel, fine, red and gray (sample consists of 50 percent quartz pebbles and 50 percent rounded clay pebbles)	354.0	377.0	23.0
bedrock	Clay, dull-brown and gray; pebbles of quartz and pieces of green schist or phyllite	377.0	400.0	23.0

Appendix 1. Lithologic descriptions.—Continued

Site name: D.C. Aquatic Resource Center PW-2 (from HSI Geotrans, Inc., 1998)

Altitude: 16 feet **Total depth:** 398 feet

Latitude / Longitude: 38° 52′ 42.01″ N / 76° 58′ 09.96″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Dark brown silty clay with brick fragments	0.0	13.0	13.0
	No sample	13.0	14.0	1.0
Qa and Qt	Dark greenish-gray clayey silt, abundant carbonaceous material, some roots, trace sand	14.0	21.0	7.0
	Dark gray silt, some clay, trace sand, abundant organic material, trace roots	21.0	28.0	7.0
	Dark greenish-gray clayey silt, some carbonaceous material, trace roots	28.0	38.0	10.0
	Light to medium brown and gray silty sand, some clay, loose, wet	38.0	40.0	2.0
	Yellow-brown, poorly sorted gravel and sand	40.0	46.0	6.0
	Light to medium gray sandy clay layer	46.0	49.0	3.0
	Medium gray gravel with fine to coarse sand	49.0	58.0	9.0
Kpc	Reddish-brown silty sand, traces of clay	58.0	102.0	44.0
	Red clay, moist , plastic, “sticky”	102.0	136.0	34.0
	Red clay, with traces of sand and gray clay, moist	136.0	168.0	32.0
Kps	Coarse sand with traces of gray clay	168.0	193.0	25.0
	Gray clay with some sand	193.0	202.0	9.0
	Coarse sand and clay, lignite runner	202.0	205.0	3.0
	Gray sandy clay	205.0	213.0	8.0
	Coarse sand and clay	213.0	242.0	29.0

Appendix 1. Lithologic descriptions.—Continued

Site name: D.C. Aquatic Resource Center PW-2 (from HSI Geotrans, Inc., 1998)

Altitude: 16 feet **Total depth:** 398 feet

Latitude / Longitude: 38º 52′ 42.01″ N / 76º 58′ 09.96″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Gray clay with some sand	242.0	251.0	9.0
	Coarse sand	251.0	262.0	11.0
	Clay with trace sand	262.0	293.0	31.0
	Sand	293.0	312.0	19.0
	Lignite	312.0	317.0	5.0
	Sand	317.0	323.0	6.0
	Clay	323.0	330.0	7.0
	Sand and clay	330.0	340.0	10.0
	Sticky clay	340.0	355.0	15.0
	Sand and some clay	355.0	362.0	7.0
	Coarse sand	362.0	392.0	30.0
bedrock	Rock, sand and clay (bedrock at 398 feet)	392.0	398.0	6.0

Appendix 1. Lithologic descriptions.—Continued

Site name: MW-2 (from DCWRRC, 1993a)

Altitude: 82.35 feet **Total depth:** 47 feet

Latitude / Longitude: 38º 54′ 23.00″ N / 77º 00′ 44.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Brown, sandy, damp, fill material	0.0	6.0	6.0
	About 7’ pieces of brick	6.0	7.5	1.5
Qte	No sample	7.5	10.0	2.5
	Brown, dry, medium grained sand	10.0	12.0	2.0
	No sample	12.0	15.0	3.0
	Brown, damp sand with some gravel	15.0	17.0	2.0
	No sample	17.0	20.0	3.0
	Brown, dry gravelly sand	20.0	22.0	2.0
Kpc	No sample	22.0	25.0	3.0
	Brownish-gray clay	25.0	27.0	2.0
	No sample	27.0	30.0	3.0
	Brown, very stiff, dry clay	30.0	32.0	2.0
	No sample	32.0	35.0	3.0
	Gray, dry clay with trace of silty sand	35.0	37.0	2.0
	No sample	37.0	40.0	3.0
	Gray, damp silty clay changes to wet sand	40.0	42.0	2.0
Kps	No sample	42.0	45.0	3.0
	Gray clayey medium grained sand	45.0	47.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: PG Cc 13 (from Cooke and others, 1952)

Altitude: 209.65 feet **Total depth:** 134 feet

Latitude / Longitude: 38º 58′ 30.00″ N / 76º 59′ 43.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Sand, clayey, grayish-orange to light brown	0.0	10.0	10.0
	Clay, silty, grayish-orange, finely micaceous	10.0	15.0	5.0
	Clay, silty, grayish-orange and dark yellow orange, micaceous; lignite fragments	15.0	20.0	5.0
	Clay, dense, tough, grayish orange to pale yellowish-orange	20.0	25.0	5.0
	Clay, sandy, grayish orange to very pale orange	25.0	30.0	5.0
	Clay, silty, soft, very pale orange to white	30.0	35.0	5.0
bedrock	Rock, schistose, soft, clayey and partially quartzitic, light olive-gray to greenish gray mica	35.0	40.0	5.0
	Rock, same as above, but somewhat darker in color, mica smaller, quartz grains less common	40.0	45.0	5.0
	Rock, same as above, few fragments feldspar, pink	45.0	50.0	5.0
	Rock, schistose, loose mica flakes, fine quartz grains	50.0	55.0	5.0
	No sample, driller reports “mica rock”	55.0	90.0	35.0
	Rock, schistose, similar to above sample	90.0	100.0	10.0
	No sample, driller reports “mica rock”	100.0	132.0	32.0
	Rock, schistose, loose mica flakes, fine quartz grains	132.0	134.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: PG Cd 9 (from Cooke and others, 1952)

Altitude: 135.4 feet **Total depth:** 160 feet

Latitude / Longitude: 38º 56′ 00.01″ N / 76º 51′ 57.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	No Sample	0.0	10.0	10.0
	Clay, silty, red-ochre	10.0	20.0	10.0
	Silt, sandy, cream-tan, slightly micaceous	20.0	30.0	10.0
	Silt, sandy, pink-red	30.0	40.0	10.0
	Silt, sandy, pink-red with dark nodules	40.0	50.0	10.0
	Clay, sandy, buff-cream	50.0	60.0	10.0
	No Sample	60.0	70.0	10.0
	Sand, medium to coarse, subangular, translucent and transparent, some grains pink and yellow quartz; some tripoli	70.0	80.0	10.0
	Sand, well-sorted, medium-grained, angular, pink-yellow; contains few black pellets of siderite (?)	80.0	90.0	10.0
	Sand, coarse, angular, moderately well-sorted, pink-white; contains some iron oxides	90.0	100.0	10.0
	Buff-white silty clay; contains some pellets of dark material	100.0	110.0	10.0

Appendix 1. Lithologic descriptions.—Continued

Site name: PG Cd 9 (from Cooke and others, 1952)

Altitude: 135.4 feet **Total depth:** 160 feet

Latitude / Longitude: 38º 56′ 00.01″ N / 76º 51′ 57.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Red-ochre sandy clay	110.0	120.0	10.0
	Red-ochre sandy clay; contains some quartz fragments	120.0	130.0	10.0
	Buff-white, slightly sandy clay	130.0	140.0	10.0
	Red, very sandy clay	140.0	150.0	10.0
	Pink-white, angular, clean, medium to coarse grained sand.	150.0	160.0	10.0
	No samples	160.0	185.0	25.0

Appendix 1. Lithologic descriptions.—Continued

Site name: PG Dc 1 (from Cooke and others, 1952)

Altitude: 290 feet **Total depth:** 365 feet

Latitude / Longitude: 38º 51′ 19″ N / 76º 56′ 05″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Ttu	Pliocene (?) deposits:			
	Gravel	0	26	26
Tc and Ta	Calvert Formation and Aquia greensand:			
	"Quicksand"	26	29	3
	Marl, green	29	89	60
TKb	Brightseat Formation and/or Monmouth Formation:			
	Shells	89	98	9
	"Mud," black	98	110	12
	Shells	110	119	9
Km and Kpc	Magothy (?) and Patapsco Formations			
	Clay, pink			
	Clay, red			
	Clay, yellow			
	Clay, blue			
	Clay, red	119	355	236
	Sand	355	365	10
	Clay, blue	At 365	--	--

Appendix 1. Lithologic descriptions.—Continued

Site name: PG Dc 3 (from Cooke and others, 1952)

Altitude: 290 feet **Total depth:** 388 feet

Latitude / Longitude: 38° 50′ 24″ N / 76° 56′ 32″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Ttu	Pliocene (?) deposits:			
	Clay, brown, and gravel	0	25	25
	Gravel	25	55	30
Tc	Calvert Formation:			
	Clay, yellow	55	70	15
Tc and Ta	Calvert Formation and Aquia greensand:			
	Marl	70	95	25
	Marl and shells	95	113	18
	Rock	113	114	1
	Marl and shells	114	123	9
TKb	Brightseat Formation and/or Monmouth Formation:			
	Rock and shells	123	125	2
	Marl		171	46
Km and Kpc	Magothy (?) and Patapsco Formations:			
	Clay	171	377	206
	Sand	377	388	11

Appendix 1. Lithologic descriptions.—Continued

Site name: PG Dc 4 (from Cooke and others, 1952)

Altitude: 250 feet **Total depth:** 620 feet

Latitude / Longitude: 38° 50′ 47″ N / 76° 57′ 10″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Ttu	Pliocene (?) deposits:			
	Clay, sand, and gravel	0	30	30
Tc, Ta, and(or) TKb	Calvert Formation, Aquia greensand, Brightseat Formation and/or Monmouth Formation:			
	Clay	30	60	30
	Marl	60	240	180
Km	Magothy (?) Formation:			
	Sand, fine (water)	240	252	12
Kpc	Potomac Group:			
	Clay, variegated	252	370	118
	Clay, sandy	370	406	36
	Clay, tough	406	458	52
	Sand, medium fine, gray (water)	458	475	17
	Clay, tough	475	620	145

Appendix 1. Lithologic descriptions.—Continued

PG Eb 1 (from Cooke and others, 1952)

Altitude: 14.3 feet **Total depth:** 603 feet

Latitude / Longitude: 38° 48′ 42.00″ N / 77° 00′ 21.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Topsoil and clay	0.0	6.5	6.5
	Gravel and "stones," large	6.5	19.0	12.5
Kpc	Variegated clay	19.0	38.0	19.0
	Gray clay	38.0	47.0	9.0
	Gray sandy clay	47.0	52.0	5.0
	Brownish-red clay	52.0	55.0	3.0
	Brownish-red clay	55.0	79.0	24.0
	Red and gray, mixed clay	79.0	90.0	11.0
	Medium-fine, gray clay	90.0	98.0	8.0
	Gummy, gray clay	98.0	107.0	9.0
	Sand (water)	107.0	123.0	16.0
	Sand (water) and clay in streaks	123.0	169.0	46.0
	Tough, red and gray clay	169.0	184.0	15.0
	Tough clay (very slow drilling)	184.0	207.0	23.0
	Shale (hard drilling), in hard and soft streaks	207.0	256.0	49.0
	Shale and clay, in hard and soft streaks	256.0	283.0	27.0
	Clay in hard and soft streaks, some sand	283.0	339.0	56.0
Kps	Mucky clay and sand, fine	339.0	429.0	90.0
	Clay and sand, sand a little coarser than above	429.0	540.0	111.0
	Thin sand lens and thick clay lens	540.0	567.0	27.0
	Sand and gravel with thin clay lens (rough drilling)	567.0	590.0	23.0
	Drills like hard rock, getting harder as it gets deeper; no rock returns expect what appears to be small quartz gravel	590.0	603.0	13.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-001 (described by Camp Dresser & McKee Inc./Hatch Mott MacDonald, written commun., 2008)

Altitude: 8.4 feet **Total depth:** 250 feet

Latitude / Longitude: 38° 52′ 20.87″ N / 77° 00′ 15.49″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa	No sample	0.0	8.0	8.0
	Moist, very soft, brown, silt. Trace of clay. Trace of fine sand at 16 feet. Dark brown with wood at 17 feet.	8.0	18.0	10.0
	Wet, dark brown, fine sand, some silt, trace clay, trace gravel, slightly organic, frequent fragments of partially decomposed wood.	18.0	20.0	2.0
	Wet, reddish brown, poorly graded fine to medium sand, trace silt.	20.0	23.0	3.0
	Wet, light gray and brown silt, with 2-inch clay layers, trace fine sand.	23.0	25.0	2.0
	Wet, light gray and brown fine sand and silt, trace fine subrounded gravel.	25.0	26.0	1.0
	Wet, light gray clay, some silt.	26.0	28.0	2.0
	Wet, light gray and brown fine sand, some clay, trace silt.	28.0	31.0	3.0
	Wet, green-gray, fine to medium sand, and fine to coarse subangular gravel, some silt.	31.0	33.0	2.0
	Wet, green-gray, well graded fine to coarse subangular gravel with fine to medium sand, trace silt.	31.0	35.0	4.0
	Wet, orange-red, poorly graded fine to coarse sand, little fine to medium subangular to subrounded gravel, trace silt.	35.0	37.0	2.0
	Wet, orange-red, well graded fine to coarse subangular to rounded gravel, some fine to coarse sand, trace silt.	37.0	45.0	8.0
	Wet, blue-green, fine sand, trace silt.	45.0	46.0	1.0
	Wet, gray, medium to coarse, subrounded gravel, some gray-green stiff clay with angular cobbles, little fine sand.	46.0	48.0	2.0
	Wet, hard, blue mottled red, clay, trace fine sand.	48.0	50.0	2.0
	Wet, hard, blue mottled red, silt, trace clay, trace fine sand.	50.0	55.0	5.0
	Wet, blue-gray, fine to medium sand, little silt.	55.0	57.5	2.5
	Wet, blue-gray, clayey fine sand, trace silt, occasional seams of stiff clay.	57.5	63.0	5.5
	Wet, blue-gray, fine to medium sand, little silt.	63.0	68.0	5.0
	Wet, blue-gray, poorly graded fine to coarse subangular sand, trace fine gravel, trace silt, trace clay, frequent seams of clay. Less clay below 75 feet.	68.0	80.0	12.0
Kps	Wet, blue-gray, medium to coarse sand, trace silt, trace clay.	80.0	82.0	2.0
	Wet, blue-gray, fine to medium sand, little to some clay.	82.0	85.0	3.0
	Wet, blue-gray, poorly graded fine to coarse sand, trace mica.	85.0	90.0	5.0
	Wet, blue-gray, fine to medium sand, little clay, trace mica.	90.0	94.0	4.0
	Wet, blue-gray, fine to medium sand, trace silt, trace fine, subangular gravel, traces of weak cementation.	94.0	99.0	5.0
	Wet, blue-gray, clayey fine to medium sand, little clay, trace silt.	99.0	100.0	1.0
	Moist to wet, hard, light gray-blue, silt and fine to medium sand, little clay.	100.0	105.0	5.0
	Moist to wet, hard, laminated brown, gray and red, clay, some fine to medium sand.	105.0	110.0	5.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-001 (described by Camp Dresser & McKee Inc./Hatch Mott MacDonald, written commun., 2008)

Altitude: 8.4 feet **Total depth:** 250 feet

Latitude / Longitude: 38º 52′ 20.87″ N / 77º 00′ 15.49″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Moist to wet, gray, silt, little fine sand, trace clay.	110.0	112.0	2.0
	Wet, gray and red-brown, fine sand, some clay, frequent seams of gray clay.	112.0	114.0	2.0
	Wet, gray, silty fine sand.	114.0	115.0	1.0
	Wet, brown, fine to medium sand and clay, with frequent clay layers.	115.0	120.0	5.0
	Wet, very stiff, dark gray, silt and fine to medium sand, little clay, occasional lignite fragments.	120.0	128.0	8.0
	Wet, gray, fine to medium sand, little silt, occasional lignite particles and fragments.	128.0	130.0	2.0
	-grades to fine to coarse sand, little clay.	130.0	135.0	5.0
	Wet, gray, fine to coarse sand, little clay.	135.0	139.0	4.0
	Wet, gray, poorly graded fine to coarse sand.	139.0	140.0	1.0
	Wet, gray, fine to medium sand, some silt, trace clay, frequent pocket of stiff clay lenses.	140.0	145.0	5.0
	Wet, gray, fine to medium sand, trace silt.	145.0	148.0	3.0
	Wet, gray, medium to coarse sand, trace silt, frequent layers of gray-green silty clay, occasional lignite particles.	148.0	158.0	10.0
	Wet, gray, silty fine to coarse sand, trace clay, trace silt.	158.0	163.0	5.0
	Wet, gray silt, and fine sand, occasional lignite fragments.	163.0	164.0	1.0
	Wet, hard, dark gray clay.	164.0	167.5	3.5
	Wet, gray, silt, some fine sand, little clay. Wet, hard, light gray and gray, mottled, silt, occasional seams of fine sand.	167.5	175.0	7.5
	Wet, hard, dark gray, clay, frequent seams of light gray fine sand.	175.0	179.0	4.0
	Moist to wet, gray, fine to medium sand, little silt.	179.0	180.0	1.0
	Moist to wet, light gray, clayey silt, some fine sand.	180.0	183.0	3.0
	Moist to wet, hard, brown to greenish gray, clay, trace silt. Dry to wet, hard, mottled red brown blue clay at 185 feet.	183.0	188.0	5.0
	Moist to wet, hard, green-gray, clayey silt, some fine sand.	188.0	194.5	6.5
	Moist to wet, gray-green, fine sand with silt. Occasional lignite particles near 199 feet.	194.5	200.0	5.5
	Moist to wet, gray-green, fine to medium sand, some clay, little silt.	200.0	211.0	11.0
	Moist to wet, gray-green, fine to medium sand, some silt	211.0	228.0	17.0
	Moist to wet, hard, light green silt.	228.0	230.0	2.0
	Moist to wet, hard, light green, clay.	230.0	235.0	5.0
	Moist to wet, blue and gray fine sand, little silt, little clay.	235.0	241.0	6.0
	Moist to wet, dark brown, fine sandy silt.	241.0	243.0	2.0
	Moist to wet, reddish brown silt.	243.0	245.0	2.0
	Moist to wet, gray mottled green clay and silt. Some fine sand.	245.0	250.0	5.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-002 (described by C. Dieter)

Altitude: 13 feet **Total Depth:** 156 feet

Latitude / Longitude: 38° 52′ 09.39″ N / 77° 00′ 06.12″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa	No recovery	0.0	9.0	9.0
	Dark brownish-gray clayey silt with organic matter	9.0	19.0	10.0
	Medium to light brown silty clay. Soft, moist, with organic matter	19.0	22.0	3.0
	Medium yellowish brown to dark chocolate brown clay with organic matter	22.0	25.5	3.5
	Sandy clay	25.5	26.0	0.5
	No recovery	26.0	28.0	2.0
	Gravelly sand. (Gravels up to 2-inch length of long diameter)	28.0	33.0	5.0
Kpc	Mottled light gray, pink, and yellowish brown silty clay	33.0	36.0	3.0
	Red clay with light gray mottling (stiff, tight clay)	36.0	56.0	20.0
	Red silty clay	56.0	57.5	1.5
	Red clay with a little light gray mottling and silty layers	57.5	61.0	3.5
	Red silty clay	61.0	72.5	11.5
	Red very fine sand, well sorted	72.5	75.5	3.0
	Red silt with zones that are more clayey and zones that are more sandy silt.	75.5	96.0	20.5
	Reddish-brown silt with zones that are more clayey and zones that are more sandy silt.	96.0	104.0	8.0
Kps	Medium brownish-gray clayey fine-grained sand	104.0	106.0	2.0
	Medium-grained, poorly sorted, sand. Becomes more clayey with some organic matter at 114.5 feet	106.0	115.0	9.0
	Medium-grained sand with a high percentage of organic matter (lignitized woody pieces)	115.0	116.0	1.0
	Fine-grained moderately well sorted clayey (tacky) sand with organic matter. Random medium gray clayey pockets.	116.0	131.0	15.0
	Coarse sand with clay and high percentage of organic matter	131.0	133.0	2.0
	Poorly sorted, subangular, coarse-grained sand. Some 0.75-inch diameter cobbles at about 140 feet	133.0	149.5	16.5
	Coarse sand with high clay content	149.5	150.5	1.0
	Medium-grained, moderately well sorted subangular sand	150.5	156.0	5.5

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-006 (described by C. Dieter)

Altitude: 12.3 feet **Total depth:** 182 feet

Latitude / Longitude: 38º 53′ 01.39″ N / 76º 58′ 16.65″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	No recovery	0.0	10.0	10.0
	Dark brown, poorly-sorted, soft, clayey silt. Fragments of glass, pebbles, sand, mica	10.0	17.0	7.0
Qa	No recovery	17.0	27.0	10.0
	Light brown to light gray, moderately well-sorted, fine-grained sand with dark grains and dark mica.	27.0	31.0	4.0
	Fine- to medium-grained sand with dark gray clay inclusions	31.0	34.0	3.0
	Dark gray, soft, silty clay with gravel (0.125-inch diameter) and trace mica. Large dark purple-red clast (?gravel?) at 40 feet.	34.0	40.0	6.0
	Poorly sorted, angular, fine- to coarse-grained sand with silt.	40.0	41.5	1.5
	Poorly sorted, subangular to angular, fine- to coarse-grained sand with gravel.	41.5	46.5	5.0
	Gravel. Some are 4-inches long and rounded.	46.5	47.0	0.5
Kpc	Light gray with light pink and yellow-brown mottled clay. Trace of sand/silt/rust colored organic matter(?) at 51 feet.	47.0	57.0	10.0
	Light gray with light pink soft, brittle, crumbly silty clay.	57.0	59.5	2.5
	Light gray clay mottled with brick red silt.	59.5	67.0	7.5
	Light pink and light gray mottled clay.	67.0	69.0	2.0
	Pink, yellow-brown, and light gray mottled clay.	69.0	77.0	8.0
	Red and light gray mottled sandy silt	77.0	80.0	3.0
	Mottled medium brown, pink-red, light gray, and yellow brown sandy, clayey, silt	80.0	87.0	7.0
	Mottled medium brown, pink-red, light gray, and yellow brown, silty, sandy clay. Less cohesive than 80–87 feet	87.0	97.0	10.0
	Multi-colored, mottled, sandy, clayey silt. More crumbly with slickensides(?) near 100 feet	97.0	103.0	6.0
Kps	Light gray, very fine-grained cohesive clayey sand mottled with light pink silt	103.0	107.0	4.0
	Light bluish-brown-gray, fine- to medium-grained clayey sand. Cohesive	107.0	111.0	4.0
	Light gray and red, very fine-grained silty clayey sand. Some zones more clayey. Some zones more silty/sandy. Less mottling starting at 118 feet.	111.0	120.0	9.0
	Cohesive, fine- to medium-grained clayey sand. Some zones more cohesive, some zones less cohesive.	120.0	123.0	3.0
	Very cohesive, slightly mottled silty clayey sand.	123.0	130.0	7.0
	Light gray, fine- to coarse-grained clayey sand. Some zones very clayey/cohesive, some zones less clayey/cohesive.	130.0	137.0	7.0
	Moderately well-sorted, subangular, medium-grained sand.	137.0	140.0	3.0
	Light gray/colored, poorly sorted, somewhat cohesive, medium- to coarse-grained sand. (Slightly more cohesive from 150–153.5 feet)	140.0	153.5	13.5
	Transitional fining downward from sand to silt to clay	153.5	156.0	2.5
	Very fine-grained silty sand	156.0	157.0	1.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-006 (described by C. Dieter)

Altitude: 12.3 feet **Total depth:** 182 feet

Latitude / Longitude: 38º 53′ 01.39″ N / 76º 58′ 16.65″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Light gray and light pink, poorly sorted, mottled clayey silty sand	157.0	160.0	3.0
	Light gray, fine- to medium-grained sand (medium cohesiveness)	160.0	169.5	9.5
	Light gray, very fine-grained clayey sand (moderately cohesive, sand/clay contact at 173 feet)	169.5	173.0	3.5
	Medium reddish-brown and light gray, yellow-brown, and dark brown mottled silty clay (dry, brittle with slickensides)	173.0	177.0	4.0
	Reddish-brown clay	177.0	178.5	1.5
	Silty clay	178.5	180.0	1.5
	Reds, yellows and orange horizontally mottled in silty sandy clay	180.0	182.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-101 (described by C. Dieter)

Altitude: 14.9 feet **Total depth:** 191 feet

Latitude / Longitude: 38º 51′ 55.99″ N / 76º 59′ 36.20″ W

Core used in sections C-C′ and D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf and Qa	Medium brown silty sand	0.0	6.0	6.0
	Medium brown, fine-grained silty sand	6.0	11.0	5.0
	Poorly sorted, fine-grained sand with mica and trace organics (some gravels 0.25- to 1-inch diameter)	11.0	16.0	5.0
	Medium brown, poorly sorted, fine-grained sand with some gravels (0.25- to 1-inch diameter)	16.0	17.0	1.0
	Medium brown, poorly sorted silty sand (sand/clay contact at 23 feet)	17.0	23.0	6.0
	Blue-gray and dark brown mottled clay with some mica and a large 2.5-inch cobble	23.0	25.5	2.5
	Light gray and reddish-brown mottled clay	25.5	27.5	2.0
	Coarsened to a light gray and reddish-brown silty sand	27.5	28.5	1.0
	Coarsened to a light gray and reddish-brown sand with gravels (0.125- to 1.5-inch diameter)	28.5	29.0	0.5
Kpc	Medium brown and red, yellow, and light gray mottled clay (some zones with silt, becomes more silty clay at 38 feet)	29.0	42.5	13.5
	Red, yellow, and light gray mottled silty clay	42.5	44.0	1.5
	Reddish-brown and light gray and dark red-purple mottled sandy clayey silt	44.0	47.0	3.0
	Red, brown, light gray, and medium brown mottled silty sandy clay (various grain sizes with colors, more sandy from 49 to 50.5 feet and more silty from 50.5 to 52 feet)	47.0	52.0	5.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-101 (described by C. Dieter)

Altitude: 14.9 feet **Total depth:** 191 feet

Latitude / Longitude: 38º 51′ 55.99″ N / 76º 59′ 36.20″ W

Core used in sections C-C′ and D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Transition to medium to light purple clayey silt	52.0	53.5	1.5
	Light gray silty clay	53.5	55.0	1.5
	Brownish-gray mottled clay	55.0	57.0	2.0
	Medium brown and light gray and red purple mottled silty clay	57.0	59.5	2.5
	Yellowish-brown and light gray, medium gray, pink, and yellow mottled silty clay	59.5	69.5	10.0
	Medium gray and purple mottled silty clay	69.5	76.0	6.5
	Pink and light gray mottled clay	76.0	77.5	1.5
	Light gray and pinkish-red mottled clay with trace of silt	77.5	80.0	2.5
	Reddish and light gray mottled silty clay	80.0	81.0	1.0
	Red, pink, and light gray mottled clay (trace of silt starting at 86 feet)	81.0	90.0	9.0
	Red and light gray mottled clay with trace of silt	90.0	94.5	4.5
	Light gray silt mottled with pinkish-red clay	94.5	96.0	1.5
	Reddish clayey silt with some light gray mottling	96.0	98.0	2.0
	Red and light gray mottled silty clay	98.0	100.0	2.0
	Dark purple-red clay with trace of silt	100.0	102.5	2.5
	Light gray clayey silt mottled with red clay	102.5	103.0	0.5
	Reddish-brown mottled silty clay	103.0	107.0	4.0
	Red and light gray mottled clay	107.0	109.0	2.0
	Red clay (less mottling than above)	109.0	110.0	1.0
	Red and light gray mottled silty clay	110.0	116.0	6.0
	Reddish-brown mottled silty clay	116.0	119.5	3.5
	Red clay with light gray small sand pockets	119.5	121.5	2.0
Kps	Sandy clay	121.5	122.5	1.0
	Red clayey sand mottled with medium yellow-brown, fine-grained sand with mica	122.5	126.0	3.5
	Medium brown, poorly sorted, fine-grained sand (slightly cohesive from 136–139 feet, some zones more cohesive than others from 139 to 142 feet)	126.0	142.0	16.0
	Medium brown, cohesive, very fine-grained sand	142.0	147.5	5.5
	Medium- to coarse-grained sand (not cohesive until 149.5 feet, slightly cohesive after that point)	147.5	150.0	2.5
	Light brown-gray, fine-grained sand (some zones more cohesive than others)	150.0	160.0	10.0
	Fine-grained, clayey (cohesive) sand	160.0	168.0	8.0
	Medium-grained sand (not as cohesive as above)	168.0	172.0	4.0
	Cohesive, medium-grained sand with lignite	172.0	179.0	7.0
	Slightly cohesive, medium- to coarse-grained sand (no lignite after 180 feet, and coarse-grained sand after 183 feet)	179.0	184.0	5.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-101 (described by C. Dieter)

Altitude: 14.9 feet **Total depth:** 191 feet

Latitude / Longitude: 38° 51′ 55.99″ N / 76° 59′ 36.20″ W

Core used in sections C-C′ and D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Medium gray, poorly sorted clay with sand, pebbles, angular clay clasts and mica (lignite at 185 feet)	184.0	185.5	1.5
	Silt with pebbles	185.5	187.0	1.5
	Cohesive, medium-grained sand with interbedded silty and sandy zones	187.0	188.0	1.0
	Silty clay with interbedded silty and sandy zones	188.0	189.0	1.0
	Silty sand with interbedded silty and sandy zones	189.0	191.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-102 (described by C. Dieter)

Altitude: 12 feet **Total depth:** 195 feet

Latitude / Longitude: 38° 51′ 51.81″ N / 77° 00′ 03.53″ W

Core used in sections C-C′ and D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Gray brownish-orange silty, clayey sand and gravel	0.0	11.0	11.0
Qa	Gravelly sand	11.0	12.5	1.5
	Poorly sorted, medium- to coarse-grained moist sand with some mica	12.5	13.0	0.5
	Medium-grained gravelly sand	13.0	19.0	6.0
	Poorly sorted, subangular sand with gravels (gravels have a diameter of 0.5 to 2 inches)	19.0	24.5	5.5
	Poorly sorted, subangular sandy gravel (gravels have a diameter of 0.25 to 1 inch)	24.5	25.0	0.5
	Poorly sorted gravelly sand	25.0	29.0	4.0
	Poorly sorted sandy gravel	29.0	31.0	2.0
Kpc	Transition to reddish-brown mottled clay	31.0	35.0	4.0
	Grayish-pink mottled clay (trace of silt)	35.0	39.0	4.0
	Grayish-brownish-pink mottled clay	39.0	41.0	2.0
	Slight transition to light brownish-gray mottled clay (trace of silt)	41.0	45.0	4.0
	Soft, pliable/brittle, light brown silty clay with grayish mottling	45.0	47.5	2.5
	Soft, pliable, light brown (silty) clay. Mottled with light gray	48.0	51.0	3.0
	Yellow, pink, brown and gray mottled clay (trace of lignite at 51 feet)	51.0	51.5	0.5
	Reddish-purple and light gray mottled clay	51.5	58.5	7.0
	Reddish-purple, gray, and yellow mottled clay (slight trace of silt)	59.0	60.0	1.0
	Transition to light gray and reddish-purple mottled (silty) clay	60.0	61.5	1.5
	Reddish-brown, light gray, and dark purple mottled clay	62.0	64.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-102 (described by C. Dieter)

Altitude: 12 feet **Total depth:** 195 feet

Latitude / Longitude: 38º 51′ 51.81″ N / 77º 00′ 03.53″ W

Core used in sections C-C′ and D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Transition to reddish-purple brown silty sandy mottled clay	64.0	65.0	1.0
	Hard, dry mottled silt	65.0	68.0	3.0
	Reddish-brown micaceous silt (trace clay)	68.0	71.0	3.0
	Transition to clayey silt	71.0	75.0	4.0
	Reddish-brown clayey silt	75.0	79.5	4.5
	Light gray and reddish-purple mottled (sandy) silt (very fine-grained sand)	79.5	81.0	1.5
	Red clay with slickensides	81.0	85.5	4.5
	Red silty clay	85.5	89.0	3.5
	Soft red clay	89.0	91.5	2.5
	Red and light gray mottled silty clay	91.5	95.5	4.0
	Red (silty) clay	95.5	101.5	6.0
	Red clay (slightly mottled with light gray with a trace of silt)	101.5	106.0	4.5
Kps	Reddish-brown silty sand	106.0	115.0	9.0
	Silty sand	115.0	116.5	1.5
	Medium brown silty very fine-grained sand	116.5	119.5	3.0
	Yellow-brown silty clay	119.5	121.0	1.5
	Transition to medium brown-gray silty sand	121.0	122.0	1.0
	Medium brown clayey sandy silt (slightly mottled with light gray)	122.0	125.0	3.0
	Light gray, cohesive, fine-grained clayey sand (less cohesive at 134–135 feet)	125.5	136.0	10.5
	Light gray, subrounded, poorly sorted, cohesive/clayey, fine- to medium-grained sand	136.0	137.5	1.5
	Transition to mostly clear and light gray, poorly sorted, medium- to coarse-grained sand (wet, slightly cohesive)	137.5	146.0	8.5
	Mostly clear and light gray, poorly sorted, medium- to coarse-grained sand with clay clasts	146.0	147.0	1.0
	Dark mushy clay	147.0	148.0	1.0
	Grades to dark to medium gray sandy silt with lignite	148.0	150.0	2.0
	Moderately well-sorted medium-grained sand with traces of silt	150.0	151.0	1.0
	Sandy silt	151.0	152.5	1.5
	Dark to medium gray sandy silt with lignite	152.5	154.0	1.5
	Dark to medium gray, fine-grained sand with some lignite	154.0	156.5	2.5
	Dark to medium gray, fine-grained sand with some lignite (some areas have clays and silts)	156.5	160.0	3.5
	Light gray, well-sorted, fine-grained sand with traces of silt, clay, and mica	160.0	161.5	1.5
	Dark gray silty clay (hard, dry,brittle)	161.5	164.0	2.5
	Very fine-grained sand	164.0	164.5	0.5
	Dark gray silty clay (hard, dry, brittle)	164.5	166.0	1.5

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-102 (described by C. Dieter)

Altitude: 12 feet **Total depth:** 195 feet

Latitude / Longitude: 38° 51′ 51.81″ N / 77° 00′ 03.53″ W

Core used in sections C-C′ and D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Very fine-grained silty sand with some lignite	166.0	166.5	0.5
	Silty clay	166.5	168.5	2.0
	Transition to light gray, poorly sorted, medium-grained sand	168.5	172.0	3.5
	Poorly sorted, coarse-grained clayey sand with lignite	172.0	173.5	1.5
	Yellow, brown, gray poorly sorted silty, clayey fine-grained sand	173.5	175.0	1.5
	Very fine-grained sandy silt	175.0	175.5	0.5
	Grading into silty sand	175.5	176.0	0.5
	Light yellow-gray, very fine-grained silty sand	176.0	183.0	7.0
	Dark gray silty clay with some slickensides	183.0	185.0	2.0
	Medium gray silty clayey sand (coarsening downwards)	185.0	188.0	3.0
	Light gray, slightly cohesive, fine- to medium- grained sand	188.0	191.5	3.5
	Fine-grained, cohesive sandy clay	191.5	195.0	3.5

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-103 (described by C. Dieter)

Altitude: 10 feet **Total depth:** 152.5 feet

Latitude / Longitude: 38° 52′ 28.78″ N / 77° 00′ 13.38″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Brown silty sand with trace organics	0.0	6.0	6.0
Qte	Medium greenish-gray sandy silt with small angular gravel (wet)	6.0	9.0	3.0
	Medium greenish gray silty clay	9.0	10.0	1.0
	Medium greenish-gray to brown silt with organic matter and few gravels	10.0	16.0	6.0
	Dark brown organic rich silty peat	16.0	26.0	10.0
	Light to medium gray sandy silt with some organic matter	26.0	29.0	3.0
	Light to medium gray very fine-grained sand with gravel near 30 feet.	29.0	31.0	2.0
	Bluish-gray to brownish gray clay. Some thin silt layers, some peat.	31.0	37.0	6.0
	Medium gray very fine-grained sand	37.0	43.0	6.0
	Medium gray silt with high percentage of organic matter (especially at 44 feet)	43.0	45.0	2.0
	Silty clay with organic matter and trace amount of mica	45.0	45.5	0.5
	Medium dark gray, very fine-grained sand to medium brownish gray fine- to medium-grained sand. Layer of large (quartzite?) cobbles.	45.5	49.0	3.5
	Medium gray stiff hard silt (some zones more sandy, more clayey)	49.0	59.0	10.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-103 (described by C. Dieter)

Altitude: 10 feet **Total depth:** 152.5 feet

Latitude / Longitude: 38° 52′ 28.78″ N / 77° 00′ 13.38″ W

Core used in section C-C′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qte	Medium brownish-gray fine-grained sand	59.0	62.5	3.5
	Light to medium gray sandy clayey silt	62.5	65.0	2.5
	Light gray fine to medium-grained clayey sand with 1–2-inch long pieces of lignite/organic matter	65.0	66.0	1.0
	Light gray medium-grained clayey sand with organic matter	66.0	71.0	5.0
	Medium to dark gray silt with high percentage of organic matter and woody pieces	71.0	76.0	5.0
	Light gray medium-grained clayey sand with organic matter	76.0	79.0	3.0
Kps	Bluish-green medium gray silty clay (hard, dry, brittle) with pockets of medium- to coarse-grained sand	79.0	83.0	4.0
	Poorly sorted, subangular, coarse- to very coarse-grained sand (clayey, tacky)	83.0	97.0	14.0
	Bluish-greenish-gray clayey silt to silty clay	97.0	99.0	2.0
	Poorly sorted, subangular, coarse- to very coarse-grained sand (some zones clayey, some zones less clayey)	99.0	111.0	12.0
	Medium bluish-gray clayey silt	111.0	112.0	1.0
	Poorly sorted, angular, clayey, coarse-grained sand	112.0	116.0	4.0
	Poorly sorted, very fine-grained silty sand with some organic matter	116.0	118.0	2.0
	Dark grayish-brown, clayey silt with trace mica	118.0	120.0	2.0
	Dark gray sandy silt with zones of high percentage of organic matter and lignite	120.0	127.0	7.0
	Dark gray silty clay with high percentage of organic matter and lignite. Some zones with more clay or very fine-grained sand.	127.0	134.0	7.0
	Fine-grained silty sand, poorly sorted with 6-inch thick layer of high organic content.	134.0	136.0	2.0
	Dark gray, slightly mottled silty clay speckled with reddish orange, black and light gray silty clay	136.0	146.0	10.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-104 (described by C. Dieter)

Altitude: 6.3 feet **Total depth:** 175 feet

Latitude / Longitude: 38º 52′ 40.83″ N / 76º 58′ 42.99″ W

Not used in cross sections

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa	Dark brown poorly sorted material (sand with pebbles and organic matter)	0.0	5.0	5.0
	Dark brownish-gray silt	5.0	32.0	27.0
	Same as above, but 3 large sub-rounded cobbles (approximately 1.5 inches long)	32.0	33.0	1.0
	Moderately well-sorted, subangular, very fine- to fine-grained sand	33.0	35.0	2.0
	Very poorly sorted, subangular, very fine- to fine-grained sand	35.0	40.0	5.0
	Poorly sorted sand with gravels. Gravels are poorly sorted and subangular. Large wood piece (1.5- to 2-inch diameter) and other smaller organic chunks.	40.0	45.0	5.0
Kpc	Light gray and red mottled silty clay	45.0	95.0	50.0
	Red and light gray mottled clay. Dry, brittle with slickensides(?)	95.0	105.0	10.0
	Light gray clay with light pink mottling (no slickensides)	105.0	109.0	4.0
	Tight, dry, plastic, purple-blue-maroon silty clay	109.0	116.0	7.0
	Red and light gray mottled silty clay	116.0	121.0	5.0
	Red and light gray mottled clayey silt	121.0	124.0	3.0
	Light gray, poorly sorted, fine- to medium-grained silty sand	124.0	125.0	1.0
	Red and light gray mottled clayey silt	125.0	127.0	2.0
Kps	Brownish red and light gray mottled silty sand	127.0	130.0	3.0
	Gray, poorly sorted, medium-grained clayey sand mottled with light gray sandy clay (with pockets of clay)	130.0	133.0	3.0
	Brownish red, poorly sorted, medium- to coarse-grained clayey sand	133.0	134.0	1.0
	Light gray, poorly sorted, angular, fine-grained sand with pebbles. (some clay)	134.0	135.0	1.0
	Light gray, moderately well sorted, fine- to medium-grained clayey sand	135.0	139.0	4.0
	Light gray, medium- to coarse-grained clayey sand	139.0	144.0	5.0
	Light gray, subangular, poorly sorted, coarse-grained slightly clayey sand (slightly tacky)	144.0	151.5	7.5
	Light gray, fine- to medium-grained slightly tacky sand	151.5	154.0	2.5
	Light gray, poorly sorted, subangular, medium- to coarse-grained clayey sand	154.0	155.0	1.0
	(Sample dropped) light gray, poorly sorted, subangular, medium-to coarse-grained clayey sand with some 0.75-inch diameter gravels	155.0	158.0	3.0
	Light gray silt with some maroon-pink mottling	158.0	160.0	2.0
	Medium gray silty clay with purplish-maroon mottling (and slickensides?)	160.0	162.0	2.0
	Light gray, poorly sorted, medium- to coarse-grained clayey sand with 1-inch long cobbles and 0.5-inch long gravel	162.0	168.5	6.5
	Light gray, poorly sorted, fine- to medium-grained clayey sand	168.5	171.0	2.5
	Light gray, poorly sorted, fine- to medium-grained clayey sand with large 0.75- to 1.25-inch subrounded cobbles	171.0	172.0	1.0
	Light gray, poorly sorted, coarse-grained clayey sand	172.0	175.0	3.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-106 (described by C. Dieter)

Altitude: 13 feet **Total depth:** 166 feet

Latitude / Longitude: 38º 53′ 46.70″ N / 76º 58′ 06.63″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Poorly sorted fill (dirt, gravel and metal)	0.0	6.0	6.0
	Landfill. (dirt with springs and terracotta and ceramic tiles)	6.0	11.0	5.0
	Landfill. Dark brown silt with metal	11.0	16.0	5.0
Qa	Poorly sorted sand with gravel (gravels 0.25 to 2-inch diameter, various pale colors)	16.0	19.5	3.5
	Light gray, poorly sorted mottled clayey silty sand with large chunks of clay and some signs of cementation	19.5	23.0	3.5
	Light to medium gray, poorly sorted silty sandy clay with organics (some light pink and yellow mottling)	23.0	26.0	3.0
	Light to medium brown-gray, poorly sorted silty coarse-grained sandy clay with organics (some light pink and yellow mottling)	26.0	33.5	7.5
	Light to medium brown-gray, coarse-grained silty clayey sand	33.5	34.5	1.0
	Coarse sand	34.5	35.0	0.5
Kpc	Bluish-gray and dark brown and orange brown mottled clay	35.0	36.0	1.0
	Reddish-brown silty sandy clay mottled with light gray, yellow, medium brown, and black silty sand mottling	36.0	42.0	6.0
	Medium brown, dense silty sandy clay (slightly mottled)	42.0	45.0	3.0
	Gradational contact to poorly sorted sandy clay	45.0	46.0	1.0
	Sand	46.0	46.5	0.5
	Light tan-gray silty clayey very fine-grained sand	46.5	52.0	5.5
	Reddish-brown silty clayey very fine-grained sand	52.0	53.0	1.0
	Medium brown silty clayey very fine-grained sand	53.0	57.0	4.0
	Medium brown, light gray, yellow, and medium gray mottled sandy clayey silt with some tiny iron precipitate/nodules	57.0	62.0	5.0
	Layered pinkish-reddish-brown, brown, and light tan mottled silty clay	62.0	64.5	2.5
	Mottled sandy clayey silt	64.5	67.0	2.5
	Dark red and light gray silty clay	67.0	69.5	2.5
	Transition to light gray and purple-red mottled silty, clayey fine-grained sand	69.5	76.0	6.5
	Light gray, very fine-grained sand (cohesive/slightly clayey)	76.0	86.0	10.0
	Medium brown-gray, fine-grained sand	86.0	97.0	11.0
	Light gray and pinkish-red mottled silty clay	97.0	99.5	2.5
	Brown-red and light gray mottled clay	99.5	100.0	0.5
	Silty clay	100.0	101.5	1.5
	Light gray and red-brown , poorly sorted, mottled silty clayey sand	101.5	102.0	0.5
	Red-brown silty clay	102.0	106.0	4.0
	Light gray and yellow, pink, and orange, mottled silty sandy clay	106.0	109.5	3.5
	Transition to light gray, well-sorted, very fine-grained sand	109.5	111.5	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-106 (described by C. Dieter)

Altitude: 13 feet **Total depth:** 166 feet

Latitude / Longitude: 38° 53′ 46.70″ N / 76° 58′ 06.63″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Poorly sorted, fine- to medium-grained sand (somewhat cohesive with light colored grains and dark minerals)	111.5	113.0	1.5
	Light bluish-gray, fine-grained,very cohesive clayey sand with some pink layered mottling and blue clay clasts	113.0	117.5	4.5
	Dark purple silty clay	117.5	120.5	3.0
	Dark purple clay	120.5	121.0	0.5
	Light gray, coarse-grained sand with some clay	121.0	123.0	2.0
	Coarse sand interbedded with gray purple-red clay	123.0	124.0	1.0
	Dark purple clay	124.0	125.0	1.0
	Coarse sand interbedded with gray purple-red clay	125.0	125.5	0.5
	Light gray silty sandy clay with some pink mottling	125.5	126.0	0.5
Kps	Light gray, fine- to medium-grained sand with multicolored grains (white, clear, tan, pink, mica, black, yellow, and orange)	126.0	146.5	20.5
	Dark gray sandy clayey silt (high organic content)	146.5	149.0	2.5
	Medium gray, fine-grained clayey silty sand with clasts of silver mica in hard cemented rock and organic matter/lignite (more clayey then sandy and more organic matter from 164 to 166 feet)	149.0	166.0	17.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-107 (described by C. Dieter)

Altitude: 30.4 feet **Total depth:** 166 feet

Latitude / Longitude: 38° 53′ 59.57″ N / 76° 58′ 09.18″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Poorly sorted, clayey landfill with glass and muck at 1 foot and large gravels and chunks of brick at 8 feet	0.0	12.5	12.5
Qa	Reddish-brown, poorly sorted silty clayey sand	12.5	15.0	2.5
Kpc	Light gray and orange-red brown mottled clay	15.0	16.0	1.0
	Light gray, pink, and yellow-orange mottled clay	16.0	19.0	3.0
	Light gray and dark purple and yellow mottled clay	19.0	22.0	3.0
	Light gray, orange and pink-red mottled clay (soft)	22.0	29.5	7.5
	Light to medium gray mottled clay, mottled with specks of dark gray, pink, and yellow	29.5	36.0	6.5
	Medium brown and pinkish-red and yellow mottled clay	36.0	41.0	5.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-107 (described by C. Dieter)

Altitude: 30.4 feet **Total depth:** 166 feet

Latitude / Longitude: 38º 53′ 59.57″ N / 76º 58′ 09.18″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Transition to medium orange-brown and light gray, orange and pink mottled silty clay	41.0	45.0	4.0
	Sandy silty clay	45.0	46.0	1.0
	Mottled silty clay with some dark pebbles (pea-sized heavy minerals?)	46.0	49.0	3.0
	Red, orange-brown and yellow-gray mottled silty clay	49.0	52.5	3.5
	Mottled silty clay	52.5	56.0	3.5
	Red brown mottled clay with little light gray and yellow clay (slickensides at 60 feet)	56.0	62.5	6.5
	Medium red-brown and light gray mottled silty clay (dark red mottling at 64 feet)	62.5	66.0	3.5
	Medium to dark gray and red-purple mottled clay	66.0	67.5	1.5
	Transition to medium gray and purple-red mottled clay	67.5	69.5	2.0
	Light gray and dark purple-red silty clay	69.5	71.5	2.0
	Purple-red clay with minor medium gray mottling (dark 0.25 inch in size clasts at 73.5 feet)	71.5	74.0	2.5
	Dark red-brown silty clay with little specks of gray clayey silt and trace of mica	74.0	81.0	7.0
	Transition to blue-gray silt	81.0	83.0	2.0
	Red-brown, brown and light silty clayey sand	83.0	85.0	2.0
Kps	Red-brown, poorly sorted, subangular, fine-grained clayey sand	85.0	86.0	1.0
	Medium blue-gray clayey silty sand (more silty sand, less clay and medium gray color at 88.8 feet)	86.0	89.0	3.0
	Medium gray, fine-grained clayey sand	92.5	96.0	3.5
	Transitions to fine- to coarse-grained sand. Less clay and not very cohesive. (less cohesive from 98 to 99 feet)	96.0	99.0	3.0
	Light to medium gray, extremely poorly sorted mottled clay, coarse sand, silt and gravels (quartz)	99.0	100.0	1.0
	Silty sandy clay	100.0	101.0	1.0
	Medium to light gray silty clayey fine-grained sand (more consistent then layer above)	101.0	104.0	3.0
	Medium to light gray, poorly sorted clayey sand	104.0	107.0	3.0
	Medium to light gray, fine- to medium-grained clayey sand (some zones more clayey, some zones more sandy)	107.0	110.5	3.5
	Medium to light gray, medium- to coarse-grained clayey sand (some zones more clayey, some zones more sandy)	110.5	114.0	3.5
	Medium blue-gray, medium- to coarse-grained silty clayey sand (some zones more clayey, some zones more sandy)	114.0	117.5	3.5
	Medium blue-gray silty sand (some zones more clayey, some zones more sandy)	117.5	122.5	5.0
	Medium brown-gray clayey silt (sand and clay contact at 122.5 feet)	122.5	125.0	2.5
	Silty sandy clay mix	125.0	125.7	0.7

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-107 (described by C. Dieter)

Altitude: 30.4 feet **Total depth:** 166 feet

Latitude / Longitude: 38° 53′ 59.57″ N / 76° 58′ 09.18″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Poorly sorted, very fine- to medium-grained sand	125.7	126.0	0.3
	Medium to light tan-gray, poorly sorted, medium-grained sand	126.0	128.5	2.5
	Light blue-gray, poorly sorted, slightly cohesive sand	128.5	129.0	0.5
	Light gray, poorly sorted, slightly cohesive medium-grained sand	129.0	132.5	3.5
	Light blue-gray, slightly cohesive fine-grained sand	132.5	135.5	3.0
	Light gray, poorly sorted, coarse-grained sand	135.5	136.0	0.5
	Poorly sorted, interbedded clay and sand	136.0	137.7	1.7
	Light gray, very fine-grained silty sand	137.5	139.0	1.5
	Light gray, very fine-grained sandy silt	139.0	142.5	3.5
	Light gray sandy clayey silt (some zones more silty, some more clayey)	142.5	152.0	9.5
	Light gray silty sand	152.0	152.5	0.5
	Medium gray sandy silt	152.5	155.5	3.0
	Medium gray silty sand	155.5	157.5	2.0
	Medium gray silt (lignite at 158 feet)	157.5	159.0	1.5
	Gray, very fine-grained silty sand	159.0	160.5	1.5
	Medium gray silty sand and sandy silt	160.5	166.0	5.5

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-108 (described by C. Dieter)

Altitude: 69.4 feet **Total depth:** 172 feet

Latitude / Longitude: 38° 54′ 39.10″ N / 76° 59′ 08.82″ W

Not used in cross-sections

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	No recovery	0.0	2.0	2.0
	Very fine-grained sand (slightly silty).	2.0	3.5	1.5
	Sand and gravels	3.5	5.5	2.0
Kpc	Light gray mottled (silty) clay. Some organic matter.	5.5	13.0	7.5
	Red, light gray, yellow-brown, mottled, silty clay with some organic matter	13.0	19.0	6.0
	Medium brown, soft, slightly mottled, clayey silt.	19.0	24.0	5.0
	Poorly sorted, clayey sand with large round 2-inch diameter cobble and 0.75-inch gravels.	24.0	26.0	2.0
	Brownish red and light gray mottled clayey silt.	26.0	29.0	3.0
	Brownish-red, mottled silty clay	29.0	33.0	4.0
	Mottled, layered, purplish red clay. (slickensides(?) at 33.5 feet)	33.0	38.0	5.0
	Red, light gray, yellow-brown, mottled silt	38.0	40.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-108 (described by C. Dieter)

Altitude: 69.4 feet **Total depth:** 172 feet

Latitude / Longitude: 38º 54′ 39.10″ N / 76º 59′ 08.82″ W

Not used in cross-sections

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Coarsening from silt to fine- to medium-grained clayey sand	40.0	42.0	2.0
	Medium gray, fine-grained, clayey sand	42.0	49.0	7.0
	Medium to light gray, poorly sorted, fine- to medium-grained clayey sand	49.0	54.0	5.0
	Light gray, fine- to medium-grained sand	54.0	56.0	2.0
	Light gray, poorly sorted, subangular, very fine- to coarse-grained clayey sand.	56.0	64.5	8.5
	Light gray, fine-grained, subangular, moderately well-sorted sand.	64.5	66.0	1.5
	Light gray, poorly sorted, subangular, fine- to coarse-grained, (slightly clayey) sand	66.0	76.0	10.0
	Light gray, sandy silt with mica	76.0	77.0	1.0
	Light gray, poorly sorted, fine- to medium-grained sand.	77.0	78.5	1.5
	Light gray and orange-brown layered, mottled silt.	78.5	79.0	0.5
	Light gray, poorly sorted, fine- to medium-grained sand. All colors of grains–dark, pink, clear, white.	79.0	88.0	9.0
	Neutral color, poorly sorted, loose, fine- to medium-grained sand. All colors of grains–dark, pink, clear, white.	88.0	96.0	8.0
	Poorly sorted, coarse-grained sand	96.0	97.0	1.0
	Extremely poorly sorted, very coarse-grained sand and gravel. All color grains, angular to subangular. (Gravels 0.25 to 2 inches in diameter)	97.0	107.0	10.0
	Medium gray, fine-grained clayey sand	107.0	108.5	1.5
	Medium gray, fine-grained sand with some clay stringers. Organic matter 111 to 112 feet.	108.5	112.5	4.0
	Medium gray, fine-grained clayey sand with silty clay lenses from 114.5 to 116 feet.	112.5	116.0	3.5
	Medium gray silty clay with some sandy lenses.	116.0	118.0	2.0
	Medium gray clayey sand mottled with light gray and brown clayey silt.	118.0	119.5	1.5
	Clayey sand	119.5	121.0	1.5
	Multi-colored (brown, purple, light tan, orange-brown) mottled silty clay. (Tight, dry, slickensides (?), crumbly)	121.0	123.0	2.0
	Light gray and red (horizontal) mottled clay. Some yellow-brown mottling, slickensides (?). Trace silt.	122.0	129.5	7.5
	Dark gray, red, brown mottled silty clay, with slickensides (?)	129.5	136.0	6.5
	Poorly sorted, subangular, gravel and cobble. Very impressive gravel with little very coarse-grained sand.	136.0	144.0	8.0
	Medium gray and pinkish-red clay with gravel.	144.0	145.2	1.2
	Light bluish gray silt with large and small cobbles (0.25 to 1.5 inches).	145.2	146.0	0.8
	Light bluish-gray clayey silt (no cobbles).	146.0	151.0	5.0
	Light bluish gray sandy silt with organic matter.	151.0	154.0	3.0
	Light bluish-gray clayey silt with lots of organic matter	154.0	155.0	1.0
	Light bluish-gray sandy, clayey silt with a high percentage of organic matter. Some zones more sandy, some more clayey.	155.0	167.0	12.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-108 (described by C. Dieter)

Altitude: 69.4 feet **Total depth:** 172 feet

Latitude / Longitude: 38° 54′ 39.10″ N / 76° 59′ 08.82″ W

Not used in cross-sections

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Light bluish-gray, poorly sorted, angular, coarse-grained clayey sand.	167.0	168.0	1.0
	1.5-inch layer of cemented coarse-grained sand.	168.0	168.2	0.2
	Light bluish-gray, poorly sorted, angular, coarse-grained sand with organic matter.	168.2	172.0	3.8

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-109 (described by C. Dieter)

Altitude: 4 feet **Total depth:** 177 feet

Latitude / Longitude: 38° 52′ 16.50″ N / 76° 59′ 15.31″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	No recovery	0.0	4.5	4.5
	Dark grayish brown clayey silt with wood, pebbles, trace organic matter. Very soft, light clay.	4.5	12.0	7.5
Qa	Coarse sand and gravel (approx. 3 in. thick)	12.0	12.3	0.3
	Dark grayish-brown silty clay with layers of heavy minerals and trace mica (only approximately 66 percent recovery)	12.3	33.0	20.8
	Sandy clayey silt with organic matter (leaves? thin, black outside, ecru on inside)	33.0	34.0	1.0
	Medium-grained poorly sorted, sand with some dark minerals	34.0	43.0	9.0
	Poorly sorted sand and gravel with some organic matter. Pebbles are all colors and sizes (2.5-inch-diameter cobbles to very fine-grained sand)	43.0	48.0	5.0
Kpc	Light bluish gray and pinkish red mottled clayey silt	48.5	54.5	6.0
	Red and light gray mottled clay	54.5	56.0	1.5
	Red clay with medium yellowish-brown very fine-grained sand stringers approximately every 4 inches.	56.0	58.0	2.0
	Reddish brown, very fine-grained sand with mica. Some zones with more or less clay. Progressively less clay starting at 86 feet.	58.0	94.0	36.0
	Fairly well-sorted, subangular, fine-grained sand. Trace of heavy minerals. Low clay content. (Medium yellow-brown color). Clayey zone at 102 feet.	94.0	106.0	12.0
	Reddish brown clayey sand with mica (transitions back and forth from sandy clay to clayey sand).	106.0	111.0	5.0
	Reddish brown silty clay	111.0	113.0	2.0
	Red and light gray mottled sandy clay. Some zones more sandy, some zones more clay	113.0	133.0	20.0
Kps	Fine-grained sand	133.0	133.5	0.5
	Dark gray and dark pinkish-red dense clay	133.0	135.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-109 (described by C. Dieter)

Altitude: 4 feet **Total depth:** 177 feet

Latitude / Longitude: 38° 52′ 16.50″ N / 76° 59′ 15.31″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Poorly sorted, subangular, coarse-grained sand	135.0	137.0	2.0
	Dark bluish-gray sandy silt	137.0	138.5	1.5
	Very fine-grained sand	138.5	140.0	1.5
	Medium bluish-gray sandy silt	140.0	141.0	1.0
	Medium bluish-gray silty sand. Some zones more clay/silt, some zones all sand (poorly sorted, subangular coarse- to very fine-grained sand)	141.0	147.0	6.0
	Light gray sandy silt with mica and heavy minerals. Sand is very fine-grained	147.0	154.0	7.0
	Very fine- to coarse-grained, poorly sorted, subangular clayey sand. Clay/silt content increases with depth. Coarse sand content decreases with depth	153.0	162.0	9.0
	Deep maroon and dark gray, very hard, dry, brittle clayey silt (with slicken-sides?)	162.0	167.0	5.0
	Clayey, silty, coarse-grained sand. Some zones with smaller grain size. Some zones with high clay content.	167.0	177.0	10.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-110 (described by C. Dieter)

Altitude: 7.2 feet **Total depth:** 177 feet

Latitude / Longitude: 38° 52′ 31.87″ N / 76° 58′ 37.78″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa	Dark brown, soft, silty clay with mica and organics, some angular clasts	0.0	19.0	19.0
	Poorly sorted, angular, very fine-grained sand to large cobbles (4 inches)	19.0	23.0	4.0
	Sand and large gravel	23.0	25.5	2.5
Kpc	Pinkish red with light gray and yellow-brown mottled clay	25.5	26.0	0.5
	Red and light gray mottled clay. Some variation in mottling and color. One foot of silty clay at 31 feet.	26.0	54.5	28.5
	Brown, light gray and red mottled clay. Some silty zones. Slickensides(?) at 54.5 feet.	54.5	66.0	11.5
	Light gray and pinkish red mottled clay. Crumbly at 68 feet.	66.0	68.0	2.0
	Light gray and deep purple-pink-red mottled silty clay.	68.0	77.5	9.5
	Red silt with light gray mottled pockets	77.5	84.0	6.5
	Light gray very fine-grained silty sand	84.0	85.0	1.0
	Light gray silt with pockets of orange-yellow-brown clay	85.0	86.0	1.0
	Light gray clay mottled with orange-yellow brown clay	86.0	87.5	1.5
	Reddish-brown and light gray silty clay (slightly mottled). Slickensides(?) at 93.8 feet	87.5	103.0	15.5

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-110 (described by C. Dieter)

Altitude: 7.2 feet **Total depth:** 177 feet

Latitude / Longitude: 38º 52′ 31.87″ N / 76º 58′ 37.78″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Maroon-red and light gray mottled clay. Slickensides near 104 feet.	103.0	114.0	11.0
	Red clay with pockets of light gray silt	114.0	116.0	2.0
	Reddish-brown, light gray and yellow-brown mottled clay. Crumbly zone with slickensides(?) at 118 feet	116.0	119.0	3.0
	Multi-colored mottled clay with some silt	119.0	128.0	9.0
	Multi-colored mottled clayey silt	128.0	129.0	1.0
	Coarse-grained sand	129.0	130.0	1.0
	Medium to light gray tight clay	130.0	131.0	1.0
	Multi-colored brownish-red silty clay with slickensides(?)	131.0	133.0	2.0
	Purplish-red and light gray mottled clayey silt	133.0	143.0	10.0
Kps	Light gray and purplish-red, mottled, silty, very fine-grained sand	143.0	146.0	3.0
	Light gray, very fine-grained silty, clayey, sand	146.0	147.5	1.5
	Light gray, fine-grained clayey sand	147.5	149.0	1.5
	Light gray, poorly sorted, subangular clayey sand	149.0	151.5	2.5
	Very poorly sorted very fine-grained sand to small pebbles	151.5	151.8	0.3
	Mottled light and medium gray and pinkish gray coarse-grained sand with clay pockets	151.8	156.0	4.2
	Light gray, medium gray, and purple gray silty sandy clay	156.0	159.0	3.0
	Med gray and purple gray clay (with slickensides (?))	159.0	161.0	2.0
	Light gray, poorly sorted, subangular, medium- to coarse-grained clayey sand. (Some clay clasts at 176.5 to 177 feet)	161.0	177.0	16.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-111 (described by C. Dieter)

Altitude: 13 feet **Total depth:** 185 feet

Latitude / Longitude: 38º 52′ 49.82″ N / 76º 58′ 08.50″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	No recovery	0.0	8.0	8.0
	Gravel and dirt fill	8.0	11.0	3.0
Qa	Dark brown, soft silt with mica and organic matter. Sandy at 12 feet with small shells	11.0	15.0	4.0
	Dark brown, soft silt with gravels and cobbles	15.0	28.0	13.0
	Very fine-grained, moderately well-sorted sand	28.0	29.0	1.0
	High organic-rich silt	29.0	29.5	0.5

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-111 (described by C. Dieter)

Altitude: 13 feet **Total depth:** 185 feet

Latitude / Longitude: 38º 52′ 49.82″ N / 76º 58′ 08.50″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa	Medium gray, very fine-grained, cohesive/clayey sand	29.5	34.5	5.0
	Medium gray, poorly sorted medium- to coarse-grained sand	34.5	36.0	1.5
	Poorly sorted, subrounded, 1- to 1.5-inch diameter cobbles	36.0	37.0	1.0
Kpc	Poorly sorted, subrounded sand and gravel	37.0	40.0	3.0
	Light gray, cohesive, sandy, clayey, silt	40.0	42.0	2.0
	Medium brown silty sand.	42.0	44.0	2.0
	Medium brown silty clayey sand to sandy clayey silt. Grades back and forth. Iron nodules at 53.5 feet.	44.0	55.0	11.0
	Slightly mottled brown, pink, light gray very fine-grained sandy, silty clay. Very cohesive. Trace mica	55.0	66.0	11.0
	Light gray, very fine-grained sandy silt.	66.0	67.5	1.5
	Light gray clay (with slickensides(?))	67.5	69.0	1.5
	Highly mottled brown, red, light gray, silty clay. Slickensides(?), crumbly, some purplish-red organic(?) silt.	69.0	77.0	8.0
	Purplish-red, brick red, mottled clayey silt/silty clay with some light gray and yellow-brown mottling.	77.0	80.0	3.0
	Purplish-red and brick red with minor yellow-brown and light gray clayey silt. Dry, crumbly, slickensides(?)	80.0	82.0	2.0
	Light gray, pinkish, mottled, sandy silt	82.0	83.0	1.0
	Purplish-red and light gray mottled silt	83.0	87.5	4.5
	Light gray, moderately well-sorted, subangular, fine-grained, sand. All grain colors	87.5	88.0	0.5
	Light gray clay.	88.0	89.0	1.0
	Light gray and pinkish-red mottled clay. Slickensides at 90 feet.	89.0	92.0	3.0
	Brownish-red, purplish-red, yellow-brown and light gray mottled silty clay	92.0	115.0	23.0
	Light gray, yellow-brown, medium brown, and light pink mottled silty clay	115.0	119.0	4.0
	Light gray, yellow-brown, medium brown, and light pink mottled clayey silt	119.0	127.5	8.5
Kps	Medium brown with light gray laminations, very, very, fine-grained clayey sand	127.5	128.0	0.5
	Light gray, very fine-grained clayey sand.	128.0	132.0	4.0
	Inter-fingered light gray, very fine-grained sand and pink silty clay.	132.0	135.0	3.0
	Light to medium gray, medium- to coarse-grained, poorly sorted, subangular, sand. All color grains. Low clay content	135.0	145.0	10.0
	Clayey, coarse-grained sand	145.0	145.5	0.5
	Coarse-grained sand with bluish-gray and pink clay clasts	145.5	147.5	2.0
	Clayey, coarse-grained sand	147.5	149.5	2.0
	Light to medium gray, medium- to coarse-grained, poorly sorted, subangular, sand. All color grains. Clayey in some zones	149.5	171.0	21.5
	Light gray, light yellow-brown, light pink-red mottled clayey silt. (Slicken-sides(?))	171.0	173.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-111 (described by C. Dieter)

Altitude: 13 feet **Total depth:** 185 feet

Latitude / Longitude: 38º 52′ 49.82″ N / 76º 58′ 08.50″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Red with light gray mottled silt.	173.0	173.5	0.5
	Medium brown, red-brown, yellow-brown layered, mottled silt. Hard and dry in some zones. Sand and clay pockets	173.5	182.0	8.5
	Medium to light gray, poorly sorted, subangular, medium- to coarse-grained clayey sand. Multi-colored grains.	182.0	185.0	3.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-112 (described by C. Dieter)

Altitude: 10.3 feet **Total depth:** 175 feet

Latitude / Longitude: 38º 53′ 15.36″ N / 76º 58′ 11.37″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Medium gray-brown, poorly sorted, gravelly sandy mud (brick chunk at 6 feet)	0.0	8.0	8.0
	Light tan, poorly sorted, muddy fill with gravels	8.0	10.0	2.0
	Burnt land fill (black, hard, tar-like)	10.0	15.0	5.0
	Dark brown mud with metal chunks and wire	15.0	18.0	3.0
	Dark to medium brown silty mud	18.0	21.5	3.5
	Dark gray-brown silty mud (low density)	21.5	30.0	8.5
	Dark gray-brown sandy mud	30.0	33.0	3.0
Qa	Medium gray-brown to tan silt coarsening downward to very fine-grained sand by 34.5 feet	33.0	35.0	2.0
	Tan fine-grained sand with a pebble coarsening to medium-grained sand by 37 feet	35.0	37.0	2.0
	Medium-grained sand coarsening to medium-grained sand with gravels (gravels are all different whites, tans, yellow, and orange)	37.0	39.0	2.0
	Very poorly sorted, very mixed sand with gravels (gravels are 0.25 to 2 inches in diameter)	39.0	40.0	1.0
Kpc	Transition to light gray, orange, red, dark brown, some pink and some purple, silty mottled clay	40.0	41.5	1.5
	Reddish-brown and yellow-tan mottled clay with a trace of dark red silt	41.5	45.0	3.5
	Reddish-brown, purple and light gray mottled silty clay with trace of sand (becomes progressively more sandy and silty)	45.0	48.5	3.5
	Dark purple-red, very fine-grained sandy clayey silt with little light gray, pink and red mottling	48.5	51.0	2.5
	Transition to dark brownish-red (silty) clay (mottled to slightly mottled)	51.0	55.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-112 (described by C. Dieter)

Altitude: 10.3 feet **Total depth:** 175 feet

Latitude / Longitude: 38º 53′ 15.36″ N / 76º 58′ 11.37″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Dark brownish-red slightly mottled clayey silt/silty clay (some very fine-grained light gray sand mottling, decreasing at 58 feet)	55.0	64.5	9.5
	Transitions to more silty clay then clayey silt	64.5	66.0	1.5
	Medium brown, dark red, and pink-orange mottled silty clay	66.0	69.0	3.0
	Medium brown, dark red, and pink-orange mottled silty clay	69.0	72.0	3.0
	Medium brown, dark red, and pink-orange mottled silty clay	72.0	75.0	3.0
	Brick red clay with thin light gray and orange mottling and a trace of silt (hard, dense) (at 86 feet, mottled with 4 inches of light gray clayey very fine-grained sand)	75.0	88.0	13.0
	Pinkish-red and light gray mottled silty clay	88.0	89.0	1.0
	Pinkish-red, hard, dense clay (slightly mottled, trace of silt)	89.0	95.0	6.0
	Dark purple-red silty clay	95.0	98.5	3.5
	Light bluish-gray, orange and red mottled clayey silt	98.5	100.0	1.5
	Speckled light bluish/greenish clayey silt with black, light to medium gray, orange and yellow mottling	100.0	101.5	1.5
	Brown, red-brown and brown-gray mottled clayey silt	101.5	106.0	4.5
	Dark red-brown and pinkish-red mottled clayey sandy silt	106.0	107.0	1.0
	Dark gray and pinkish-red clay	107.0	108.0	1.0
	Dark gray clayey silt	108.0	112.0	4.0
	Dark gray clayey silt (mottled with some light gray, very fine-grained sand)	112.0	114.0	2.0
	Dark gray sandy clayey silt (at 120.5 feet becomes less sandy)	114.0	122.0	8.0
	Dark gray silty clay (more sandy silty clay at 124 feet and back to silty clay at 125 feet)	122.0	125.0	3.0
	Dark gray sandy clayey silt	125.0	129.0	4.0
Kps	Medium to light gray, poorly sorted, subangular to subrounded, medium- to coarse-grained sand (more fine-grained sand at 135 feet with more cohesion/clay, returns to medium- to coarse-grained at 138 feet)	129.0	143.5	14.5
	Grades into fine-grained clayey sand	143.5	145.0	1.5
	Light to medium gray mottled silty clay/clayey silt	145.0	147.0	2.0
	Dark purple-gray and medium gray mottle silt (dry, changes to sandy silt at 148 feet)	147.0	148.5	1.5
	Dark purple-red silty clay (with slickensides)	148.5	151.0	2.5
	Light gray sandy silt mottled with purple-red clayey silt	151.0	152.5	1.5
	Transitions to clayey silty mottled sand	152.5	153.5	1.0
	Light tan, poorly sorted, clayey (cohesive) sand	153.5	155.0	1.5
	Back to light to medium gray, orange and brown, mottled silty sand	155.0	156.5	1.5
	Light and dark gray clay mottled with red, yellow, and brown silty clay/clayey silt (slickensides at 158.5 feet)	156.5	161.0	4.5
	Dark gray silty clay mottled with light gray and organic/dark matter	161.0	162.0	1.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-112 (described by C. Dieter)

Altitude: 10.3 feet **Total depth:** 175 feet

Latitude / Longitude: 38º 53′ 15.36″ N / 76º 58′ 11.37″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Dark gray silt (coarsening down to 165 feet)	162.0	163.0	1.0
	Medium gray sandy silt	163.0	164.5	1.5
	Light tan to white, very fine-grained silty sand	164.5	165.5	1.0
	Light tan-brown mottled clayey sandy silt	165.5	169.0	3.5
	Light gray, moderately well-sorted, very fine-grained sand	169.0	175.0	6.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-201 (described by C. Dieter)

Altitude: 20.2 feet **Total depth:** 216 feet

Latitude / Longitude: 38º 49′ 07.93″ N / 77º 01′ 05.78″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Fill	0.0	2.0	2.0
Qa	Fine-grained sand	2.0	5.0	3.0
	Light gray, very fine-grained silty clayey sand	5.0	6.0	1.0
	Multi-colored, poorly sorted, subrounded, fine- to medium-grained sand	6.0	9.5	3.5
	Large cobbles at contact	9.5	10.0	0.5
	Light tan/brown silty clay	10.0	12.5	2.5
	Medium blue-gray silty clay	12.5	16.0	3.5
	Medium blue-gray clayey silt	16.0	33.5	17.5
	Poorly sorted sand and gravel (gravel is fine-grained to 2-inch diameter and rounded to subrounded)	33.5	41.0	7.5
	Multi-colored coarse-grained sand and gravel (gravels up to 3-inch diameter)	41.0	47.0	6.0
	Multi-colored, poorly sorted, subangular to subrounded, coarse-grained sand and gravels (4-inch-diameter large cobble at 149.9 feet and larger gravels (approximately 0.75-inch-diameter) at 151 feet)	47.0	51.0	4.0
	Poorly sorted gravelly sand (subrounded gravels and subangular sand)	51.0	56.0	5.0
	Multi-colored, poorly sorted, coarse-grained gravelly sand (most gravels are less than 0.5 inches)	56.5	68.0	11.5
	Transition to poorly sorted, fine-grained clayey sand	68.0	73.5	5.5
	Poorly sorted sand and gravel	73.5	76.0	2.5
Kpc	Light blue-gray, fine-grained sand (slightly clayey/cohesive, some clay starting at 83 feet)	76.0	87.0	11.0
	Transition to light blue-gray sandy silty clay	87.0	88.5	1.5

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-201 (described by C. Dieter)

Altitude: 20.2 feet **Total depth:** 216 feet

Latitude / Longitude: 38° 49′ 07.93″ N / 77° 01′ 05.78″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Medium blue-gray with brown and light gray mottled silty clay	88.5	91.0	2.5
	Light brown-gray with yellow-brown and brown mottled silty clay	91.0	96.0	5.0
	Light gray and red brown mottled clayey silt	96.0	97.5	1.5
	Red and light gray mottled silty clay	97.5	100.5	3.0
	Medium red-brown, light gray and pink-brown mottled silty clay	100.5	101.5	1.0
	Medium blue-gray clayey silt	101.5	102.5	1.0
	Light gray and brown, very fine-grained mottled sandy clay	102.5	106.0	3.5
	Medium brown, blue-gray and brown mottled clay (some silty zones)	106.0	109.0	3.0
	Medium brown, blue-gray and brown mottled silty clay	109.0	110.5	1.5
	Transition to light blue-gray and brown, very fine-grained mottled clayey silty sand (coarsening downward, medium-grained by 115 feet)	110.5	115.0	4.5
	Poorly sorted, fine- to medium-grained clayey sand	115.0	117.5	2.5
	Medium brown and light gray and red-brown mottled silty clay	117.5	120.0	2.5
	Medium to dark brown-gray silty clay	120.0	122.5	2.5
	Medium to dark red-brown and medium gray mottled silty clay	122.5	126.0	3.5
	Medium yellow-brown silty clay (with little light gray mottling)	126.0	127.5	1.5
	Medium brown and light gray and light pink-red mottled silty clay	127.5	137.0	9.5
	Grades to light blue-gray mottled sandy silt (with organics)	137.0	138.0	1.0
	Medium yellow-brown silty clay (trace of sand)	138.0	139.0	1.0
	Light gray and red brown mottled silty clay	139.0	140.0	1.0
	Mottled clayey silt and silty clay	140.0	143.0	3.0
	Light blue-gray and red mottled clayey silt	140.0	147.0	7.0
	Medium brown, red silty clay (with little light blue-gray mottling)	147.0	149.5	2.5
	Medium brown, red-brown silty clay (with little light gray mottling)	149.5	164.0	14.5
	Transition to light gray and light pink mottled silt	164.0	166.0	2.0
Kps	Light gray, very fine-grained clayey sand (trace of organic matter)	166.0	168.5	2.5
	Light gray, very fine-grained sand (slightly cohesive, cohesion variable around 180 feet) (3-inch cobble at 178 feet, some 1.5-inch diameter clay clasts at 183 feet)	168.5	184.5	16.0
	Light gray, slightly cohesive, medium-grained sand (few gravels near 186 feet)	184.5	186.5	2.0
	Medium brown-gray sandy silty clay with medium blue-gray horizontal laminations	186.5	188.5	2.0
	Medium gray silt (dry and brittle)	188.5	190.5	2.0
	Medium brown sandy silty clay	190.5	194.0	3.5
	Poorly sorted, fine-grained clayey sand	194.0	195.0	1.0
	Medium brown sandy silty clay	195.0	196.0	1.0
	Light gray and red-brown mottled silty clay (only approximately 6 feet of core recovered from 196 to 216 feet)	196.0	216.0	20.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-202 (described by C. Dieter)

Altitude: 157.7 feet **Total depth:** 336 feet

Latitude / Longitude: 38° 49′ 47.03″ N / 77° 00′ 52.12″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Poorly sorted sand and gravel (fill)	0.0	9.0	9.0
Qtt	Poorly sorted, sand and gravel (sands are subangular and moderately sorted) (gravels are 0.25 to 1.25 inches in diameter, fewer gravels with depth)	9.0	16.0	7.0
	Poorly to moderately sorted, subangular sand with gravels (gravels 0.25 to 2.5 inches in diameter)	16.0	26.0	10.0
	Light gray and oxidized orange silty clay (softer tacky clay)	26.0	29.5	3.5
	Light gray and orange clayey silt (less orange oxidation with depth, trace of organics around 35 feet)	29.5	35.0	5.5
	Transition to light gray sandy silt	35.0	35.5	0.5
	Very fine-grained sand	35.5	36.0	0.5
	Very fine-grained clayey sand	36.0	42.0	6.0
	Light tan, very fine-grained sand (some clay pockets and 3-inch-thick clay layer near 44 feet)	42.5	45.5	3.0
	Very fine-grained, gravelly sand	45.5	46.0	0.5
	Light colored (white/clear), moderately well-sorted, subangular sand	46.0	56.0	10.0
	Light colored, fine- to medium-grained sand	56.0	61.0	5.0
	Light colored and some gray, medium- to coarse-grained sand	61.0	64.5	3.5
Kpc	Medium gray and flaky oxidized orange mottled silty clay (similar to clay above approximately 30 feet)	64.5	66.0	1.5
	Light gray and orange silty clay	66.0	69.5	3.5
	Medium gray and brown-red mottled silty clay	69.5	71.0	1.5
	Medium gray and light brown and yellow/orange mottled silty clay (with trace of sand)	71.0	75.0	4.0
	Light to medium gray and orange and pink silty sandy clay with some organic matter and lignite (medium-grained sand)	75.0	76.0	1.0
	Silty sandy clay	76.0	78.0	2.0
	Light gray and brown, yellow, and orange mottled clayey silt (trace of sand)	78.0	79.0	1.0
	Light gray, yellow-orange and red-brown, highly mottled silty clay with sand	79.0	83.0	4.0
	Brown and light gray sandy silty clay	83.0	86.0	3.0
	Light gray, yellow, brown and red-brown (horizontal layered colors) clay (trace of silt)	86.0	96.0	10.0
	Light gray, light brown and red-brown mottled clay	96.0	97.5	1.5
	Medium gray-brown and light gray and medium pink mottled clay	97.5	102.0	4.5
	Light gray and red-brown mottled silty clay (slightly more red-brown, pink and gray mottling starting at 100 feet)	102.0	117.0	15.0
	Light gray, brown and red mottled silty clay	118.0	120.5	2.5
	Red-brown, light gray and pink-red mottled silty clay	120.5	122.5	2.0
	Red-brown, light gray and pink-red mottled clayey silt	122.5	125.0	2.5
	Transition to light gray clayey silt	125.0	126.0	1.0
	Red-brown and light gray mottled clayey silt	126.0	128.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-202 (described by C. Dieter)

Altitude: 157.7 feet **Total depth:** 336 feet

Latitude / Longitude: 38º 49′ 47.03″ N / 77º 00′ 52.12″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Red-brown and light gray mottled clayey silt/silty clay	128.0	130.0	2.0
	Medium gray and medium brown clayey silt (changes to silty clay at 132.5 feet)	130.0	133.0	3.0
	Medium brown and medium gray, poorly sorted, mottled clayey silty sand (some clayey and sandy pockets)	133.0	136.0	3.0
	Medium red-brown silty clay (little light to medium gray mottling)	136.0	139.0	3.0
	Medium to dark brown silty clay (little mottling)	139.0	147.0	8.0
	Medium brown and medium gray silty clay	147.0	150.0	3.0
	Medium brown and medium gray mottled clayey silt	150.0	153.5	3.5
	Medium brown, pink, light gray and red mottled clayey silt	153.5	155.0	1.5
	Medium brown, pink, light gray and red mottled clayey sandy silt (sand is very fine-grained)	155.0	156.0	1.0
Sandy zone	Medium gray, very cohesive clayey silty sand (little mottling and some organics) (zone with less clay at 159.9 feet)	156.0	159.5	3.5
	Medium gray, medium-grained clayey sand	159.5	162.0	2.5
	Medium- to coarse-grained sand with some clay	162.0	164.0	2.0
	Pink and light colored, poorly sorted, subangular to subrounded, very fine- to coarse-grained sand with gravel (0.25-inch diameter gravels)	164.0	169.5	5.5
	Very fine-grained clayey sand	169.5	170.0	0.5
	Medium gray, cohesive, clayey fine- to medium-grained sand	170.0	179.5	9.5
Kpc	Transition to mottled light gray silt and red-brown clay	180.0	180.5	0.5
	Medium gray silt with some red clay mottling (dry)	180.5	183.0	2.5
	Medium gray silt (dry with slickensides and fracturing of core)	183.0	186.0	3.0
	Medium gray and brown mottled silty clay with a trace of sand (less mottling 186 to 189 feet and increased sand content 193 to 202 feet)	186.0	202.0	16.0
	Light to medium gray silty clay mottled with light gray and light orange-brown with trace of sand (shell fragments?)	202.0	206.0	4.0
	Medium yellow-brown, soft silty clay with pockets of light gray clayey sand and some black organics	206.0	207.5	1.5
	Light gray and medium brown mottled clayey silt with sand, organics and 0.12-inch-diameter red iron precipitates. (Some zones have more clay or more sand)	207.5	210.0	2.5
	Light gray with pink-brown and yellow-brown mottled silty clay with trace of sand	210.0	213.0	3.0
	Light gray, dry, brittle silty clay. (some light pink-red mottling)	214.0	216.0	2.0
	Medium brown silty clay with a little light gray mottling	216.0	232.5	16.5
	Transition to red-brown, dry, brittle clay mottled with light gray silt (some zones with more very fine-grained light gray silty sand and some zones with more red-brown clayey silt)	232.5	235.5	3.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-202 (described by C. Dieter)

Altitude: 157.7 feet **Total depth:** 336 feet

Latitude / Longitude: 38° 49′ 47.03″ N / 77° 00′ 52.12″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Poorly sorted clayey sandy silt	235.5	236.0	0.5
	Medium brown silty clay	236.0	237.5	1.5
	Medium brown clay with little light gray mottling	237.5	241.0	3.5
Sandy zone	Transition to cohesive, fine-grained sand with red clay and silt	241.0	242.0	1.0
	Fine- to medium-grained clayey sand (some zones more clay or sand)	242.0	245.5	3.5
	Light gray silt with pink-brown silty clay	245.5	246.0	0.5
	Fine- to medium-grained clayey sand	246.0	248.0	2.0
	Light gray and pink-brown mottled clayey sand with some clay pockets	248.0	249.0	1.0
	Light gray, fine- to medium-grained clayey sand (less cohesive than above)	249.0	251.0	2.0
	Light brown, fine- to medium-grained clayey sand	251.0	252.0	1.0
	Coarse- to medium-grained clayey sand (some zones more cohesive)	252.0	253.0	1.0
	Poorly sorted, medium-grained clayey sand	253.0	256.0	3.0
Kpc	Light gray, pink-red, brown, yellow and black mottled silty sandy clay	256.0	258.0	2.0
	Medium red-brown and brown and little light gray mottled silty sandy clay	258.0	260.0	2.0
	Medium brown and light gray, yellow, red, black and orange mottled clayey silt with trace of sand	260.0	262.5	2.5
	Medium red-brown mottled silty clay	262.5	265.5	3.0
	Dark to medium gray and orange mottled clayey silt (with traces of sand and organics at 265.5 feet)	265.5	273.0	7.5
	Transition to medium gray, very fine-grained clayey sand	273.0	276.0	3.0
	Light gray and red-brown mottled silty clay	276.0	282.0	6.0
	Medium gray and red-brown mottled silty clay	282.0	287.0	5.0
	Medium brown-gray, medium gray, and yellow-brown silty clay	287.0	290.0	3.0
	Dark gray, medium gray, and yellow-brown silty clay	290.0	294.0	4.0
	Light to medium gray and red-brown mottled silty clay	294.0	296.0	2.0
	Medium brown-gray silty clay (little mottling)	296.0	300.0	4.0
	Medium brown-gray and red-brown and orange mottled silty clay	300.0	306.0	6.0
	Medium brown-gray, red-brown, and orange mottled silty clay with horizontal color variations of dark brown-red, light gray, medium gray and black (light gray,very fine-grained sandy zone at 310 feet)	306.0	312.0	6.0
Kps	Medium brown, fine- to medium-grained clayey silty sand	312.0	316.0	4.0
	Medium brown and light gray and pink-red mottled clayey silty sand (zones with more sand or clay)	316.0	319.0	3.0
	Medium gray to medium brown mottled clayey silt with sand (brittle)	319.0	320.0	1.0
	Medium gray to medium brown, poorly sorted sandy clayey silt (zones with more sand or more silt)	320.0	326.0	6.0
	Mottled gray and red clay with sand, iron oxide clasts, lignite, and slickensides	326.0	336.0	10.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-203 (described by C. Dieter)

Altitude: 33.2 feet **Total depth:** 206 feet

Latitude / Longitude: 38º 51′ 29.30″ N / 77º 00′ 10.46″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	No recovery	0.0	10.5	10.5
Kpc	Yellow, orange-brown sandy clay	10.5	12.0	1.5
	No recovery	12.0	15.5	3.5
	Yellow-orange-brown poorly sorted sandy, silty, pebbly (0.3 to 1.0 inch diameter) clay	15.5	18.5	3.0
	Poorly sorted (very fine-grained sand to pebbles) clayey sand with pink grains	18.5	19.5	1.0
	Light bluish gray clay with dark brown and light yellowish gray mottling	19.5	22.0	2.5
	No recovery	22.0	25.0	3.0
	Light bluish gray clay with light pinkish mottling	25.0	27.5	2.5
	Light bluish gray clayey fine-grained sand. 3-inch thick zone near 30 feet with dark brown clayey mottling	27.5	32.0	4.5
	No recovery	32.0	35.5	3.5
	Light gray, fine- to medium-grained, poorly sorted clayey (tacky) sand	35.5	42.0	6.5
	No recovery	42.0	48.0	6.0
	Light bluish-gray clay, mottled with medium pink-brown clay	48.0	55.5	7.5
	Light greenish bluish gray silty clay with medium brown mottling	55.5	56.5	1.0
	Light bluish gray clay mottled with dark brown clay	56.5	59.0	2.5
	Brownish-red clay with light bluish gray, brown and pink mottling	59.0	69.0	10.0
	Light gray clay with red mottling	69.0	72.0	3.0
	Red and light gray mottled clay (more stiff, dry, and dense than clay above)	72.0	89.0	17.0
	Medium gray with dark pinkish, medium yellow, and brownish-gray mottling. Clay is hard, tight, and plastic.	89.0	96.0	7.0
	Light gray and red mottled clay	96.0	124.0	28.0
	Light gray and red, multi-colored mottled sandy clay	124.0	126.0	2.0
	Multi-colored silty clay with some iron precipitates/nodules near 129 feet.	126.0	131.0	5.0
	Multi-colored sandy clay	131.0	137.5	6.5
	Light gray, clayey, very fine-grained sand with decreasing clay to 139 feet.	137.5	139.0	1.5
	Light gray and red clay to silty clay, mottled	139.0	142.0	3.0
	Light gray and red mottled sandy silty clay (with some zones with more medium- to coarse-grained sand than others)	142.0	164.0	22.0
Kps	Light bluish/brownish gray, poorly sorted, subrounded, fine- to medium-grained clayey sand. Some zones with more clay, some zones with less clay. One 2-inch translucent yellow rounded cobble	164.0	206.0	42.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-204 (described by C. Dieter)

Altitude: 158 feet **Total depth:** 329 feet

Latitude / Longitude: 38° 50′ 55.03″ N / 77° 00′ 20.65″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qtt	Poorly sorted sand and gravel (gravels from 0.4 to 4 inches in diameter)	0.0	20.0	20.0
	Multicolored, poorly sorted, subangular, medium- to coarse-grained sand (sand and clay contact at 24 feet)	20.0	24.0	4.0
Kpc	Medium brown-red clay (little light gray and black mottling between 24 and 27 feet)	24.0	33.5	9.5
	Medium brown-red clay (some gray mottling)	33.5	38.0	4.5
	Medium brown-red and light gray mottled clay	38.0	43.0	5.0
	Red-brown and light gray mottled silty clay	43.0	47.0	4.0
	Medium brown-red and light gray mottled sandy silty clay	47.0	49.5	2.5
	Medium brown and light gray mottled silty clay (some dark red coloring)	49.5	55.0	5.5
	Coarse-grained sand	55.0	55.5	0.5
	Clay	55.5	56.0	0.5
	Coarse-grained sand	56.0	56.5	0.5
	Light gray, medium brown and red silty sandy clay	56.5	57.0	0.5
	Pink-red, light gray and brown mottled silty clay	57.0	60.0	3.0
	Red, brown and gray mottled clay	60.0	71.0	11.0
	Red-brown and gray mottled silty clay (more silty than above)	71.0	74.0	3.0
	Red-brown and gray mottled clay with trace of silt	74.0	77.0	3.0
	Red-brown mottled silty clay (little gray mottling)	77.0	80.0	3.0
	Red-brown mottled clay (trace of silt)	80.0	83.0	3.0
	Red brown silty clay with trace of sand (some brown and yellow-brown mottling)	83.0	87.0	4.0
	Red-brown mottled clay (trace of silt)	87.0	94.0	7.0
	Medium gray, medium purple, and red-brown, mottled clay	94.0	97.0	3.0
	Medium purple and red-brown mottled clayey silt	97.0	103.0	6.0
	Medium purple and red-brown mottled silty clay	103.0	108.5	5.5
	Medium gray with light gray, purple, and brown mottled clayey silty	108.5	110.5	2.0
	Medium blue-gray with pink, purple, and brown mottled clayey silt (trace of sand near 113 feet)	110.5	114.0	3.5
	Mottled clayey sandy silt (becomes more silty and sandy at 116 feet)	114.0	117.0	3.0
	Silt, sand and clay intermixed (pockets of sand, clay, and silt)	117.0	120.0	3.0
	Medium- to coarse-grained sand with pockets of silty clay	120.0	121.0	1.0
	Light brown and light gray clay	121.0	123.0	2.0
	Poorly sorted, subangular, medium- to fine-grained sand with some zones of clayey pockets	123.0	130.5	7.5
	Light gray silty clay with slickensides	130.5	131.0	0.5
	Light gray and light purple mottled clay	131.0	133.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-204 (described by C. Dieter)

Altitude: 158 feet **Total depth:** 329 feet

Latitude / Longitude: 38° 50′ 55.03″ N / 77° 00′ 20.65″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Light gray and little light purple mottled sandy clayey silt	133.0	134.0	1.0
	Light gray, purple and brown mottled sandy silty clay	134.0	140.0	6.0
	Light gray sandy clayey silt	140.0	142.0	2.0
Sandy zone	Light blue-gray, fine-grained clayey sand	142.0	144.0	2.0
	Sandy clay	144.0	145.0	1.0
	Clayey sand	145.0	146.0	1.0
	Fine-grained silty sand	146.0	147.0	1.0
	Light gray, medium-grained silty clayey sand (some zones more clayey than others)	147.0	150.0	3.0
	Light gray, fine- to coarse-grained clayey sand (more and less clayey zones but fairly cohesive throughout)	150.0	153.5	3.5
	Light gray, fine-grained clayey sand	153.5	156.0	2.5
Kpc	Contact with light gray clay with yellow and brown silty and organic mottling	156.0	157.0	1.0
	Light tan silty clay	157.0	160.0	3.0
	Medium tan and light gray clayey silt	160.0	163.0	3.0
	Medium tan and light gray sandy silty clay	163.0	167.0	4.0
	Medium tan, poorly sorted sandy clayey silt (some zones more sandy, some more clayey starting at 170 feet)	167.0	173.0	6.0
	Light gray-tan mottled sandy silty clay	173.0	173.5	0.5
	Light gray-tan mottled clayey silt	173.5	174.0	0.5
	Light gray and dark purple mottled silty clay	174.0	176.5	2.5
	Dark gray and purple mottled silty clay	176.5	177.0	0.5
	Medium gray silty clay	177.0	178.5	1.5
	Light gray and pink-purple silty clay	178.5	181.5	3.0
	Light gray and brown and purple mottled silty clay	181.5	188.5	7.0
	Light gray and purple-red mottled silty clay (becomes more red with less mottling starting at 195 feet)	188.5	197.0	8.5
	Medium gray and purple-red mottled clay	197.0	200.0	3.0
	Brown, medium gray and purple-red mottled clay	200.0	203.0	3.0
	Medium gray clay (slightly mottled with light gray)	203.0	205.0	2.0
	Transition to medium gray, slightly mottled silt	205.0	207.0	2.0
	Light brown-gray clayey silt	207.0	209.0	2.0
	Light gray, slightly mottled silt	209.0	210.0	1.0
	Medium gray and purple-red mottled clayey silt	210.0	213.0	3.0
	Medium blue-gray, fine-grained clayey sand	213.0	213.5	0.5
	Medium gray, fine-grained clayey silty sand	213.5	218.0	4.5
	Medium gray clayey sandy silt	218.0	222.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: SAS-204 (described by C. Dieter)

Altitude: 158 feet **Total depth:** 329 feet

Latitude / Longitude: 38° 50′ 55.03″ N / 77° 00′ 20.65″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Medium gray clayey fine-grained sand (some zones more clayey and some more sandy)	222.0	232.0	10.0
	Medium gray clayey silt	232.0	238.0	6.0
	Medium brown, poorly sorted sandy clayey silt (some red and light gray mottling)	238.0	243.5	5.5
	Light gray and pink-red mottled clayey silt (brittle and dry)	243.5	245.5	2.0
	Red and light gray and brown mottled silty clay (brittle and dry)	245.5	246.0	0.5
	Red and light gray mottled silty clay	246.0	247.0	1.0
	Red and light gray mottled clayey silt	247.0	252.0	5.0
	Grades to silty clayey sand	252.0	255.0	3.0
	Light gray and light pink, poorly sorted and mottled silt, sand, and clay	255.0	257.0	2.0
	Medium gray, purple-red, brown, and yellow mottled clayey silt grading to silty clay	257.0	262.0	5.0
	Red-brown and gray mottled clayey silt with a trace of sand	262.0	265.0	3.0
	Light gray and green-brown mottled clayey silt with a trace of sand	265.0	268.0	3.0
	Light gray and red mottled clayey silt	268.0	269.0	1.0
	Transition to clayey sandy silt	269.0	272.0	3.0
	Medium red-brown silt with light blue-gray, very fine-grained silty sandy mottling	272.0	274.4	2.4
	Hard, dry mottled clayey silt (more sandy zones starting at 275 feet)	274.4	277.5	3.1
	Medium gray and purple-red mottled silty clay with a trace of sand at 281 feet	277.5	282.0	4.5
	Medium gray, brown, and purple-red mottled clayey silt	282.0	283.5	1.5
Kps	Transition to medium brown-gray, very fine-grained clayey sand (coarse-grained sand with clay pockets at 285.5 feet)	283.5	287.0	3.5
	Loose, moderately sorted, fine- to medium-grained sand [occasional zones (~2 to 4 inches) with clay]	287.0	292.0	5.0
	Medium gray, poorly sorted clayey sand (some zones mostly clay, some with mostly sand starting at 295.5 feet)	292.0	298.5	6.5
	Poorly sorted medium-grained sand with low clay content	298.5	302.0	3.5
	Medium gray, poorly sorted, fine-grained clayey sand (fine- to medium-grained sand starting at 308 feet and some organic matter at 311.5 feet)	302.0	312.0	10.0
	Dark gray and brown silt with trace of mica and organic matter	312.0	316.0	4.0
	Medium brown-gray clayey sandy silt	316.0	320.0	4.0
	Medium gray and purple-red and black (layered) mottled clayey sandy silt with trace of mica and organic matter	320.0	324.5	4.5
	Fine-grained sand (very little clay or silt)	324.5	328.0	3.5
	Poorly sorted, bedded, silty coarse-grained sandy clay	328.0	329.0	1.0

Appendix 1. Lithologic descriptions.—Continued

Site name: USNA PW-3 (from Schnabel Engineering Associates, 1995)

Altitude: 14 feet **Total depth:** 306 feet

Latitude / Longitude: 38º 54′ 34.00″ N / 76º 57′ 32.97″ W

Core used in section D-D′

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Tan, fine to medium grained sand	0.0	10.0	10.0
	Fat clay, gray with thin sand layers	10.0	40.0	30.0
	Brown, fine silty sand	40.0	50.0	10.0
	Red-brown and gray lean clay	50.0	100.0	50.0
	Red-brown and gray lean clay with sand	100.0	120.0	20.0
	Brown fine grained sand	120.0	130.0	10.0
	Red-brown and gray lean clay with fine to medium grained sand	130.0	140.0	10.0
Kps	Gray fine to medium grained sand (lignite below 170 feet, clay layer from 170 to 172 feet)	140.0	200.0	60.0
	Red-brown and gray, lean clay with sand	200.0	230.0	30.0
	Gray fine sand and Gray, subangular to subrounded, medium to coarse grained sand	230.0	250.0	20.0
	Red-brown, lean clay with sand and lignite	250.0	270.0	20.0
	Gray, subangular to subrounded, medium to course sand (probable boulder at 289 feet)	270.0	290.0	20.0
	Red and gray lean clay with sand and lignite (Rock at 306 feet)	290.0	306.0	16.0
bedrock				

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ba 9 (described by C. Klohe on March 10, 2006)

Altitude: 81.26 feet **Total depth:** 24 feet

Latitude / Longitude: 38° 56′ 06.5″ N / 76° 58′ 41.4″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Soil. Fill. Brown to red-brown poorly sorted silt (with sand, gravel, and clay). Some zones contain quartz pebbles (0.4- to 1.6-inch diameter). Some dark minerals.	0.0	2.0	2.0
	Medium to light brown, silty sand, silt, and sandy silt. 2-inch layer of unconsolidated green schist, light-tan sand, pebbles, and dark minerals. 3-inch layer of light-tan, well-sorted, silty fine-grained sand. Thin layer of light tan clay with dark gray stone (1-inch diameter). (3.5 feet of core recovery)	2.0	4.0	2.0
Kpc	Mottled, poorly sorted clay with some zones of high percent light gray sand. Includes dark gray, dark brown, light gray, light brown, and maroon clays. At 7 feet, poorly sorted zone of dark gray clasts	4.0	7.0	3.0
	Medium brown clay mottled with light gray, red, and yellow clay. 0.1- to 0.3-inch-diameter twig in core near 8 feet on top of zone with large crystalline rock chunk.	7.0	8.0	1.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ba 9 (described by C. Klohe on March 10, 2006)

Altitude: 81.26 feet **Total depth:** 24 feet

Latitude / Longitude: 38° 56′ 06.5″ N / 76° 58′ 41.4″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Medium-brown, fining upward sequence of well-sorted, very fine silty sand, fine sand, and well-rounded quartzite cobbles up to 0.25-inch diameter.	8.0	10.5	2.5
	Black and white speckled to light gray to black and white speckled, poorly sorted, silty, fine- to medium-grained sand.	10.5	12.0	1.5
	Light gray to light green-gray sandy clay with thin layers of poorly sorted, dark brown sand.	12.0	14.0	2.0
	Light-orange and tan, poorly sorted, medium-grained sand. Sand grains are multicolored (pinks, whites, grays, medium browns, and dark browns).	14.0	16.0	2.0
	Poorly sorted, medium- to coarse-grained sand with white residue.	16.0	17.0	1.0
	Light tan to white, slightly mottled silt. Some zones with very fine, well-sorted sand.	17.0	20.0	3.0
	Light yellow sandy silt grading to pink-gray clayey silt at 22 feet.	20.0	24.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ba 10 (described by C. Klohe on March 6, 2006)

Altitude: 74.43 feet **Total depth:** 20 feet

Latitude / Longitude: 38° 55′ 34.4″ N / 76° 58′ 21.4″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Light orange-brown, sandy, clayey silt. Poorly sorted. Some pebbles. Some zones with clay or organics. (3 feet of recovery)	0.0	4.0	4.0
	Light orange-brown, silty, clayey, fine-grained sand with some pebbles. (3.5 feet of core recovery)	4.0	8.0	4.0
Qa	Dark brown to light tan, silty, clayey sand. Some zones with organics. Light brown and light gray, mottled, silty sand with organics. (3.5 feet of core recovery)	8.0	10.0	2.0
	Light orange-brown, silty sand with organic material.	10.0	11.0	1.0
	Light orangish-brown silty sand with organic material.	11.0	12.0	1.0
	Medium brown, fine- to medium-grained, silty sand. Wet.	12.0	14.0	2.0
Kpc	Light tan to light gray sandy, silty clay. Wet.	14.0	15.5	1.5
	Light gray sandy clay. Some iron staining.	15.5	16.0	0.5
	Maroon to light brown silt. Some zones of light gray or light pink silt. Moderately well-sorted.	16.0	20.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ca 6 (Hansen, 1968)

Altitude: 80 feet **Total depth:** 340 feet

Latitude / Longitude: 38° 53′ 30.00″ N / 76° 59′ 46.98″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qfe	Sand, brown and gravel	0.0	35.0	35.0
Kpc	Clay, brown	35.0	75.0	40.0
	Clay, brown and sand	75.0	100.0	25.0
	Sand, yellow and clay	100.0	105.0	5.0
	Clay, blue	105.0	158.0	53.0
	Clay, sandy; blue	158.0	175.0	17.0
	Sand, blue and clay	175.0	196.0	21.0
	Clay, “tough”; blue	196.0	242.0	46.0
Kps	Sand	242.0	256.0	14.0
	Clay, “tough”; blue	256.0	272.0	16.0
	Sand	272.0	288.0	16.0
	Clay, “tough”; blue	288.0	307.0	19.0
	Sand and gravel	307.0	328.0	21.0
bedrock	Granite (?)	328.0	340.0	12.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ca 30 (Tenbus, 2003)

Altitude: 3 feet **Total depth:** 30.5 feet

Latitude / Longitude: 38° 54′ 05.8″ N / 76° 57′ 34.2″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa and Qt	Clayey silt (ML), dark greenish gray (5Y 4/1), with thin, nearly black streaks of organic silt (OL) from 0.3 to 1.5 ft	0.0	3.1	3.1
	Organic silt (OL), very dark gray (2.5Y 3/0), soft, seems to have a faint organic or petroleum odor	3.1	4.0	0.9
	Clayey silt (ML), dark gray (5Y 4/0)	4.0	5.3	1.3
	Silt with fine sand (ML), dark gray (5Y 4/0)	5.3	5.5	0.2
	Fine sand (SP), dark gray (5Y 5/2), some lignite at 7.5 ft	5.5	7.5	2.0
	Silt to clayey silt (ML), dark gray (5Y 5/2), slight color change at 8.5 ft to dark gray (5Y 4/1)	7.5	9.5	2.0
	Silty clay (CL), dark gray (5Y 4/0)	9.5	11.8	2.3
	Sandy clay (SC), same as above with medium sand	11.8	12.0	0.2
	Silty clay (CL), gray (5Y 6/0), stiff, with a gradual transition to very stiff from 13.0 to 13.5 ft	12.0	13.5	1.5
	Silty clay (CL), marbled olive and brown, dry, very stiff, becomes hard clay from 17.9 to 18.0 ft	13.5	18.0	4.5
	Clay (CL), gray (%Y 6/0), medium stiff	18.0	19.8	1.8

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ca 30 (Tenbus, 2003)

Altitude: 3 feet **Total depth:** 30.5 feet

Latitude / Longitude: 38° 54′ 05.8″ N / 76° 57′ 34.2″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa and Qt	Gravel, sand, and silt mixture (GM), variegated color, top is reddish yellow (7.5 YR 6/8), color changes to pale olive (5Y 6/3) from 21.0 to 24.5 ft. Contains cobbles as large as 60 millimeters in diameter	19.8	24.5	4.7
	Sandy clay (SC), variegated	24.5	24.8	0.3
	Clay, sand, and gravel mix (GC), light yellowish brown (2.5Y 6/4), gravel sizes to 25 millimeters	24.8	25.0	0.2
	Sandy clay (SC), pale olive (5Y 6/2)	25.0	26.5	1.5
	Poorly graded fine sand (SP), pale olive (5Y 6/2)	26.5	29.5	3.0
Kpc	Clay (CL), red and olive marbled, very stiff	29.5	30.5	1.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ca 32, MW-4 (from DCWRRC, 1993a)

Altitude: 80 feet **Total depth:** 42 feet

Latitude / Longitude: 38° 53′ 32.00″ N / 76° 59′ 46.98″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Brown, damp, sand and fill material	0.0	5.0	5.0
Qfe	Brown, damp, medium grained sand	5.0	6.5	1.5
	No Sample	6.5	10.0	3.5
	Brown, damp, medium grained sand with	10.0	11.5	1.5
	No Sample	11.5	15.0	3.5
	Brown, damp to wet, gravelly sand with some pebbles	15.0	16.5	1.5
	No Sample	16.5	20.0	3.5
	Moist gravel (quartz pebbles)	20.0	21.5	1.5
	No Sample	21.5	25.0	3.5
	Brown, wet sand and gravel	25.0	26.5	1.5
	No Sample	26.5	30.0	3.5
	Brown, wet sand with gravel	30.0	31.5	1.5
	No Sample	31.5	35.0	3.5
	Brown, wet sand with gravel	35.0	36.5	1.5
	No Sample	36.5	40.0	3.5
Kpc	Gray, damp to wet silty clay	40.0	42.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ca 33 (described by C. Klohe on August 5, 2005)

Altitude: 67.75 feet **Total depth:** 40 feet

Latitude / Longitude: 38° 53′ 49.8″ N / 76° 59′ 28.3″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qfe	Gravels and tan, silty sand.	0.0	1.5	1.5
	Tan brown silty sand with gravels.	1.5	12.0	10.5
	Brown silty sand.	12.0	16.5	4.5
	Tan silty fine sand with well-sorted gravels	16.5	30	13.5
	No core recovery. Lost circulation at 34 feet.	30.0	38.0	8.0
Kpc	Tan silty clay.	38.0	40.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ca 34 (described by C. Klohe on August 10, 2005)

Altitude: 19.61 feet **Total depth:** 45.5 feet

Latitude / Longitude: 38° 52′ 45.6″ N / 76° 58′ 35.1″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Sod and topsoil.	0.0	0.5	0.5
	Tan silty sand with gravels.	0.5	1.5	1.0
	Yellowish-brown silty sand.	1.5	4.0	2.5
Qa	Tan silty sand with poorly sorted gravel.	4.0	5.0	1.0
	Less tan silty sand than interval above with more large gravels.	5.0	6.0	1.0
	Poorly sorted gravels with little tan silty sand.	6.0	8.0	2.0
	Grayish-tan silty sand with clay mixed in. Less gravel than interval above.	8.0	11.5	3.5
	Greenish-gray, silty, clayey sand with little gravel. Lost circulation at 17 feet. (possible water).	11.5	21.0	9.5
Kpc	Gray, silty, clayey sand (no gravel).	21.0	31.0	10.0
	Gray, silty sand.	31.0	41.5	10.5
	Light gray, silty, clayey sand.	41.5	43.5	2.0
	Gray clay (core sample).	43.5	45.5	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ca 35, USNA PW-2 (from A.C. Schultes of Maryland, Inc. [n.d.], Job #2616)

Altitude: 149.6 feet **Total depth:** 265 feet

Latitude / Longitude: 38º 54′ 29.20″ N / 76º 58′ 36.00″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Fine clay sand with clay. Subangular to subrounded, brown	0.0	5.0	5.0
Kpc	Clay with sand. Brown and gray	5.0	90.0	85.0
	Clay with sand. Red-brown. Sand layers at 115-117, 122-124, and below 150 feet.	90.0	168.0	78.0
	Fine clayey sand with clay lenses. Red-brown	168.0	178.0	10.0
Kps	Fine to medium sand with clay lenses. Clay layers below 255 feet	178.0	265.0	87.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Ca 38 (described by C. Klohe on March 13, 2006)

Altitude: 45 feet **Total depth:** 24.0 feet

Latitude / Longitude: 38° 54′ 16.07″ N / 76° 58′ 15.54″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Soil. Poorly sorted, tan, sandy silt with gravels. Some quartzite gravels 0.25- to 1.5-inch diameter. Red-brown silt with gravels. (2.5 feet recovery)	0.0	4.0	4.0
Kpc	Light reddish-brown silty clay (slightly mottled with light yellowish-orange clay). Organic matter visible at 5.5 feet. Organic matter with black mottling from 6 to 8 feet.	4.0	8.0	4.0
	Red-brown silty clay with zone of light brown/tan silty sand at approximately 10 feet.	8.0	10.0	2.0
	Reddish-brown clay.	10.0	11.0	1.0
	Red clay.	11.0	12.0	1.0
	No recovery.	12.0	16.0	4.0
	Light red-brown, sandy silt with a trace amount of organic matter.	16.0	18.5	2.5
	Light brown, orange and red mottled silty clay. Some organic matter.	18.5	20	1.5
	Light brown to light gray, very well-sorted, very fine-grained, clayey, silty sand.	20.0	21.5	1.5
	Light gray clay and red and gray mottled clay.	21.5	23	1.5
	Yellow,-gray,-green, brown and light gray mottled clay.	23.0	24.0	1.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cb 7 (Tenbus, 2003)

Altitude: 4 feet **Total depth:** 27.9 feet

Latitude / Longitude: 38° 54′ 59.5″ N / 76° 56′ 34.0″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qa and Qt	Gravel and sand mixture (GP), light yellowish brown (2.5Y 6/3). Sand is coarse, subrounded, with cobbles up to 35 millimeters. Occasional small (~5 millimeters) anthropogenic glass fragments noted	0.0	1.7	1.7
	Gravel, sand, and silt mixture (GM), light yellowish brown (2.5Y 5/3), cobbles up to 50 millimeters. Small glass fragment near 2.8 ft	1.7	2.8	1.1
	Fine poorly graded sand (SP), same color as above (2.5Y 5/3)	2.8	3.5	0.7
	Silty clay (CL), grayish brown (2.5Y 5/2), soft	3.5	6.8	3.3
	Fine silty sand (SM), color not uniform, generally dark gray to dark olive. Predominantly very dark gray (5Y 3/0)	6.8	8.1	1.3
	Medium clean sand (SP) with lignite chunks (possibly old leafy material), light gray (5Y 7/2)	8.1	8.7	0.6
	Silty clay (CL), very dark gray (5Y 3/0), some lignite	8.7	9.1	0.4
	Gravel-sand mixture (GW), no silt, color is variable shades of brown and gray, cobbles up to 50 millimeters	9.1	12.0	2.9
	Gravel-sand mixture (GW), same as above, red (2.5YR 4/8) mixed with pale yellow (2.5Y 7/4)	12.0	13.0	1.0
	Fine poorly graded sand (SP), very pale brown (10YR 7/3), no clay or silt, subrounded grains, with a thin layer of fine sand and gravel, red (2.5YR 4/8) from 14.0 to 14.1 ft below land surface	13.0	25.2	12.2
	Same material as above, color includes reddish brown mottles (2.5YR 5/3)	25.2	25.7	0.5
	Fine poorly graded sand (SP), very pale brown (10YR 7/3), no clay or silt, subrounded grains	25.7	27.9	2.2

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cb 8, MW-1 (from DCWRRC, 1993a)

Altitude: 61 feet **Total Depth:** 277 feet

Latitude / Longitude: 38° 52′ 52.00″ N / 76° 57′ 27.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Cuttings: Tan, medium grained sand	0.0	22.0	22.0
	No sample	22.0	25.0	3.0
	Fine to coarse grained clayey sand	25.0	26.5	1.5
	No sample	26.5	30.0	3.5
	Reddish-brown and gray, dry, very stiff clay	30.0	31.5	1.5
	No sample	31.5	35.0	3.5
	Greenish-gray, hard to very stiff clay with trace of sand (damp)	35.0	36.5	1.5
	No sample	36.5	40.0	3.5
	Greenish-gray clay with trace of sand	40.0	41.5	1.5
	No sample	41.5	45.0	3.5

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cb 8, MW-1 (from DCWRRC, 1993a)

Altitude: 61 feet **Total Depth:** 277 feet

Latitude / Longitude: 38º 52′ 52.00″ N / 76º 57′ 27.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kpc	Reddish-brown to brown, hard, clay	45.0	46.5	1.5
	No sample	46.5	50.0	3.5
	Reddish-brown, dry clay	50.0	51.5	1.5
	No sample	51.5	55.0	3.5
	Brown, very hard, dry clay	55.0	56.5	1.5
	No sample	56.5	60.0	3.5
	Brown, hard and stiff, dry clay	60.0	61.5	1.5
	No sample	61.5	65.0	3.5
	Brown, hard, dry clay	65.0	66.5	1.5
	No sample	66.5	70.0	3.5
	Reddish-brown, hard, dry clay	70.0	71.5	1.5
	No sample	71.5	75.0	3.5
	Purple, hard and stiff, dry clay	75.0	76.5	1.5
	No sample	76.5	80.0	3.5
	Purple, hard, dry clay	80.0	81.5	1.5
	No sample	81.5	85.0	3.5
	Reddish-brown, hard, dry clay	85.0	86.5	1.5
	No sample	86.5	90.0	3.5
	Reddish-brown, very hard, dry clay	90.0	91.5	1.5
	No sample	91.5	95.0	3.5
	Reddish-brown, dry clay	95.0	96.5	1.5
	No sample	96.5	97.0	0.5
	Very hard clay with lenses of sand	97.0	98.5	1.5
	No sample	98.5	107.0	8.5
	Clay, very hard, brown to gray and purple to reddish-brown	107.0	108.5	1.5
	No sample	108.5	117.0	8.5
	Reddish clay with some sand lenses	117.0	118.5	1.5
	No sample	118.5	127.0	8.5
	Reddish-brown, dry clay	127.0	128.5	1.5
	No sample	128.5	137.0	8.5
	Reddish-brown clay	137.0	138.5	1.5
	No sample	138.5	147.0	8.5
	Brown, hard, dry clay	147.0	148.5	1.5
	No sample	148.5	157.0	8.5
	Reddish-brown clay with some gravel and sand lenses (damp)	157.0	158.5	1.5
	No sample	158.5	167.0	8.5
	Reddish-brown, very hard, dry clay	167.0	168.5	1.5
	No sample	168.5	242.0	73.5
	Brown, very hard, dry clay	242.0	242.5	0.5

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cb 8, MW-1 (from DCWRRC, 1993a)

Altitude: 61 feet **Total Depth:** 277 feet

Latitude / Longitude: 38º 52′ 52.00″ N / 76º 57′ 27.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Grayish, coarse grained clayey sand (water intercepted at 238 feet and rose to 40 feet below land surface)	243.0	250.0	7.0
	No sample	250.0	256.0	6.0
	Reddish-brown, very dense clayey sand with trace of gravel (wet)	256.0	260.0	4.0
	Coarse grained sand with trace of gravel	260.0	277.0	17.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cb 9, MW-B1 (DCWRRC, 1993b)

Altitude: 45.52 feet **Total depth:** 19 feet

Latitude / Longitude: 38º 53′ 55.00″ N / 76º 55′ 54.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Fill material, clayey, brown	0.0	5.0	5.0
Qa	Tan, damp, medium grained clayey sand	5.0	6.5	1.5
	No Sample	6.5	10.0	3.5
	Brown, wet, medium to coarse grained, gravelly sand	10.0	11.5	1.5
	No Sample	11.5	15.0	3.5
	Brown, wet, medium to coarse grained sand with gravels	15.0	16.5	1.5

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cb 11 (described by C. Klohe on March 13, 2006)

Altitude: 59.99 feet **Total depth:** 24 feet

Latitude / Longitude: 38° 53′ 32.1″ N / 76° 56′ 41.2″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of bnterval (feet)	Thickness (feet)
dgf	Topsoil and fill. Poorly sorted silt with gravel, rocks, and debris. Lower 1 foot is medium brown to orange-brown silty sand with 0.25-inch diameter gravels throughout. (2.5 feet of sample recovery)	0.0	4.0	4.0
	Fill. Poorly sorted, medium brown to orange-brown silty sand with poorly sorted gravels. Bottom 4 feet is tight, hard, and dry, light orange silt with inclusions of red, dark gray, and light gray clay chunks as well as pebbles and a 1.5-inch dark gray angular gravel. (2.5 feet of sample recovery)	4.0	8.0	4.0
Qa	Mottled light to medium gray sandy silt with zones of high percent organic matter (woody material) and poorly sorted gravels and coarse sand. (2.0 feet of sample recovery).	8.0	12.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cb 11 (described by C. Klohe on March 13, 2006)

Altitude: 59.99 feet **Total depth:** 24 feet

Latitude / Longitude: 38° 53′ 32.1″ N / 76° 56′ 41.2″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of bnterval (feet)	Thickness (feet)
Qa	Medium brownish-gray silty clay with a high percent of organic matter. Contains sticks (0.25 inch) to twigs (0.5 inch) and thin layers of organic material (leaves) throughout.	12.0	13.5	1.5
	Very fine, well sorted, light orange, yellow-brown clayey sand. Zone of high organic content from 14.5 to 15.0 feet with 0.12-inch diameter woody twigs.	13.5	16.0	2.5
	Light gray to light tan, clayey, fine-grained sand. Some zones with large pieces of organic matter, especially near 19.7 feet. Wet.	16.0	20.0	4.0
Kpc	Reddish maroon-brown clay (tight, stiff) with approximately 5 percent light gray mottling.	20.0	24.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cb 12 (described by C. Klohe on August 2, 2005)

Altitude: 60.59 feet **Total depth:** 81 feet

Latitude / Longitude: 38° 53′ 32.1″ N / 76° 56′ 41.2″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Gravel and topsoil.	0.0	0.3	0.3
	Tannish-brown silty sand with small gravel.	0.3	3.0	2.7
	Brown sandy clay with gravels.	3.0	5.0	2.0
Qa	Brown sandy clay.	5.0	13.0	8.0
	Grayish-tan silty sand.	13.0	17.0	4.0
	Tan silty sand.	17.0	20.0	3.0
Kpc	Reddish-tan clayey sand.	20.0	22.0	2.0
	Red sandy clay.	22.0	40.0	18.0
	Little sample return. Possible lithology change at 42 feet.	40.0	42.0	2.0
	Tan silty sand.	42.0	43.5	1.5
	Grayish-pink clay. (Core sample)	43.5	45.5	2.0
	Tan silty sand. Poor sample return (easier drilling from top of interval).	45.5	47.0	1.5
	Tan silty sand. Very loose. Wet.	47.0	50.0	3.0
	Tan silty sand.	50.0	54.0	4.0
	Grayish-pink sandy clay (split-spoon core sample).	54.0	56.0	2.0
	Tan silty clay.	56.0	66.5	10.5
	Tan silty sand. Loose. Very wet.	66.5	69.0	2.5
	Brownish-gray sandy clay to greenish-gray silty clay. (core sample)	69.0	71.0	2.0
	Tan silty sand	71.0	72.5	1.5
	No sample	72.5	81.0	8.5

Appendix 1. Lithologic descriptions.—Continued

Site name: WE Cc 3 (described by C. Klohe on March 2, 2006)

Altitude: 88.70 feet **Total depth:** 24 feet

Latitude / Longitude: 38° 53′ 27.0″ N / 76° 54′ 48.5″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Topsoil	0.0	0.5	0.5
dgf	Light red-brown and light gray clayey, sandy, silt with poorly sorted (0.25- to 0.75-inch diameter) quartz gravel.	0.5	3.0	2.5
dgf	Light brown to yellow-orange silt.	3.0	4.0	1.0
Qa	Yellow-orange and light gray clayey silt.	4.0	5.0	1.0
Qa	Gravel layer at upper contact (5-foot depth) with dark gray to light red-brown clay.	5.0	6.0	1.0
Qa	Medium brown, silty, fine-grained sand.	6.0	7.0	1.0
Qa	Yellow-orange, very fine-grained silty sand.	7.0	8.0	1.0
Qa	Coarsening downward sequence of yellow-orange silt to very fine-grained silty sand to light tan fine-grained sand with quartz gravels 0.25 to 1.25 inches in diameter. (2.5 feet of sample recovery)	8.0	12.0	4.0
Qa	Fine sandy silt (wet) above medium brown silty clay above light tan fine-grained sand (approximately 0.5 feet) above coarsening downward sequence of medium gray clay to medium gray silt to light tan fine-grained sand. (3.0 feet of sample recovery) Cobbles at 12.0 feet.	12.0	16.0	4.0
Qa	Moderately well-sorted, fine- to medium-grained, light orange-tan sand. Wet.	16.0	24.0	8.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WW Bc 8 (described by C. Klohe on March 1, 2006)

Altitude: 123.39 feet **Total depth:** 32 feet

Latitude / Longitude: 38° 55′ 19.3″ N / 77° 01′ 26.9″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Soil. Medium brown-gray clay. Medium to light tan, fine-grained, poorly sorted, silty sand, with some clay. (2.0 feet of recovery)	0.0	4.0	4.0
dgf	Medium to light tan, fine-grained, poorly sorted, silty sand, some large gravels and clay. Bottom of interval has a 2- to 4-inch layer of orange-brown silty clay layer on top of a 1-inch layer of organic rich soil with large fragments of broken glass. (1.0 foot of sample recovery)	4.0	8.0	4.0
dgf	Organic rich, dark brown silt with coarse sand, gravel, and broken glass.	8.0	8.5	0.5
dgf	Medium yellow-brown silt with poorly sorted angular pebbles 0.25 to 1.0 inch in size.	8.5	9.5	1.0
dgf	Gray, silty clay mottled with red and brown silty clay. Some pebbles, gravels, and coarse sands (poorly sorted).	9.5	11.0	1.5
Qfe	Light gray clay mottled with red-orange clay.	11.0	16.0	5.0
Qfe	Light gray silt (transition to no mottling).	16.0	17.0	1.0
Qfe	Dark gray silty clay.	17.0	20.0	3.0
Qfe	Light brown silt with some thin layers of silt and fine sand.	20.0	22.0	2.0
Qfe	Light brown silt transitioning to thinly laminated light gray, organics (black), and yellow-orange silty clay. Cobbles with fine sand at 24 feet.	22.0	24.0	2.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WW Bc 8 (described by C. Klohe on March 1, 2006)

Altitude: 123.39 feet **Total depth:** 32 feet

Latitude / Longitude: 38° 55′ 19.3″ N / 77° 01′ 26.9″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Kps	Light gray, poorly sorted, fine- to medium- grained silty sand with white (calcareous) silt that leaves light gray to white residue. Some thin layers of cobbles (0.4- to 0.8-inch diameter), iron staining, and organics.	24.0	28.0	4.0
	Medium to light gray, poorly sorted, medium-grained, silty sand with white residue. Interval also includes light gray clay. Poor sample recovery.	28.0	32.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WW Bc 9 (described by C. Klohe on March 3, 2006)

Altitude: 133.60 feet **Total Depth:** 36.0 feet

Latitude / Longitude: 38° 55′ 27.8″ N / 77° 00′ 07.7″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
dgf	Soil, fill (silt and stones). Zone with lignite, glass, and light colored wood chips. Bottom of interval contains silt with cobbles. (3.0-feet of sample recovery)	0.0	4.0	4.0
	No sample recovery.	4.0	8.0	4.0
Kpc	Red-brown clay with organic material and iron nodules. Some nodules are hard and others are pliable like dark clay.	8.0	13.5	5.5
	Transition from reddish clay to medium gray silt with minor traces of organics. Some thin (less than 0.25 inches) layers of very fine silty sand.	13.5	16.0	2.5
	Medium to dark gray sandy silt. Some zones with a higher percent of very fine-grained sand. Interval ranges from no mottling to light gray to maroon mottling.	16.0	23.0	7.0
	Thin layer of clayey sand at top of interval then dark gray silty clay. Fairly brittle.	23.0	25.5	2.5
Kps	Medium gray, fine-grained sand. Wet.	25.5	28.0	2.5
	Transition zone from a medium gray, fine-grained, sandy clay to very fine-grained, light yellow-gray sand. Wet.	28.0	29.0	1.0
	Light tan, fine-grained sand with approximately 5 percent black grains (organic or dark mineral). Fairly well-sorted.	29.0	31.5	2.5
	Same as above except increase in silt/clay content.	31.5	32.0	0.5
	Fine sand, medium sand, and gravel. Fining upward. Gravel 0.12- to 0.75-inch diameter, angular to rounded. (1.0 foot of sample recovery)	32.0	36.0	4.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WW Cc 26 (from Hansen, 1968)

Altitude: 65 feet **Total depth:** 85 feet

Latitude / Longitude: 38º 54′ 10.00″ N / 77º 01′ 53.97″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to bottom of interval (feet)	Thickness (feet)
Qfe	Clay, sandy, yellow	0.0	23.0	23.0
	Clay, sandy, blue	23.0	41.0	18.0
	Sand, medium and gravel	41.0	45.0	4.0
	Sand, coarse and gravel	45.0	53.0	8.0
	Clay, "tough"; blue and black	53.0	65.0	12.0
	Sand, coarse and gravel	65.0	68.0	3.0
	Gravel	68.0	77.0	9.0
bedrock	Rock, "rotten"; grading into hard rock	77.0	85.0	8.0

Appendix 1. Lithologic descriptions.—Continued

Site name: WW Cc 37 (described by R. Starsoneck on August 11, 2005)

Altitude: 84 feet **Total depth:** 36 feet

Latitude / Longitude: 38° 54′ 43.41″ N / 77° 01′ 34.66″ W

Geologic map units	Description	Depth to top of interval (feet)	Depth to Bottom of Interval (feet)	Thickness (feet)
dgf	Topsoil and tan silty sand with gravels (1.5 to 2.0 feet)	0	2.5	2.5
Qt	Dark gray silty, clayey sand	2.5	4.5	2.0
	Greenish-gray clayey sand	4.5	6.0	1.5
	Tannish-gray clayey sand and clay	6.0	11.0	5.0
	Tan silty clay	11.0	13.0	2.0
	Tan silty clay with gravel	13.0	26.0	13.0
	Tan sandy clay	26.0	32.0	6.0
	No return from augers	32.0	36.0	4.0

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Appendix 2. Continuous Groundwater-Level and Temperature Measurements at Sites We Bb 3, We Bb 4, We Cb 5, We Cb 6, We Cb 8, and We Cb 12

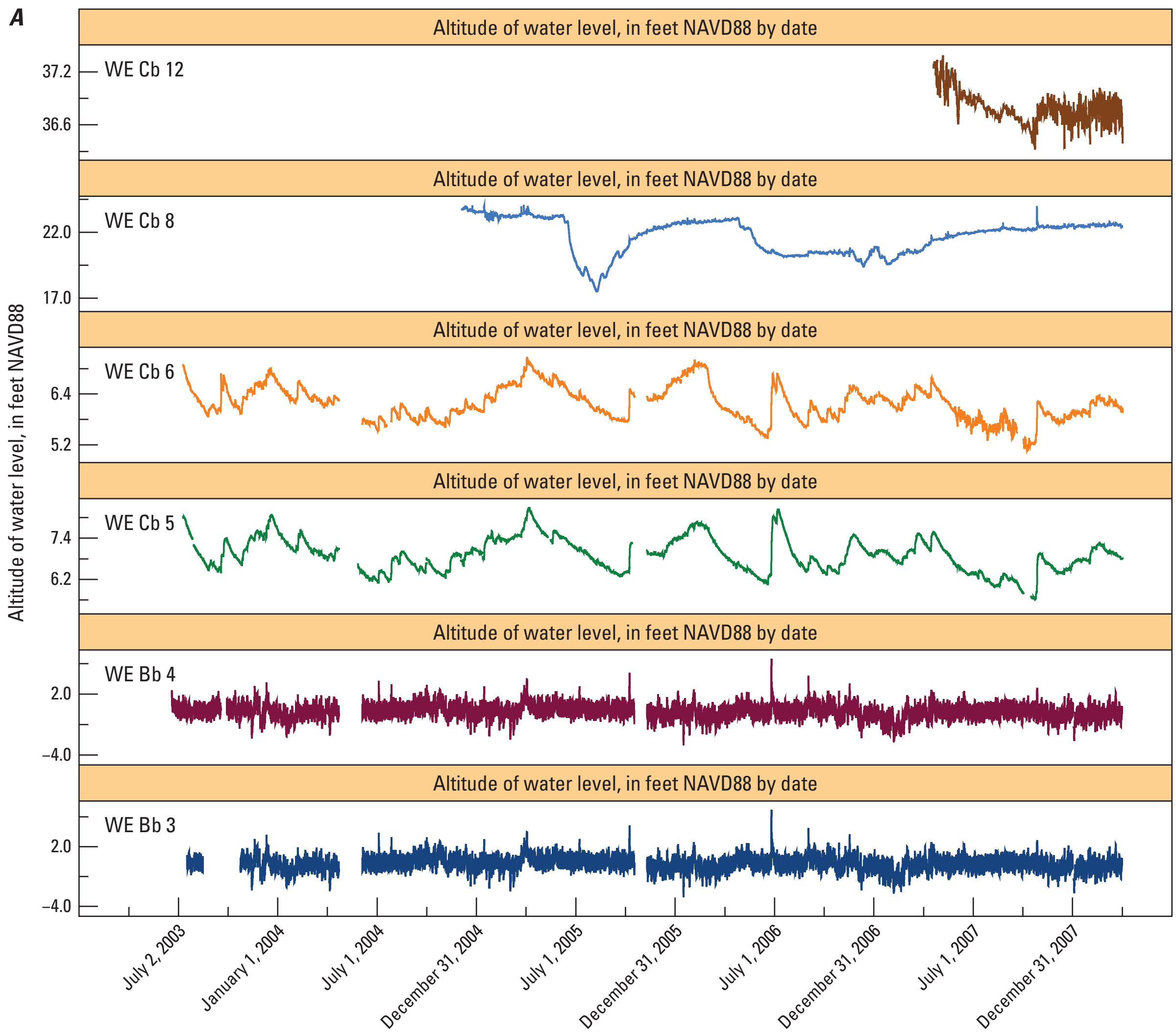

Figure 2.1. *A*, Continuous groundwater level and *B*, temperature measurements at sites WE Bb 3, WE Bb 4, WE Cb 5, WE Cb 6, WE Cb 8, and WE Cb 12. Altitudes of water levels are shown in feet relative to North American Vertical Datum of 1988 (NAVD88).

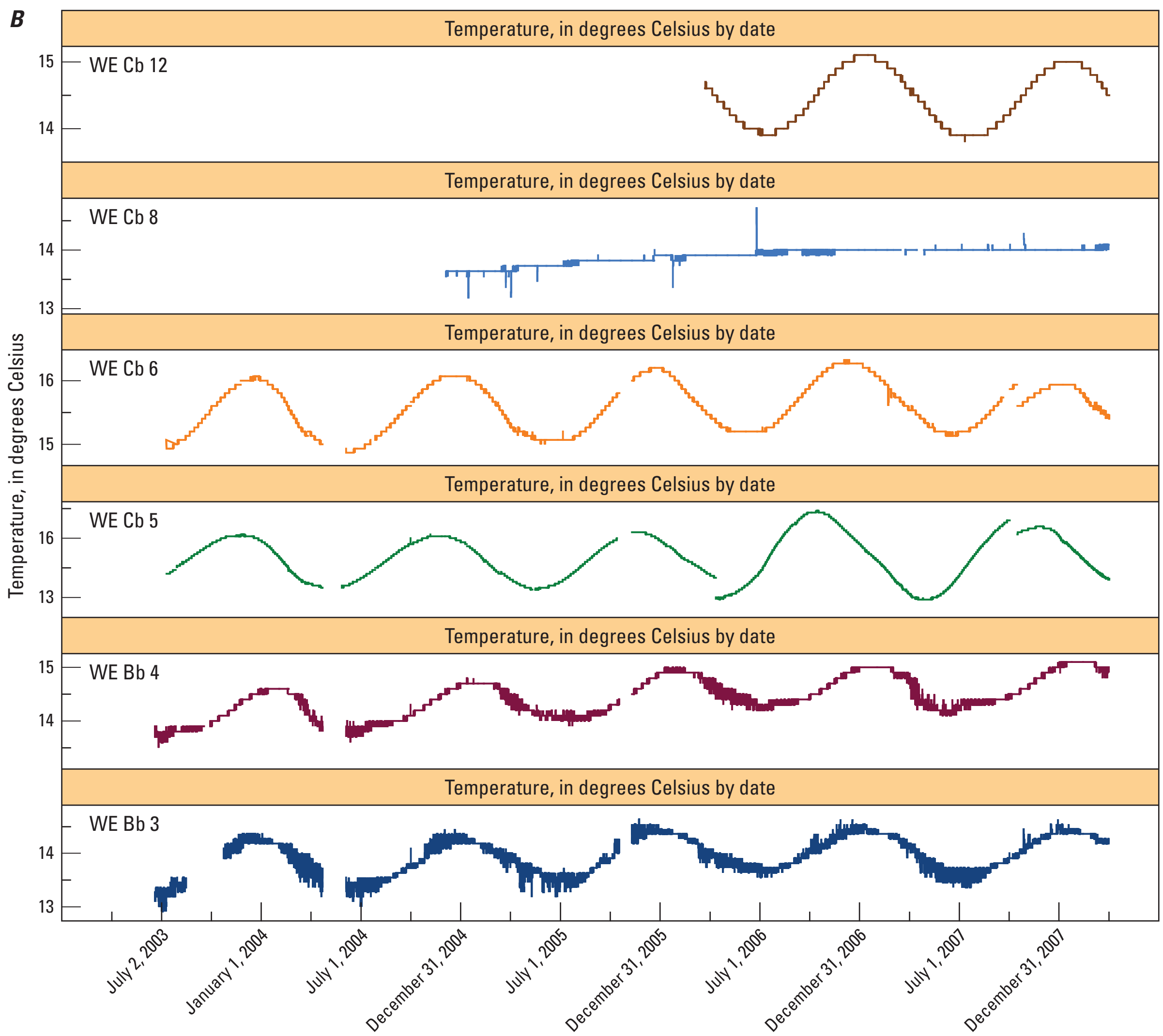

Figure 2.1. *A*, Continuous groundwater level and *B*, temperature measurements at sites WE Bb 3, WE Bb 4, WE Cb 5, WE Cb 6, WE Cb 8, and WE Cb 12.—Continued

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