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NSB KINGS BAY
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LETTER WITH ATTACHED DRAFT SOIL CHEMISTRY AND GROUNDWATER QUALITY OF WATER TABLE ZONE OF SURFICIAL AQUIFER 1998 AND 1999 FOR REVIEW NSB KINGS BAY GA

10/25/2001

NSB KINGS BAY

NSB Kings Bay Administrative Record
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DEPARTMENT OF THE NAVY

NAVAL SUBMARINE BASE
1063 USS TENNESSEE AVENUE
KINGS BAY, GEORGIA 31547-2606

IN REPLY REFER TO:

5090
Ser FE4/2409
25 OCT 2001

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Mr. Bruce Khaleghi
Georgia Department of Natural Resources
Environmental Protection Division
205 Butler Street, SE, Suite 1252
Atlanta, GA 30334

Dear Mr. Khaleghi:

Please find for your review enclosure (1), an advance draft of the U.S. Geological Survey report, "Soil Chemistry and Ground-Water Quality of the Water-Table Zone of the Surficial Aquifer, Naval Submarine Base Kings Bay, Camden County, Georgia, 1998 and 1999". This study shows no difference between the background concentrations of constituents tested in soil and groundwater when compared to concentrations at our Installation Restoration Sites 5 and 16. Site 5 is listed in our Hazardous Waste Permit HW-014 (S&T)-3 as Solid Waste Management Unit number 4, Army Reserve Disposal Area, Towhee Trail. Site 16 is listed in our permit as Solid Waste Management Unit number 6, Army Reserve Disposal Area near Old Sewage Lagoon 3990.

This letter and its enclosure will serve as our final Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) Report for Installation Restoration Sites 5 and 16, per our discussion with Mr. Hendricks of your office during our Restoration Advisory Board meeting August 23, 2001.

I certify under penalty of law that this document and all attachments were prepared under my direct supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

The SUBASE Kings Bay point of contact is Ken Yargus, (912) 673-2001, extension 1217. Please address all correspondence to "Commanding Officer, Naval Submarine Base, Kings Bay, 1063 USS TENNESSEE Avenue, Kings Bay, GA 31547-2606."

Sincerely,

Kim Weinburger
for M. E. SCHAEFER
Captain, CEC, USN
F&E Director
By direction of the
Commanding Officer

Enclosure: 1. Soil Chemistry and Ground-Water Quality of the Water-Table Zone of the Surficial Aquifer, Naval Submarine Base Kings Bay, Camden County, Georgia, 1998 and 1999

Copy to:
SOUTHNAVENGCOM (Anthony Robinson)
U.S. Geological Survey (David Leeth)
J.A. Jones Environmental Services (Sam Ross)
COMNAVREG-SE

Soil Chemistry and Ground-Water Quality of the Water-Table Zone of the Surficial Aquifer, Naval Submarine Base Kings Bay, Camden County, Georgia,1998 and1999

by David C. Leeth

U.S. Geological Survey

Water-Resources Investigations Report 01-xxx

Prepared in cooperation with

U.S. DEPARTMENT OF THE DEFENSE
U.S. DEPARTMENT OF THE NAVY
SOUTHERN DIVISION NAVAL FACILITIES ENGINEERING COMMAND

Atlanta, Georgia
2001

ENCLOSURE (1)

U.S. DEPARTMENT OF THE INTERIOR
GALE A. NORTON, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information write to:

State Representative
U.S. Geological Survey
Peachtree Business Center, Suite 130
3039 Amwiler Road
Atlanta, GA 30360

Copies of this report can be purchased from:

U.S. Geological Survey
Branch of Information Services
Denver Federal Center
Box 25286
Denver, CO 80225-0286

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VERTICAL DATUM

Sea Level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called "Sea Level Datum of 1929."

Soil Chemistry and Ground-Water Quality of the Water-Table Zone of the Surficial Aquifer, Naval Submarine Base Kings Bay, Camden County, Georgia, 1998 and 1999

By David C. Leeth

ABSTRACT

In 1998, the U.S. Geological Survey, in cooperation with the U.S. Department of the Navy, began an investigation to determine background ground-water quality of the water-table zone of the surficial aquifer and soil chemistry at Naval Submarine Base Kings Bay, Camden County, Georgia, and to compare these data to two abandoned solid waste-disposal areas (referred to by the U.S. Navy as Sites 5 and 16). The quality of water in the water-table zone generally is within the U.S. Environmental Protection Agency (USEPA) drinking-water regulation. The pH of the ground water in the study area ranged from 4.0 to 7.6 standard units, with a median value of 5.4. Water from 29 wells is above the range and 3 wells are within the range of the USEPA secondary drinking-water regulation (formerly known as the Secondary Maximum Contaminant Level or SMCL) of 6.5 to 8.5 standard units. Also, water from one well at Site 5 had a chloride concentration of 570 milligrams per liter (mg/L,), which is above the USEPA secondary drinking-water regulation of 250 mg/L. Sulfate concentrations in water from two wells at Site 5 are above the USEPA secondary drinking-water regulation of 250 mg/L.

Of 22 soil-sampling locations for this study, three locations had concentrations above the detection limit for either volatile organic compounds (VOCs), base-neutral acids (BNAs), or pesticides. VOCs detected in the study area include toluene in one background sample; and acetone in one background sample and one sample from Site 16—however, detection of these two compounds may be a laboratory artifact. Pesticides detected in soil at the Submarine Base include two degradates of DDT: 4,4′-DDD in one background sample, 4,4′–DDE in one background sample and one sample from Site 16; and dibenzofuran in one sample from Site 16. BNAs were detected in one background sample and in two samples from Site 16.

Hypothesis testing, using the Wilcoxon rank-sum test (also known as the Mann-Whitney test), indicates no statistical difference between ground-water constituent concentrations from Sites 5 and 16, and background concentrations.

Hypothesis testing, however, indicates the concentration of barium in background ground-water samples is greater than in ground-water samples collected at Site 16.

INTRODUCTION

Naval Submarine Base Kings Bay (NSB), a U.S. Department of the Navy (Navy) facility in Camden County, Ga., has been a Trident Submarine installation since 1982. From the early 1950's until 1978, the facility was operated by the U.S. Department of the Army (Army) as a military ocean terminal (fig. 1). In 1978, the Navy began operation of Kings Bay as a fleet ballistic-missile-support facility; and in 1979, the base was officially named Naval Submarine Base Kings Bay (NSB Kings Bay).

Because of past activities by the Army, NSB Kings Bay has several sites that were used to dispose of solid waste. Preliminary results from investigations at two of these sites (5 and 16) (fig. 2)indicate concentrations of metals in ground water from the water-table zone of the surficial aquifer and organic compounds in the soil are above detection limits (U.S. Department of the Navy, 1994a, b). These results, however, could be a reflection of background conditions at NSB Kings Bay. Also, organic compounds detected in soil are associated with the pesticide DDT, which was used extensively nationwide until 1973 (U.S. Environmental Protection Agency, 1990a). Until the current study (2001), background water-quality and soil conditions at the NSB Kings Bay had not been quantified; instead, previous studies focused on small-scale, site-specific ground-water conditions.

In 1998, the U.S. Geological Survey (USGS), in cooperation with the Navy, began an investigation to compile and compare background ground-water-quality and soil conditions at two areas affected by past solid-waste disposal. Data collected during this study will be used by the Navy to assess the quality of water in the water-table zone of the surficial aquifer; and thus, allow the Navy to more effectively manage ground-water resources and monitor the water-table zone.

Purpose and Scope

This report describes background ground-water quality of the water-table zone of the surficial aquifer and soil chemistry at NSB Kings Bay; then compares background conditions to ground-water-quality data and soil chemistry from two areas affected by past landfill solid-waste disposal. Long-term water-level data and data to define the configuration of the water table at Sites 5 and 16 were collected to help define long-term water-level fluctuations and ground-water flow directions (fig. 2).

Study objectives were to:

- define background ground-water-quality conditions using selected field properties and concentrations of trace metals, and major ions in the water-table zone of the surficial aquifer, using a network of monitoring wells;
- define background soil chemistry of selected organic compounds from a network of soil-sampling locations;
- define the vertical and horizontal extent of areas that may have been affected by past landfill solid-waste disposal;
- compare data on background conditions to data collected in areas that may be impacted by landfill solid-waste disposal; and
- determine long-term water-level fluctuations and the configuration of the water table at sites impacted by past landfill solid-waste disposal.

The study area encompasses about 12 square miles (mi^2) of the NSB Kings Bay and adjacent area; the surficial aquifer was evaluated from land surface to a depth of about 35 feet (ft). The scope of the work included observation-well drilling, soil boring and hand augering, examination of geophysical logs and surveys; water-level measurements; sampling ground water from 29 wells for chemical analysis; and sampling soil at 22 locations for chemical analysis.

Previous Investigations

Herrick (1965) discussed the subsurface extent of Pliocene (?)-Pleistocene deposits in coastal Georgia. Gregg and Zimmerman (1974) discussed the geologic and hydrologic controls of chloride contamination in aquifers at Brunswick, Ga. Geologic and hydrogeologic data for NSB Kings Bay were discussed in the initial environmental impact statement for the base (U.S. Army Corps of Engineers, 1977) and by a follow-up study specifically addressing the extent of the unconfined ground-water system (U.S. Army Corps of Engineers, 1978). Soils and Materials Engineers, Inc., discussed the ground-water resources in Pliocene to Holocene deposits at Skidaway Island, Ga. (1986a), and in Miocene deposits at Colonel s Island, Ga. (1986b).

Several authors have described the hydrogeology, geology, and water quality in aquifers located in southeastern Georgia—an area that encompasses NSB Kings Bay. Brown (1984) evaluated the impact of development on availability and quality of ground water in eastern Nassau County, Fla., and southeastern Camden County, Ga. Saltwater intrusion and water quality in the Floridan aquifer system of northeastern Florida—including southern Camden County, Ga.—was evaluated by Spechler (1994). Recent site-specific investigations that have evaluated the hydrology and geology of NSB Kings Bay include site remediation reports for the Navy (U.S. Department of the Navy, 1993, 1994a, b). Leeth (1998) described the hydrogeology and water-quality data of the surficial aquifer—including the water table—near Site 11 at the northern end of the base. Selected data on estuarine, surface- and ground-water quality, and estuarine sediment data were reported by Leeth and Holloway (2000).

More areally extensive studies include those of Krause and Randolph (1989) who conducted a digital model evaluation of the Floridan aquifer system and compiled an extensive bibliography on the hydrology and geology of southeastern Georgia, and adjacent parts of Florida and South Carolina. Krause and others (1984) presented hydrogeologic data for coastal Georgia. Clarke and others (1990) described the geology and ground-water resources of coastal Georgia, including the surficial aquifers. A review and revision of the shallow lithostratigraphy of the Georgia Coastal Plain was discussed in detail by Huddlestun (1988).

Description of the Study Area

Description of the physiography and climate of the NSB Kings Bay study area is included to aid readers in comparing site-specific data from this report with data from other locations. NSB Kings Bay is in southeastern Camden County, Ga., and is bounded to the north by Crooked River State Park; to the east by Crooked River and Cumberland Sound; to the south by the corporate boundary of St Marys, Ga.; and to the west by Georgia State Highway 40-Spur (fig. 1). NSB Kings Bay lies in the Barrier Island Sequence District, Sea Island Section of the Coastal Plain Province of Georgia (Clark and Zisa, 1976). Topographic relief across NSB Kings Bay is low, with the minimum altitude of sea level to the east and a maximum altitude of about 34 feet (ft) above sea level to the west. Topographic relief is largely a result of relict shorelines that were formed during global sea level decline (Leve, 1966).

The study area consists of about 12 mi^2, approximately centered around the NSB Kings Bay boundary (fig. 1). The two areas possibly affected by past landfill solid-waste practices are referred to by the Navy as Site 5 and Site 16. These sites are both located in the east-central portion of the base (fig. 2).

The climate of Camden County, Ga., is humid subtropical and is characterized by long, warm, relatively wet summers, and mild relatively dry winters. The mean-annual rainfall for Camden County ranges from about 52 to 54 inches (St. Johns River Water Management District, 1977). About 60 percent of the annual rainfall occurs from June through September, ranging from about 6 to 8 inches per month. October through May are the driest months, when normal rainfall ranges from about 2 to 4 inches per month (Brown, 1984). Evapotranspiration in southern Camden County is about 30 to 40 inches per year, with about 60 percent occurring from April through September (Brown, 1984).

Well-Numbering System

Observation wells used in this report are numbered according to a system based on the USGS index of topographic maps. Each 7.5-minute topographic quadrangle in Georgia has been given a number and letter designation beginning at the southwestern corner of the State. Numbers increase eastward and letters increase alphabetically northward. Quadrangles in the northern part of the area are designated by double letters. The letters "I", "II", "O", and "OO" are omitted. Wells inventoried in each quadrangle are numbered consecutively beginning with 1. Thus, the 17th well numbered on the 33E quadrangle is designated 33E017. For this study, all wells are located on the USGS Harriet's Bluff 7.5-minute topographic quadrangle designated 33E in the well-numbering system outlined above.

In addition to permanent monitor wells, temporary piezometers were used to measure water levels; and temporary monitor wells were used to collect water samples. A summary of well identification (grid numbers), well name, location and selected construction information for wells used in this report is given in table 1. Additional information on well locations and construction specifications, and geologic and hydrologic data from this report may be accessed through the USGS National Water Information System (*http://water.usgs.gov/ga/nwis/gw*) or at the USGS Georgia District Office, Atlanta, Ga.

Table 1. Well-construction data for selected wells, Naval Submarine Base Kings Bay, Camden County, Georgia
[do., ditto]

Well number	Well name	Sampling location	Well use	Latitude	Longitude	Altitude (feet)		
						Top of screen	Bottom of screen	Land surface
33E119	KBA-05-01	background[1/]	water quality	30.8012	-81.54387	13.5	3.5	16
33E120	KBA-05-02	do.	do.	30.8019	-81.54356	10.6	0.6	13.1
33E121	KBA-05-03	Site 5	do.	30.8014	-81.54254	12.0	2.0	15.04
33E122	KBA-05-04	do.	do.	30.801	-81.54305	13.2	3.2	15.74
33E123	KBA-05-05	do.	water level, water quality	30.80112	-81.54161	11.6	1.6	15.13
33E124	KBA-05-06	do.	do.	30.80107	-81.54116	13.2	3.2	16.47
33E125	KBA-05-07	do.	water quality	30.80082	-81.54163	12	2.0	14.54
33E126	KBA-16-01	Site 16	do.	30.79112	-81.5358	10.4	.4	17.28
33E127	KBA-16-02	do.	do.	30.79156	-81.53608	7.8	-2.2	15.28
33E128	KBA-16-03	do.	water level, water quality	30.79156	-81.53687	10.3	.3	16.34
33E129	KBA-16-04	background	do.	30.79108	-81.53787	10.7	.7	15.65
33E131	LF-01	do.	water quality	30.79	-81.5116	11.8	2.3	20.13
33E132	DW-1	do.	do.	30.7977	-81.52	5.89	-3.6	10.96
33E133	MC-01	do.	do.	30.7775	-81.5166	9.0	-.5	14.21
33E134	PW-01	do.	do.	30.7925	-81.5638	12.4	7.4	27.37
33E135	TP-01	do.	do.	30.7847	-81.5594	11.5	6.5	26.45
33E136	SW-01	do.	do.	30.7858	-81.5513	11.5	6.7	21.72
33E137	PZ-05-01	Site 5	water level	30.80063	-81.54221	11.8	6.8	12.31
33E138	PZ-05-02	do.	do.	30.80061	-81.54341	12.5	7.5	14.88
33E139	PZ-05-03	do.	do.	30.80062	-81.54413	14.6	9.6	16.46
33E140	PZ-05-04	do.	do.	30.80103	-81.54361	15	10	15.31
33E141	PZ-05-05	do.	do.	30.80152	-81.54376	14.7	10.4	14.68
33E142	PZ-05-06	do.	do.	30.80183	-81.54344	15.1	10.9	15.06
33E143	PZ-05-07	do.	do.	30.80115	-81.54232	14.9	10.4	14.93
33E144	PZ-05-08	do.	do.	30.80103	-81.54305	15.4	10.4	15.97
33E145	PZ-05-09	do.	do.	30.80164	-81.54231	14.5	9.5	15.48
33E146	PZ-05-10	do.	do.	30.80168	-81.54265	12.9	7.9	15.17
33E147	PZ-05-11	do.	do.	30.80119	-81.54185	11.9	6.9	14.7
33E148	PZ-16-01	Site 16	do.	30.79106	-81.53537	10.9	5.9	12.31
33E149	PZ-16-02	do.	do.	30.79168	-81.53528	10	5.0	14.21
33E150	PZ-16-03	do.	do.	30.79173	-81.53627	6.7	1.7	13.22
33E151	PZ-16-04	do.	do.	30.79145	-81.53606	9.0	4.0	12.67
33E152	PZ-16-05	do.	do.	30.79106	-81.5364	11.6	6.6	14.8
33E153	PZ-16-06	do.	do.	30.79061	-81.5364	12.5	7.5	14.92
33E154	PZ-16-07	do.	do.	30.79065	-81.5354	12.6	7.6	14.78
33E155	PZ-16-08	do.	do.	30.79035	-81.53583	11.6	6.6	17.49
33E156	PZ-16-09	do.	do.	30.791	-81.5358	11.1	6.1	16.97
33E157	BG-01	background	water quality	30.80331	-81.54399	5.9	.9	15.5
33E158	BG-02	do.	do.	30.8018	-81.54027	6.1	1.1	15.5
33E159	BG-03	do.	do.	30.8007	-81.54609	5.3	.3	15
33E160	BG-04	do.	do.	30.8	-81.54788	5.5	.5	15
33E161	BG-05	do.	do.	30.78852	-81.54014	0.8	-4.3	10.5
33E162	BG-06	do.	do.	30.79929	-81.54886	5.4	.4	15
33E163	BG-07	do.	do.	30.78766	-81.534	7.2	2.2	11.5
33E164	BG-08	do.	do.	30.78984	-81.5339	5.1	.1	9.5
33E165	BG-09	do.	do.	30.79265	-81.53696	-1.7	-6.7	8
33E166	BG-10	do.	do.	30.79536	-81.53695	-0.7	-5.7	9
33E167	BG-11	do.	do.	30.79143	-81.54045	0.6	-4.5	10
33E168	BG-12	do.	not sampled[2/]	30.78728	-81.53543	5.7	.7	13.5
33E169	BG-13	do.	water quality	30.7994	-81.5441	5.6	.5	15

[1/]Sample collected outside of Sites 5 and 16 areas.

[2/]Well was not sampled because of insufficient water..

Hydrogeology

Camden County is underlain by about 5,500 ft of Cretaceous to Holocene Coastal Plain strata (Wait and Davis, 1986). These strata consist of unconsolidated to semi-consolidated clastic sediments, and semi-consolidated to consolidated carbonate sediments which strike southwest to northeast, and dip and thicken to the southeast. The strata unconformably overlie Proterozoic felsic volcanic rocks in northern Camden County, and Paleozoic metamorphic rocks in southern Camden County (Chowns and Williams, 1983). NSB Kings Bay lies southeast of a structural dome that is centered northwest Woodbine, Ga., on the northern flank of the Southeast Georgia Embayment (fig. 1).

Hydrogeologic units in the study area include, in descending order, the surficial aquifer (Miller, 1986; Krause and Randolph, 1989; and Clarke and others, 1990); the upper and lower Brunswick aquifers (Clarke and others, 1990); and the Floridan aquifer system (Miller, 1986). In this report, only the water-table zone of the surficial aquifer, as described by Leeth (1998), is discussed.

A general description of the lithology and hydrology of the water-table zone of the surficial aquifer is included herein and shown in figure 3. For a more extensive discussion of the water-table zone, the reader is referred to Leeth (1998). The lithology of the water-table zone consists of fine-to-medium sand of the undifferentiated surficial sand, Satilla Formation, and the upper part of the Cypresshead Formation of Huddlestun (1988). Water in these sediments occurs under unconfined (water table) conditions. The thickness of the water-table zone generally varies between 60 and 80 ft across the study area, largely as a result of variations in topography (Leeth, 1998). In addition, because the thickness of the surficial aquifer is computed from the water-table surface to the base of the aquifer, temporal variations in the water-table surface also will affect thickness. It also should be noted that, because of an increase in the clay and silt content with depth, there is a resistance to vertical ground-water flow between about 10 and 40 ft below sea level (Leeth, 1998)—this resistance can be the basis for division of the water table into upper and lower parts. In this report, only the upper part (about the top 35 ft) of the water- table zone is considered. Analysis of aquifer-test data from the water-table zone (Leeth, 1998) yielded a range of hydraulic conductivity from 6.7 to 13 feet per day (ft/day).

Acknowledgments

The cooperation and assistance of Mr. Anthony B. Robinson and Ms. Rhonda Bath of the U.S. Department of the Navy, NSB Kings Bay, are gratefully acknowledged.

METHODS OF INVESTIGATION

Methods of investigation consisted of both indirect and direct measurements of various hydrologic and geologic properties, including test drilling, water-level and rainfall measurements, chemical analysis of soil and water-quality samples, aerial photograph analysis, and pine-stand age estimation (Harlow and others, 1978). Graphical and statistical methods are used to help describe water-quality data.

Long-term continuous and synoptic water-level measurements were made at selected wells. Synoptic water-level measurements were used to construct a water-table map for Sites 5 and 16 (fig. 4). Continuous water-level measurements in three wells were used to assess water-level fluctuations and trends in the water table (fig. 5).

For this study, 13 wells were installed in the water-table zone of the surficial aquifer to collect water samples for chemical analysis (only 12 of the 13 were used to collect water samples), and 20 piezometers were installed in the water-table zone to measure water levels. Seventeen existing wells completed in the water-table zone were used to measure water levels and collect water samples for chemical analysis. Wells were installed with a Geoprobe™ system using 1.5-inch polyvinyl chloride (PVC) casing and screen. A 2.5-inch-diameter probe was pushed into the aquifer material, then removed and a screen was placed in the resultant hole. Screens were 5-ft long, with 0.010-inch slots, and each well was completed with a 1 to 2-ft thick bentonite seal. Piezometers were constructed using a hand auger and completed with 1-inch PVC pipe and screen. Screens were 5-ft long with 0.010-inch slots. A 3-inch-diameter stainless-steel hand auger was advanced about 2 ft below the water-table surface; then removed and a screen placed in the resultant hole. Piezometers were completed using natural aquifer material (sand) with no bentonite seal.

Sampling Methods

Water samples from 29 wells were analyzed for field properties, dissolved concentrations of inorganic constituents, and selected metals. Field properties were measured using standard USGS techniques (Wilde and others, 1988). Specific conductance, pH, dissolved oxygen, and water temperature were measured using a multiple-electrode sonde in a flow-through chamber (Hydrolab II™). Before measuring, the electrodes were calibrated for pH and specific conductance using quality-control standards; because the sonde contains a calibrated thermistor, standards were not brought to sample temperature.

Well-purging procedures were as follows: (1) the static water level was measured, using an electric water-level indicator; (2) well volume was calculated based on the static water level and well diameter; (3) a nonaerating, submersible pump was slowly lowered into the well so that particulates were not disturbed; and (4) the pump was started and the pump rate adjusted to limit drawdown. At a minimum, three well volumes were purged from the well before samples were collected. In addition, field measurements were recorded during purging. If field measurements did not stabilize after three volumes were removed, purging was continued until field measurements stabilized. Both unfiltered (total) and filtered (dissolved) samples were collected. Filtered samples were collected by passing ground water through a 0.45-micrometers per meter (μm) Supor® (polyethersulfone) capsule filter. All samples to be analyzed for metals (excluding mercury) were contained in acid-rinsed 250-milliliter (mL) high density polyethylene (HDPE) bottles and preserved with 1 mL of nitric acid. Samples to be analyzed for mercury were contained in acid-rinsed 250-mL glass jars and preserved with 10 mL of a nitric-acid, potassium-dichromate mix. Samples to be analyzed for major ions were contained in 500-mL HDPE bottles with no preservatives. Samples to be analyzed for nutrients were contained in 125-mL HDPE jars that were field rinsed and chilled to 4° C after sample collection.

Twenty-four soil samples, including two duplicate soil samples, were collected and analyzed for volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), organochlorine pesticides (pesticides), dioxins, and furans. Soil samples were collected using a 3-inch-diameter stainless-steel bucket auger over a 6-inch interval from depths between 3 and 7 ft below land surface. Soil was placed in 250-mL wide-mouth glass jars without preservatives.

Historical aerial photographs were used to help verify the location and extent of Sites 5 and 16. Photographs were compiled for the area surrounding and including the Naval Submarine Base Kings Bay (which appears on the Harrietts Bluff, 7.5-minute USGS topographic quadrangle map). Aerial photographs were obtained from the USGS, Earth Resources Observation Systems (EROS), EROS Data Center, Sioux Falls, S. Dak., for years 1957, 1974, 1977, and 1993. The photography was flown at different heights (varying by year) and by different agencies with varied quality. Four digital orthophoto quadrangle (DOQ) images that cover the area of Harrietts Bluff topographic quadrangle were used to georeference the photographs. DOQ data were compiled from source imagery (aerial photography) flown in February of 1988.

A truck-mounted 4-inch-diameter auger was used to drill verification borings within areas that were identified on the aerial photographs. Drill sites were selected based upon ease of access, geophysical anomalies identified in previous reports, (U.S. Department of the Navy, 1994a, b) and the estimated landfill boundaries located from aerial photography. Auger flights were advanced in 5-ft runs using a one-to-one downfeed to rotation ratio, where practicable. Augers were retrieved every 5 ft and were examined for landfill material. Depths of borings ranged from 10 to 25 ft. Each boring was terminated in undisturbed sediment at a minimum of 5 ft below the base of the landfill material. Finally, at Site 5 estimates of pine-stand age were used to positively identify areas that had been undisturbed for a minimum of 30 years (the approximate time when the landfill would have been active). Pine-stand age was estimated using allometric correlation of the trunk diameter at breast height versus age.

Laboratory Methods

Water-quality analyses were performed by the USGS water-quality laboratory in Ocala, Fla., based on the USGS National Water Quality Laboratory (NWQL) methods described by Fishman (1993). Water-quality analyses included common ions, selected trace metals, and nutrients. Soil analyses were performed by Quanterra Environmental Services (Quanterra), Denver, Colo., under the direction of the NWQL using USEPA (U.S. Environmental Protection Agency, 1996) methods. Soil analyses included dioxins and furans, pesticides, SVOCs, and VOCs.

Inorganic water-quality analyses for concentrations of common ions and trace elements were analyzed by using inductively-coupled plasma, with the exception of lead (graphite furnace atomic absorption) and mercury (cold-vapor atomic absorption). SVOCs and VOCs were analyzed in soils by purge-and-trap gas chromatography and electron-impact mass spectrometry (GC/MS)—USEPA methods 8260B and 8270C, respectively. Pesticides were analyzed by purge-and-trap gas chromatography (GC)—USEPA method 8081A—and dioxins and furans were analyzed by high-resolution gas chromatography and low-resolution mass spectroscopy (HRGC/LRMS)—USEPA method 8280 (U.S. Environmental Protection Agency, 1996).

A reporting level is the smallest measured concentration of a constituent that may be reliably reported using a given analytical method (for some constituents, the reporting level occasionally may be raised due to matrix interference in a sample). In general, data values reported are equal to or less than the detection limits of the cited USEPA methods. In some instances, reported values are estimated because the laboratory used methods that differed from the USEPA method. For example, a value will be reported as estimated when the sample required dilution.

Quality Assurance and Control

To detect any measurement bias and variability associated with data collection and laboratory analyses, quality-assurance and quality-control (QA/QC) procedures were used in this study. Quality-control samples were collected to ensure that contamination did not occur during the collection, transport, storage, and analysis of samples. During this study, field quality control was verified using trip blanks and duplicate samples. Trip blanks consisted of three 40-mL glass vials filled with pesticide-grade water. The trip blanks were transported to the field in insulated coolers, remained unopened in the field, and were sent to the NWQL and Quanterra laboratories and analyzed with the samples. The purpose of a trip blank is to assess the impact of shipping conditions on the sample and subsequent data. Duplicate samples also were collected, shipped, and analyzed. The purpose of duplicate samples is to assess any impact on the data of collecting, shipping, and analyzing the samples. Laboratory QA/QC included but was not limited to daily blanks, daily standards, daily instrument tuning, and quality-control check samples. Laboratory QA/QC procedures for ground-water samples are described by Pritt and Raese (1995). Laboratory QA/QC procedures for soils samples are described by Quanterra Environmental Services (1997).

Comparison Between Background and Landfill Ground-Water Quality

In this report, water-quality data are used to characterize the background ground-water quality of the water-table zone at NSB Kings Bay and to compare the background ground-water-quality data to areas that have been affected by past landfill disposal. In addition, these data were compared to Georgia Department of Natural Resources, Environmental Protection Division (GaEPD) (1993) and U.S. Environmental Protection Agency (1990a, b) drinking-water standards. Laboratory analytical methods used in this study were selected because of the low reporting limits, which were markedly lower than the drinking-water standards.

Background ground-water quality was determined by locating and examining the water quality of wells representative of uncontaminated conditions. Background monitoring wells were placed mostly in undisturbed areas indicated from aerial photographs. Three wells, however, were located in disturbed areas—one on a firebreak and two located within a utility (power line) right-of-way. It is unlikely that either activity would have affected the ground-water quality.

Concentrations of major ions in ground-water samples from background wells were examined for anomalies or outliers to ensure that wells chosen to represent background conditions were not affected by human activities. Trilinear (Piper) diagrams, used in this report, are a graphical method of water-quality data presentation that can be used to associate water samples with different water types or to compare major ion concentrations between two areas. Also, linear trends and other relations that may be important are more readily apparent on Piper diagrams. Additional graphical methods include dot plots of location and concentration that allow a visual comparison of background-constituent concentrations against concentrations in areas that were possibly impacted by past landfill disposal (Sites 5 and 16) (fig. 2).

Finally, hypothesis testing using the nonparametric Wilcoxon rank-sum test (also known as the Mann-Whitney test) was used to compare the different groups of data (Helsel and Hirsch, 1995). As Helsel and Hirsch (1995) pointed out, hypothesis testing offers two advantages over more traditional graphical methods:

- hypothesis tests insure that every analyst of data using the same methods will arrive at the same result—computations can be checked on and agreed to by others; and
- hypothesis tests present a measure of the strength of the evidence (the p-value)—the decision to reject a hypothesis is augmented by the risk of that decision being incorrect.

In this report, the initial or null hypothesis (H_0) for the test statistic was that the median concentrations of a given constituent for background samples and landfill samples are equal. This leads to an alternative hypothesis (H_1) that median concentrations at a site were not equal to background concentrations. If x represents background concentrations and y represents the concentration at a particular site, the null hypothesis can be expressed:

H_0: x and y are samples from the same distribution, or
H_0: Probability $(x \geq y) = 0.025$.

H_1: x and y are samples from different distributions, or
H_1: Probability $(x \geq y) \neq 0.025$.

In this report, the error rate—or significance level (α-level)—selected is 5 percent (0.05). The error rate (α) is a "management tool" that gives the probability of incorrectly rejecting the null hypothesis (typically called a Type I error by statisticians). This value is independent of the data and arbitrary; however, statisticians typically use 5 percent (0.05); and thus, the value is used here. The null hypothesis is rejected if the p-value is less than the α-level and can be expressed more succinctly:

Reject H_0 when: p-value < 0.025

If the original null hypothesis was rejected (that x and y were the same), the hypothesis test was computed again, using the null hypothesis (H_0) that the median concentrations of a given constituent for background samples is greater than the median concentration at a particular landfill site. The null hypothesis leads to the alternative hypothesis (H_1) that the median concentration of a given constituent for background samples and concentrations at a particular site are equal, thus:

H_0: x is from a distribution that is generally higher than y, or
H_0: Probability $(x > y) \geq 0.025$.

H_1: y is from a distribution that is generally higher than x
H_1: Probability $(x \geq y) \leq 0.025$.

The error rate for this test was identical to the error rate used for the original test.

Ground-Water-Level and Precipitation Data Collection

Long-term continuous and synoptic water levels were measured in selected wells and piezometers near Sites 5 and 16 (fig. 2). Long-term water levels were collected using a transducer and data-logger set to collect hourly measurements of the water levels from wells 33E123, 33E124 and 33E128 (fig. 5). Synoptic water levels were collected from selected wells and piezometers located near Sites 5 and 16 using an electric water-level indicator to show the configuration of the water-table surface (table 1). Precipitation data were collected at Site 5 near well 33E124 using a tipping-bucket rain gage and data-logger set to collect hourly measurements.

CONFIGURATION OF THE WATER TABLE AT SITES 5 AND 16

Ground-water-level and precipitation data were used to determine water-level trends and the configuration of the water table at Sites 5 and 16 (fig. 4). These data can be used to compare water levels in the study area with similar settings along the Georgia coast. These data may also be useful in estimating recharge rates and ground-water flow velocities.

Water-level hydrographs were compared to precipitation bar graphs to evaluate ground-water-level trends and seasonal variations in the water table at Sites 5 and 16 (fig. 5). October through May generally are the drier months when normal rainfall ranges from 2 to 4 inches per month (Brown, 1984). Precipitation data collected adjacent to well 33E124 (at Site 5) are consistent with seasonal patterns described by Brown (1984) who determined that 60 percent of annual rainfall occurs from June through September, with a range of about 6 to 8 inches a month. Generally, ground-water levels peak during periods of high precipitation, such as late July 1998; and recede during periods of low precipitation, such as February through September 1999 (fig. 5). Although the wells are located relatively close to tidal estuaries, there is no evidence of tidally induced water-level fluctuations in the wells. Water levels declined from 2 to 5 ft in all wells from October 1998 to October 1999.

The water-table surface at Sites 5 and 16 was delineated using synoptic water-level measurements made in selected wells and piezometers on March 13, 1998. At Site 5, ground water flows from northwest to southeast; at Site 16, ground water flows from southwest to the northeast (fig. 4). Because the water table generally is a subdued replica of the land surface (Heath, 1983), one can infer from examination of topographic data that ground water from both sites eventually discharges into tributaries of the North River.

SOIL CHEMISTRY

Results from the chemical analysis of soil samples from auger borings completed in the shallow subsurface were used to compare the geochemical variability of soils at Sites 5 and 16 to background soil conditions. Of the 22 locations sampled in this study, samples from three borings—SS-02, SS-05, and SS-16-04—have concentrations above the detection limit for either VOCs, base-neutral acids (BNAs) or pesticides (fig. 6, table 2). Also, samples from three borings—SS-02, SS-16-01 and SS-16-04—have concentrations of VOCs or pesticides that were below the detection limit but could be estimated from the analytical results (fig. 6, table 2). In a duplicate sample from boring SS-16-04, the pesticide degradate 4,4′-DDE was detected at an estimated concentration of about 0.93 microgram per kilogram (μg/kg); however, this compound was not detected in the original sample.

VOCs detected in the study area include toluene in the sample from boring SS-02 and acetone in samples from borings SS-05 and SS-16-01 (fig. 6, table 2). Detection of VOCs in soil is questionable because VOCs volatilize soon after contacting the atmosphere. Conditions that could contribute to detection of VOCs in soil include either recent spillage or longer residence time in soil because of saturation in water or sorption into high liquid limit clays. There is no evidence to suggest that recent spillage could be a factor for either the background samples where VOCs were detected (toluene from SS-02 and acetone from SS-05) or for the acetone in the sample collected from boring SS-16-01. Both background sites are fairly remote and inaccessible, and active waste disposal at Sites 5 and 16 ceased decades ago. A more plausible explanation could be that these detections are laboratory artifacts, likely from incomplete instrument cleaning between analyses.

Pesticides detected in soil at NSB Kings Bay include, 4,4′-DDD and 4,4′-DDE, both degradates of DDT and dibenzofuran (table 2). The detection of pesticides in background soil samples is similar to that of the two sites. It is reasonable to expect the random detection of pesticides in soil at NSB Kings Bay at both background locations and from areas affected by past landfill disposal. The use of broad-spectrum pesticides, such as DDT prior to the early 1970's, is well documented in scientific and popular literature. While data on the national distribution of pesticides in soils are not available, data from more than 38,000 community water-supply wells published by the USEPA (1990d) indicate that over 10 percent of the wells contained pesticides or their degradates. Detections of pesticides in water-supply wells indicate that the occurrence of pesticides in the subsurface is pervasive in the United States and a similar percentage of occurrences would seem likely for soil data (U.S. Environmental Protection Agency, 1990d). A USGS study in the Apalachicola-Chattahoochee-Flint River basin shows that in bed-sediment samples organochlorine insecticides—such as chlordane and DDT—are common in the basin (Frick and others, 1998). At NSB Kings Bay, the percentage of pesticides detected is much less than the 10 percent detected by the USEPA (1990d). These data suggest there is no difference between the occurrence of pesticides in background soils (locally and nationally) and the occurrence in soils at Sites 5 and 16. Thus, either the landfills do not contain pesticides or the pesticides are immobilized by organic matter so that detection is not possible.

BNAs were detected in samples collected from borings SS-02, SS-16-01, and SS-16-04 at NSB Kings Bay (fig. 6, table 2). Many BNA compounds detected at NSB Kings Bay have been detected in soil samples and are known to occur throughout the United States and Canada (Ogner and Schnitzer, 1970). All BNAs detected at NSB Kings Bay are associated with pesticides—most are creosol derivatives used as emulsifiers for application of DDT. Because BNA compounds are associated with pesticide application, occur naturally, and have similar occurrences in both background and site samples, there is no evidence to suggest that background concentrations differ from concentrations for either Site 5 or Site 16.

Table 2. Concentration of constituents detected in soil sampled at Naval *Submarine Base Kings Bay, Camden County, Georgia,* September 1998 and October 1999

[Constituent concentrations analyzed by Quantera Environmental Services, Denver, Colorado; do., ditto; BNA, base-neutral acids; VOC, volatile organic compound; DDD, Dichlorodiphenyldichloroethane; DDE, Dichlorodiphenyldichloroethylene]

Sample number	Sampling location	Constituent	Constituent type	Concentration (micrograms per kilogram)	Detection limit (micrograms per kilogram)
SS-02	background[1/]	4-methylphenol	BNA	1,400	330
SS-02	do.	toluene	VOC	26	5.0
SS-02	do.	4,4'-DDD	pesticide	[2/]0.51	1.7
SS-02	do.	4,4'-DDE	do.	[1/]1.4	1.7
SS-05	do.	acetone	VOC	70	25
SS-16-01	Site 16	acenaphthene	BNA	390	330
SS-16-01	do.	acetone	VOC	[1/]15	25
SS-16-01	do.	2-methylnaphthalene	BNA	[1/]250	330
SS-16-01	do.	dibenzofuran	BNA	[1/]110	330
SS-16-01	do.	fluorene	BNA	[1/]120	330
SS-16-04	do.	diethyl phthalate	BNA	[1/]1,100	330
SS-16-04	do.	phenanthrene	BNA	[1/]74	330
SS-16-04	do.	4,4'-DDE	pesticide	[1/, 3/].93	1.7

[1/]Sample collected outside of Sites 5 and 16 areas.

[2/]Estimated.

[3/]Duplicate sample.

GROUND-WATER QUALITY

Results from the chemical analysis of water samples from the water-table zone at NSB Kings Bay were used to compare background water-quality conditions with the geochemical variability of ground water in areas that have been affected by past landfill disposal. Water samples collected from selected wells were analyzed for dissolved concentrations of inorganic constituents including trace metals. Field properties—pH, specific conductance, and water temperature—were measured onsite before sample collection. Analysis of water from 21 wells was used to represent background conditions; from 5 wells to represent conditions at Site 5; and from 3 wells to represent conditions at Site 16 (table 3).

Water-quality data for field properties including pH, specific conductance, dissolved oxygen, and major inorganic constituents routinely are used to describe the general chemical composition and aesthetic and taste characteristics of ground water. Values for pH, specific conductance and dissolved oxygen were measured in all 29 wells in the study, and major constituents were measured in 21 wells (table 3). Major constituents and properties that were outside the aesthetically based USEPA recommended secondary drinking-water regulation (SDWR) (formerly known as the Secondary Maximum Contaminant Level or SMCL) (U.S. Environmental Protection Agency, 1990b) include pH, sodium, chloride, and sulfate. The pH of ground water in the study area ranged from 4.0 to 7.6 standard units with a median value of 5.4 standard units. the pH of water from most of the wells is outside the acceptable SDWR range of 6.5 to 8.5 standard units (table 3) with only three wells—33E131, 33E132, and 33E157—within the SDWR range. The sodium concentration in well 33E120 is 270 mg/L; which is worth noting because the USEPA (1976) recommends that persons on a salt-restricted diet avoid drinking water with concentrations greater than 270 mg/L. Also, a chloride concentration of 570 mg/L in water from well 33E120 is above the SDWR. Sulfate concentrations in wells 33E120 and 33E122 are above the SDWR of 250 mg/L. Finally, the specific conductance of 9,560 microsiemens per centimeter (µS/cm) at 25 $^{\circ}$ Celsius in water from well 33E132 is very high and likely due to the proximity of the well to an estuary (water from this well was not analyzed for chloride).

Table 3. Field properties and inorganic constituents in water from test wells, Naval Submarine Base Kings Bay, Camden County, Georgia, September 1998, January 1999, and October 1999

[analyses by U.S. Geological Survey, Ocala, Florida; units—mg/L, milligrams per liter; µS/cm, microsiemens/centimeter; do., ditto; < less than, —, no data]

Well number	Well type	Date	Specific conductance (µS/cm)	Dissolved oxygen (mg/L),	Field pH (standard units)	Nitrogen, ammonia, as N dissolved (mg/L)	Nitrogen, nitrite, as N, dissolved (mg/L)	Orthophosphate phosphorous, as P, dissolved (mg/L)	Calcium, dissolved (mg/L)	Magnesium, dissolved (mg/L)	Sodium, dissolved (mg/L)	Potassium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Sulfate, dissolved (mg/L)	Fluoride, dissolved (mg/L)	Silica, dissolved (mg/L)
33E119	background	10/07/99	350	<0.5	4.9	1.20	<.01	.01	39	2.1	8.9	.7	38	93	<.1	5.2
33E120	do.	10/07/99	2,820	<.5	4.2	4.90	.01	.02	270	9.8	270	1.9	570	610	<.1	7.8
33E121	Site 5	09/15/98	284	<.5	5.4	—	—	—	—	—	—	—	—	—	—	—
33E122	do.	10/07/99	924	<.5	5.6	.30	<.01	.02	110	8.7	78	9.2	46	400	<.1	2.7
33E123	do.	10/06/99	145	<.5	5.2	.40	<.01	.01	11	1.7	8.6	.3	15	29	<.1	1.6
33E124	do.	10/06/99	200	<.5	5.5	6.90	.01	.02	4.9	2.6	11	3.8	16	28	<.1	4.7
33E125	do.	10/06/99	146	<.5	5.6	.09	<.01	.01	17	5.4	3.4	.5	4.4	23	<.1	3.1
33E126	Site 16	09/15/98	368	<.5	5.8	—	—	—	—	—	—	—	—	—	—	—
33E127	do.	10/05/99	334	<.5	6.0	2.40	.01	.02	55	3.8	4.5	3.5	5.3	11	<.1	1.4
33E128	do.	10/05/99	268	<.5	5.7	1.70		.03	40	2.5	5.5	8.3	9.4	18	<.1	2.1
33E129	background	09/15/98	305	<.5	5.2	3.20	.01	.03	26	4.5	17	9.9	29	13	<.1	9.4
33E131	do.	01/29/99	1,500	<.5	6.7	—	—	—	—	—	—	—	—	—	—	—
33E132	do.	01/29/99	9,560	<.5	6.6	—	—	—	—	—	—	—	—	—	—	—
33E133	do.	01/29/99	2,000	<.5	5.5	—	—	—	—	—	—	—	—	—	—	—
33E134	do.	01/29/99	360	<.5	4.0	—	—	—	—	—	—	—	—	—	—	—
33E135	do.	01/29/99	261	<.5	4.8	—	—	—	—	—	—	—	—	—	—	—
33E136	do.	01/29/99	307	<.5	6.1	—	—	—	—	—	—	—	—	—	—	—
33E157	do.	10/06/99	668	<.5	7.6	.20	.01	.45	120	5.0	11	.6	23	4.9	.2	18
33E158	do.	10/06/99	173	<.5	4.0	2.30	.02	.01	.3	2.5	10	1.8	20	9.5	<.1	2
33E159	do.	10/06/99	190	<.5	5.9	.09	.01	.12	3.8	5.3	180	.2	35	21	.1	6.5
33E160	do.	10/06/99	223	<.5	4.5	.06	.01	.02	5.3	4.1	22	.2	34	34	.2	5.9
33E161	do.	10/05/99	249	<.5	4.5	.20	.01	.01	2.7	6.0	27	.7	63	9.4	<.1	10
33E162	do,	10/06/99	148	<.5	4.5	1.90	.01	.18	15	1.1	5	1.9	13	27	.7	4.3
33E163	do.	10/05/99	130	<.5	5.0	4.70	.01	.02	.7	1.2	14	5.1	13	5.5	<.1	4.5
33E164	do.	10/05/99	111	1.1	4.9	2.70	.01	.02	3.1	2.2	6	4.0	10	13	<.1	4.2
33E165	do.	10/05/99	308	<.5	5.4	.70	.01	.57	35	2.7	19	1.9	42	.8	.1	23
33E166	do.	10/05/99	135	<.5	4.9	1.70	.01	.01	11	2.6	5	7.3	11	12	<.1	7.3
33E167	do.	10/05/99	82	<.5	4.8	2.90	<.01	.02	.3	1.1	4	3.4	8.4	6.6	<.1	3.8
33E169	do.	10/06/99	113	.01	5.6	.09	.01	.02	1.1	.5	17	.3	23	2.7	<.1	7.5

Piper trilinear diagrams and dot plots were used to graphically compare background water-quality data with data collected from Sites 5 and 16. Piper diagrams can be used to distinguish water types of different water samples, and show geochemical trends and other relations that may be important for water-quality interpretation. The piper diagram shown in figure 7 displays no apparent trends or groupings in the major ion composition of water collected in this study. Whereas the composition of water at Site 5 seems to be higher for sulfate and chloride than at Site 16, the composition of waters from Sites 5 and 16 fall within the same area of the diagram as the composition of background water, indicating that there is little difference between percentage composition of background water and water from Sites 5 and 16. Water composition varies throughout the study area (fig. 7), which likely reflects the diverse nature of the soils that overlie the surficial aquifer, the vegetation, and localized areas of recharge at NSB Kings Bay.

Dot plots—a variation of the scatter plot—are used to show the differences between two or more groups of variables (Helsel and Hirsch, 1995). Dot plots for selected constituents and field properties for both whole water (total) and filtered (dissolved) trace-element samples collected from wells at Sites 5 and 16, and background wells are shown in figure 8. When a constituent or property was outside the USEPA primary maximum contaminant level (MCL) or SDWR, a line(s) showing the MCL or SDWR was plotted (U.S. Environmental Protection Agency, 1990b, 1990c).

Dot plots, comparing background water quality to water quality at Sites 5 and 16, indicate for the constituents and properties examined, the maximum value of water from background wells is greater than the maximum value for Site 5 and Site 16. Also, the range of background constituent concentrations and property values at Sites 5 and 16 lies within the range of concentrations and values of background water. Two exceptions are the relatively high concentrations (below the MCL) of chromium and vanadium detected in wells at Site 5. The relatively high chromium concentration is from a whole-water sample from well 33E124. A dissolved sample collected from well 33E124 at the same time and using the same equipment, had a chromium concentration below the detection limit; the high whole-water concentration was not replicated when the well was resampled. The relatively high vanadium concentration is from a whole-water sample from well 33E125. As was the case for well 33E124, the dissolved sample collected from well 33E125 at the same time and using the same equipment, had a vanadium concentration below the detection limit. Possible causes of these anomalous concentrations of chromium and vanadium would include particulate contamination of the sample (from formation sediment), contamination of the sample from sampling equipment (a stainless-steel pump was used for water collection), or improper sample handling during sample bottling or sample analysis.

P-values from the Wilcoxon rank-sum test were computed for constituents with a minimum of three concentrations values above the detection limit (table 4). Hypothesis testing indicates that when comparing constituent concentrations at each former solid waste-disposal site (Sites 5 and 16) to background concentrations and using the null hypothesis (H_0), the populations are equal—the null hypothesis can be rejected only when comparing barium concentrations at Site 16 to background concentrations. Furthermore, recompiling these values using the null hypothesis (H_0) that the concentration of barium in background ground water is greater than the concentration in ground water at Site 16, indicates that the null hypothesis cannot be rejected for this case. From examination of the p-values, there is no difference between constituent concentrations from Site 5, Site 16, and background concentrations—except for concentrations of barium. Hypothesis testing indicates that background barium concentrations are higher than concentrations at Site 16.

Table 4. P-values computed using the Wilcoxon rank-sum hypothesis test comparing site concentrations to background concentrations assuming the populations are equal, Naval Submarine Base Kings Bay, Camden County, Georgia, September 1998 and October 1999
[—, denotes data not sufficient for hypothesis testing]

Constituent	Site 5		Site 16	
	Total	Dissolved	Total	Dissolved
Arsenic	0.369	0.741	—	0.356
Barium	.085	.074	0.010 [1/].996	.013 [1/].996
Beryllium	—	—	—	—
Cadmium	—	—	—	—
Chromium	.356	.571	.571	—
Cobalt	.203	—	—	—
Copper	—	—	—	—
Lead	—	—	—	—
Nickel	.525	—	—	—
Vanadium	.732	.887	—	—
Zinc	.463	.596	.414	.596
Selenium	—	—	—	—
Bromide	—	.709	—	—

[1/]Denotes p-value assuming that background concentrations are greater than site concentrations

SUMMARY

In 1998, the U.S. Geological Survey, in cooperation with the U.S. Department of the Navy (Navy), began an investigation at the Naval Submarine Kings Bay (NSB Kings Bay) to compare background water-quality and soil conditions to conditions at two sites impacted by past solid-waste disposal (landfills). Investigations to date (2001) have focused on assessing water-quality and soil conditions at individual sites; however, these data were not sufficient to allow the Navy to make sound management decisions regarding possible remediation of the sites.

During 1998-1999, 13 wells and 20 piezometers were installed in the water-table zone of the surficial aquifer to measure water levels and to evaluate water chemistry. Water samples from 29 wells were analyzed for dissolved concentrations of inorganic constituents and selected metals. Twenty-two soil samples and two duplicate soil samples, were collected and analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, dioxins, and furans. Historical aerial photographs for years 1957, 1974, 1977, and 1993 and pine-stand ages were used to help verify the location and extent of two former landfills. A truck-mounted 4-inch-diameter auger was used to drill verification borings within areas that were identified in the aerial photos.

In soil, only three samples from three locations out of the 22 sampled locations have concentrations above the detection limit for VOCs, base-neutral acids (BNAs), or pesticides. One sample was collected from background locations and two samples were collected from former landfill sites. VOCs detected in soils at two background sites includes toluene and acetone, which typically have very short residence times in soils; detection of these compounds is likely an artifact of the laboratory analyses. Pesticides detected in soil at NSB Kings Bay include, 4,4′-DDD (one background site) and 4, 4′-DDE (one background and one former landfill site), both degradates of DDT, and dibenzofuran (one former landfill). Data collected during this study suggest there are no differences between concentrations of pesticides at background wells and concentrations in ground water at Sites 5 and 16. BNAs were detected at one background and one former landfill site. All BNAs detected are associated with pesticides; most are creosol derivatives used as emulsifiers for application of DDT. Many BNAs compounds detected are known to occur naturally throughout the United States. Because BNA compounds are associated with pesticide applications. Because of these factors and because BNAs have similar occurrences in background and site samples, there is no evidence that concentrations for past landfill sites differ from background concentrations.

In ground water, trace-metal concentrations were below the U.S. Environmental Protection Agency (USEPA) maximum contaminant levels. In addition, graphical comparison of trace metal concentrations indicates the range of concentrations for background samples is similar to that of samples collected from former landfill disposal sites. Results from hypothesis testing, using the Wilcoxon rank-sum test, do not indicate differences in concentration between background concentrations and concentrations at former landfill sites—except for barium. Hypothesis test results for barium indicate that background concentrations of barium are likely to be higher than barium concentrations detected at Site 16.

Major ion chemistry and field properties for ground-water samples indicate that for all but three of the wells sampled, pH was outside the acceptable range of the USEPA secondary drinking-water regulation (formerly known as the Secondary Maximum Contaminant Level or SMCL). Chloride concentrations in well 33E120 exceeded the secondary drinking-water regulation; and sulfate concentrations in wells 33E120 and 33E122 also exceeded the secondary drinking-water regulation.

Finally, a comparison of soil chemistry and water quality at background sites to soil chemistry and water quality from landfill disposal sites, does not indicate any appreciable difference between background and site-specific concentrations; however, pH data indicate that the quality of water in the water-table zone at Naval Submarine Base Kings Bay is aesthetically poor.

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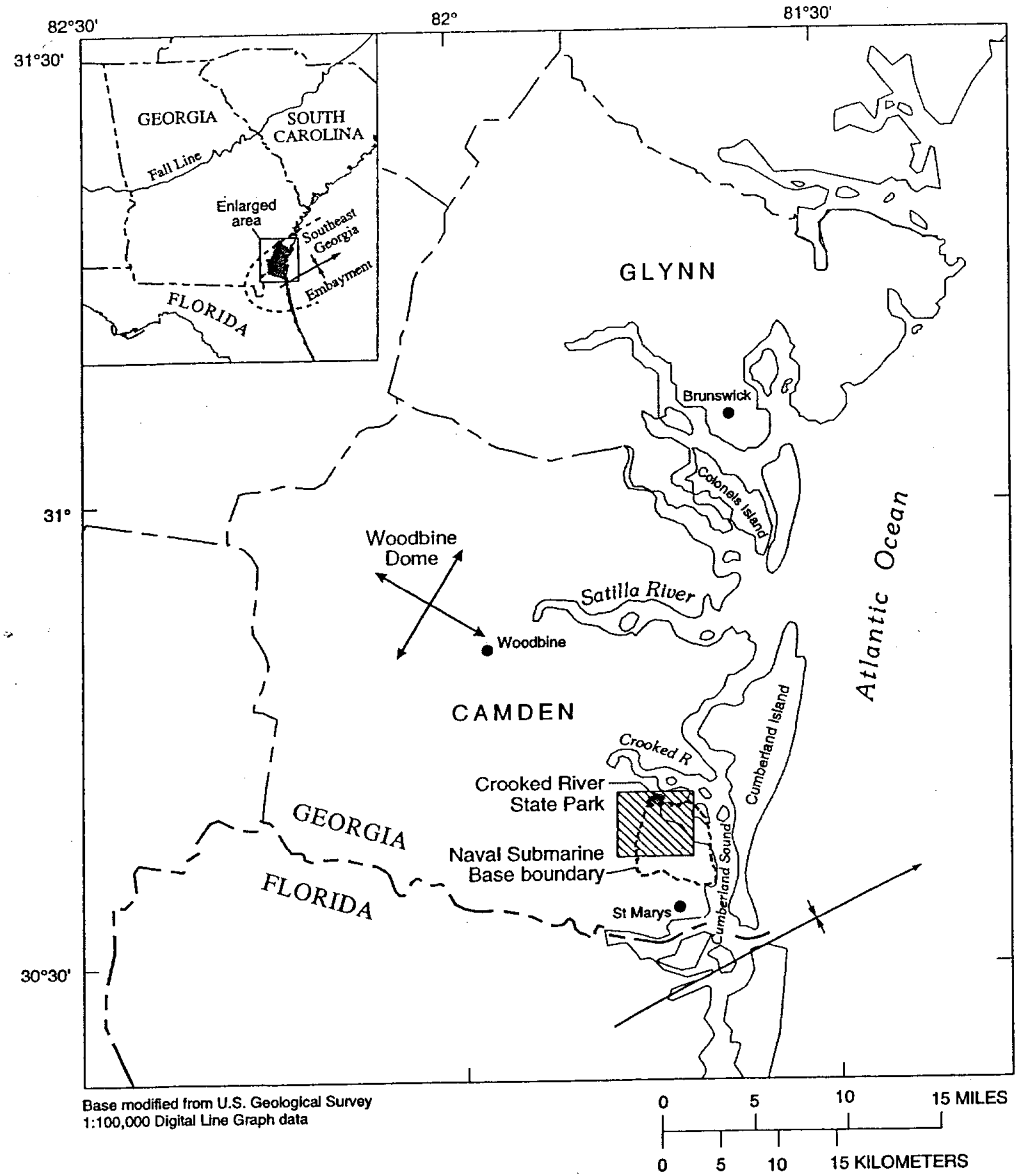
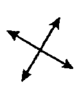


EXPLANATION


STUDY AREA—See figure 2 for detailed map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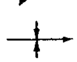
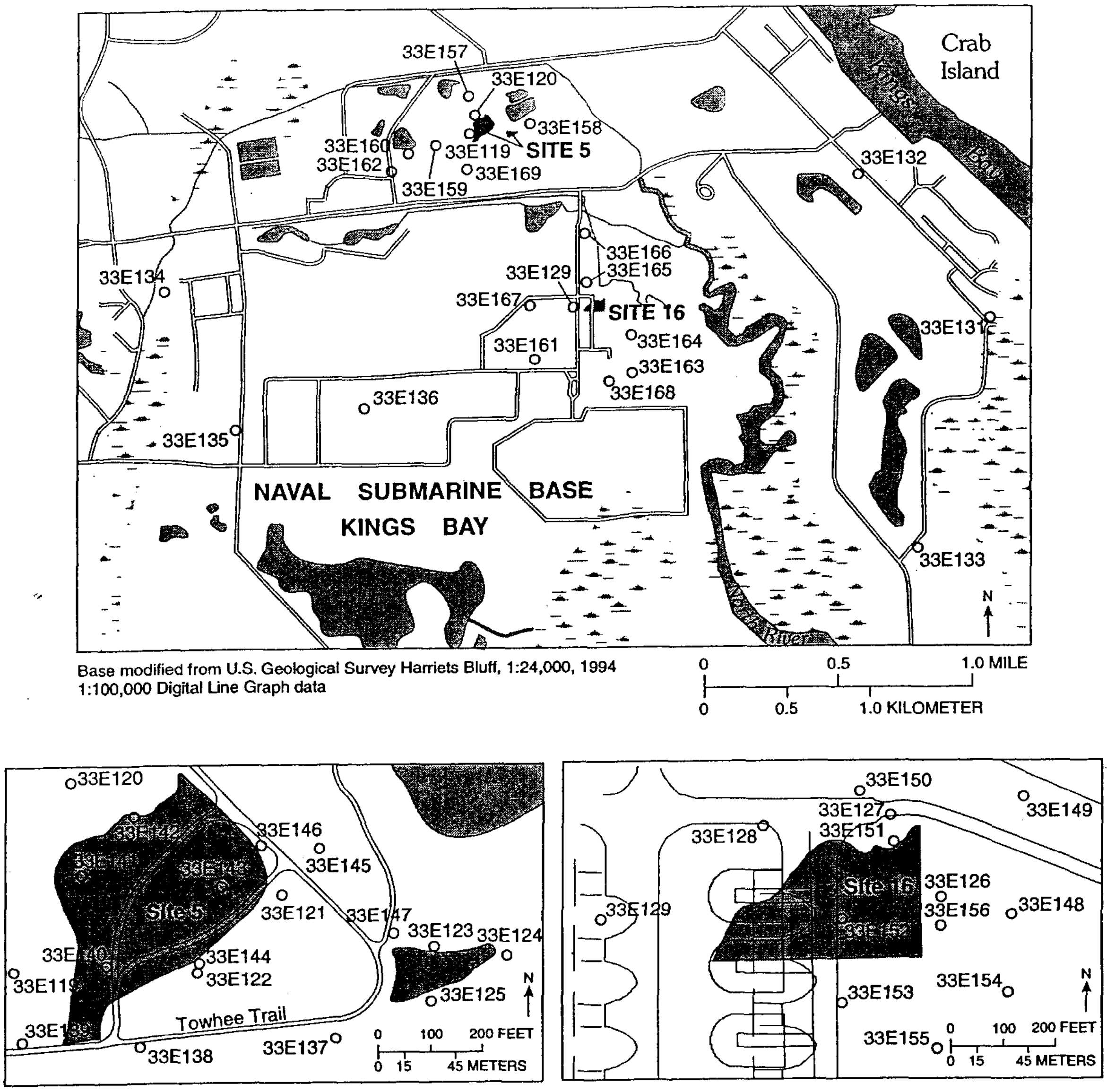

APPROXIMATE AXIS OF SOUTHEAST GEORGIA EMBAYMENT

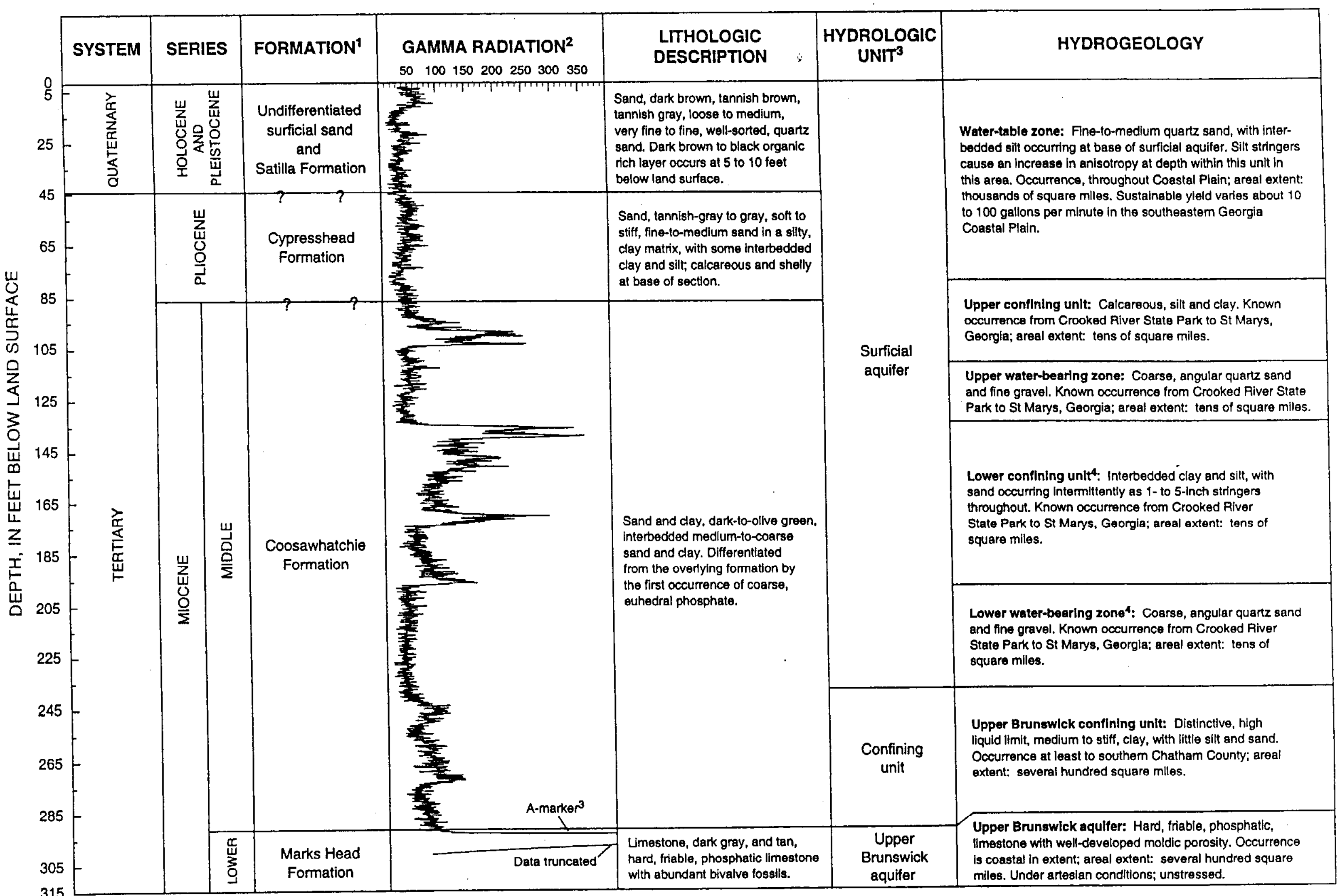
Figure 1. Study area, structural features, and Naval Submaine Base Kings Bay boundary, southeastern Georgia.



EXPLANATION

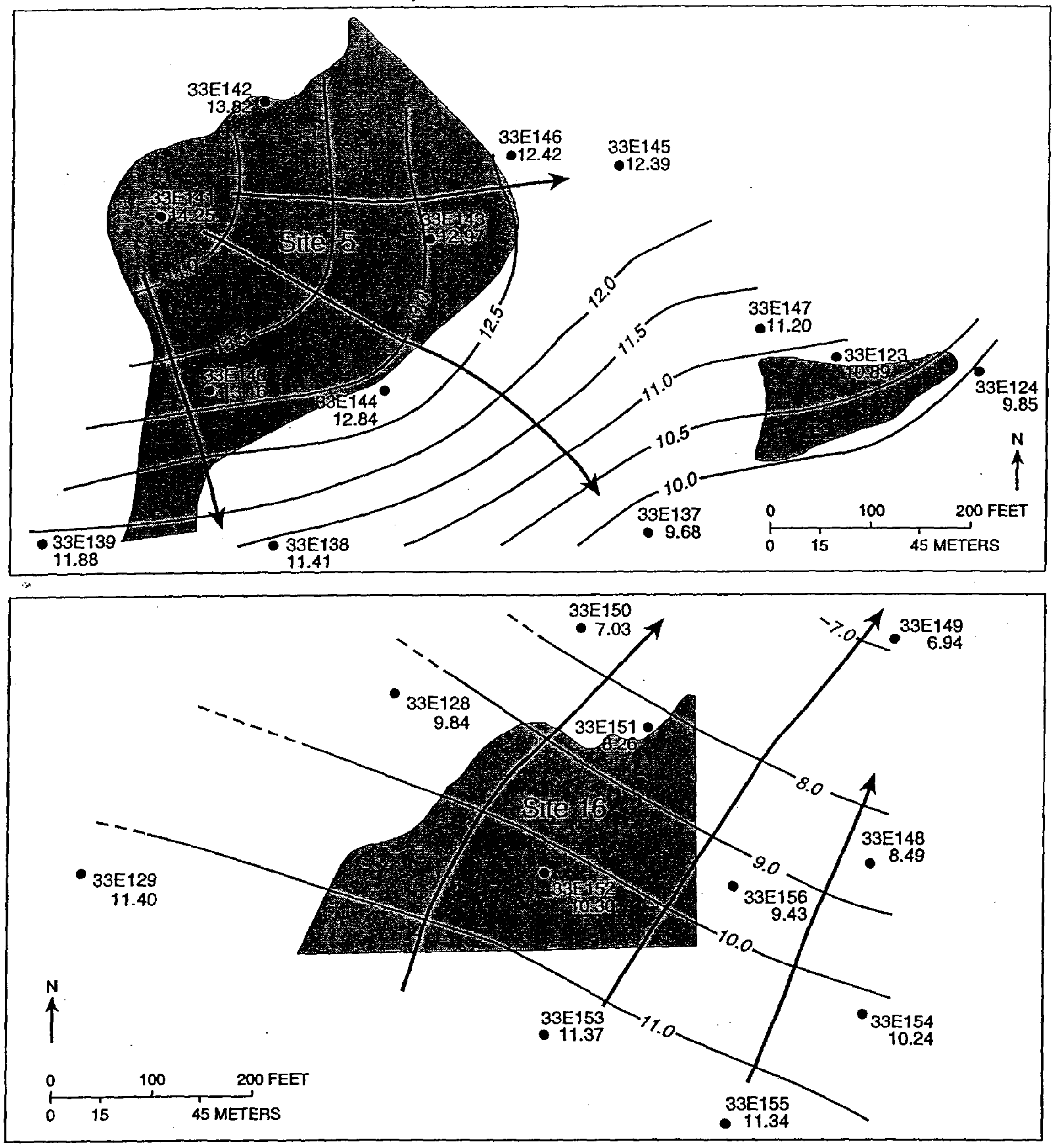
○33E138 GROUND-WATER SAMPLING SITE AND IDENTIFICATION

Figure 2. Sites 5 and 16 and wells sampled for chemical analysis to characterize background water-qualty conditions, Naval Submarine Base Kings Bay, Camden County, Georgia.



[1] From Huddlestun, 1988.
[2] Natural gamma values reported in counts per second.
[3] From Clarke and others, 1990.
[4] Water-bearing properties based on lithology, no hydraulic data currently available.

Figure 3. Lithostratigraphy and hydrogeology of Miocene and younger sediments, Naval Submarine Base Kings Bay, Camden County, Georgia (Leeth, 1998).



EXPLANATION

APPROXIMATE EXTENT OF FORMER LANDFILLS (SITES 5, 16)

— *10.5* – – WATER-LEVEL CONTOUR—Shows altitude of water table on March 13, 1998. *Contour intervals 0.5 foot (Site 5) and 1.0 foot (Site 16). Datum is sea level.* Dashed were approximately located

→ GENERALIZED DIRECTION OF GROUND-WATER FLOW

33E124 • 9.85 WELL—Top number is well identification number. Bottom number is water-level altitude in feet above sea level

Figure 4. Altitude of water-table surface at Sites 5 and 16, Naval Submarine Base Kings Bay, Camden County, Georgia, March 13, 1998.

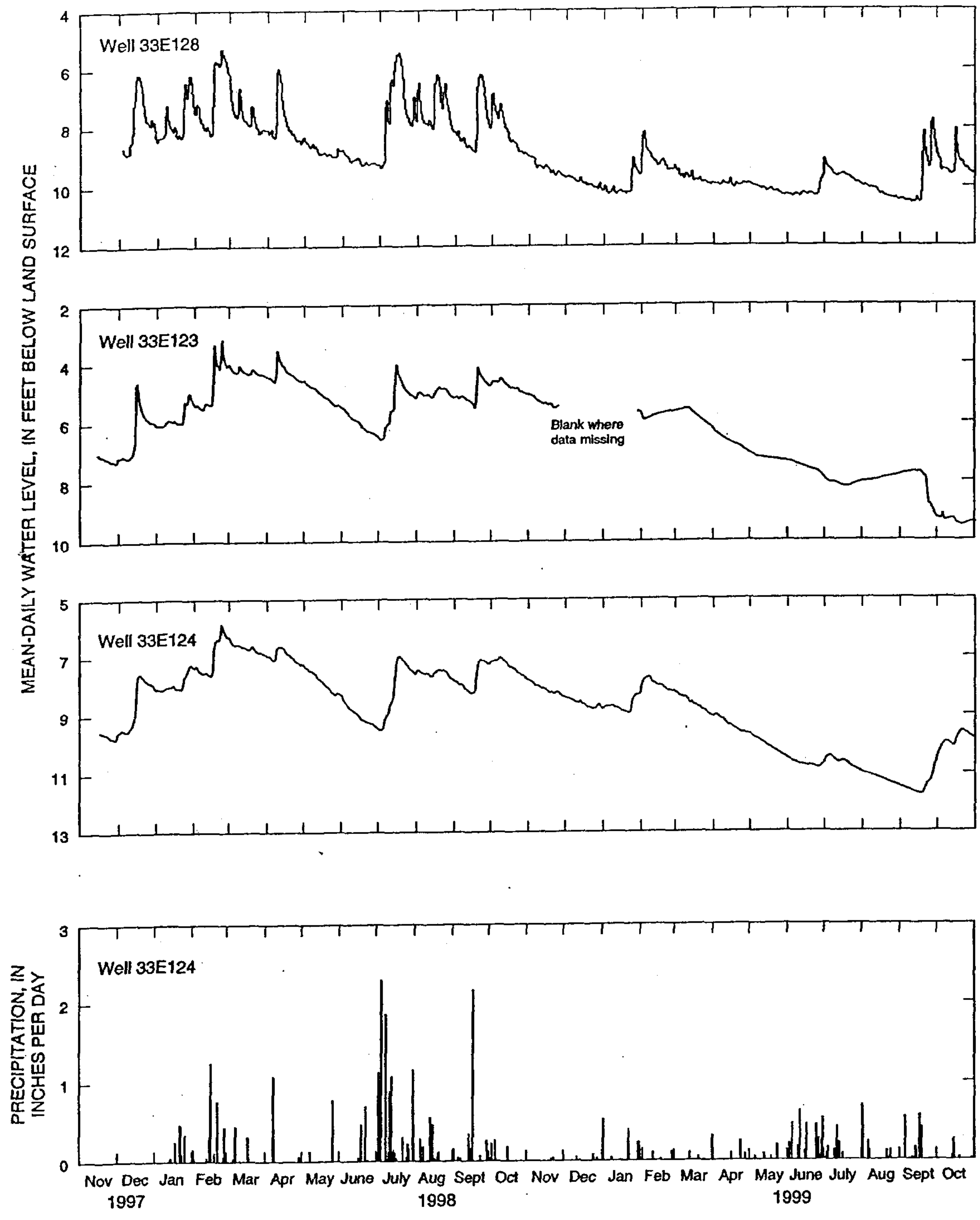
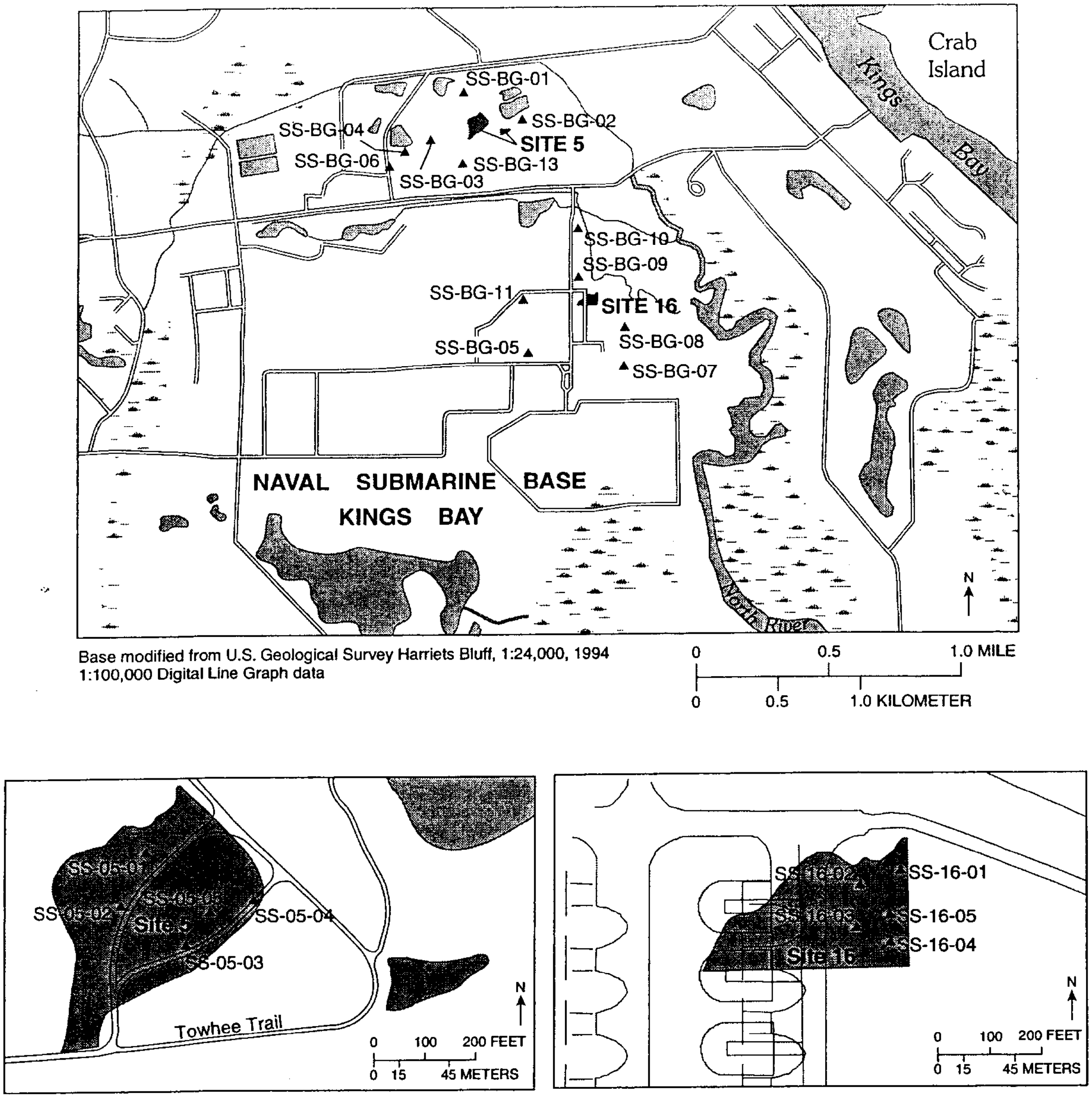


Figure 5. Water-table fluctuations in wells 33E123, 33E124, and 33E128 and daily precipitation at well 33E124, Sites 5 and 16, Naval Submarine Base Kings Bay, Camden County, Georgia, November 1997 to October 1999.



EXPLANATION

SS-05-02 ▲ SOIL SAMPLING SITE AND IDENTIFICATION

Figure 6. Sites 5 and 16, and location of soil samples collected for chemical analysis, Naval Submarine Base Kings Bay, Camden County, Georgia.

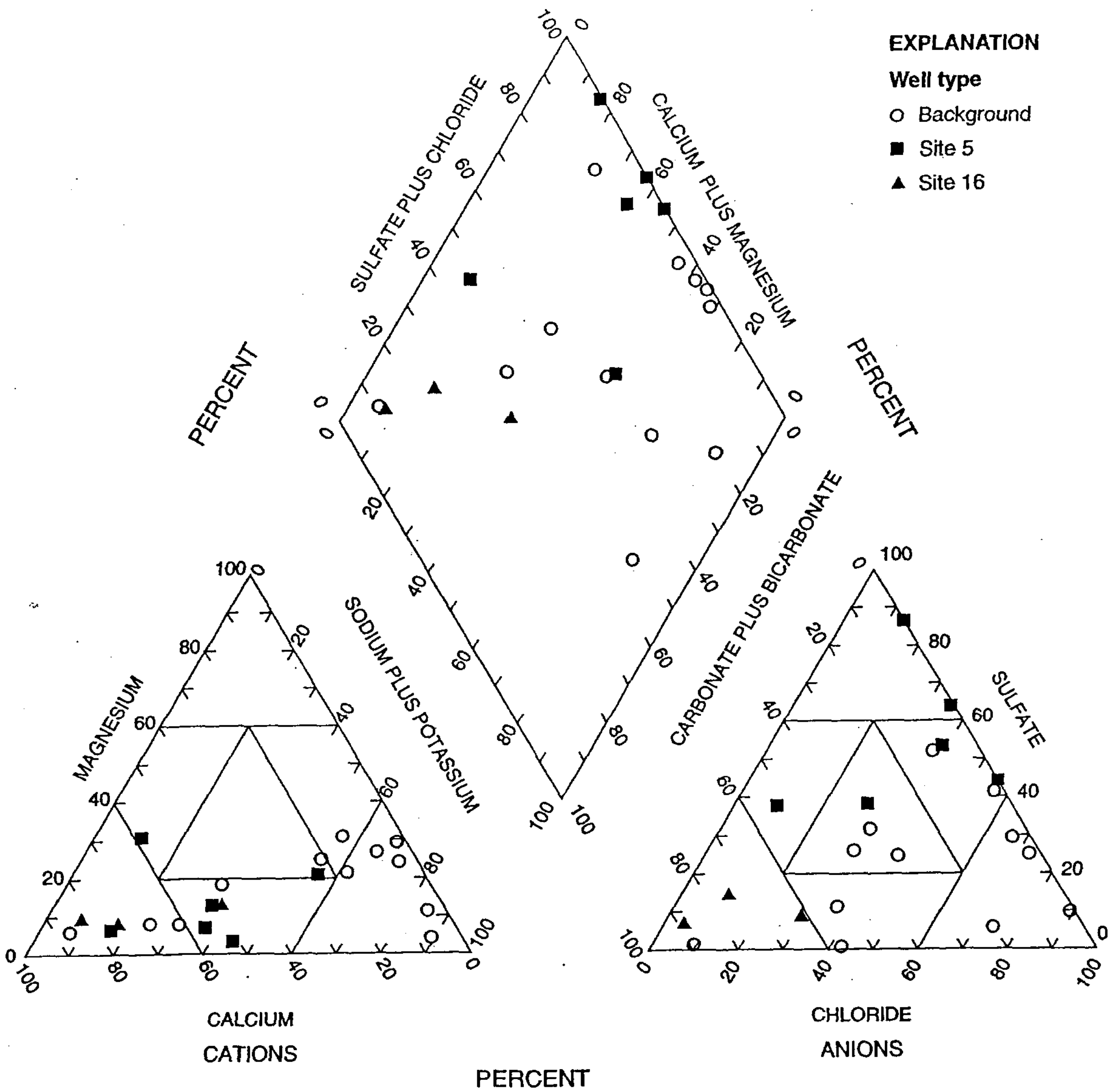


Figure 7. Percentage composition of major ionic constituents in water from background wells and wells at Sites 5 and 16, Naval Submarine Base Kings Bay, Camden County, Georgia.

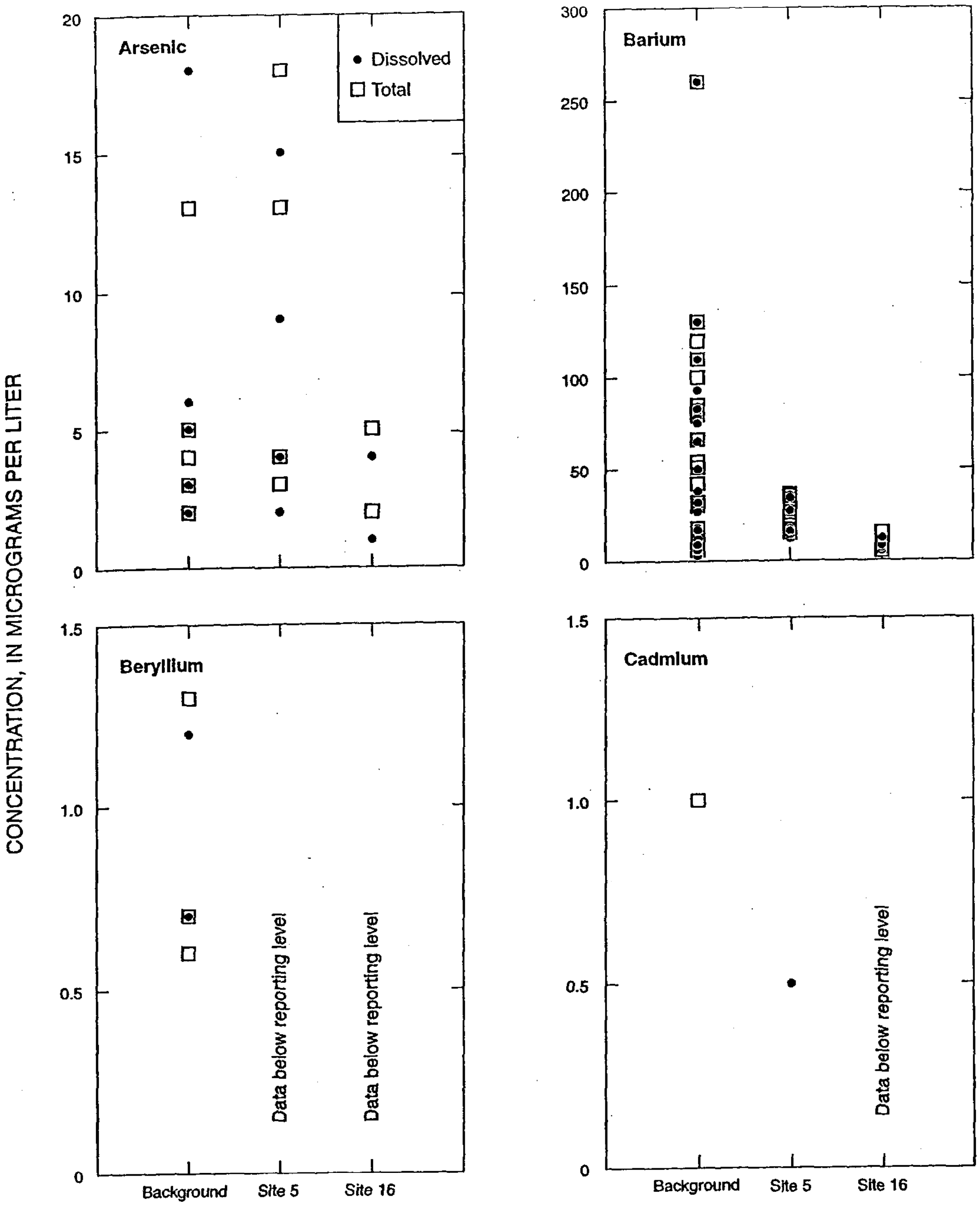


Figure 8. Dot plots of selected inorganic constituents and field properties, grouped by location, Naval Submarine Base Kings Bay, Camden County, Georgia, 1998–99.

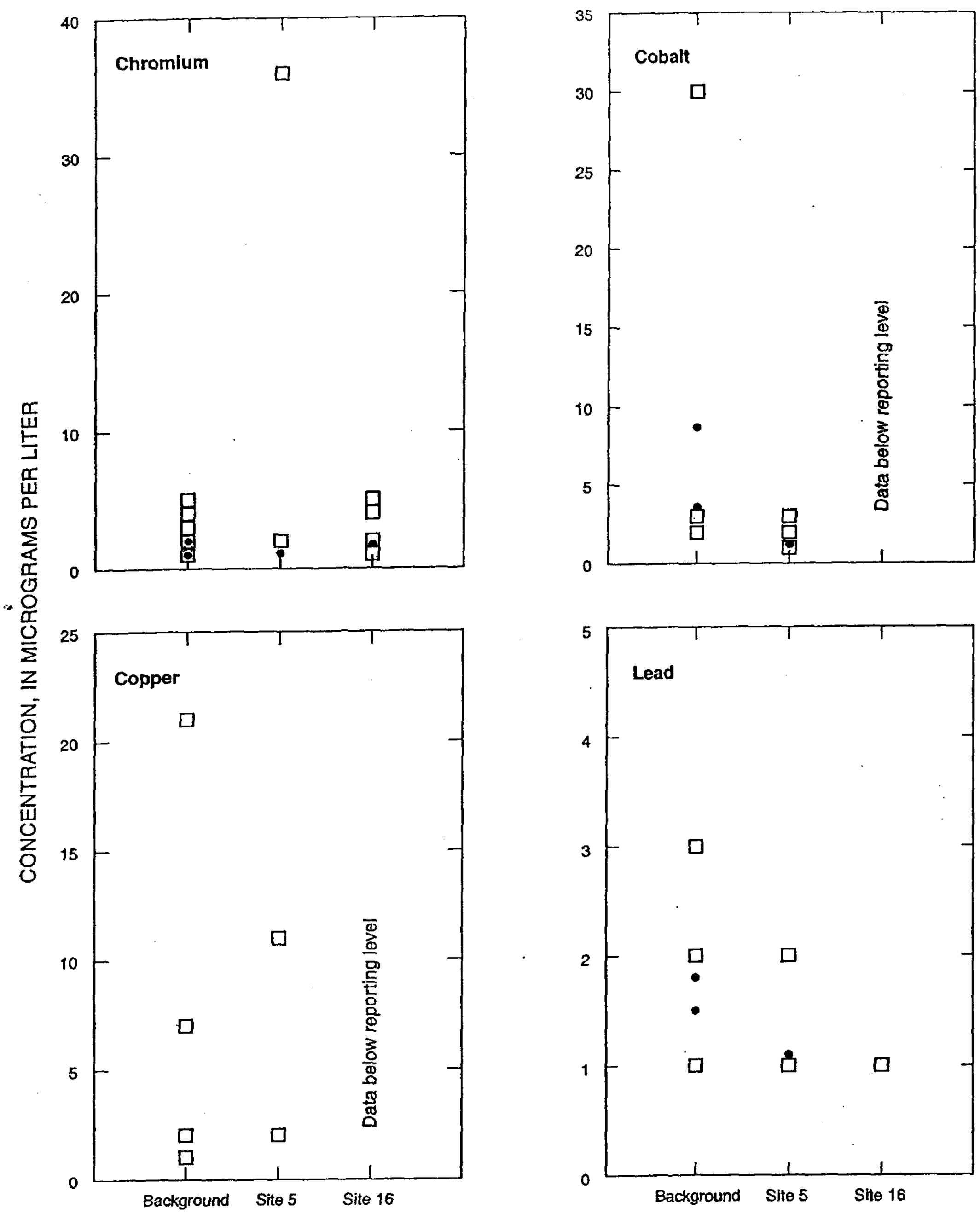


Figure 8. Dot plots of selected inorganic constituents and field properties, grouped by location, Naval Submarine Base Kings Bay, Camden County, Georgia, 1998–99 —continued.

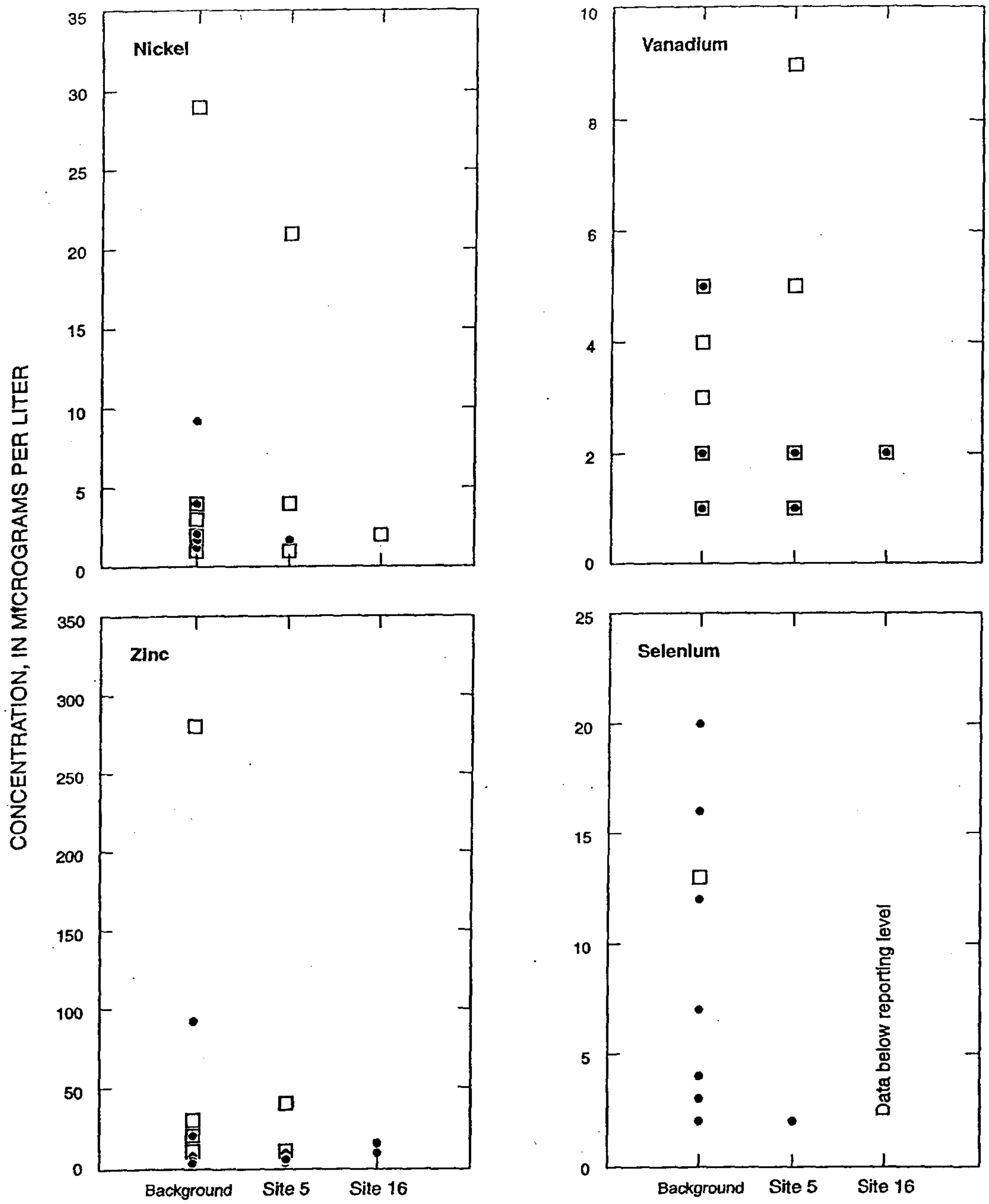


Figure 8. Dot plots of selected inorganic constituents and field properties, grouped by location, Naval Submarine Base Kings Bay, Camden County, Georgia, 1998–99 —continued.

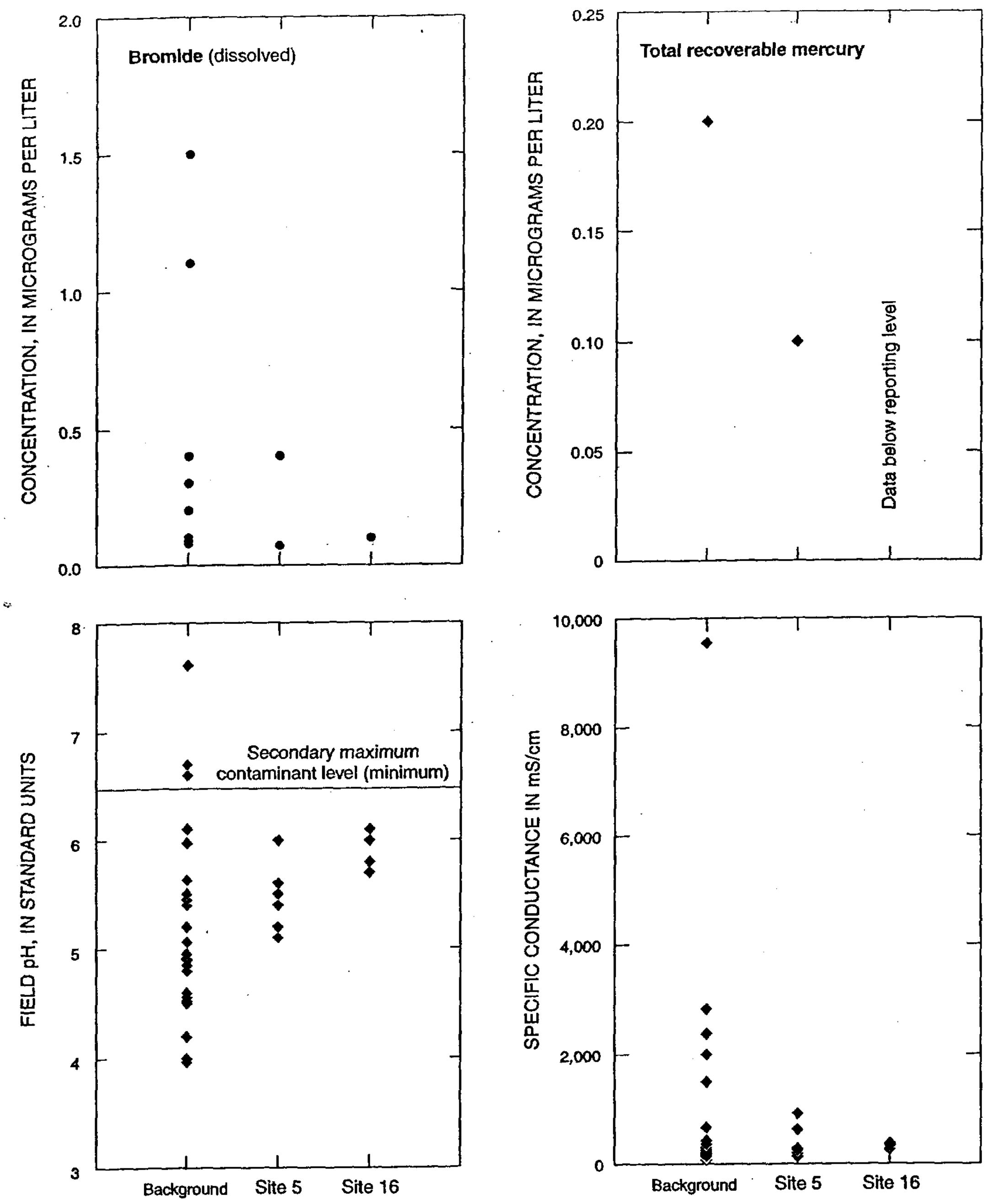


Figure 8. Dot plots of selected inorganic constituents and field properties, grouped by location, Naval Submarine Base Kings Bay, Camden County, Georgia, 1998–99 —continued.

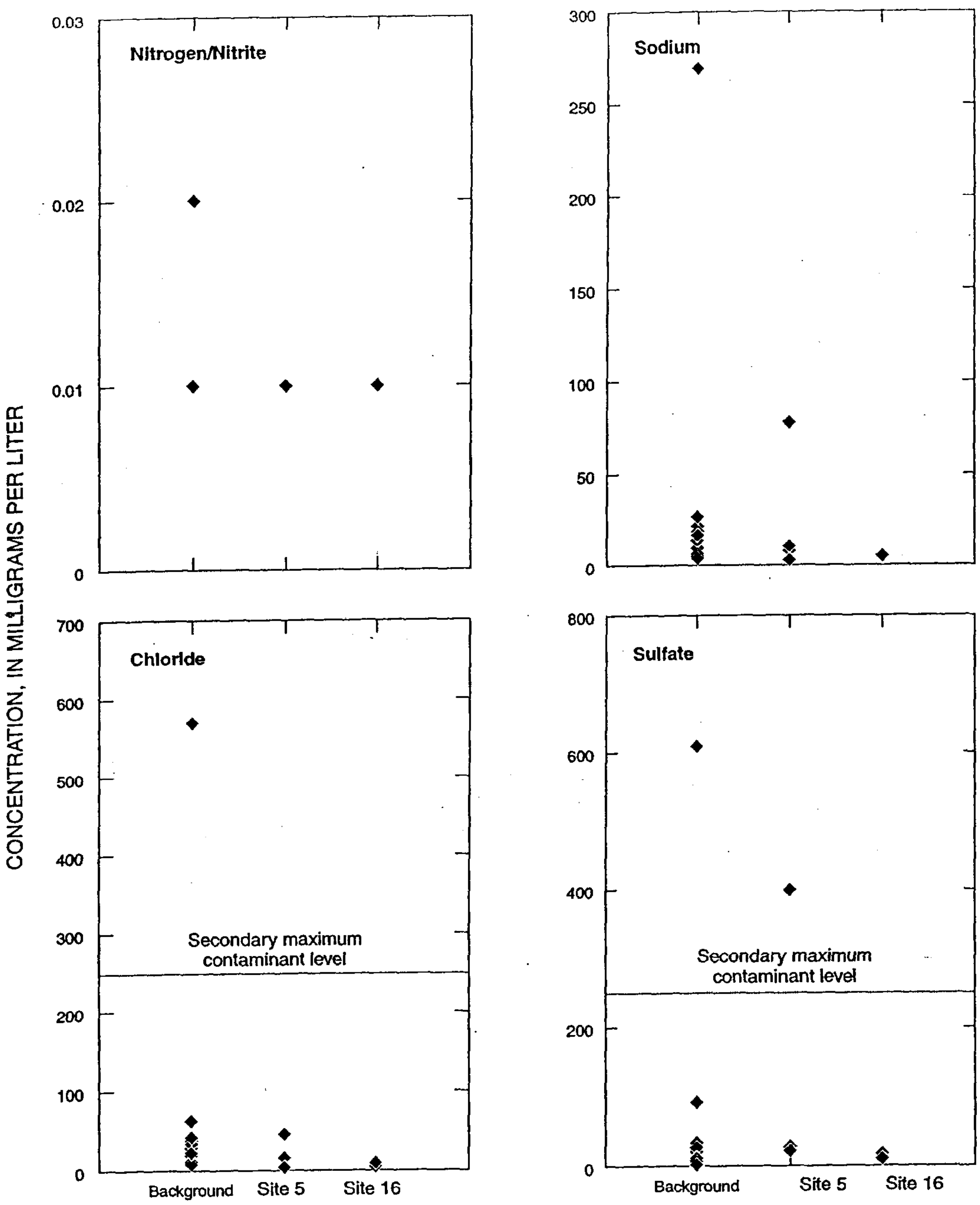


Figure 8. Dot plots of selected inorganic constituents and field properties, grouped by location, Naval Submarine Base Kings Bay, Camden County, Georgia, 1998–99 —continued.