CHEMICAL AND RADIOCHEMICAL CONSTITUENTS IN WATER FROM WELLS IN THE VICINITY OF THE NAVAL REACTORS FACILITY, IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, IDAHO, 2000

By Roy C. Bartholomay, LeRoy L. Knobel, Betty J. Tucker, and Brian V. Twining

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED UNITS

Multiply	By	To obtain
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
acre-foot (acre-ft)	1,233	cubic meter
foot per mile (ft/mi)	.1894	meter per kilometer
picocurie per liter (pCi/L)	.037	becquerel per liter

For temperature, degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the equation:
°F = (1.8)(°C) + 32.

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

Abbreviated units used in report: mg/L (milligram per liter); µg/L (microgram per liter); pCi/L (picocuries per liter).

CHEMICAL AND RADIOCHEMICAL CONSTITUENTS IN WATER FROM WELLS IN THE VICINITY OF THE NAVAL REACTORS FACILITY, IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, IDAHO, 2000

by **Roy C. Bartholomay, LeRoy L. Knobel, Betty J. Tucker, and Brian V. Twining**

Abstract

The U.S. Geological Survey, in response to a request from the U.S. Department of Energy's Pittsburgh Naval Reactors Office, Idaho Branch Office, sampled water from 13 wells during 2000 as part of a long-term project to monitor water quality of the Snake River Plain aquifer in the vicinity of the Naval Reactors Facility, Idaho National Engineering and Environmental Laboratory, Idaho. Water samples were analyzed for naturally occurring constituents and anthropogenic contaminants. A total of 52 samples were collected from the 13 monitoring wells. The routine samples contained detectable concentrations of total cations and dissolved anions, and nitrite plus nitrate as nitrogen. Most of the samples also contained detectable concentrations of gross alpha- and gross beta-particle radioactivity and tritium. Eight quality-assurance samples also were collected and analyzed; four were field-blank samples, and four were replicate samples. Most of the field-blank samples contained less-than-detectable concentrations of target constituents.

INTRODUCTION

The Idaho National Engineering and Environmental Laboratory (INEEL), encompassing about 890 mi^2 of the eastern Snake River Plain in southeastern Idaho (fig. 1), is operated by the U.S. Department of Energy (DOE). INEEL facilities are used in the development of peacetime atomic-energy applications, nuclear safety research, defense programs, and advanced energy concepts. At the Naval Reactors Facility (NRF) (fig. 1), one facility at the INEEL, small amounts of some constituents have been released to the environment as described in two NRF Remedial Investigation/Feasibility Studies (Bettis Atomic Power Laboratory, 1994, 1997).

This study was conducted by the U.S. Geological Survey (USGS) in cooperation with the DOE's Pittsburgh Naval Reactors Office, Idaho Branch Office (IBO). IBO is responsible for the NRF at the INEEL. IBO requires information about the mobility of radionuclide- and chemical-waste constituents in the Snake River Plain aquifer. Waste-constituent mobility is determined principally by (1) the rate and direction of ground-water flow; (2) the locations, quantities, and methods of waste disposal; (3) waste-constituent chemistry; and (4) the geochemical processes taking place in the aquifer (Orr and Cecil, 1991, p. 2).

Purpose and Scope

In 1989, IBO requested that the USGS initiate a water-quality data-collection program in the vicinity of the NRF at the INEEL (fig. 1). The purpose of the data-collection program is to provide IBO with water-chemistry data to evaluate the effect of NRF activities on the water quality of the Snake River Plain aquifer.

Through 1995, the data-collection program consisted of three rounds of sample collection. Round one was a one-time sampling of each well for a comprehensive suite of chemical constituents that approximates those contained in the U.S. Environmental Protection Agency's (EPA) Ground-Water Monitoring List—Appendix IX (U.S. Environmental Protection Agency, 1989, p. 636–642). Round two consisted of bimonthly collection of samples five times from each well that were analyzed for the chemical constituents listed in Appendix III-EPA Interim Primary Drinking Water Standards, the constituents listed as parameters establishing

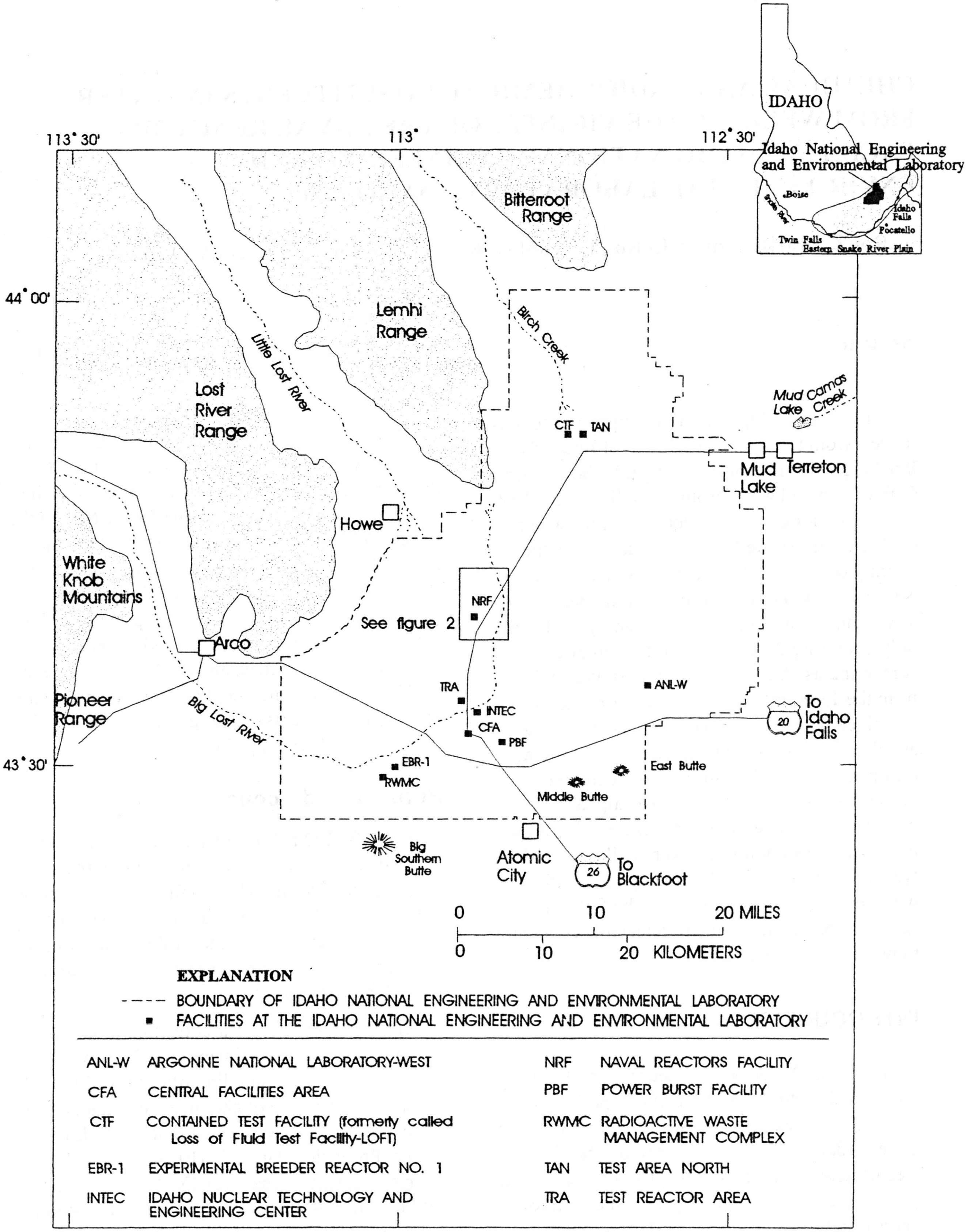

Figure 1. Location of the Idaho National Engineering and Environmental Laboratory, Naval Reactors Facility, and other selected facilities.

ground-water quality, and selected measurements used as indicators of ground-water contamination (U.S. Environmental Protection Agency, 1989, p. 660–661, 730). Additional constituents analyzed during round two included copper, nickel, zinc, and extractable acid and base/neutral compounds. Round-three samples were collected quarterly through 1995. Constituents analyzed in 1994 included chloride, chromium, iron, lead, mercury, nickel, nitrate, silver, sodium, and sulfate. Other round-three measurements were gross alpha- and gross beta-particle radioactivity, pH, specific conductance, and total organic carbon (TOC). The round-three sampling program was expanded in 1995 to include analyses for aluminum, antimony, arsenic, barium, beryllium, cadmium, copper, manganese, selenium, thallium, tritium, and zinc. As a result of expanded laboratory procedures, rounds one through three of the sample-collection program included analyses for constituents in addition to those listed above. Results of analyses of rounds one through three samples were presented by Knobel, Bartholomay, and others (1992), Bartholomay and others (1993), Tucker and others (1995), and Bartholomay and others (1997).

An analysis by Westinghouse Electric Corporation of the water-chemistry data collected for the NRF monitoring program during 1989–95 indicated that several changes to the program would improve the overall usefulness of the data. As a result, several older wells were eliminated from the program and replaced by monitoring wells specifically constructed to meet NRF needs and strategically placed to better intercept potential chemical plumes in ground water. To differentiate between the data generated from the NRF sampling program in rounds one through three (1989–95) and subsequent data (1996), the samples collected in 1996 were designated round-four samples (Knobel and others, 1999). Wells sampled in rounds one through three that were eliminated from the program included four water-supply production wells with line shaft turbine pumps (NRF-1, -2, -3, and -4; fig. 2) and three monitoring wells (USGS 15, USGS 17, and Water Supply INEL-1; fig. 2) with dedicated submersible pumps. The six newly constructed monitoring wells that were added to the sampling program in 1996 were NRF-8, -9, -10, -11, -12, and -13 (fig. 2). All of these wells and the older monitoring wells that remain in the monitoring network (NRF-6, NRF-7, USGS 12, 97, 98, 99, and 102; fig. 2) have dedicated submersible pumps.

At the end of 1996, NRF increased validation requirements for ground-water data on the basis of documents that supported the Record of Decision for the Industrial Waste Ditch and NRF landfills. Because the USGS National Water Quality Laboratory (NWQL) could not supply this documentation cost effectively, NRF personnel sampled the wells during the first quarter of 1997. Subsequently, in June 1997, USGS again assumed sampling duties as part of the USGS Department of Defense Environmental Conservation Program (DODEC). Under DODEC, sample analyses are contracted to Quanterra Environmental Laboratory Services, which changed its name to Severn Trent Laboratories in early 2000. Starting in June of 1997, water samples collected by the USGS were analyzed by the Severn Trent Laboratories. Results from the 1997–98 sampling were presented by Bartholomay, Knobel, and others (2000). Results from the 1999 sampling were presented by Bartholomay and others (2001). This report presents results from the 2000 sampling. These samples are designated round-five samples. Location of wells sampled are shown in figure 2.

The constituent list for round-five samples was modified slightly from the round-four constituent list because differences in laboratory services offered by the two laboratories. The constituents included in the round-five sampling program and analytical results are presented in tables 3 through 8 at the back of this report. Field measurements and calculations for round-five samples included alkalinity as $CaCO_3$, pH, specific conductance, temperature, total dissolved solids (TDS), and turbidity. Total dissolved solids were estimated by multiplying specific conductance by 0.543 as determined by Olmstead (1962, fig. 5). Round-five samples were collected quarterly at each well.

Hydrologic Conditions

The Snake River Plain aquifer is one of the most productive aquifers in the United States (U.S. Geological Survey, 1985, p. 193). The aquifer underlies the eastern Snake River Plain, a large,

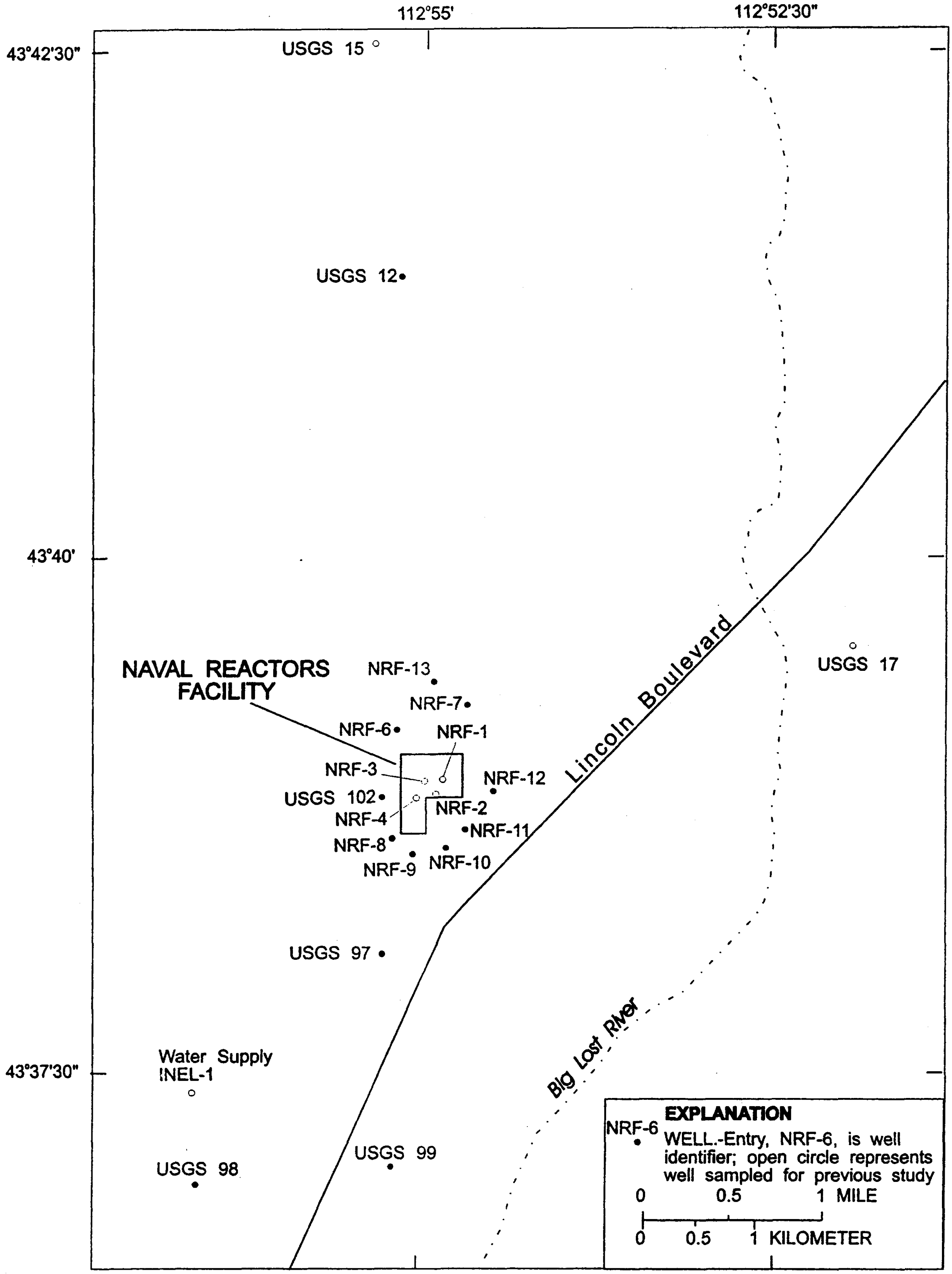

Figure 2. Location of wells, Naval Reactors Facility and vicinity, Idaho National Engineering and Environmental Laboratory.

arcuate, structural basin in southeastern Idaho (fig. 1), and consists of a thick sequence of basalts and sedimentary interbeds.

Surface Water

The Big Lost River drains more than 1,400 mi^2 of mountainous area that includes parts of the Lost River Range and the Pioneer Range west of the INEEL (fig. 1). Flow in the Big Lost River infiltrates to the Snake River Plain aquifer along its channel and in sinks and playas near its terminus. Since 1965, excess runoff has been diverted to spreading areas in the southwestern part of the INEEL where much of the water rapidly infiltrates to the aquifer. Other surface drainages that recharge the Snake River Plain aquifer at the INEEL include the Little Lost River, Birch Creek, and Camas Creek (fig. 1) (Bartholomay, Tucker, and others, 2000, p. 15).

Ground Water

Recharge to the Snake River Plain aquifer is principally from infiltration of applied irrigation water, infiltration of streamflow, and ground-water underflow from adjoining mountain drainage basins. Some recharge may be from direct infiltration of precipitation, although the small amount of annual precipitation on the plain (8 in. at the INEEL), evapotranspiration, and the great depth to water (in places exceeding 900 ft) probably minimize this source of recharge (Bartholomay, Tucker, and others, 2000, p. 14–15).

Water in the Snake River Plain aquifer moves principally through fractures and interflow zones in the basalt. Most ground water moves through the upper 800 ft of saturated rocks. Hydraulic conductivities of basalt in the upper 800 ft of the aquifer, estimated from INEEL-wide transmissivity data, are from about 0.01 to 32,000 ft/day (Anderson and others, 1999, p. 1). Estimated hydraulic conductivities in a 10,365-ft deep test hole near NRF are smaller; at depths exceeding 1,500 ft, hydraulic conductivities are from 0.002 to 0.03 ft/day (Mann, 1986, p. 21). The effective base of the Snake River Plain aquifer in the western part of the INEEL is from about 815 to 1,710 ft below land surface (Anderson and others, 1996, table 3, p. 23).

Depth to water in wells completed in the Snake River Plain aquifer is from about 200 ft below land surface in the northern part of the INEEL to more than 900 ft in the southeastern part; in the vicinity of NRF, depth to water is about 375 ft below land surface. In March–May 1998, the altitude of the water table was about 4,575 ft above sea level near Test Area North (fig. 1) and about 4,430 ft above sea level near the Radioactive Waste Management Complex (fig. 1); near the NRF, the water table was about 4,475 ft above sea level. Water generally flows southward and southwestward beneath the INEEL at an average hydraulic gradient of about 4 ft/mi; however, significant local variation in flow direction is common. Beneath the NRF, water generally flows southward. From March–May 1995 to March–May 1998, water-level changes in INEEL wells ranged from a 7-ft rise in wells north of the NRF to a 1- to 2-ft rise in wells in the northern part of the INEEL; near the NRF, the water-level rise was about 4 to 6 ft. Water levels generally increased at the INEEL during 1996–98 because of infiltration of streamflow in the Big Lost River below Arco, and an overall increase of recharge to the Snake River Plain aquifer (Bartholomay, Tucker, and others, 2000, p. 17–20).

Ground water moves southwestward from the INEEL and eventually discharges as springs along the Snake River downstream from Twin Falls, about 100 mi southwest of the INEEL (fig. 1). Approximately 4.25 million acre-ft of ground water was discharged in 1998 (Bartholomay, Tucker, and others, 2000).

Guidelines for Interpreting Results of Radiochemical Analyses

Concentrations of radionuclides are reported with an estimated sample standard deviation, **s**, that is obtained by propagating sources of analytical uncertainty in measurements. The following guidelines for interpreting analytical results are based on an extension of a method proposed by Currie (1984).

In the analysis for a particular radionuclide, laboratory measurements are made on a target sample and a prepared blank. Instrument signals for the sample and the blank vary randomly. Therefore, it is essential to distinguish between two key aspects of the problem of detection: (1) the instrument signal for the sample must be larger than the signal observed for the blank before the decision can be made that the radionuclide was detected; and (2) an estimation must be made of the minimum radionuclide concentration that will yield a sufficiently large observed signal before the correct decision can be made for detection or nondetection of the radionuclide. The first aspect of the problem is a qualitative decision based on an observed signal and a definite criterion for detection. The second aspect of the problem is an estimation of the detection capabilities of a given measurement process.

In the laboratory, instrument signals must exceed a critical level of 1.6**s** before the qualitative decision can be made as to whether the radionuclide was detected. At 1.6**s**, there is a 95-percent probability that the correct conclusion—not detected—will be made. Given a large number of samples, as many as 5 percent of the samples with measured concentrations larger than or equal to 1.6**s**, which were concluded as being detected, might not contain the radionuclide. These measurements are referred to as false positives and are errors of the first kind in hypothesis testing.

Once the critical level of 1.6**s** has been defined, the minimum detectable concentration can be determined. Radionuclide concentrations that equal 3**s** represent a measurement at the minimum detectable concentration. For true concentrations of 3**s** or larger, there is a 95-percent or larger probability that the radionuclide was detected in a sample. In a large number of samples, the conclusion—not detected—will be made in 5 percent of the samples that contain true concentrations at the minimum detectable concentration of 3**s**. These measurements are referred to as false negatives and are errors of the second kind in hypothesis testing.

True radionuclide concentrations between 1.6**s** and 3**s** have larger errors of the second kind. That is, there is a larger-than-5-percent probability of false negative results for samples with true concentrations between 1.6**s** and 3**s**. Although the radionuclide might have been detected, such detection may not be considered reliable; at 1.6**s**, the probability of a false negative is about 50 percent.

The critical level and minimum detectable concentration are based on counting statistics alone and do not include systematic or random errors inherent in laboratory procedures. The values 1.6**s** and 3**s** vary slightly with background or blank counts, with the number of gross counts for individual analyses, and for different radionuclides. In this report, radionuclide concentrations less than 3**s** are considered to be below a "reporting level." The critical level, minimum detectable concentration, and reporting level aid the reader in the interpretation of analytical results and do not represent absolute concentrations of radioactivity which may or may not have been detected.

Many analytical results of environmental radioactivity measurements are at or near zero. If the true concentration for a given radionuclide is zero, a given set of analytical results for that radionuclide should be distributed about zero, with an equal number of negative and positive measurements. Negative analytical results occur if the radioactivity of a water sample is less than the background radioactivity or the radioactivity of the prepared blank sample in the laboratory (American Society for Testing and Materials, 1992, p. 126; Knobel, Orr, and Cecil, 1992, p. 51).

Guidelines for Interpreting Results of Inorganic and Organic Analyses

The term "reporting level" used for radiochemical analyses should not be confused with the term "reporting limit" used for inorganic and organic analyses. In this report, the term "reporting limit" is the lowest level at which measurements become quantitatively meaningful (Quanterra Environmental Services, 1998). Because of unpredictable matrix effects on detection limits, the laboratory reporting limits are set somewhat higher than the analytical method detection limits. Because of this, some estimated results are given.

Acknowledgments

The authors are grateful to Kelly D. Willie of Bechtel-Bettis Corporation and Tracey Spencer of the USGS for technically reviewing the manuscript.

METHODS AND QUALITY ASSURANCE

The methods used for collecting water samples generally followed the guidelines established by the USGS (Stevens and others, 1975; Wood, 1981; Claassen, 1982; W.L. Bradford, USGS, written commun., 1985; Wilde and others, 1998; Hardy and others, 1989). Descriptions of methods used for analysis are found in reports by Quanterra Environmental Services (1998) and Thatcher and others (1977). The methods used in the field and the quality-assurance practices are described in the following sections.

Sample Containers and Preservatives

Sample containers and preservatives differed depending on the constituent(s) for which analyses were requested. Samples for inorganic and organic analyses were placed in bottles containing necessary preservatives in accordance with laboratory requirements. Containers and preservatives for inorganic and organic analyses were supplied by the Severn Trent Laboratories. Samples for radiochemical analyses were placed in containers and preserved in accordance with laboratory requirements specified by Timme (1995). Containers and preservatives were supplied by the NWQL and had undergone a rigorous quality-control procedure (Pritt, 1989, p. 75) to minimize sample contamination. The containers and preservatives used for this study are listed in table 1 (all tables located at the end of report).

Sampling Locations and Sample Collection

Samples were collected from 13 monitoring wells (NRF-6, -7, -8, -9, -10, -11, -12, -13, USGS 12, 97, 98, 99, and 102) equipped with dedicated submersible pumps. NRF-6, -7, -13, and USGS 12 are upgradient of the NRF; USGS 102 is west of NRF; NRF-11 and -12 are east of NRF; and the remaining monitoring wells are downgradient of NRF (fig. 2).

Samples were collected from a portable sampling apparatus attached to the dedicated submersible pumps. The apparatus was decontaminated before sampling at each site by rinsing with deionized water. Samples were collected after three well-bore volumes of water were purged from each well and field measurements indicated probable hydraulic and chemical stability. After collection, sample containers were sealed with laboratory film, labeled, and stored under secured conditions. Water samples were placed in ice chests, chilled when appropriate, sealed, and shipped the same day to the laboratory.

Conditions at the sampling site during sample collection were recorded in a field logbook, and a chain-of-custody record was used to track samples from the time of collection until delivery to the laboratory. These records are available for inspection at the USGS INEEL Project Office. The results of field measurements and calculations for alkalinity, pH, specific conductance, water temperature, TDS, and turbidity are listed in table 2.

Quality Assurance

Internal quality control and the overall quality-assurance practices used by the Severn Trent Laboratories are described in a report by Quanterra Environmental Services (1998). The water samples were collected by personnel assigned to the INEEL Project Office in accordance with a quality-assurance plan for quality-of-water activities (Mann, 1996). Comparative studies to determine agreement between analytical results for water-sample pairs by laboratories involved in the INEEL Project Office's quality-assurance program are summarized by Wegner (1989), Williams (1996), and Williams (1997). Additional quality assurance used for the 2000 sampling program included four field-blank samples and four replicate samples. Bottles for the field-blank samples were filled in the field camper with the respective inorganic-free, tritium-free, and organic-free waters. Bottles were opened at the well while sample collection occurred. These field-blank samples help evaluate potential for sample contamination due to field and laboratory condtions. After collection of the primary sample, a replicate sample was immediately collected. Many organizations use the term "sequential replicate" rather than "replicate" sample. These replicate samples help evaluate precision of the sample collection and analytical processes of laboratories.

ANALYTICAL RESULTS

During the period beginning in January 2000 and ending in November 2000, four sets of quarterly water samples were collected for round five of the NRF sampling program (table 2). All wells were sampled four times. Quality-assurance samples included four field-blank samples: NRF-12 (QAS-80), USGS 12 (QAS-76), USGS 97 (QAS-81), USGS 102 (QAS-77), and four replicate samples: NRF-7 (QAS-75), NRF-8 (QAS-78), NRF-10 (QAS-82), and USGS 99 (QAS-79).

Dissolved Anions and Total Cations

Water samples were analyzed for concentrations of dissolved chloride and sulfate and concentrations of total calcium, magnesium, potassium, and sodium (table 3).

Concentrations of calcium in samples from the 13 wells ranged from 24.2 to 107 mg/L. Concentrations of chloride ranged from 4.6 to 181 mg/L. Concentrations of magnesium ranged from 9.0 to 30.1 mg/L. Concentrations of potassium ranged from an estimated 1.6 to 5.1 mg/L. Concentrations of sodium ranged from 8.0 to 82.9 mg/L. Concentrations of sulfate ranged from 13.0 to 99.4 mg/L.

Concentrations of calcium in three of the four field-blank samples ranged from an estimated 0.069 to 1.4 mg/L. Selected field blank samples also contained some estimated concentrations of chloride, magnesium, potassium, sodium, and sulfate, but most constituents were not detected.

Total Trace Elements

Water samples collected in 2000 were analyzed for concentrations of total aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc (table 4).

Aluminum.—Aluminum was detected in at least one sample from all wells except USGS 99; detectable concentrations ranged from an estimated 23 µg/L in USGS 98 to 16,800 µg/L in a sample from NRF-13.

Antimony.—Antimony was not detected in most samples.

Arsenic.—Arsenic was not detected in most samples.

Barium.—Concentrations of barium ranged from 56 µg/L in NRF-6 to 200 µg/L in NRF-13.

Beryllium.—Beryllium was not detected in most samples.

Cadmium.—Cadmium was not detected in any samples.

Chromium.—Concentrations of chromium ranged from an estimated 3.7 µg/L in USGS 102 to 310 µg/L in NRF-13.

Copper.—Copper was detected in at least one sample from all wells; detectable concentrations ranged from an estimated concentration of 1.3 µg/L in USGS 12 to 330 µg/L in USGS 98.

Iron.—Concentrations of iron ranged from an estimated 16 µg/L in USGS 98 to 15,100 µg/L in a sample from NRF-13.

Lead.—Lead was not detected in many samples; detectable concentrations were as large as 8.2 µg/L in a sample from USGS 98.

Manganese.—Manganese was detected in most samples; detectable concentrations ranged from an estimated 0.92 µg/L in NRF-9 to 260 µg/L in NRF-13.

Mercury.—Mercury was not detected in most samples.

Nickel.—Nickel was not detected in most samples; detectable concentrations were as large as an estimated 95 µg/L in a sample from NRF-13.

Selenium.—Estimated concentrations of selenium were detected in about half the samples.

Silver.—Silver was not detected in any samples.

Thallium.—Thallium was not detected in any samples.

Zinc.—Zinc was not detected in most samples; detectable concentrations were as large as 160 µg/L in a sample from USGS 98.

Field-blank samples contained either no detectable concentrations of trace elements or estimated concentrations smaller than the respective reporting limits.

Dissolved and Total Nutrients

Water samples were analyzed for concentrations of dissolved nitrite as nitrogen and for total concentrations of kjeldahl nitrogen, nitrite plus nitrate as nitrogen, and phosphorus as phosphorus (table 5).

Kjeldahl nitrogen.—Kjeldahl nitrogen was not detected in most samples; detectable concentrations were as large as 0.93 mg/L in a sample from NRF-6.

Nitrite as nitrogen.—Nitrite as nitrogen was detected in only one sample; NRF-10 contained an estimated concentration of 0.005 mg/L.

Nitrite plus nitrate as nitrogen.—Concentrations ranged from 0.46 mg/L in NRF-7 to 2.3 mg/L in NRF-9.

Phosphorus as phosphorus.—Phosphorus as phosphorus was detected in most samples; detectable concentrations were as large as 0.50 mg/L in a sample from NRF-13.

Field-blank samples contained either no detectable concentrations of nutrients or had estimated concentrations smaller than the reporting limits.

Total Organic Carbon and Total Organic Halogens

Water samples were analyzed for concentrations of TOC and total organic halogens (TOX) (table 5). TOC and TOX were not detected in most samples. TOX were not detected in any field-blank samples. One field-blank sample for TOC contained an estimated concentration of 0.25 mg/L.

Gross Alpha- and Gross Beta-Particle Radioactivity

Water samples were analyzed for concentrations of dissolved gross alpha- and gross beta-particle radioactivity by the Severn Trent Laboratories in Richland, Wash. through a contract with the NWQL using a residue procedure. Concentrations of radioactive constituents larger than or equal to 3 times the 1s uncertainty are considered to be above the reporting level in this report. All analytical measurements are listed in table 6. For a more detailed discussion of reporting levels for radioactive constituents and measurements, see the section of this report titled "Guidelines for Interpreting Results of Radiochemical Analyses."

Gross alpha-particle radioactivity.—Gross alpha-particle radioactivity is a measure of the total radioactivity given off as alpha particles during the radioactive decay process. For convenience, laboratories report the radioactivity as if it all were given off by one radionuclide. In this report, concentrations are reported as thorium-230 in picocuries per liter. Concentrations of dissolved gross alpha-particle radioactivity are listed in table 6.

Concentrations of gross alpha-particle radioactivity as thorium-230 ranged from 1.28±0.25 pCi/L in NRF-7 to 3.73±0.9 pCi/L in NRF-6. Concentrations in all the field blank samples were less than the reporting level.

Gross beta-particle radioactivity.—Gross beta-particle radioactivity is a measure of the total radioactivity given off as beta particles during the radioactive decay process. For convenience, laboratories report the radioactivity as if it all were given off by one radionuclide, cesium-137, in picocuries per liter. Concentrations of dissolved gross beta-particle radioactivity are listed in table 6.

Concentrations of gross beta-particle radioactivity as cesium-137 ranged from 0.853±0.65 pCi/L in NRF-9 to 8.46±0.95 pCi/L in NRF-13. Concentrations in all the field blank samples were less than the reporting level.

Strontium-90

Water samples were analyzed for strontium-90 by chemical separation and beta counting (table 6). The concentrations of strontium-90 in all samples were less than the reporting level.

Tritium

Water samples were analyzed for tritium by the University of Georgia Center for Isotopic Studies Laboratory through a contract with the NWQL by enrichment and liquid scintillation (table 6). Concentrations of tritium ranged from less than the defined minimal detectable activity (MDA) in NRF-7 to 173.58±11.9 pCi/L in NRF-10. Concentrations in all the field-blank samples were less than MDA.

Selected Gamma-Emitting Radioisotopes

Gamma spectrometry involves using a series of detectors to simultaneously determine the concentrations of a variety of radionuclides by their characteristic gamma emissions. The radionuclide identified in selected samples was cesium-137. Concentrations of all the radionuclides identified using gamma spectrometry are given in table 6. Concentrations reported as cesium-137 in all the regular and field-blank samples were less than the reporting level.

Regulatory Volatile and Base/Neutral Organic Compounds

Water samples collected in August 2000 were analyzed for 59 regulatory volatile organic compounds (table 7) and 21 base/neutral organic compounds (table 8). Six of the samples were destroyed in shipping and were resampled in November. Alpha- and gamma-chlordane were not analyzed for in the six samples collected in November. The concentration of chloroform in one sample (NRF-6) was 0.1 µg/L. Concentrations of all other regulatory volatile compounds in all samples were less than the reporting limits. Concentrations of base/neutral organic compounds in all samples were less than the reporting limits.

SUMMARY

The USGS, in response to a request from the U.S. Department of Energy's Pittsburgh Naval Reactors Office, Idaho Branch Office, sampled water from 13 wells during 2000 as part of a long-term project to monitor water quality of the Snake River Plain aquifer in the vicinity of the NRF, INEEL, Idaho. Water samples were collected and analyzed for naturally occurring constituents and anthropogenic contaminants. A total of 52 samples were collected from the 13 monitoring wells, which were equipped with dedicated submersible pumps. Eight quality-assurance samples also were collected and analyzed; four were field-blank samples and four were replicate samples.

The ranges of concentrations of dissolved anions and total cations follow: calcium, 24.2 to 107 mg/L; chloride, 4.6 to 181 mg/L; magnesium, 9.0 to 30.1 mg/L; potassium, an estimated 1.6 to 5.1 mg/L; sodium, 8.0 to 82.9 mg/L; and sulfate, 13.0 to 99.4 mg/L.

Samples were analyzed for 17 trace elements. Antimony, arsenic, beryllium, cadmium, copper, lead, mercury, nickel, selenium, silver, thallium, and zinc were not detected in most samples. Concentrations of manganese, nickel, and zinc were as large as 260, 95, and 160 µg/L, respectively. Aluminum, manganese, and iron were detected in most samples. The largest concentration of iron was 15,100 µg/L. The ranges of concentrations for barium and chromium were 56 to 200 µg/L and an estimated 3.7 to 310 µg/L, respectively. Concentrations of the predominant nitrogen-bearing compound, nitrite plus nitrate as nitrogen, ranged from 0.46 to 2.3 µg/L.

TOC and TOX were not detected in most samples.

Concentrations of dissolved gross alpha- and gross beta-particle radioactivity and tritium exceeded the reporting level in most samples. Concentrations of strontium-90 and gross gamma as cesium-137 were less than the reporting level in all samples.

One regulatory volatile organic compounds was detected in one sample. Concentrations of the base/neutral organic compounds in all samples were less than the reporting limits.

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Table 1. Containers and preservatives used for water samples, Naval Reactors Facility and vicinity
[Abbreviations: L, liter; mL, milliliter. Symbols: HNO_3, nitric acid; H_2SO_4, sulfuric acid; HCL, hydrochloric acid; °C, degrees Celsius. Samples were shipped by overnight-delivery mail]

Type of property or constituent	Container		Preservative		Other treatment
	Type	Size	Type	Volume	
Specific conductance	Polyethylene	1L	None	None	Filter
Cations, total recoverable	Polyethylene	500 mL	HNO_3	10 mL	None
Trace elements, total recoverable	Polyethylene	500 mL	HNO_3	10 mL	None
Nitrite	Polyethylene	1 L	None	None	Filter
Nutrients, total recoverable	Glass, baked	500 L	H_2SO_4	2 mL	Chill 4°C
Total organic carbon	Glass, baked	500 L	H_2SO_4	2 mL	Chill 4°C
Total organic halogens	Glass, baked	250 mL	H_2SO_4	1 mL	Chill 4°C
Gross alpha- and beta-particle radioactivity	Polyethylene, acid-rinsed	1L	Ultrex HNO_3	8 mL	Filter
Strontium-90	Polyethylene, acid-rinsed	1L	Ultrex HNO_3	8 mL	Filter
Tritium	Polyethylene, acid-rinsed	500 mL	None	None	None
Gamma	Polyethylene, acid-rinsed	1L	Ultrex HNO_3	8 mL	Filter
Purgeable organic compounds	Glass, baked	40 mL	HCL	4 drops	Chill
Semi-volatile organic compounds	Glass, baked	1L	None	None	Chill

Table 2. Results of measurements of water for alkalinity, pH, specific conductance, temperature, and turbidity, and calculated total dissolved solids, Naval Reactors Facility and vicinity

[Sample identifier: see figure 2 for location of sites. QAS indicates quality-assurance sample, 75 is sample number, R indicates replicates, B indicates field blank. Date sampled: (m/d/y), month/day/year; time, military units. Units: Alkalinity as calcium carbonate ($CaCO_3$) in milligrams per liter. pH, negative base-10 logarithm of hydrogen ion activity in moles per liter; specific conductance, microsiemens per centimeter at 25 degrees Celsius (deg C); temperature, deg C; total dissolved solids, milligrams per liter calculated from specific conductance; turbidity, nephlometric turbidity units. Abbreviation: NR, not recorded; NA, not analyzed. Symbol: *, estimated result]

Sample identifier	Date sampled m/d/y	Time	Alkalinity as $CaCO_3$	pH	Specific conductance (field)	Specific conductance (lab)	Temperature	Total dissolved solids	Turbidity
NRF-6	1/31/00	1240	184	7.9	1154	1110	11.5	627	6.46
	5/1/00	1220	184	8.0	1168	1120	11.5	634	9.23
	8/1/00	1230	185	7.7	1097	1060	11.5	596	8.91
	11/6/00	1250	181	7.9	1150	1010	11.5	624	6.94
NRF-7	1/31/00	1140	104	8.3	250	253	14.0	136	14.7
QAS-75R	1/31/00	1200	104	8.3	250	255	14.0	136	14.7
NRF-7	5/1/00	1130	107	8.3	263	264	14.5	143	18.4
	8/1/00	1120	99	8.0	245	249	15.5	133	4.3
	11/6/00	1200	104	8.2	253	206	14.5	137	13.0
NRF-8	2/1/00	1000	214	8.0	589	576	11.5	320	.78
	5/2/00	1025	210	8.0	580	572	11.5	315	NR
QAS-78R	5/2/00	1100	210	8.0	580	570	11.5	315	NR
NRF-8	8/2/00	1230	204	7.9	572	560	11.5	311	1.47
	11/7/00	1120	205	7.9	569	524	11.5	309	3.87
NRF-9	2/1/00	1040	208	8.0	618	604	11.5	336	.38
	5/2/00	1125	205	8.0	613	602	11.5	333	.37
	8/3/00	0900	208	7.8	608	598	11.5	330	.82
	11/8/00	1205	205	8.0	606	566	11.5	329	.43

Table 2. Results of measurements of water for alkalinity, pH, specific conductance, temperature, and turbidity, and calculated total dissolved solids, Naval Reactors Facility and vicinity—Continued

Sample identifier	Date sampled m/d/y	Time	Alkalinity as $CaCO_3$	pH	Specific conductance (field)	Specific conductance (lab)	Temperature	Total dissolved solids	Turbidity
NRF-10	2/1/00	1120	201	8.0	590	578	11.5	320	1.58
	5/2/00	1220	197	8.0	578	569	11.5	314	1.95
	8/3/00	0800	189	7.9	572	557	11.5	311	2.86
	11/9/00	1135	200	8.0	565	495	11.5	307	2.02
QAS-82R	11/9/00	1200	200	8.0	565	501	11.5	307	2.02
NRF-11	2/1/00	1205	206	8.0	615	605	11.5	334	1.98
	5/3/00	1035	205	8.0	606	598	11.5	329	2.91
	8/3/00	0955	202	7.8	606	594	11.5	329	2.12
	11/9/00	1040	201	8.0	601	525	11.5	326	2.10
NRF-12	2/2/00	1035	204	7.9	648	638	11.5	352	4.61
	5/3/00	1135	204	8.0	636	628	12.0	345	7.27
	8/3/00	1104	201	7.8	630	622	12.0	342	2.86
QAS-80B	8/3/00	1130	NA	8.5	1	1.6*	22.5	.54	.13
NRF-12	11/6/00	1345	199	7.9	628	549	11.5	341	3.5
NRF-13	2/2/00	1325	91	8.0	586	587	16.5	318	172
	5/3/00	1235	99	8.0	596	596	17.5	324	98.0
	8/3/00	1250	104	7.8	609	605	17.5	331	91.0
	11/8/00	1310	96	8.0	567	528	12.0	308	102
USGS 12	2/2/00	0925	203	7.9	465	462	11.5	252	.40
QAS-76B	2/2/00	1000	NA	6.4	2	7.2	16.5	1	.17
USGS 12	5/3/00	0930	196	7.9	463	461	11.5	251	.30

Table 2. Results of measurements of water for alkalinity, pH, specific conductance, temperature, and turbidity, and calculated total dissolved solids, Naval Reactors Facility and vicinity—Continued

Sample identifier	Date sampled m/d/y	Time	Alkalinity as $CaCO_3$	pH	Specific conductance (field)	Specific conductance (lab)	Temperature	Total dissolved solids	Turbidity
USGS 12	8/2/00	0835	198	7.8	461	457	12.0	250	.34
	11/8/00	0950	210	7.9	471	441	11.5	256	.43
USGS 97	2/1/00	0915	216	8.0	600	585	11.5	326	.24
	5/2/00	0930	214	8.0	593	584	11.5	322	.56
	8/2/00	1135	213	7.9	587	576	11.5	319	.34
	11/9/00	0930	213	7.9	581	515	11.5	315	.30
QAS-81B	11/9/00	0950	NA	5.6	1	3.1	15.5	.54	NR
USGS 98	2/1/00	0745	174	7.8	438	432	12.0	238	.35
	5/2/00	0745	177	8.0	437	434	12.0	237	NR
	8/2/00	0940	180	7.9	442	435	12.5	240	.92
	11/7/00	0915	178	7.9	439	409	12.0	238	.80
USGS 99	2/1/00	0830	216	7.9	532	516	11.5	289	1.27
	5/2/00	0840	213	8.0	536	528	11.5	291	1.09
	8/2/00	1035	213	7.8	535	530	11.5	291	1.12
QAS-79R	8/2/00	1115	213	7.8	535	529	11.5	291	1.12
USGS 99	11/7/00	1020	210	7.9	538	497	11.0	292	1.43
USGS 102	1/31/00	1325	213	7.9	586	577	11.5	318	.66
	5/1/00	1325	207	8.1	576	568	12.0	313	.57
QAS-77B	5/1/00	1345	NA	8.2	4	1.5*	17.5	2	.23
USGS 102	8/1/00	1335	210	7.8	570	563	11.5	310	1.23
	11/9/00	1250	208	8.0	567	504	11.5	308	.38

Table 3. Concentrations of dissolved anions and total cations, Naval Reactors Facility and vicinity
[Analysis were performed by Severn Trent Laboratories. Analytical results in milligrams per liter. Sample identifier: see figure 2 for location of sites. QAS indicates quality-assurance sample, 75 is sample number, R, replicate, B, field blank. Date sampled: (m/d/y), month/day/year. Abbreviations: ND, analysis not detected; G, reporting limit elevated due to matrix interference. Symbols: *, estimated result; #, reporting limit was elevated due to high analyte values]

Sample identifier	Date sampled m/d/y	Calcium (total)	Chloride (dissolved)	Magnesium (total)	Potassium (total)	Sodium (total)	Sulfate (dissolved)
NRF-6	1/31/00	96.9	158#	27.1	4.8*	82.9	92.1#
	5/1/00	103	177#	27.0	4.0*	76.4	92.2#
	8/1/00	92.8	176#	26.2	4.1*	73.8	99.4#
	11/6/00	107	181#	30.1	4.5*	78.0	96.2#
NRF-7	1/31/00	25.9	4.7	9.4	3.3*	11.5	13.4
QAS-75R	1/31/00	25.6	4.6	9.4	3.0*	10.6	13.0
NRF-7	5/1/00	28.9	4.6	9.1	2.9*	8.0	13.6
	8/1/00	24.2	5.2	9.0	2.9*	8.1	13.8
	11/6/00	26.7	5.1	9.8	3.3*	9.3	13.7
NRF-8	2/1/00	64.7	32.7	22.1	2.0*	13.8	33.2
	5/2/00	70.5	32.5	22.8	1.9*	12.7	33.3
QAS-78R	5/2/00	70.4	32.5	22.8	2.0*	14.1	33.4
NRF-8	8/2/00	61.2	33.2	20.8	2.1*	13.9	34.0
	11/7/00	69.7	30.7	22.3	2.4*	16.0	32.5
NRF-9	2/1/00	67.2	39.5	22.3	2.2*	16.4	39.6
	5/2/00	72.6	40.1	22.9	2.4*	16.2	40.4
	8/3/00	63.1	40.6	21.1	2.3*	15.7	41.1
	11/8/00	75.5	39.1	23.0	2.7*	17.9	39.2
NRF-10	2/1/00	63.4	36.8	21.8	2.4*	14.5	36.8
	5/2/00	68.5	37.4	22.1	2.3*	13.8	37.8
	8/3/00	59.7	38.4	20.4	2.3*	13.1	38.9
	11/9/00	68.0	36.7	21.3	2.5*	14.7	37.8
QAS-82R	11/9/00	66.6	36.5	20.9	2.5*	15.1	37.8
NRF-11	2/1/00	65.4	40.9	22.2	2.3*	17.5	38.4
	5/3/00	68.8	41.2	21.5	2.3*	17.3	39.1
	8/3/00	61.2	42.1	20.8	2.2*	16.4	39.9
	11/9/00	72.4	37.2G	22.2	2.5*	19.5	38.5
NRF-12	2/2/00	66.8	49.2	22.0	2.4*	20.8	45.2
	5/3/00	70.8	49.0	21.8	2.6*	20.6	45.5
	8/3/00	62.9	48.9	21.0	2.6*	19.4	45.9

Table 3. Concentrations of dissolved anions and total cations in water, Naval Reactors Facility and vicinity—Continued

Sample identifier	Date sampled m/d/y	Calcium (total)	Chloride (dissolved)	Magnesium (total)	Potassium (total)	Sodium (total)	Sulfate (dissolved)
QAS-80B	8/3/00	ND	ND	ND	ND	ND	.74*
NRF-12	11/6/00	67.5	47.4	22.8	2.6*	20.5	43.7
NRF-13	2/2/00	84.8	64.6#	27.2	5.1	12.0	78.8#
	5/3/00	72.0	65.4#	21.5	3.7*	10.1	78.2#
	8/3/00	62.6	72.3#	20.2	4.0*	10.1	81.8#
	11/8/00	69.1	59.0#	20.4	4.3*	12.0	72.1#
USGS 12	2/2/00	52.0	12.0	17.7	1.8*	10.8	21.8
QAS-76B	2/2/00	.069*	1.3*	.021*	ND	ND	ND
USGS 12	5/3/00	55.1	12.6	17.4	1.8*	11.1	22.7
	8/2/00	51.6	14.0	17.4	1.9*	11.0	23.5
	11/8/00	57.8	13.6	18.0	1.9*	11.3	23.5
USGS 97	2/1/00	64.7	32.9	22.6	2.1*	15.5	33.3
	5/2/00	70.1	32.9	23.1	1.9*	14.4	33.7
	8/2/00	60.8	33.6	21.1	2.1*	15.4	34.7
	11/9/00	69.3	30.6	22.1	2.4*	17.5	32.8
QAS-81B	11/9/00	1.4	.70*	.049*	.25*	1.3*	ND
USGS 98	2/1/00	46.1	13.6	18.7	1.9*	8.2	21.1
	5/2/00	50.8	14.1	19.4	1.9*	8.4	21.9
	8/2/00	46.9	15.5	18.7	1.8*	8.5	22.7
	11/7/00	50.8	13.9	19.2	2.1*	10.0	21.8
USGS 99	2/1/00	56.8	19.5	21.2	1.7*	13.8	25.0
	5/2/00	63.0	20.9	22.2	1.8*	13.6	26.0
	8/2/00	56.6	23.2	21.1	1.6*	12.8	27.3
QAS-79R	8/2/00	54.5	23.0	20.2	1.6*	13.3	27.4
USGS 99	11/7/00	61.4	21.3	21.4	2.1*	15.4	26.8
USGS 102	1/31/00	64.6	31.9	22.1	1.8*	15.1	32.6
	5/1/00	67.1	31.8	21.4	2.1*	15.1	33.4
QAS-77B	5/1/00	.072*	ND	.012*	ND	ND	ND
USGS 102	8/1/00	60.5	31.4	20.7	1.9*	13.5	32.9
	11/9/00	67.3	29.7	21.0	2.7*	16.4	32.3

Table 4. Concentrations of selected total trace elements in water, Naval Reactors Facility and vicinity
[Analysis were performed by Severn Trent Laboratories. Analytical results in micrograms per liter. Sample identifier: see figure 2 for location of sites. QAS indicates water quality assurance sample, 75 is the sample number; R, replicate; B, field blank. Date sampled: (m/d/y), month/day/year. Abbreviations: ND, indicates not detected; W, Post digestion spike recovery fell between 40-85 percent due to matrix interference; D, result was obtained from the analysis of a dilution; Q, elevated reporting limit due to high analyte levels. Symbol: *, indicates estimated concentration]

Constituent	NRF-6 1/31/00	NRF-6 5/1/00	NRF-6 8/1/00	NRF-6 11/6/00	NRF-7 1/31/00	QAS-75R 1/31/00	NRF-7 5/1/00	NRF-7 8/1/00	NRF-7 11/6/00
Aluminum	ND	ND	ND	27*	370	380	330	27*	330
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	3.5*	ND	ND	ND	3.9*	5.0*	ND	ND	ND
Barium	64	57	56	65	66	68	58	57	63
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	25DQ	27DQ	20*D	28DQ	12	12	12	12	13
Copper	2.1*	ND	ND	ND	2.4*	2.8*	ND	ND	7.2*
Iron	810	1,100	420	1,500	570	700	440	110	940
Lead	ND	ND	ND	ND	2.3*	2.4*	ND	ND	ND
Manganese	5.6*	7.7*	3.7*	9.6*	15	18	13	3.8*	15
Mercury	ND	ND	.06*	.04*	ND	ND	ND	.06*	.03*
Nickel	8.8*	13*	8.0*	25*	9.9*	10*	8.5*	7.0*	9.2*
Selenium	4.9*	ND	5.0*	ND	ND	4.6*	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	3.7*	ND	ND	ND	31	6.8*	ND	3.0*	ND

Table 4. Concentrations of selected total trace elements in water, Naval Reactors Facility and vicinity—Continued

Constituent	NRF-8 2/1/00	NRF-8 5/2/00	QAS-78R 5/2/00	NRF-8 8/2/00	NRF-8 11/7/00	NRF-9 2/1/00	NRF-9 5/2/00	NRF-9 8/3/00	NRF-9 11/8/00
Aluminum	63*	50*	82*	30*	3,400	ND	ND	ND	42*
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	3.5*	ND	ND	ND
Barium	140	130	130	130	150	150	140	140	130
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	.58*
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	6.9	7.5	7.6	8.2	23W	8.6	11	11D	7.7W
Copper	2.0*	ND	ND	ND	4.0*	1.7*	ND	ND	ND
Iron	160	100	110	250	2,900	55*	110	330	76*
Lead	ND	2.4*	2.3*	ND	ND	ND	ND	ND	ND
Manganese	2.2*	1.7*	1.4*	2.0*	44	ND	ND	2.9*	.92*
Mercury	ND	.03*	ND	.06*	.03*	ND	ND	.03*	.03*
Nickel	ND	ND	ND	ND	8.5*	ND	ND	ND	ND
Selenium	ND	4.7*	5.0	3.8*	4.8*	ND	4.1*	ND	4.6*
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	ND	ND	ND	10*	2.9*	ND	ND	ND	ND

Table 4. Concentrations of selected total trace elements in water, Naval Reactors Facility and vicinity—Continued

Constituent	NRF-10 2/1/00	NRF-10 5/2/00	NRF-10 8/3/00	NRF-10 11/9/00	QAS-82R 11/9/00	NRF-11 2/1/00	NRF-11 5/3/00	NRF-11 8/3/00	NRF-11 11/9/00
Aluminum	50*	ND	ND	52*	42*	330	50*	26*	56*
Antimony	ND	ND	ND	ND	ND	ND	4.5*	ND	ND
Arsenic	3.0*	ND	ND	ND	ND	3.5*	ND	ND	ND
Barium	150	130	130	120	120	160	140	140	130
Beryllium	ND	ND	ND	.78*	.63*	ND	ND	ND	.73*
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	11W	11	12	8.5W	8.4W	17	15	16	11W
Copper	2.2*	ND	ND	ND	ND	3.2*	ND	ND	ND
Iron	130	56*	81*	60*	72*	1,300	130	220	67*
Lead	ND	2.0*	1.7*	ND	ND	ND	ND	ND	ND
Manganese	3.8*	1.6*	2.3*	1.9*	2.1*	16	1.5*	2.5*	ND
Mercury	ND	.03*	ND	ND	ND	ND	ND	ND	ND
Nickel	22*	21*	14*	14*	13*	ND	5.7*	5.8*	6.7*
Selenium	ND	3.9*	ND	5.8*	6.4*	4.3*	3.8*	4.1*	5.6*
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	19*	ND	4.0*	ND	ND	5.0*	ND	ND	ND

Table 4. Concentrations of selected total trace elements in water, Naval Reactors Facility and vicinity—Continued

Constituent	NRF-12 2/2/00	NRF-12 5/3/00	NRF-12 8/3/00	QAS-80B 8/3/00	NRF-12 11/6/00	NRF-13 2/2/00	NRF-13 5/3/00	NRF-13 8/3/00	NRF-13 11/8/00
Aluminum	ND	29*	ND	ND	ND	16,800	3,000	3,300	3,400
Antimony	ND	ND	ND	ND	ND	ND	3.8*	ND	ND
Arsenic	3.0*	ND	ND	ND	ND	4.4*	ND	ND	ND
Barium	170	150	150	ND	160	200	100	110	100
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	.83*
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	18W	26DQ	17	ND	16W	310DQ	79DQ	94D	190DQ
Copper	1.5*	ND	ND	ND	ND	28	6.9*	5.1*	6.7*
Iron	120	170	63*	ND	73*	15,100	3,100	3,000	3,900
Lead	ND	ND	1.8*	ND	ND	6.1	1.6*	3.1*	1.9*
Manganese	ND	1.5*	ND	ND	ND	260	50	52	60
Mercury	ND	.03*	ND	ND	.04*	ND	ND	ND	.04*
Nickel	15*	13*	9.3*	ND	8.2*	48	30*	25*	95*
Selenium	3.2*	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	ND	ND	ND	3.1*	ND	39	8.3*	12*	11*

Table 4. Concentrations of selected total trace elements in water, Naval Reactors Facility and vicinity—Continued

Constituent	USGS 12 2/2/00	QAS-76B 2/2/00	USGS 12 5/3/00	USGS 12 8/2/00	USGS 12 11/8/00	USGS 97 2/1/00	USGS 97 5/2/00	USGS 97 8/2/00	USGS 97 11/9/00	QAS-81B 11/9/00
Aluminum	ND	ND	35*	ND	190	ND	ND	ND	34*	44*
Antimony	ND	ND	3.6*	ND	ND	ND	ND	ND	ND	ND
Arsenic	3.0*	ND	ND	ND	ND	3.1*	ND	ND	ND	ND
Barium	130	ND	120	120	120	150	140	140	130	ND
Beryllium	ND	ND	ND	ND	.56*	ND	ND	ND	.56*	.8*
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	5.7	ND	5.9	5.9	5.9W	6.3	6.9	6.7	4.7*W	.9*
Copper	1.3*	1.0*	ND	ND	5.2*	2.6*	ND	ND	ND	ND
Iron	57*	ND	27*	21*	430	29*	29*	120	19*	18*
Lead	1.3*	1.8*	ND	ND	ND	2.5*	4.5	3.6	ND	ND
Manganese	1.2*	ND	ND	ND	5.3*	ND	ND	ND	ND	ND
Mercury	ND	ND	ND	.06*	.03*	ND	ND	.06*	ND	ND
Nickel	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	5.9	ND	ND	ND	4.7*	3.5*	2.8*	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	ND	ND	ND	ND	ND	110	110	110	79	ND

Table 4. Concentrations of selected total trace elements in water, Naval Reactors Facility and vicinity—Continued

Constituent	USGS 98 2/1/00	USGS 98 5/2/00	USGS 98 8/2/00	USGS-98 11/7/00	USGS 99 2/1/00	USGS 99 5/2/00	USGS 99 8/2/00	QAS-79R 8/2/00	USGS 99 11/7/00
Aluminum	ND	23*	ND	ND	ND	ND	ND	ND	ND
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	4.1*	ND	ND	ND	ND	ND	ND	ND	ND
Barium	60	59	60	61	110	110	110	110	110
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	5.4	7.0	6.0	6.2	5.2	8.2	5.3	5.7	5.2
Copper	3.3*	330	ND	17*	3.5*	9.9*	ND	ND	2.7*
Iron	16*	1,100	99*	140*	350	130	58*	110	95*
Lead	3.7	8.2	4.6	ND	2.8*	5.3	1.9*	2.1*	1.9*
Manganese	1.8*	17	1.5*	ND	1.7*	ND	ND	ND	ND
Mercury	ND	.03*	.06*	.04*	ND	ND	.06*	.06*	.04*
Nickel	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	ND	3.4*	ND	ND	ND	4.8*	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	140	160	140	130	110	110	90	92	100

Table 4. Concentrations of selected total trace elements in water, Naval Reactors Facility and vicinity—Continued

Constituent	USGS 102 1/31/00	USGS 102 5/1/00	QAS-77B 5/1/00	USGS 102 8/1/00	USGS 102 11/9/00
Aluminum	ND	45*	ND	ND	38*
Antimony	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND
Barium	140	120	ND	120	110
Beryllium	ND	ND	ND	ND	.6*
Cadmium	ND	ND	ND	ND	ND
Chromium	6.4	7.1	ND	6.9*D	3.7*W
Copper	3.5*	ND	ND	ND	ND
Iron	100	320	ND	50*	120
Lead	1.6*	ND	ND	2.2*	ND
Manganese	ND	3.3*	ND	ND	1.2*
Mercury	ND	.03*	.06*	.06*	ND
Nickel	ND	ND	ND	ND	ND
Selenium	3.8*	ND	ND	4.6*	ND
Silver	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND
Zinc	ND	ND	ND	ND	ND

Table 5. Concentrations of dissolved and total nutrients, total organic carbon, and total organic halogens in water, Naval Reactors Facility and vicinity

[Analysis were performed by Severn Trent Laboratories. Analytical results in milligrams per liter. Sample identifier: see figure 2 for location of sites. QAS indicates quality-assurance sample, 75 is sample number, R, replicate, B, field blank. Date sampled: (m/d/y), month/day/year. Abbreviations: ND, analysis not detected; BB, bottle broke; NS, not sampled; Q, reporting level is elevated due to high analyte values. Symbol: *, estimated result]

Sample identifier	Date sampled m/d/y	Kjeldahl nitrogen (total)	Nitrite (dissolved)	Nitrite plus nitrate (total)	Phosphorus (total)	Total organic carbon	Total organic halogens
NRF-6	1/31/00	0.93	ND	1.7	0.091	0.40*	ND
	5/1/00	ND	ND	1.8	ND	.54*	.012*
	8/1/00	ND	ND	1.9	.098	ND	.007*
	11/6/00	BB	ND	BB	BB	BB	BB
	11/7/00	ND	NS	1.9	.073	ND	.007*
NRF-7	1/31/00	.078*	ND	.50	.038*	.78*	ND
QAS-75R	1/31/00	ND	ND	.48	.041*	ND	ND
NRF-7	5/1/00	ND	ND	.46	.032*	ND	ND
	8/1/00	ND	ND	.46	.082	ND	ND
	11/6/00	ND	ND	.54	.087	ND	ND
NRF-8	2/1/00	.26*	ND	2.2	.069	ND	ND
	5/2/00	ND	ND	1.9	.056	ND	ND
QAS-78R	5/2/00	ND	ND	2.0	.051	ND	ND
NRF-8	8/2/00	ND	ND	1.9	.05	.38*	ND
	11/7/00	.72	ND	1.8	.11	.44*	ND
NRF-9	2/1/00	.82	ND	2.1	.059	ND	ND
	5/2/00	ND	ND	2.3	.055	ND	ND
	8/3/00	ND	ND	2.1	.045*	ND	ND
	11/8/00	ND	ND	2.0	.054	.41*	ND
NRF-10	2/1/00	ND	.005*	1.7	.065	ND	ND
	5/2/00	ND	ND	1.8	.037*	ND	ND
	8/3/00	ND	ND	1.9	.039*	ND	ND
	11/9/00	ND	ND	1.9	.052	ND	ND
QAS-82R	11/9/00	ND	ND	1.8	.039*	.46*	ND
NRF-11	2/1/00	.59	ND	1.9	.059	ND	ND
	5/3/00	.45*	ND	2.0	.021*	.31*	.005*

Table 5. Concentrations of dissolved and total nutrients, total organic carbon, and total organic halogens in water, Naval Reactors Facility and vicinity

Sample identifier	Date sampled m/d/y	Kjeldahl nitrogen (total)	Nitrite (dissolved)	Nitrite plus nitrate (total)	Phosphorus (total)	Total organic carbon	Total organic halogens
	8/3/00	ND	ND	2.1	.04*	.73*	ND
	11/9/00	ND	ND	1.8	.041*	ND	ND
NRF-12	2/2/00	ND	ND	1.9	.066	ND	ND
	5/3/00	.25*	ND	1.9	.028*	.26*	ND
	8/3/00	ND	ND	1.8	.046*	ND	.004*
QAS-80B	8/3/00	ND	ND	.058*	.029*	ND	ND
NRF-12	11/6/00	ND	ND	1.9	.049*	ND	ND
NRF-13	2/2/00	ND	ND	.75	.50	ND	ND
	5/3/00	ND	ND	.85	.094	ND	ND
	8/3/00	ND	ND	.82	.14	ND	.003*
	11/8/00	ND	ND	.81	.12	1.0	ND
USGS 12	2/2/00	.67	ND	.90	.052	.26*	ND
QAS-76B	2/2/00	.31*	ND	.041*	.022*	ND	ND
USGS 12	5/3/00	.35*	ND	.89	.025*	ND	ND
	8/2/00	ND	ND	.93	.046*	ND	ND
	11/8/00	ND	ND	.89	.037*	ND	ND
USGS 97	2/1/00	.23*	ND	1.9	.054	ND	ND
	5/2/00	ND	ND	2.1	.043*	.31*	.004*
	8/2/00	ND	ND	2.0	.06	ND	ND
	11/9/00	ND	ND	2.1	.037*	ND	ND
QAS-81B	11/9/00	ND	ND	.086*	.024*	ND	ND
USGS 98	2/1/00	ND	ND	1.1	.052	ND	ND
	5/2/00	ND	ND	1.3	.046*	.31*	ND
	8/2/00	ND	ND	1.3	.041*	.45*	ND
	11/7/00	ND	ND	1.2	.04*	ND	ND
USGS 99	2/1/00	.17*	ND	1.6	.059	ND	ND
	5/2/00	ND	ND	1.7	.023*	.38*	ND
	8/2/00	ND	ND	1.9	.033*	ND	ND
QAS-79R	8/2/00	ND	ND	1.8	.04*	ND	ND

Table 5. Concentrations of dissolved and total nutrients, total organic carbon, and total organic halogens in water, Naval Reactors Facility and vicinity

Sample identifier	Date sampled m/d/y	Kjeldahl nitrogen (total)	Nitrite (dissolved)	Nitrite plus nitrate (total)	Phosphorus (total)	Total organic carbon	Total organic halogens
USGS 99	11/7/00	ND	ND	1.7	.046*	.38*	ND
USGS 102	1/31/00	.22*	ND	1.9	.052	ND	ND
	5/1/00	ND	ND	1.9	.022*	.40*	ND
QAS-77B	5/1/00	ND	ND	ND	ND	.25*	ND
USGS 102	8/1/00	ND	ND	1.7	.044*	ND	ND
	11/9/00	.44*	ND	1.6	ND	ND	ND

Table 6. Concentrations of gross alpha-particle radioactivity, gross beta-particle radioactivity, strontium-90, tritium, and cesium-137 in water, Naval Reactors Facility and vicinity

[Analyses were performed by the Severn Trent Laboratories using a residue procedure for gross alpha- and beta-particle radioactivity, chemical separation for strontium-90, and gamma spectroscopy for cesium-137. Tritium analyses were done by the University of Georgia using electrolytic enrichment and liquid scintillation. Analytical results and uncertainties—for example, 2.14±0.95—in picocuries per liter. Analytical uncertainties are reported as 1s. Concentrations that meet or exceed the reporting level of 3 times the 1s value are shown in boldface type. Sample identifier: see figure 2 for location of sites. QAS indicates quality-assurance sample, 75 is sample number, R, replicate, B, field blank. Date sampled: (m/d/y), month/day/year. Abbreviations: Th-230, thorium-230; Cs-137, cesium-137; MDA, defined minimal detection activity]

Sample identifier	Date sampled m/d/y	Gross alpha-particle radioactivity, as Th-230	Gross beta-particle radioactivity, as Cs-137	Strontium-90	Tritium	Cesium-137
NRF-6	1/31/00	2.14±0.95	**5.80±1.05**	-0.0207±0.09	**69.23±4.92**	0.31±0.29
	5/1/00	1.52±0.9	**6.42±1.5**	.0754±0.09	**59.04±4.24**	-.676±0.37
	8/1/00	**3.73±0.9**	**7.97±1.35**	.016±0.12	**57.94±4.08**	.189±0.385
	11/6/00	**2.92±0.8**	**7.92±1.2**	-.00297±0.085	**59.2±4.24**	-.504±0.22
NRF-7	1/31/00	**1.28±0.325**	**3.56±0.46**	.11±0.09	<3.79	.711±0.345
QAS-75R	1/31/00	**2.03±0.445**	**4.33±0.5**	.16±0.1	3.11±1.11	-.053±0.41
NRF-7	5/1/00	**1.63±0.43**	**6.14±0.75**	.135±0.085	<MDA	-.299±0.285
	8/1/00	**1.28±0.34**	**6.77±0.8**	.0126±0.14	<1.72	.541±0.37
	11/6/00	**1.72±0.32**	**5.48±0.65**	.044±0.08	<4.5	.115±0.2
NRF-8	2/1/00	**1.74±0.55**	**3.36±0.6**	.103±0.095	**38.4±2.88**	-.0672±0.335
	5/2/00	**2.44±0.6**	**4.09±0.75**	.0602±0.11	**50.37±3.72**	.163±0.34
QAS-78R	5/2/00	**1.66±0.55**	**5.34±0.85**	-.0328±0.11	**53.78±3.9**	.604±0.38
NRF-8	8/2/00	**3.28±0.6**	**4.35±0.65**	.082±0.125	**36.64±2.62**	.0785±0.345
	11/7/00	**2.53±0.55**	**4.49±0.65**	.139±0.08	**48.5±3.5**	.42±0.225
NRF-9	2/1/00	**3.55±0.8**	**4.2±0.65**	.146±0.1	**90.04±6.36**	.101±0.405
	5/2/00	**3.58±0.85**	.853±0.65	-.0526±0.075	**83.44±5.9**	-.348±0.325
	8/3/00	**1.82±0.5**	**5.67±0.85**	.0451±0.125	**77.09±5.38**	-.168±0.365
	11/8/00	**2.28±0.5**	**6.46±0.8**	.0756±0.75	**78.06±5.46**	.0843±0.21

Table 6. Concentrations of gross alpha-particle radioactivity, gross beta-particle radioactivity, strontium-90, tritium, and cesium-137 in water, Naval Reactors Facility and vicinity—Continued

Sample identifier	Date sampled m/d/y	Gross alpha-particle radioactivity, as Th-230	Gross beta-particle radioactivity, as Cs-137	Strontium-90	Tritium	Cesium-137
NRF-10	2/1/00	**2.25±0.6**	**4.32±0.7**	.101±0.1	**123.15±8.54**	.527±0.375
	5/2/00	**2.71±0.65**	**4.77±0.9**	-.00554±0.115	**115.59±7.97**	.314±0.285
	8/3/00	**2.15±0.55**	**5.42±0.85**	.0905±0.135	**173.58±11.9**	-.361±0.38
	11/9/00	**2.56±0.55**	**5.73±0.75**	.122±0.085	**109.99±7.62**	.193±0.255
QAS-82R	11/9/00	**2.21±0.485**	**4.62±0.65**	.0525±0.075	**113.4±7.82**	-.267±0.225
NRF-11	2/1/00	**1.7±0.5**	**4.41±0.75**	.0574±0.095	**113.06±7.93**	.158±0.33
	5/3/00	**2.98±0.75**	**5.3±0.95**	.0314±0.105	**105.4±7.27**	-.0396±0.315
	8/3/00	1.59±0.55	**3.41±0.7**	.0422±0.115	**92.89±6.46**	-.007±0.285
	11/9/00	**1.82±0.46**	**5.78±0.8**	.0765±0.08	**136.72±9.44**	.251±0.245
NRF-12	2/2/00	**3.36±0.9**	**4.74±0.75**	-.0086±0.095	**64.15±4.84**	-.272±0.305
	5/3/00	**2.63±0.7**	**4.72±0.85**	.132±0.11	**60.8±4.43**	.0644±0.29
	8/3/00	**3.27±0.75**	**2.89±0.8**	-.0908±0.125	**51.57±3.68**	.472±0.355
QAS-80B	8/3/00	.105±0.075	.461±0.29	-.0462±0.8	<3.06	.175±0.36
NRF-12	11/6/00	**2.11±0.5**	**6.51±0.8**	-.0658±0.07	**54.02±3.86**	-.305±0.26
NRF-13	2/2/00	**2.05±0.6**	**5.4±0.7**	-.0717±0.09	**48.33±3.65**	-.0743±0.34
	5/3/00	**2.79±0.75**	**6.35±0.95**	.163±0.135	**39.68±2.9**	.569±0.41
	8/3/00	**2.05±0.465**	**5.65±0.8**	.156±0.165	**41.71±3.26**	.664±0.31
	11/8/00	**1.77±0.465**	**8.46±0.95**	.0302±0.75	**31.51±2.58**	-.0971±0.23
USGS 12	2/2/00	**1.91±0.5**	**2.65±0.5**	.099±0.095	**74.58±5.31**	.82±0.39
QAS-76B	2/2/00	-.0283±0.0385	-.07±0.125	.0763±0.105	<3.21	.258±0.34
USGS 12	5/3/00	**2.26±0.55**	**3.95±0.7**	.0678±0.095	**67.08±4.7**	-.218±0.375

Table 6. Concentrations of gross alpha-particle radioactivity, gross beta-particle radioactivity, strontium-90, tritium, and cesium-137 in water, Naval Reactors Facility and vicinity—Continued

Sample identifier	Date sampled m/d/y	Gross alpha-particle radioactivity, as Th-230	Gross beta-particle radioactivity, as Cs-137	Strontium-90	Tritium	Cesium-137
USGS 12	8/2/00	**2.17±0.415**	**3.50±0.65**	.19±0.125	**46.65±3.24**	-.219±0.34
	11/8/00	**2.90±0.6**	**5.51±0.75**	.052±0.075	**52.92±3.72**	.338±0.25
USGS 97	2/1/00	**2.65±0.65**	**3.04±0.55**	.074±0.1	**54.37±3.96**	-.0727±0.29
	5/2/00	**3.00±0.75**	**3.99±0.85**	.0796±0.1	**49.06±3.58**	.214±0.37
	8/2/00	**1.38±0.39**	**4.78±0.8**	.113±0.155	**39.76±2.96**	-.229±0.3
	11/9/00	**1.7±0.43**	**5.16±0.75**	.0108±0.075	**43.74±3.23**	-.115±0.215
QAS-81B	11/9/00	.0906±0.08	.979±0.34	-.0162±0.08	<4.19	.352±0.235
USGS 98	2/1/00	**1.76±0.46**	**2.39±0.48**	-.0488±0.09	**18.83±1.73**	-.00596±0.305
	5/2/00	**1.68±0.45**	**4.86±0.75**	.128±0.105	**19.06±1.66**	-.387±0.325
	8/2/00	**1.75±0.38**	**3.63±0.6**	.00781±0.125	**12.43±1.0**	.054±0.295
	11/7/00	**1.87±0.385**	**4.04±0.6**	.104±0.85	**13.45±1.39**	.316±0.23
USGS 99	2/1/00	**2.43±0.7**	**2.91±0.6**	.172±0.095	**28.03±2.32**	.785±0.355
	5/2/00	1.39±0.48	**3.97±0.75**	-.108±0.125	**30.37±2.27**	.402±0.335
	8/2/00	**1.82±0.5**	**4.30±0.7**	.246±0.135	**18.47±1.39**	-.241±0.365
QAS-79R	8/2/00	**2.97±0.55**	**5.09±0.75**	.0794±0.14	**23.93±1.82**	-.288±0.345
USGS 99	11/7/00	**2.09±0.47**	**4.34±0.65**	.14±0.085	**25.19±1.97**	.153±0.185
USGS 102	1/31/00	**1.77±0.55**	**3.38±0.6**	.152±0.1	**58.4±4.18**	.269±0.38
	5/1/00	**2.71±0.7**	**4.70±0.9**	.0198±0.085	**55.59±4.06**	-.251±0.345
QAS-77B	5/1/00	-.0943±0.042	.186±0.255	.0265±0.085	<MDA	-.204±0.325
USGS 102	8/1/00	**1.93±0.435**	**6.14±0.85**	.103±0.13	**38.25±2.7**	-.531±0.325
	11/9/00	**2.04±0.455**	**6.04±0.8**	-.0704±0.07	**47.22±3.46**	-.33±0.185

Table 7. Regulatory volatile organic compounds for which water samples were analyzed, Naval Reactors Facility and vicinity

[Analyses were performed by the Severn Trent Laboratories using U.S. Environmental Protection Agency method 524.2. Reporting limits are in micrograms per liter]

Compound	Reporting limit	Compound	Reporting limit
Benzene	0.5	1,2-Dichloropropane	0.1
Bromobenzene	.2	1,3-Dichloropropane	.1
Bromochloromethane	.2	2,2-Dichloropropane	.5
Bromodichloromethane	.1	1,1-Dichloropropylene	.1
Bromoform	.1	cis-1,3-Dichloropropylene	.1
Bromomethane	.5	trans-1,3-Dichloropropylene	.1
n-Butylbenzene	.2	Ethylbenzene	.1
sec-Butylbenzene	.2	Hexachlorobutadiene	.2
tert-Butylbenzene	.2	Isopropylbenzene	.1
Carbon tetrachloride	.1	4-Isopropyltoluene	.1
Chlorobenzene	.2	Methyl-t-butyl ether (MTBE)	.5
Chloroethane	.5	Naphthalene	.2
Chloroform	.1	n-Propylbenzene	.1
Chloromethane	.5	Styrene	.2
2-Chlorotoluene	.2	1,1,1,2-Tetrachloroethane	.1
4-Chlorotoluene	.2	1,1,2,2-Tetrachloroethane	.1
Dibromochloromethane	.1	Tetrachloroethylene	.2
1,2-Dibromo-3-chloropropane (DBCP)	.2	Toluene	.5
1,2-Dibromoethane (EDB)	.1	1,2,3-Trichlorobenzene	.2
Dibromomethane	.1	1,2,4-Trichlorobenzene	.2
1,2-Dichlorobenzene	.1	1,1,1-Trichloroethane	.1
1,3-Dichlorobenzene	.1	1,1,2-Trichloroethane	.1
1,4-Dichlorobenzene	.1	Trichloroethylene	.1
Dichlorodifluoromethane	.5	Trichlorofluoromethane	.5
1,1-Dichloroethane	.1	1,2,3,-Trichloropropane	.2
1,2-Dichloroethane	.1	1,2,4-Trimethylbenzene	.1
1,1-Dichloroethylthene	.2	1,3,5-Trimethylbenzene	.1
cis-1,2-Dichloroethylene	.1	Vinyl chloride	.2
trans-1,2-Dichloroethylene	.1	Xylenes (total)	.2
Dichloromethane	.5		

Table 8. Base/neutral organic compounds for which water samples were analyzed, Naval Reactors Facility and vicinity

[Analyses were performed by the Severn Trent Laboratories using U.S. Environmental Protection Agency method 525.2. Reporting limits are in micrograms per liter]

Compound	Reporting limit	Compound	Reporting limit
Alachlor	0.1	Endrin	0.01
Aldrin	.1	Heptachlor	.04
Atrazine	.1	Heptachlor epoxide	.02
Benzo [a]pyrene	.02	Hexachlorobenzene	.1
gamma-BHC (Lindane)	.02	Hexachlorocyclopentadiene	.1
Butachlor	.1	Methoxychlor	.1
alpha-chlordane	.1	Metolachlor	.1
gamma-chlordane	.1	Metribuzin	.1
Dieldrin	.1	Propachlor	.1
Di (2-ethylhexyl) adipate	.6	Simazine	.07
Di(2-ethylhexyl) phthalate	.6		