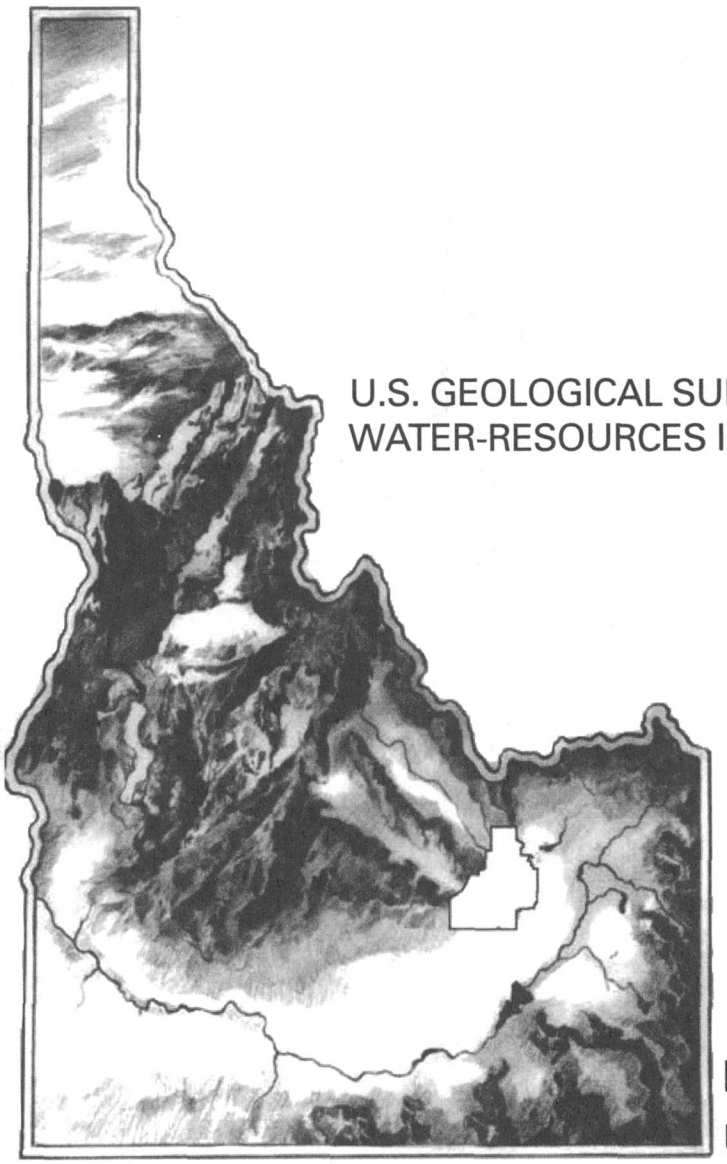
DOE/ID-22167

Rec'd 12/18/00

HYDROLOGIC CONDITIONS AND DISTRIBUTION OF SELECTED CONSTITUENTS IN WATER, SNAKE RIVER PLAIN AQUIFER, IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, IDAHO, 1996 THROUGH 1998



U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS REPORT 00-4192

Prepared in cooperation with the U.S. DEPARTMENT OF ENERGY

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Idaho Falls, Idaho
September 2000

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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

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CONTENTS

FIGURES

Figures 1–5. Maps showing:

TABLES

CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED UNITS

Multiply	*By*	*To obtain*
inch (in.)	25.4	millimeter
foot (ft)	.3048	meter
mile (mi)	1.609	kilometer
acre	.4047	hectare
square mile (mi^2)	2.590	square kilometer
gallon (gal)	3.785	liter
acre-foot (acre-ft)	1,233	cubic meter
foot per mile (ft/mi)	.1894	meter per kilometer
foot squared per day (ft^2/day)	.09290	meter squared per day
cubic foot per second per mile ((ft^3/s)/mi)	.01760	cubic meter per second per kilometer
pound (lb)	.4536	kilogram
curie (Ci)	$3.7x10^{10}$	becquerel
picocurie per milliliter (pCi/mL)	.037	becquerel per milliliter
picocurie per liter (pCi/L)	.037	becquerel per liter

For temperature, degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °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 United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated units used in report: µg/L (microgram per liter), mg/L (milligram per liter), and µS/cm (microsiemens per centimeter) at 25°C.

HYDROLOGIC CONDITIONS AND DISTRIBUTION OF SELECTED CONSTITUENTS IN WATER, SNAKE RIVER PLAIN AQUIFER, IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, IDAHO, 1996 THROUGH 1998

By Roy C. Bartholomay, Betty J. Tucker, Linda C. Davis, and Michael R. Greene

Abstract

Radiochemical and chemical wastewater discharged since 1952 to infiltration ponds and disposal wells at the Idaho National Engineering and Environmental Laboratory (INEEL) has affected water quality in the Snake River Plain aquifer. The U.S. Geological Survey, in cooperation with the U.S. Department of Energy, maintains a monitoring network at the INEEL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the aquifer. This report presents an analysis of water-level and water-quality data collected from the Snake River Plain aquifer during 1996–98.

Water in the Snake River Plain aquifer moves principally through fractures and interflow zones in basalt, generally flows southwestward, and eventually discharges at springs along the Snake River. The aquifer is recharged principally from infiltration of irrigation water, infiltration of streamflow, and ground-water inflow from adjoining mountain drainage basins. Water levels in wells throughout the INEEL generally increased during 1996–98.

Detectable concentrations of radiochemical constituents in water samples from wells in the Snake River Plain aquifer at the INEEL decreased or remained constant during 1996–98. Decreased concentrations are attributed to reduced rates of radioactive-waste disposal, sorption processes, radioactive decay, and changes in waste-disposal practices. Tritium concentrations in water samples decreased as much as 9.3 picocuries per milliliter (pCi/mL) during 1996–98 and ranged from 0.29±0.06 to 18.7±0.8 pCi/mL in 1998. Strontium-90 concentrations remained constant or decreased during 1996–98 and ranged from 2.1±0.6 to 41.1±1.5 picocuries per liter in 1998. During 1996–98, the concentrations of cobalt-60, cesium-137, americium-241, plutonium-238, and plutonium-239, -240 (undivided) in water samples from all wells sampled at the INEEL were below the reporting level.

Detectable concentrations of chemical constituents in water from the Snake River Plain aquifer at the INEEL were variable during 1996–98. In 1998, water from one well south of the Test Reactor Area contained 168 micrograms per liter (µg/L) of dissolved chromium; other water samples contained from less than 14 to 26 µg/L. Sodium and chloride concentrations in the southern part of the INEEL increased slightly or remained constant during 1996–98 because of long-term increased waste-disposal rates. Nitrate concentrations remained relatively constant or decreased during 1996–98 because of decreases in disposal rates and dilution by recharge water.

During 1996–98, concentrations of 1 to 12 purgeable organic compounds were detected in water from wells at the INEEL. Concentrations of 1,1,1-trichloroethane were above the reporting level in all three wells sampled near the Idaho Nuclear Technology and Engineering Center. Concentrations of several purgeable organic compounds exceeded their reporting levels in wells at or near the Radioactive Waste Management Complex because of waste-disposal practices.

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, environmental research, and advanced energy concepts. Radiochemical and chemical wastewater generated at these facilities has been discharged to onsite infiltration ponds and disposal wells since 1952. Wastewater disposal has resulted in detectable concentrations of several waste constituents in water from the Snake River Plain aquifer underlying the INEEL.

The DOE requires information about the mobility of dilute radiochemical- and chemical-waste constituents in the Snake River Plain aquifer. Waste-constituent mobility is determined, in part, 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. This study was conducted by the U.S. Geological Survey (USGS) in cooperation with the DOE's Idaho Operations Office.

Purpose and Scope

In 1949, the U.S. Atomic Energy Commission, which later became the DOE, requested that the USGS describe the water resources of the area now known as the INEEL. The purpose of the resulting study was to characterize these resources before the development of nuclear-reactor testing facilities. The USGS since has maintained a monitoring network at the INEEL to determine hydrologic trends and to delineate the movement of facility-related radiochemical and chemical wastes in the Snake River Plain aquifer.

This report presents an analysis of water-level and water-quality data collected from wells in the Snake River Plain aquifer during 1996–98 as part of the continuing hydrogeologic investigation at the INEEL. The report describes the distribution and concentration of selected radiochemical and chemical constituents in ground water at the INEEL. An analysis of water-level and water-quality data collected during 1996–98 from perched ground-water zones in unsaturated rocks beneath infiltration ponds and waste-burial sites overlying the Snake River Plain aquifer at several INEEL facilities will be presented in a separate report.

Acknowledgments

The DOE's Radiological and Environmental Sciences Laboratory (RESL) provided radiochemical analyses of water samples. Technical staff at the RESL during 1996–98 were under the supervision of R. Douglas Carlson, Director. The authors are grateful for technical review of the manuscript by Deborah Parliman, USGS hydrologist, and Linford J. Campbell, Idaho Department of Water Resources hydrogeologist.

Previous Investigations

Several reports that describe the geology and hydrology of the INEEL have been published, and a list of references and copies of reports can be obtained at the USGS INEEL Project Office.

The conditions of ground water and distribution of selected wastewater constituents in the Snake River Plain aquifer are discussed in a series of annual reports describing the National Reactor Testing Station (NRTS). The series includes reports by Jones (1961); Olmstead (1962); Morris and others (1963, 1964, 1965); Barraclough, Teasdale, and Jensen (1967); and Barraclough, Teasdale, and others (1967). The generalized geologic framework of the NRTS was presented by Nace and others (1975). An analysis of the influence of waste disposal on the geochemistry of ground water at the NRTS is presented in a report by Robertson and others (1974). A comprehensive discussion on the hydrology of the solid waste burial ground, now the Radioactive Waste Management Complex (RWMC) is given in Barraclough and others (1976). Later reports present data on hydrologic conditions at the

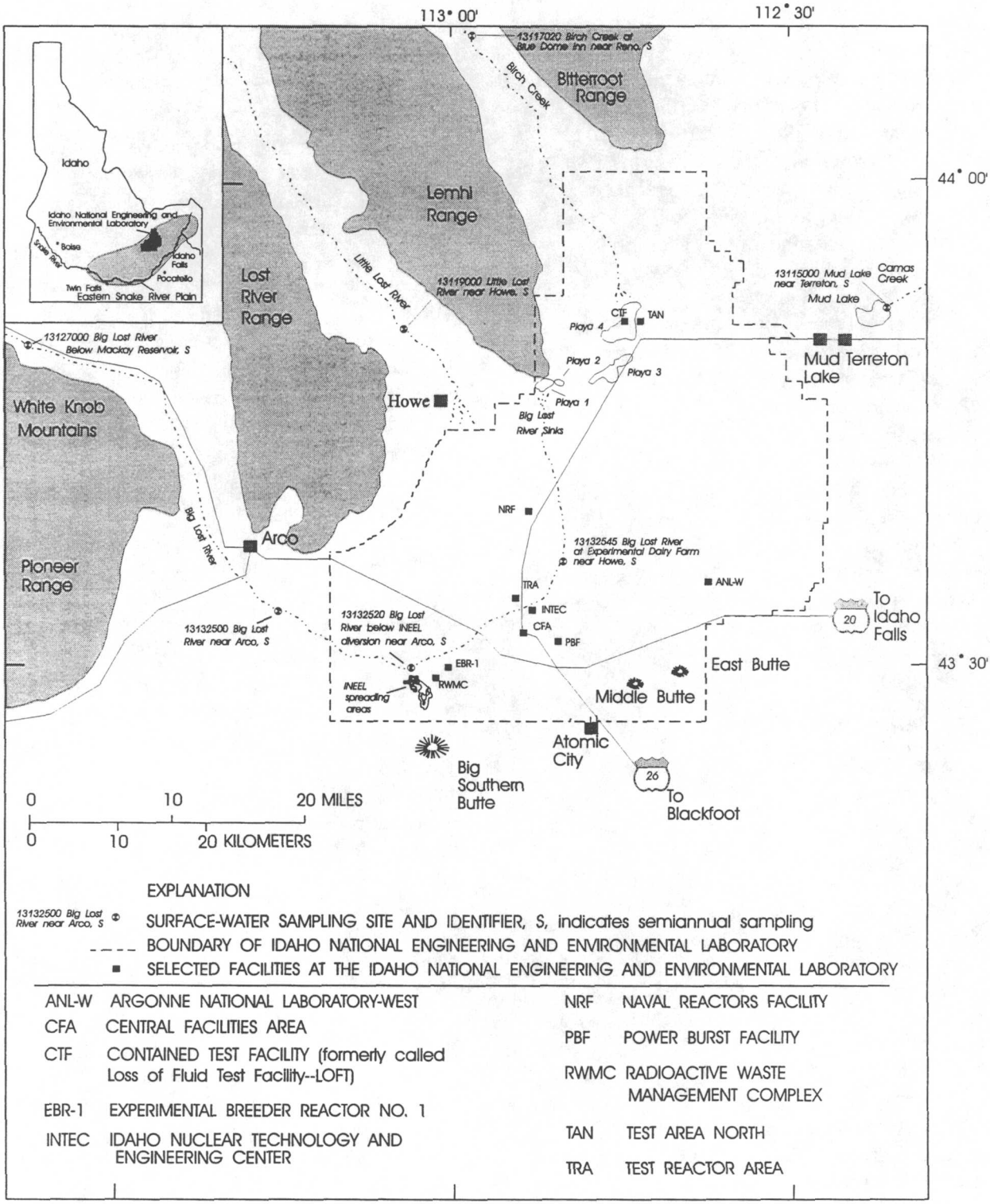


Figure 1. Location of the Idaho National Engineering and Environmental Laboratory, surface-water sampling sites, and selected facilities.

INEEL: Barraclough and Jensen (1976) described hydrologic data during 1971–73; Barraclough and others (1981) described hydrologic conditions during 1974–78; Lewis and Jensen (1985) described hydrologic conditions during 1979–81; Pittman and others (1988) described hydrologic conditions during 1982–85; Orr and Cecil (1991) described hydrologic conditions during 1986–88; Bartholomay and others (1995) described hydrologic conditions during 1989–91; and Bartholomay and others (1997) described hydrologic conditions during 1992–95.

Cecil and others (1991) discussed mechanisms responsible for formation of perched ground water at the Test Reactor Area (TRA) and Idaho Chemical Processing Plant (ICPP) and described the distribution of chemical and radiochemical constituents in perched ground water at the TRA, ICPP, and RWMC during 1986–88. Tucker and Orr (1998) described the hydrologic conditions and concentrations of selected radiochemical and chemical constituents in perched ground water during 1989–91. Bartholomay (1998) described the distribution of selected radiochemical and chemical constituents in perched ground water during 1992–95.

Ground-Water Monitoring Networks

Ground-water monitoring networks are maintained at the INEEL to characterize the occurrence, movement, and quality of water and to delineate waste-constituent plumes in the Snake River Plain aquifer. These networks consist of wells from which periodic water-level and water-quality data are obtained. Data from the monitoring networks are on file at the USGS INEEL Project Office.

Water-level monitoring network.—The water-level network was designed to determine hydraulic-gradient changes that influence the rate and direction of ground-water and waste-constituent movement in the Snake River Plain aquifer, to identify sources of recharge to the aquifer, and to measure the effects of recharge. Water levels in 151 wells were monitored during 1996–98. Water levels were measured annually in 25 wells, semiannually in 49 wells, quarterly in 66 wells, monthly in 8 wells, and continuously in 3 wells. The location of wells and frequency of water-level measurements as of December 1998 are shown in figures 2 and 3.

Water-quality monitoring network.—The radiochemical and chemical character of water in the Snake River Plain aquifer is determined from analyses of water samples collected as part of a comprehensive sampling program to identify contaminant concentrations and to define the pattern of waste migration in the aquifer. Water samples from surface-water sites at or near the INEEL and from wells in perched ground-water zones are analyzed to document the chemical quality of water that recharges the aquifer. Numerous water samples are collected near areas of detailed study, such as the TRA, Idaho Nuclear Technology and Engineering Center (INTEC), Naval Reactors Facility (NRF), RWMC, Test Area North (TAN), and Central Facilities Area (CFA).

The type, frequency, and depth of ground-water sampling generally depend on the information needed in a specific area. Water samples routinely are collected and analyzed for concentrations of tritium, strontium-90, cobalt-60, cesium-137, plutonium-238, the sum of plutonium-239 and plutonium-240 (undivided), americium-241, gross alpha- and beta-particle radioactivity, chromium, sodium, chloride, sulfate, nitrate, purgeable organic compounds, and measurements of specific conductance, pH, and temperature. In addition, as part of the INEEL ground-water monitoring program adopted in 1994 (Sehlke and Bickford, 1993), several wells also were sampled for fluoride, an extensive suite of trace elements, and total organic carbon. Water samples are analyzed for the radiochemical constituents at the RESL at the INEEL and for chemical constituents at the National Water Quality Laboratory (NWQL) in Denver, Colo. The location of surface-water sites and wells that constituted the water-quality monitoring network as of December 1998, and the frequency of sample collection are shown in figures 1, 4, and 5 and in table 1. A sample schedule that lists the constituents analyzed at each site is given by Mann (1996, attachment 1).

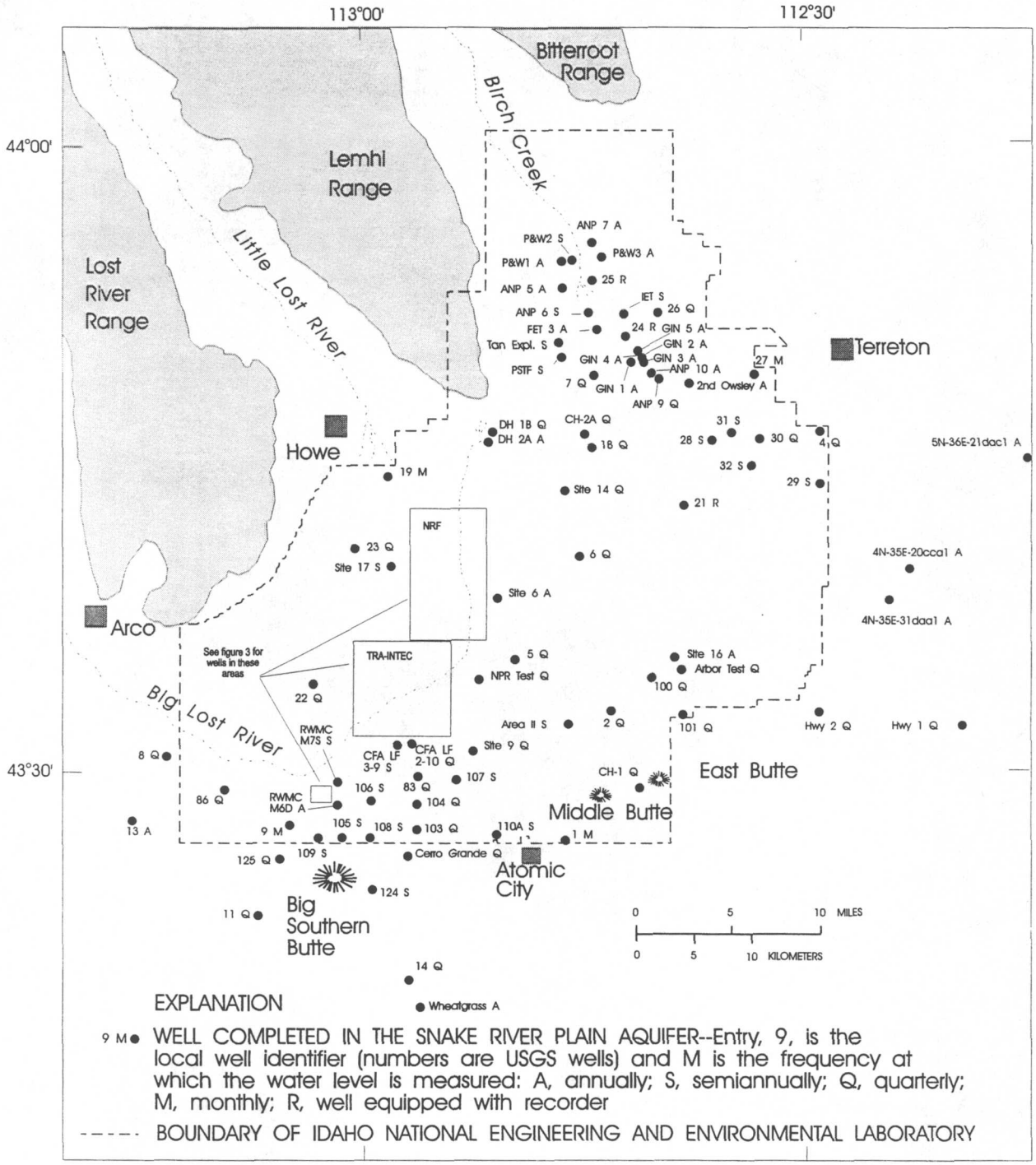


Figure 2. Location of wells and frequency of water-level measurements (as of December 1998) in the Snake River Plain aquifer, Idaho National Engineering and Environmental Laboratory and vicinity.

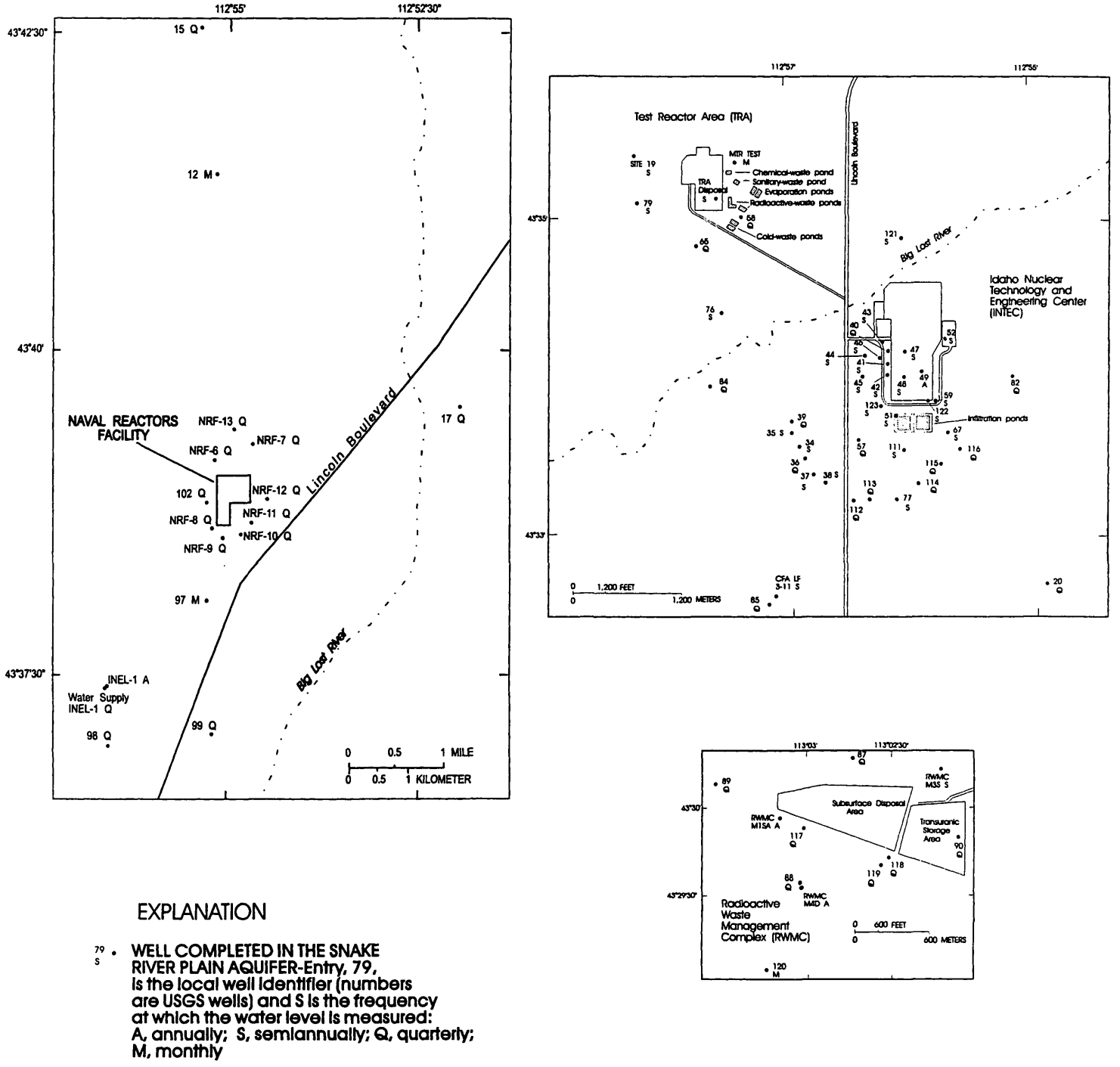


Figure 3. Location of wells and frequency of water-level measurements (as of December 1998) in the Snake River Plain aquifer, Naval Reactors Facility, Test Reactor Area, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex.

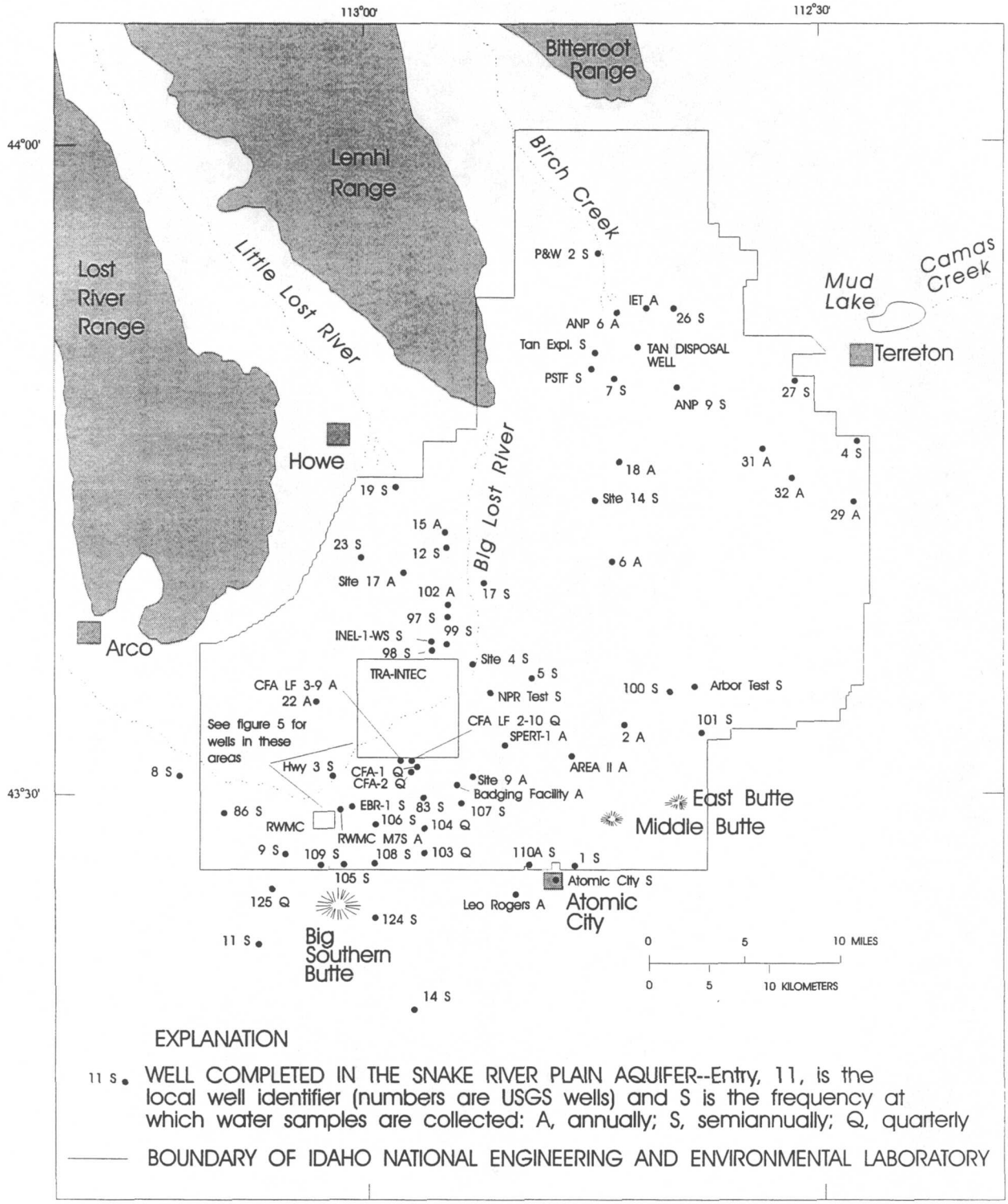


Figure 4. Location of wells and frequency of water-sample collections (as of December 1998) in the Snake River Plain aquifer, Idaho National Engineering and Environmental Laboratory and vicinity.

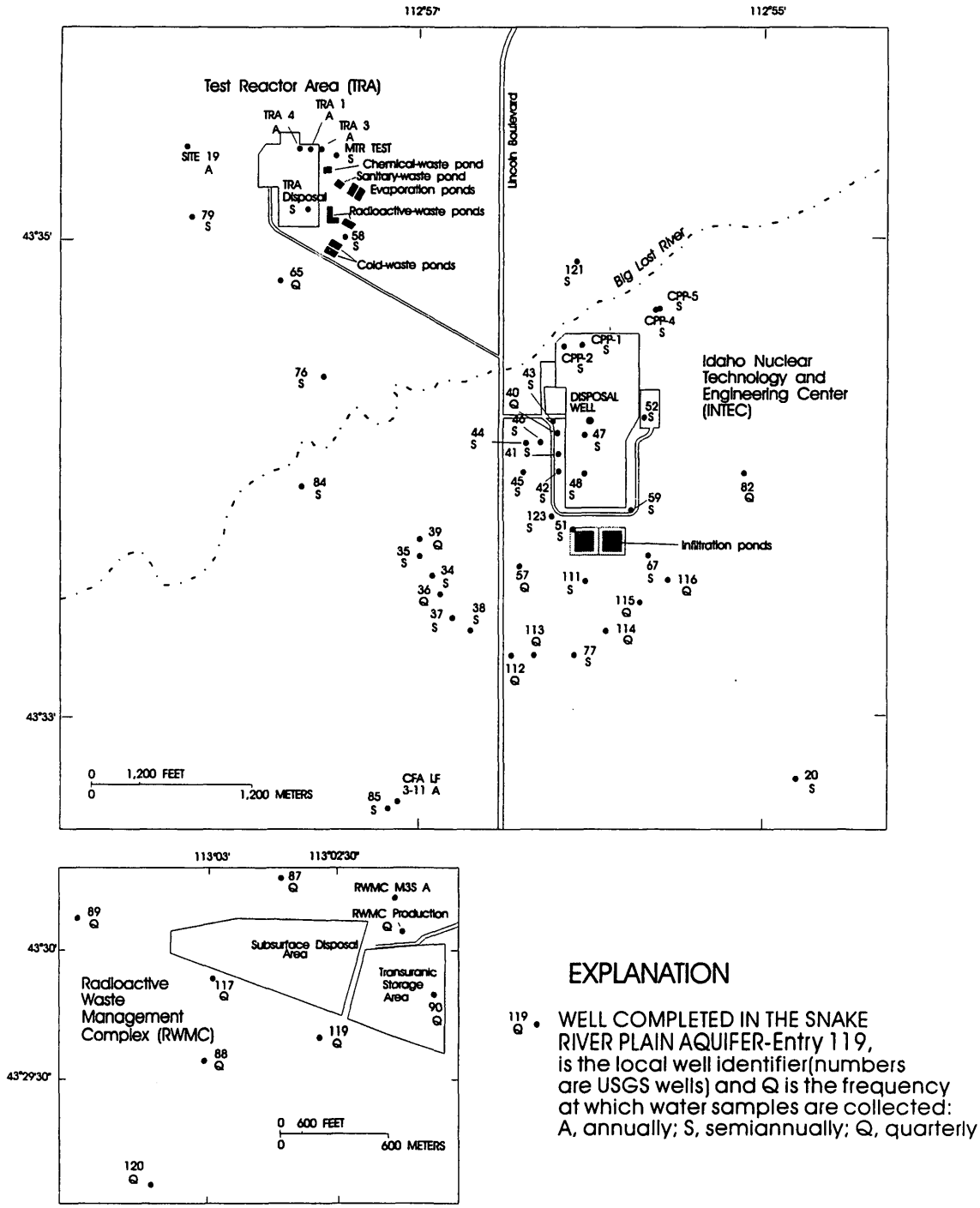


Figure 5. Location of wells and frequency of water-sample collections (as of December 1998) in the Snake River Plain aquifer, Test Reactor Area, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex.

The methods used in sampling and analyzing for selected constituents generally follow the guidelines established by the USGS (Goerlitz and Brown, 1972; Stevens and others, 1975; Wood, 1981; Claassen, 1982; W.L. Bradford, written commun., 1985; Wershaw and others, 1987; Fishman and Friedman, 1989; Faires, 1992; Fishman, 1993; and Wilde and others, 1998). Water samples analyzed by the NWQL and RESL are collected in accordance with a quality-assurance plan for quality-of-water activities conducted by personnel at the INEEL Project Office. The plan was finalized in June 1989, revised in March 1992 and again in 1996 (Mann, 1996), and is available for inspection at the USGS Project Office at the INEEL. In general, about 10 percent of the samples collected are for quality assurance. Quality-assurance samples include blanks, equipment blanks, splits, duplicates, and replicates. Comparative studies to determine agreement among analytical results for water-sample pairs analyzed by laboratories involved in the INEEL Project Office quality-assurance program are summarized by Wegner (1989), Williams (1996, 1997), and Williams and others (1998). Additional quality-assurance studies by personnel at the INEEL Project Office include an evaluation of field-sampling and preservation methods for strontium-90 (Cecil and others, 1989), a comparison of different pump types used for sampling purgeable organic compounds (Knobel and Mann, 1993), an analysis of tritium and strontium-90 concentrations in water from wells after purging different borehole volumes (Bartholomay, 1993), an analysis of the effect of different preservation methods on nutrient concentrations (Bartholomay and Williams, 1996), and an analysis of two analytical methods for the determination of gross alpha- and beta-particle radioactivity (Bartholomay and others, 1999).

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 non-detection 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 1.6s before the qualitative decision can be made as to whether the radionuclide was detected. At 1.6s, there is about 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 1.6s, 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 1.6s has been defined, the minimum detectable concentration may be determined. Concentrations that equal 3s represent a measurement at the minimum detectable concentration. For true concentrations of 3s 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 3s. These measurements are referred to as false negatives and are errors of the second kind in hypothesis testing.

True radionuclide concentrations between 1.6s and 3s 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 1.6s and 3s. Although the radionuclide might have been detected, such detection may not be considered reliable; at 1.6s, 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 1.6s and 3s 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 3s 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. Analytical uncertainties are reported as 1s in this report for consistency with past reports.

Waste-Disposal Sites at the Idaho National Engineering and Environmental Laboratory

Wastewater disposal sites at INEEL facilities have been the principal sources of radioactive- and chemical-waste constituents in water from the Snake River Plain aquifer. In the past, wastewater disposal sites have included infiltration ponds and ditches, drain fields, and disposal wells. From 1996 to 1998, wastewater was discharged into infiltration and evaporation ponds and drain fields. Waste materials buried at the RWMC (fig. 1) also are sources of some constituents in ground water. Radioactive-waste-disposal data presented in this report were obtained from a series of radioactive-waste-management information reports (French and others, 1997b; French and Taylor, 1998, and French and others, 1999b). Chemical-waste-disposal data were obtained from a series of nonradiological-waste-management information reports (French and others, 1997a; 1998; 1999a). The radioactive- and chemical-waste-disposal data are collected by contractors at each facility.

Test Reactor Area.—Since 1959, low-level radioactive, chemical, and sanitary wastewater has been discharged to infiltration and evaporation ponds. Cooling-tower wastewater was discharged to radioactive-waste infiltration ponds from 1952 to 1964, to the Snake River Plain aquifer through a 1,267-ft-deep disposal well (TRA disposal, fig. 3) from 1964 until March 1982, and into two cold-waste infiltration ponds from 1982 to the present. During 1996–98, about 220 million gal/yr of wastewater was discharged to infiltration and evaporation ponds at the TRA (fig. 3).

The average annual discharge to the radioactive-waste infiltration and evaporation ponds was about 116 million gal during 1960–98 (fig. 3). The volume of wastewater and the amount of tritium discharged to the radioactive-waste ponds during this period are shown in figure 6. The average annual discharge for 1996–98 was about 4.9 million gal and was much less than the long-term average annual discharge.

In 1976, the DOE contractor at the TRA began a three-phase program to reduce radioactivity in wastewater. The first phase ran from 1976 to 1980 and the second phase ran from 1981 to 1987. The contractor finished the final phase of the program in 1993. The volume of radioactive wastewater discharged at the TRA decreased because of this program. In August 1993, two lined evaporation ponds replaced the radioactive-waste infiltration ponds (B.R. Orr, USGS, oral commun., 1996). The evaporation ponds theoretically should prevent radioactive wastewater from entering the aquifer.

During 1974–79, about 10 percent of the radioactivity in wastewater discharged was attributed to tritium; in 1980, about 50 percent was attributed to tritium; and in 1981–85, about 90 percent was attributed to tritium (Pittman and others, 1988, p. 22). Since 1986, about 97 percent of the radioactivity in wastewater discharged at the TRA was attributed to tritium (fig. 6).

A chemical-waste infiltration pond has been used for disposal of chemical wastewater from an ion-exchange system at the TRA since 1962 (fig.

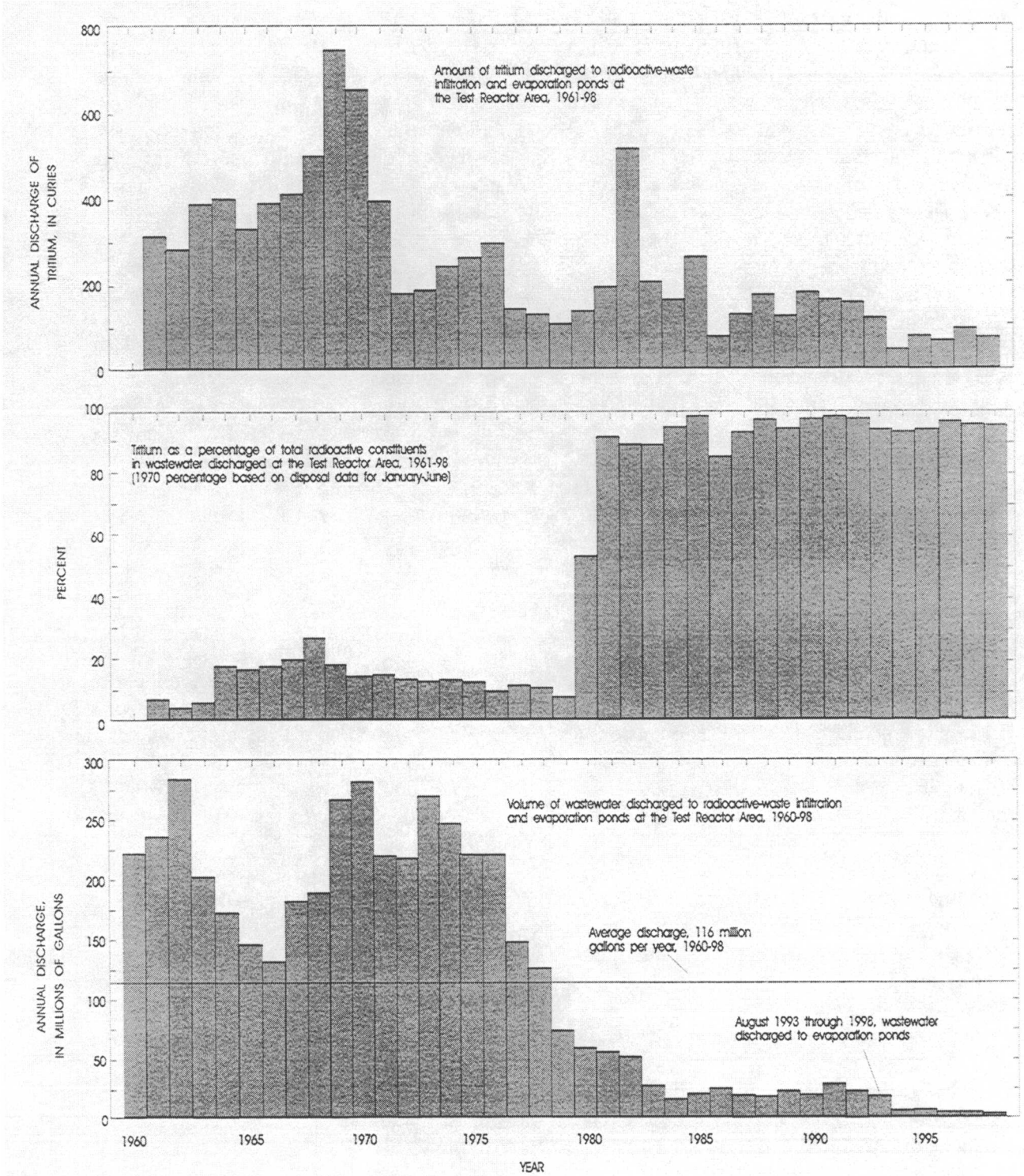


Figure 6. Amount of tritium discharged, tritium as a percentage of total radioactive constituents in wastewater discharged, and volume of wastewater discharged to the radioactive-waste infiltration and evaporation ponds at the Test Reactor Area, 1960–98.

3). The average annual discharge to this pond was about 17.5 million gal for the period 1962–98. The average annual discharge for 1996–98 was 5.8 million gal, 33 percent of the long-term average. Sulfate and sodium hydrate were the predominant constituents in the chemical wastewater. The sodium hydrate consists of a 50 percent sodium hydroxide solution (Ron Talman, oral commun., 1999). During 1996–98, average annual amounts of about 210,280 lb of sulfate and 98,800 lb of sodium hydrate were discharged to the chemical-waste infiltration pond. Additionally, about 11,100 lb of sodium ion were discharged in October 1996 (French and others, 1997a). Average annual concentrations of sulfate and sodium hydrate in the wastewater were about 4,300 and 2,000 mg/L, respectively.

The TRA disposal well, which currently is used as an observation well, was used from 1964 to March 1982 to inject nonradioactive wastewater from cooling-tower operations at the TRA into the Snake River Plain aquifer. Since March 1982, this wastewater has been discharged to two cold-waste infiltration ponds (fig. 3). The average annual discharge to the well and the infiltration ponds was about 226 million gal during 1964–95 and about 181 million gal during 1996–98. This wastewater contained an average annual amount of about 402,000 lb of sulfate and 94,000 lb of other chemicals during 1996–98.

About 28 million gal/yr of sewage effluent was discharged to a sanitary-waste infiltration pond at the TRA during 1996–98 (fig. 3). In 1989, the sewage effluent contained about 1,070 lb of chloride and 1,550 lb of hypochlorite. Chloride and hypochlorite were not reported as part of the sewage effluent after February 1990.

Idaho Nuclear Technology and Engineering Center.—From 1952 to February 1984, the INTEC discharged most of its low-level radioactive, chemical, and sanitary wastewater into the Snake River Plain aquifer through a 600-ft-deep disposal well (fig. 5). The average annual discharge of wastewater to the well was about 363 million gal (Pittman and others, 1988, p. 24). Two infiltration ponds currently are being used for wastewater disposal (fig. 3). The first pond was completed in February 1984 and the second pond was completed in October 1985. The volume of wastewater discharged to the well and infiltration ponds during 1962–98 is shown in figure 7. The annual discharge to the well and ponds ranged from 260 million gal in 1963 to 665 million gal in 1993 and averaged about 440 million gal. The average annual discharge during 1996–98 was about 570 million gal .

Most of the radioactivity in wastewater discharged to the infiltration ponds at the INTEC is attributed to tritium. Tritium has accounted for more than 90 percent of the radioactivity in wastewater discharged at the INTEC since 1970 (fig. 7). During 1986–88, a total of 556 Ci of tritium was discharged at the INTEC and the average annual amount was 185 Ci (Orr and Cecil, 1991, p. 20). During 1990–91, only 2.7 Ci of tritium was discharged and during 1992 and 1995 only about 0.3 Ci was discharged. No tritium was discharged during 1989, 1993, 1994, and 1996–98 (fig. 7).

During 1996–98, chloride, fluoride, nitrate, sodium, and sulfate were the predominant chemical constituents in wastewater discharged to the INTEC infiltration ponds. Average annual amounts of about 1,166,000 lb of chloride; 1,070 lb of fluoride; 86,700 lb of nitrate; 708,000 lb of sodium, and 146,000 lb of sulfate were in wastewater discharged at the INTEC.

Naval Reactors Facility.—Wastewater at the NRF (fig. 1) is discharged to a 3-mi-long industrial-waste ditch and to sewage ponds. During 1996–98, about 50 million gal/yr of wastewater was discharged to the industrial-waste ditch. About 17.6 million gal/yr of sewage effluent was discharged to the sewage ponds. The 1996–98 disposal rates represent a decrease from 1992–95, when 163 million gal/yr was discharged (Bartholomay and others, 1997, p. 17).

Chloride, sulfate, and sodium were the predominant chemical constituents in wastewater discharged to the industrial-waste ditch. About 1,136,000 lb of chloride, 45,500 lb of sulfate, and 524,400 lb of sodium was discharged annually during 1996–98. These amounts reflect disposal-

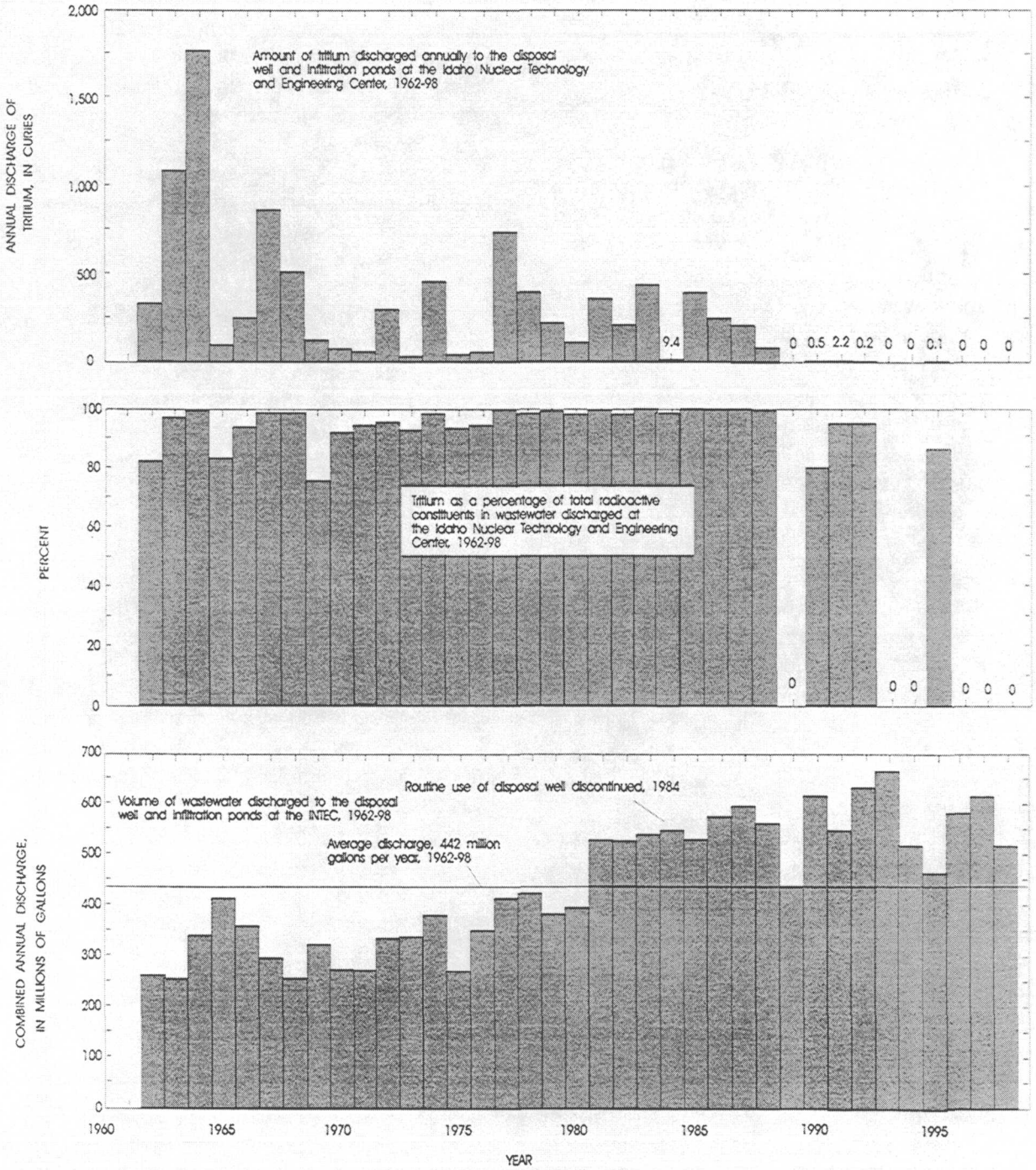


Figure 7. Amount of tritium discharged, tritium as a percentage of total radioactive constituents in wastewater discharged, and volume of wastewater discharged to the disposal well and infiltration ponds at the Idaho Nuclear Technology and Engineering Center, 1962–98.

rate increases for chloride and sodium and decreases for sulfate from the average annual amounts discharged during 1992–95 (Bartholomay and others, 1997, p. 17). The average annual amount of all other chemical constituents in the wastewater was about 330 lb.

Radioactive Waste Management Complex.—Solid and liquid radioactive and chemical wastes have been buried in trenches and pits at the Subsurface Disposal Area (SDA) at the RWMC (fig. 3) since 1952. These constituents include transuranic wastes (buried in trenches until 1970), other radiochemical and inorganic chemical constituents, and organic compounds. Before 1970, little or no sediment was retained between the excavation bottoms and the underlying basalt. Since 1970, a layer of sediment has been retained in excavations to inhibit downward migration of waste constituents.

About 9,600 Ci of plutonium-238; 160,000 Ci of plutonium-239; 38,000 Ci of plutonium-240; 960,000 Ci of plutonium-241; and 365,000 Ci of americium-241 was buried in the SDA during 1952–70 (Becker and others, 1998, table 4-1). An estimated 88,400 gal of organic waste was buried before 1970 (Mann and Knobel, 1987, p. 1). These buried wastes included about 24,400 gal of carbon tetrachloride; 39,000 gal of lubricating oil; and about 25,000 gal of other organic compounds, including trichloroethane, trichloroethylene, perchloroethylene, toluene, and benzene.

Test Area North.—From 1953 to 1972, low-level radioactive, chemical, and sanitary wastewater was discharged at TAN (fig. 1) into the Snake River Plain aquifer through a 310-ft-deep disposal well (TAN Disposal, fig. 4). In 1972, the disposal well was replaced by a 35-acre infiltration pond. No records are available as to the amount of radioactivity in wastewater was discharged at TAN before 1959. During 1959–93, about 61 Ci of radioactivity in wastewater discharged to the disposal well and infiltration pond. Of this amount, about 20 Ci was discharged to the disposal well in 1968 and 1969 in response to problems with an evaporator used to reduce the volume of liquid waste (Energy Research and Development Administration, 1977, p. II–110, II–111). No radioactive liquid waste has been discharged since 1993.

An average of about 6.6 million gal/yr of chemical wastewater was discharged to the infiltration pond at the Technical Support Facility during 1996–98. The predominant constituents were chloride and sodium. Average annual amounts of 6,900 lb of chloride and 4,500 lb of sodium were discharged. The average annual amount of all other chemical constituents in the wastewater was about 760 lb.

Central Facilities Area.—About 65 Ci of radioactivity in about 1,500 million gal of wastewater was discharged to the sewage-plant tile drain field at the CFA (fig. 1) from 1952–93. Most of the radioactive wastes discharged to this drain field were from pumpage of production well CFA-1 (fig. 4), which obtains water from within the INTEC contaminant plume in the Snake River Plain aquifer. Most of the radioactivity in wastewater discharged at the CFA is attributed to tritium. Since 1993, no radioactivity has been recorded in wastewater discharged at the CFA.

An average of about 39.4 million gal/yr of chemical wastewater was discharged to a pond at CFA during 1996–98. Chloride and sodium are the predominant chemical constituents in the wastewater. During 1996–98, average annual amounts of about 7,800 lb of chloride and 5,300 lb of sodium were discharged. The average annual amount of all other constituents in the wastewater was about 6,300 lb; about 5,400 lb was from disposal of janitorial supplies.

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

Recharge to the Snake River Plain aquifer is principally from infiltration of applied irrigation water, infiltration of streamflow, and ground-water inflow 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.

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 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 at sinks and playas at the river's terminus. To avoid flooding at the INEEL facilities, excess runoff has been diverted since 1965 to spreading areas in the southwestern part of the INEEL (Bennett, 1990, p. 15), where much of the water rapidly infiltrates to the aquifer. Other surface drainages that provide recharge to the Snake River Plain aquifer at the INEEL include Birch Creek, Little Lost River, and Camas Creek (fig. 1).

The average streamflow in the Big Lost River below Mackay Reservoir (fig. 1) for the 82-yr period of record (water years 1905, 1913–14, and 1920–98) was 224,900 acre-ft/yr (Brennan and others, 1999, p. 183). Streamflow in the Big Lost River below Mackay Reservoir (fig. 8) ranged from 261,600 acre-ft (116 percent of average flow) during the 1996 water year (Brennan and others, 1997, p. 209) to 300,000 acre-ft (133 percent of average flow) during the 1997 water year (Brennan and others, 1998, p. 216). Streamflow recorded for the Big Lost River near Arco (fig. 1) during the 1996, 1997, and 1998 water years was 52,040, 109,000, and 116,700 acre-ft/yr, respectively (Brennon and others, 1997, 1998, and 1999). The Big Lost River below the INEEL diversion near Arco (fig. 1), and the INEEL diversion at its head near Arco (fig. 8) also had streamflow during 1996–98. Combined rates of flow ranged from 36,130 acre-ft/yr in 1996 (Brennan and others, 1997, p. 211, 213) to 102,520 acre-ft/yr in 1998 (Brennan and others, 1999, p. 185, 187).

Recharge to the Snake River Plain aquifer downstream from Arco is substantial during wet years because of infiltration of streamflow from the Big Lost River channel, diversion areas, sinks, and playas. For example, measured infiltration losses at various discharges ranged from 1 to 28 $(ft^3/s)/mi$ (Bennett, 1990, p. 1). Bennett (1990) considers streamflow losses to evapotransporation minor compared with infiltration losses. Channel losses from Arco to the diversion to the INEEL spreading areas averaged about 15,000 acre-ft/yr during 1996–98 (Brennan and others, 1997, 1998, and 1999). Recharge from the INEEL spreading areas increased from about 3,280 acre-ft/yr in water year 1996 to 33,200 acre-ft in water year 1998 (Brennan and others, 1997, 1998, and 1999).

Ground Water

Water in the Snake River Plain aquifer moves principally through interflow and fracture zones in the basalt. A significant proportion of the ground water moves through the upper 200 to 800 ft of basaltic rocks (Mann, 1986, p. 21). Ackerman (1991, p. 30) reported a range of transmissivity of basalt in the upper part of the aquifer to be from 1.1 to 760,000 ft^2/d. Since the report by Ackerman (1991) was published, additional data have become available. Data on additional specific-capacity tests and estimates of transmissivity are presented in Bartholomay and others (1997). These data were collected and analyzed according to the same methods reported by Ackerman (1991). The additional data fall within the range of estimated transmissivities reported by Ackerman (1991). Anderson and others (1999) reported a range of hydraulic conductivity at the INEEL of .01 to 32,000 ft/day. The hydraulic conductivity of underlying rocks is 0.002 to 0.03 ft/day, several orders of magnitude smaller (Mann, 1986, p. 21). The effective base of the Snake River Plain aquifer at the INEEL probably ranges from about 815 to 1,710 ft below land surface (Anderson and others, 1996, table 3).

Depth to water in wells completed in the Snake River Plain aquifer ranges from about 200 ft in the northern part of the INEEL to more than 900 ft in the southeastern part. In March-May 1998, the altitude of the water table was about 4,600 ft above sea level in the northern part of the INEEL

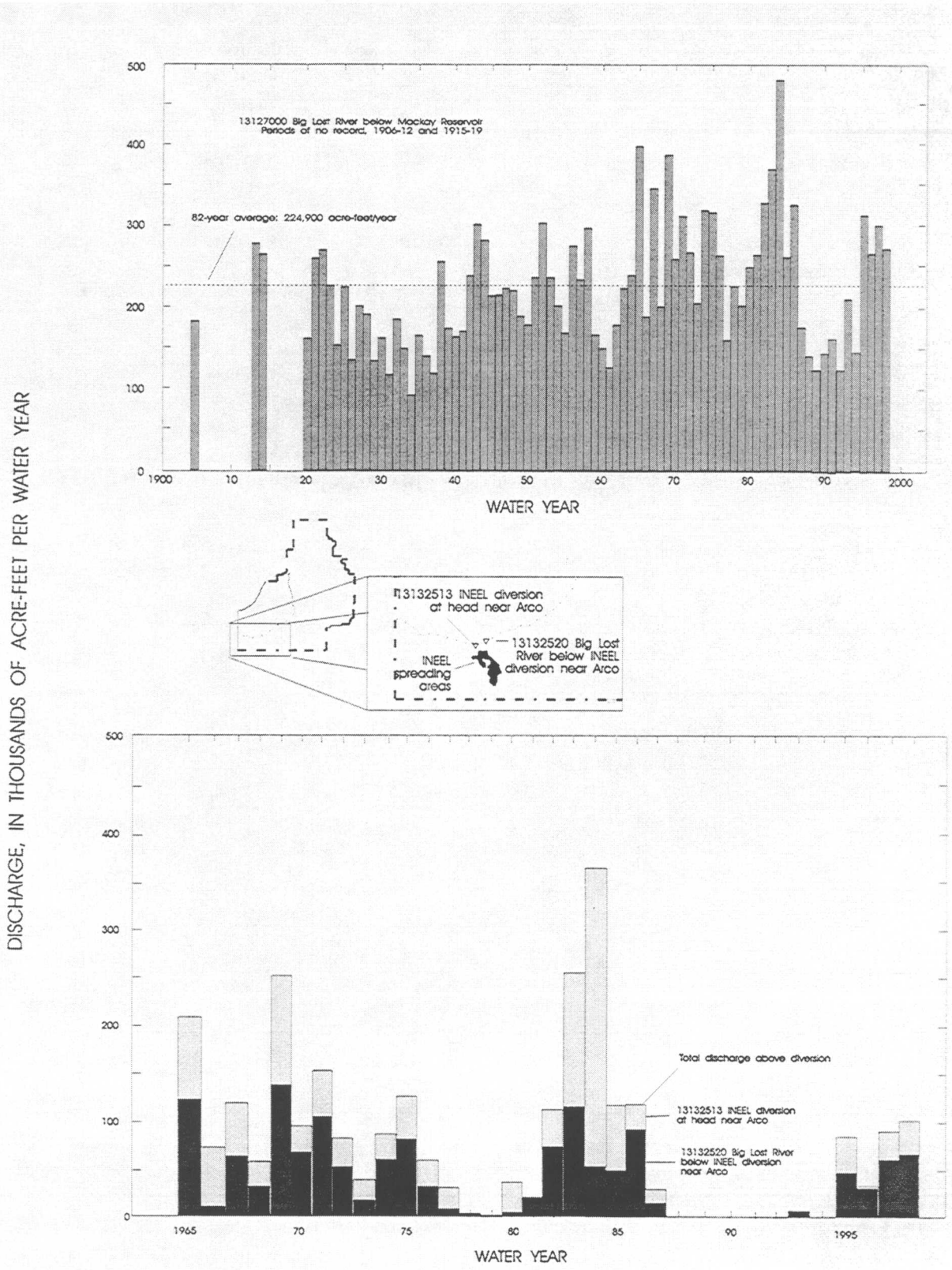


Figure 8. Discharge of the Big Lost River below Mackay Reservoir (water years 1905, 1913–14, and 1920–98), Big Lost River below the INEEL diversion near Arco, and the INEEL diversion at head near Arco (water years 1965–98).

(fig. 9) and about 4,420 ft above sea level in the southwestern part. Water flowed southward and southwestward beneath the INEEL (fig. 9) at an average hydraulic gradient of about 4 ft/mi. Locally, however, the hydraulic gradient ranged from about 2 to 10 ft/mi. From March-May 1995 to March-May 1998, water levels generally increased throughout the INEEL. Water-level increases ranged from about 1 to 2 ft in wells in the northern part to about 7 ft in wells in the west-central part of the INEEL (fig. 10). The larger water-level increase in wells in the west-central part of the INEEL is attributed to infiltration from the Big Lost River.

Water levels monitored in wells 12, 17, 23 (fig. 2), and 20 (fig. 3) show long-term water-level changes in the Snake River Plain aquifer at different locations at the INEEL. Water levels in these wells fluctuated in response to infiltration of streamflow (fig. 11). Long-term water-level fluctuations ranged from about 11 ft in well 20 to about 27 ft in well 12. Water levels in these wells increased from 1996 to 1998 because of infiltration of streamflow in the Big Lost River below Arco, and an overall increase in recharge to the Snake River Plain aquifer.

Ground water moves southwestward from the INEEL and eventually is discharged to springs along the Snake River near Twin Falls, 100 mi southwest of the INEEL. About 4.25 million acre-ft of ground water was discharged to the Snake River from the Snake River Plain aquifer in the 1998 water year (Tom Brennan, USGS, written commun., 1999).

SELECTED RADIOCHEMICAL AND CHEMICAL CONSTITUENTS IN AND PHYSICAL PROPERTIES OF WATER IN THE SNAKE RIVER PLAIN AQUIFER

Contaminant plumes of radiochemical and chemical constituents in the Snake River Plain aquifer at the INEEL are attributed to waste-disposal practices. The areal distribution of the plumes are approximately defined from concentrations of these constituents in water samples from wells completed in the aquifer. No attempt is made to determine the vertical extent and distribution of these plumes. Radiochemical and chemical constituents detected in ground water at the INEEL include tritium, strontium-90, cobalt-60, cesium-137, plutonium-238, plutonium-239, -240 (undivided), americium-241, gross alpha- and beta-particle radioactivity, dissolved and hexavalent chromium, sodium, chloride, sulfate, nitrate, fluoride, trace elements, purgeable organic compounds, and total organic carbon.

Tritium

A tritium plume has developed in the Snake River Plain aquifer from disposal of wastewater at the INEEL since the 1950's. The principal sources of tritium in the aquifer have been the injection of wastewater through the disposal well at INTEC and the discharge of wastewater to the infiltration ponds at the INTEC and TRA (fig. 5). About 31,620 Ci of tritium has been discharged to the well and infiltration ponds since 1952. Since 1993, tritium at TRA has been discharged to lined evaporation ponds, which theoretically should prevent migration to the aquifer. Routine use of the disposal well at INTEC ended in February 1984; subsequently, most radioactive wastewater has been discharged to the infiltration ponds. During 1996–98, no tritium was discharged to the ponds at the INTEC. Tritium has a half-life of 12.3 years (Walker and others, 1989, p. 20).

In October 1998, concentrations of tritium in water that exceeded the reporting level ranged from 0.29±0.06 to 18.7±0.8 pCi/mL and the tritium plume extended southwestward in the general direction of ground-water flow (fig. 12). The area of the plume in which concentrations exceeded the maximum contaminant level (MCL) of 20 pCi/mL (U.S. Environmental Protection Agency, 1998, p. 338) was about 2.4 mi^2 in 1991 (Bartholomay and others, 1995). In October 1998, concentrations of tritium in all water samples were less than the MCL.

Tritium concentrations in water from wells in the Snake River Plain aquifer decreased by as much as 9.3 pCi/mL during 1996–98. Tritium concentrations in water from well CFA LF 3-9 (fig.

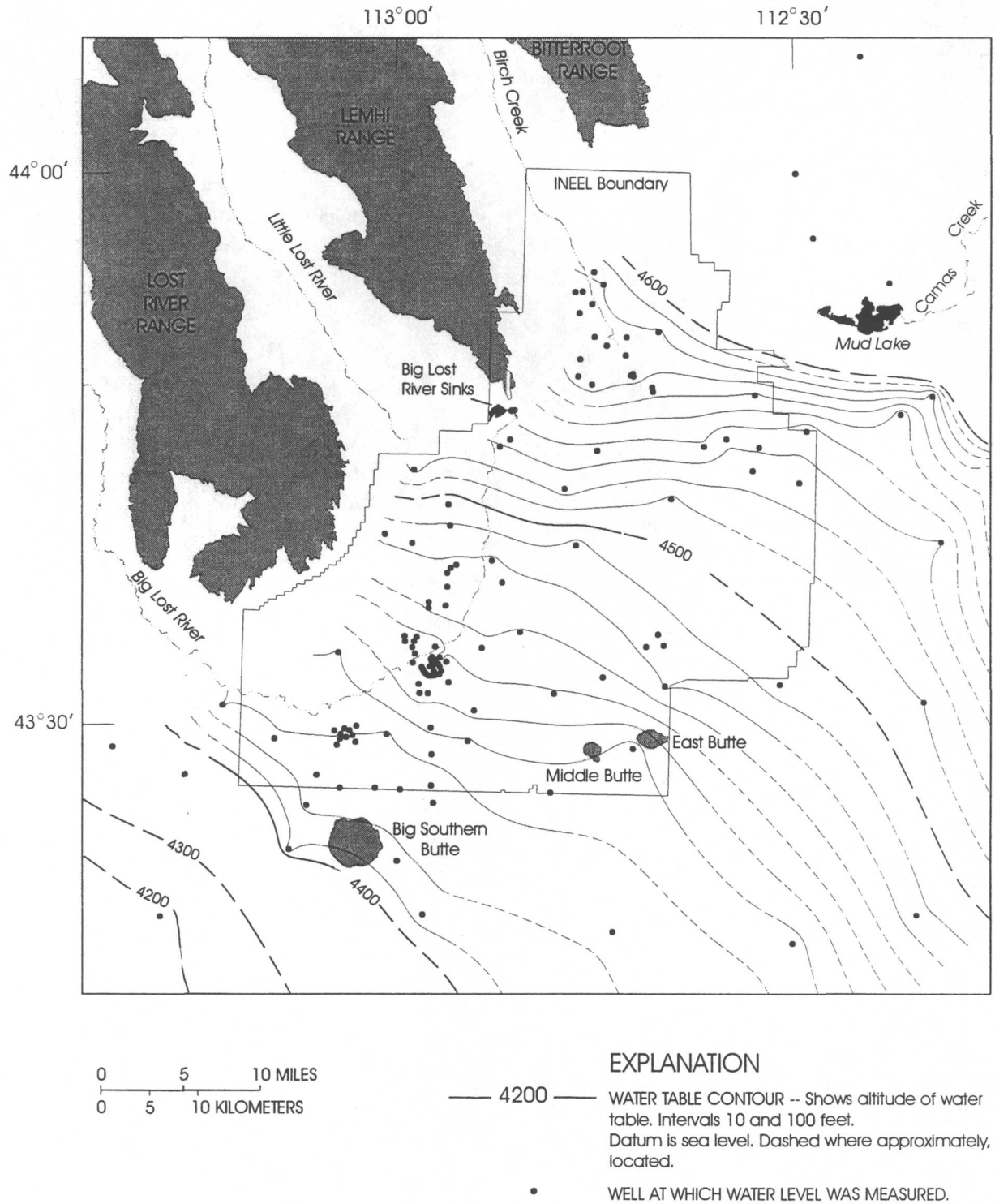


Figure 9. Altitude of the water table in the Snake River Plain aquifer in the vicinity of the Idaho National Engineering and Environmental Laboratory, March–May 1998.

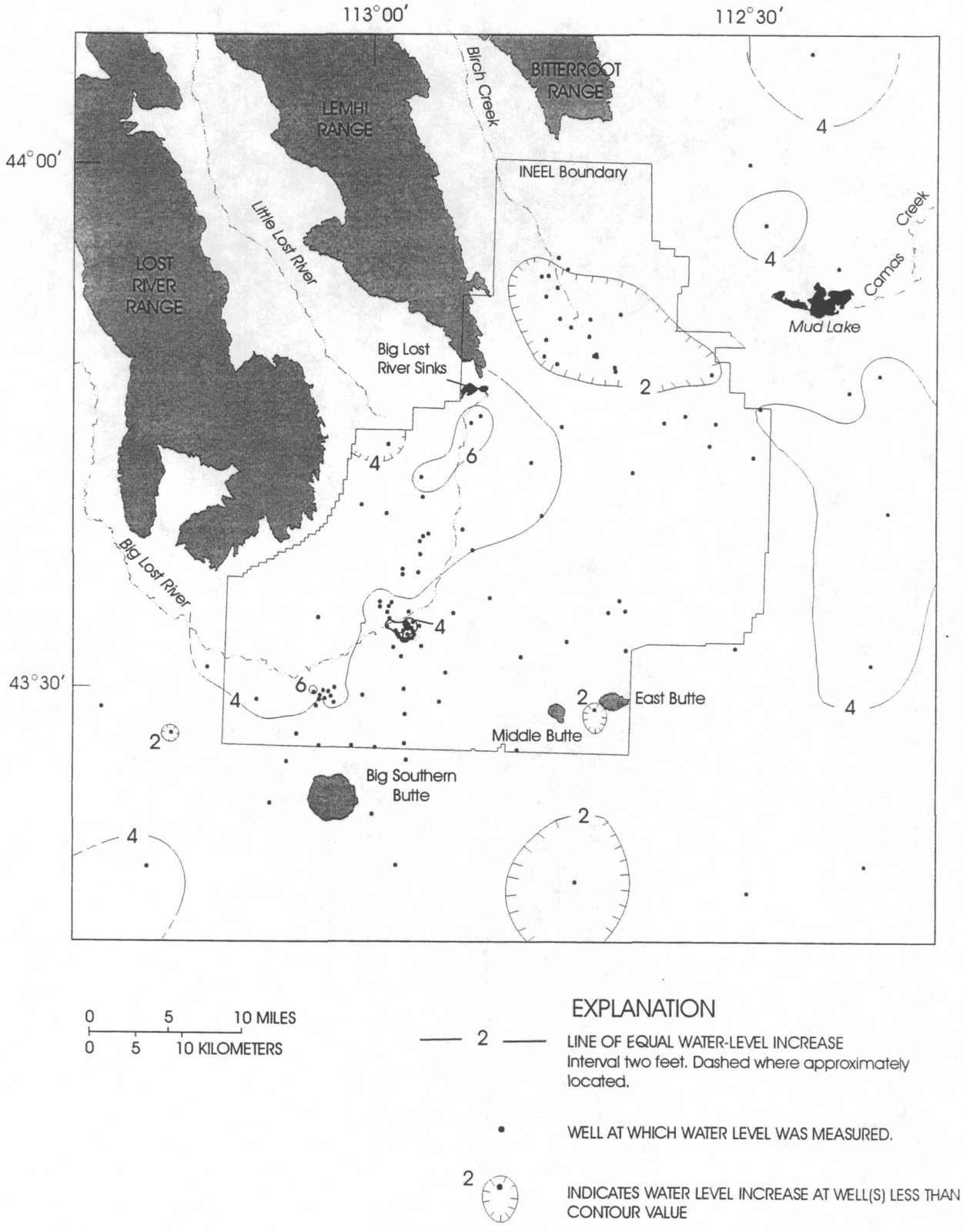


Figure 10. Generalized increase in ground-water levels in the Snake River Plain aquifer in the vicinity of the Idaho National Engineering and Environmental Laboratory, March–May 1995 to March–May 1998.

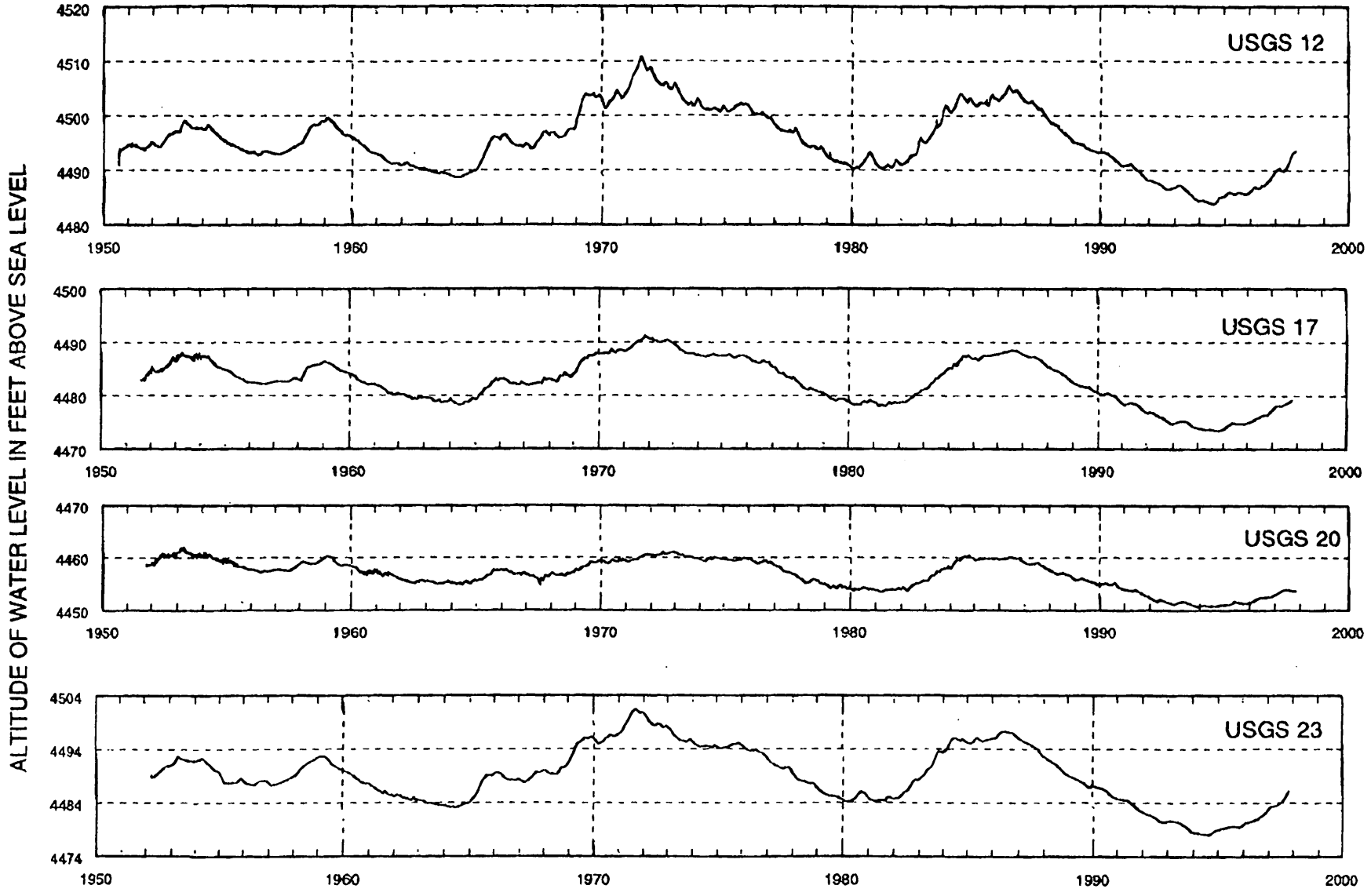


Figure 11. Water levels in four wells in the southwestern part of the Idaho National Engineering and Environmental Laboratory, 1950–98.

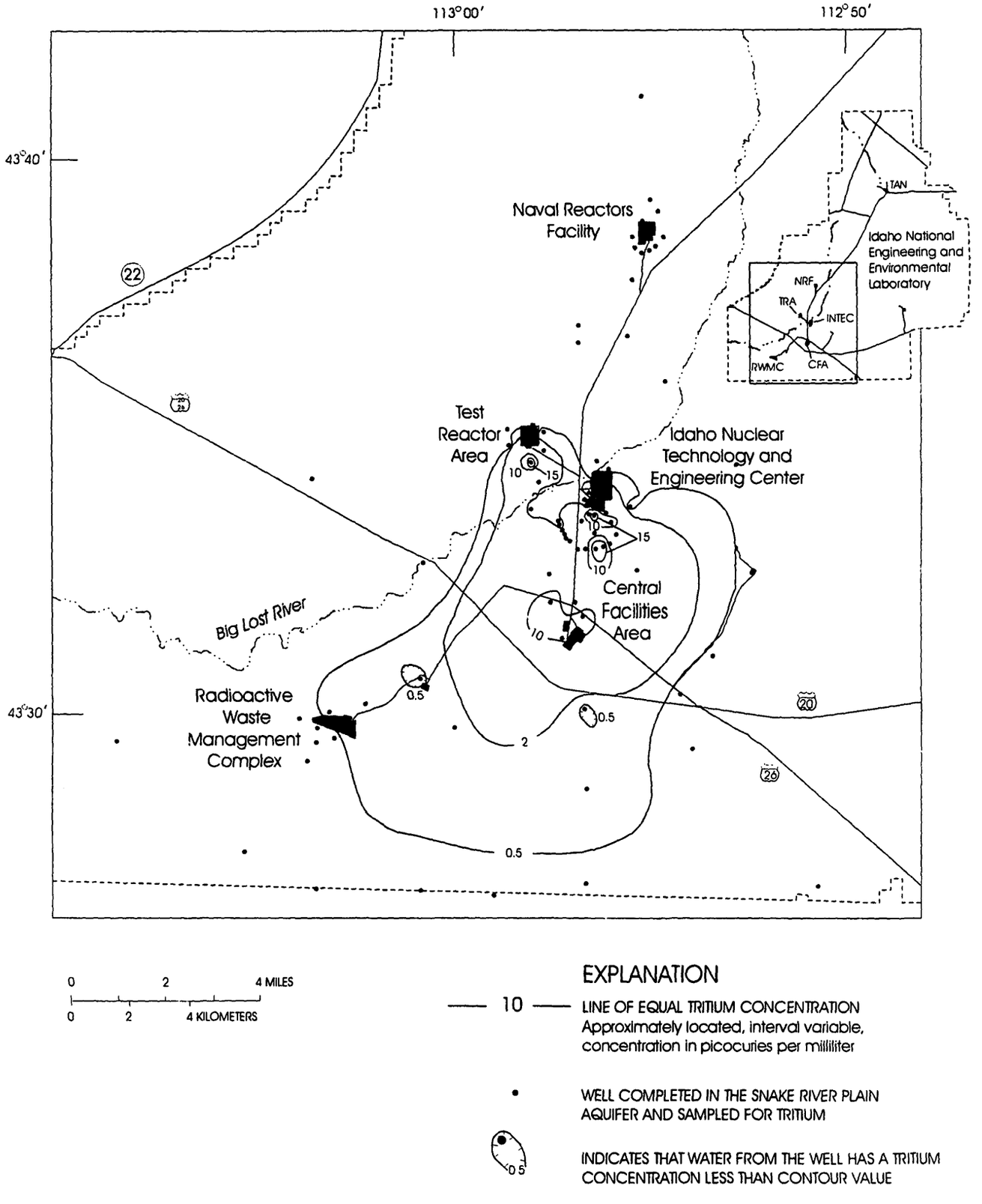


Figure 12. Distribution of tritium in water from the Snake River Plain aquifer at the Idaho National Engineering and Environmental Laboratory, October 1998.

5), north of CFA, decreased from 24.1±1.0 pCi/mL in July 1995 to 14.8±0.6 pCi/mL in July 1998. Tritium concentrations in water from well 65 (fig. 5), near the TRA, decreased from 21.2±0.9 pCi/mL in 1995 to 15.9±0.7 pCi/mL in 1998. Tritium concentrations in water from well 77, south of the INTEC (fig. 5), decreased from 25.1±1.0 pCi/mL in 1995 to 18.2±0.7 pCi/mL in 1998 (table 2). Tritium concentrations in water from wells 103, 105, and 108, near the southern boundary of the INEEL (fig. 4), exceeded the reporting level during 1983–85 (Pittman and others, 1988, p. 51; Mann and Cecil, 1990, p. 27). From 1985 to 1995, tritium concentrations in water from these wells were less than the reporting level (Bartholomay and others, 1997, p. 27). In October 1998, concentrations in water from well 105, at the boundary, and from well 124, south of the boundary, exceeded the reporting level and were 0.31±0.06 and 0.3±0.06 pCi/mL, respectively. These concentrations are similar to tritium concentrations reported by Busenberg and others (2000) from these two wells. Lower detection limits for tritium established by the RESL in the mid-1990's allowed for lower concentrations of tritium to be identified during 1996–98.

Tritium concentrations in water from wells 83 and EBR-1 (fig. 4) within the tritium plume (fig. 12) were below the reporting level. Well 83 penetrates about 250 ft of the Snake River Plain aquifer and EBR-1 penetrates about 490 ft of the aquifer. Most of the other wells in the tritium plume penetrate only the uppermost 50 to 200 ft of the aquifer. Tritium concentrations in water from wells 83 and EBR-1 were below the reporting level probably because of dilution by water from deeper zones (Mann and Cecil, 1990, p. 18).

Tritium concentrations in water from wells south of the disposal well at INTEC generally decreased during 1980–98 (table 2) in response to a decreased rate of tritium disposal from the INTEC. Tritium concentrations in water from well 59 near the INTEC infiltration ponds (fig. 5) generally have decreased since 1980, but were unusually large in October 1983, 1985, 1991, and 1995 (table 2). The larger concentrations in 1983 and 1985 correlate with higher tritium discharge rates (fig. 7). In 1986, the well was modified because perched water was detected outside the casing. A video log of well 59 after modifications in 1986 showed that some water from the perched zone was still seeping into the well. The larger concentrations in 1991 and 1995 may be attributed to seepage from a perched zone. The increased concentrations also correlate with the use of the east infiltration pond and with disposal of tritium to the ponds. The smaller concentrations in well 59 in 1989, 1993, 1994, 1996–98 correlate with years in which no tritium was discharged to the infiltration ponds (fig. 7).

Long-term radioactive-decay processes and an overall decrease in tritium disposal rates contributed to decreased concentrations of tritium in water from most of the wells at the INEEL during 1996–98. Of the total of 31,620 Ci of tritium discharged to the aquifer from 1952 to 1998, only about 6,000 Ci remained after radioactive decay. The average combined rate of tritium disposal at the TRA and INTEC during 1952–95 was about 722 Ci/yr; the average combined rate was 222 Ci/yr (31 percent of the long-term average) during 1984–95 (Bartholomay and others, 1997). Since 1995, no tritium has been discharged at INTEC. Also, the distribution of tritium concentrations in ground water probably has been affected by the shutdown of the disposal well at INTEC in 1984 and the subsequent discharge of wastewater to infiltration ponds. Lower detection limits used by RESL account for tritium concentrations in water from USGS 105 and 124 that exceeded the reporting level in 1998.

Strontium-90

A strontium-90 plume has developed in the Snake River Plain aquifer from the disposal of wastewater at the INEEL. During 1962–63, more than 33 Ci of strontium-90 in wastewater was discharged into a pit at the INTEC (Robertson and others, 1974, p. 117). In addition, during 1952–98, about 24 Ci of strontium-90 was in wastewater injected directly into the aquifer through the disposal well and discharged to infiltration ponds at the INTEC. About 93 Ci of strontium-90 was discharged to radioactive-waste infiltration and evaporation ponds at the TRA during 1952–98.

During 1996–98, about 0.03 Ci of strontium-90 was discharged to infiltration ponds at the INTEC. Strontium-90 has a half-life of 29.1 years (Walker and others, 1989, p. 29).

In October 1998, concentrations of strontium-90 in water from 20 wells exceeded the reporting level. Concentrations ranged from 2.1±0.6 to 41.1±1.5 pCi/L and the plume extended southwestward in the general direction of ground-water flow (fig. 13). Concentrations of strontium-90 in water samples from most wells have remained relatively constant or decreased since 1989 (table 3). The concentrations in water from wells 37 and 45 have been variable. Concentrations in water from well 37 were above the reporting level through 1990 and during 1992–94 and 1996–98, but were below the reporting level in 1991 and 1995 (table 3). Concentrations in water from well 45 were below the reporting level during 1984–89, 1992, 1994–97, but were above the reporting level in 1990, 1991, 1993, 1998, and in a replicate sample collected in 1995 (table 3). The October 1995 concentration of 76±3 pCi/L in water from well 47 was larger than concentrations in previous samples, but the quality-assurance replicate concentration of 47±2 pCi/L was similar to concentrations in previous samples. The October 1998 concentration of 41.1±1.5 pCi/L indicates a slight decrease. Wells 57 and 113 also indicate an overall decrease in strontium-90 concentrations with time (table 3). The MCL for strontium-90 in drinking water is 8 pCi/L (U.S. Environmental Protection Agency, 1998).

Before 1989, strontium-90 concentrations had been decreasing because of changes in disposal practices and processes of radioactive decay, diffusion, dispersion, and dilution from natural recharge (Orr and Cecil, 1991, p. 35). The relatively constant concentrations in water from most of the wells sampled during 1992–95 may have been due, in part, to a lack of recharge from the Big Lost River. Also, an increase in disposal of other chemical constituents into the infiltration ponds may have affected the exchange capacity of strontium-90 in the unsaturated zone (Bartholomay and others, 1997). Bunde and others (1997; 1998) showed that certain concentrations of magnesium, calcium, potassium, and sodium will compete for sites on sediment and cause strontium to be mobile in solution. The decrease of strontium-90 concentrations in some wells during 1996–98 may be attributed to several factors previously mentioned, including the increase in natural recharge, a decrease in disposal rates, and radioactive decay.

Strontium-90 has not been detected within the eastern Snake River Plain aquifer beneath the TRA. This can be explained partly by the exclusive use of waste-disposal ponds rather than the disposal well for radioactive-wastewater disposal at TRA. Sorption processes in the unsaturated and perched water zones beneath the waste-disposal pond likely have lessened strontium-90 migration at the TRA. In addition, stratigraphy beneath the TRA is different from that beneath the INTEC in that more sediment is present below TRA (Anderson, 1991, p. 22–28).

Cobalt-60

During 1952–93, about 438 Ci of cobalt-60 in wastewater was discharged to the TRA radioactive-waste infiltration ponds. Before 1974, the average disposal rate was about 18 Ci/yr; during 1974–88, the average disposal rate was 2.3 Ci/yr (Orr and Cecil, 1991, p. 35). During 1989–91, about 0.5 Ci of cobalt-60 was discharged to the ponds; during 1992–93, about 3.1 Ci of cobalt was discharged to the ponds. The half-life of cobalt-60 is 5.27 years (Walker and others, 1989, p. 25).

Cobalt-60 concentrations in water from well 65 (fig. 5), south of the TRA, exceeded the reporting level through 1985 (Orr and Cecil, 1991, p. 35) but have not been detected since 1985. The decrease in discharge of cobalt-60 to the TRA radioactive-waste infiltration ponds and change to use of evaporation ponds, radioactive decay, and sorption processes in the unsaturated and perched ground-water zones may have contributed to the absence of detectable concentrations of cobalt-60 in ground water near the TRA since 1985.

Cobalt-60 concentrations in water from the TAN disposal well (fig. 4) exceeded the reporting level because of the discharge of radioactive

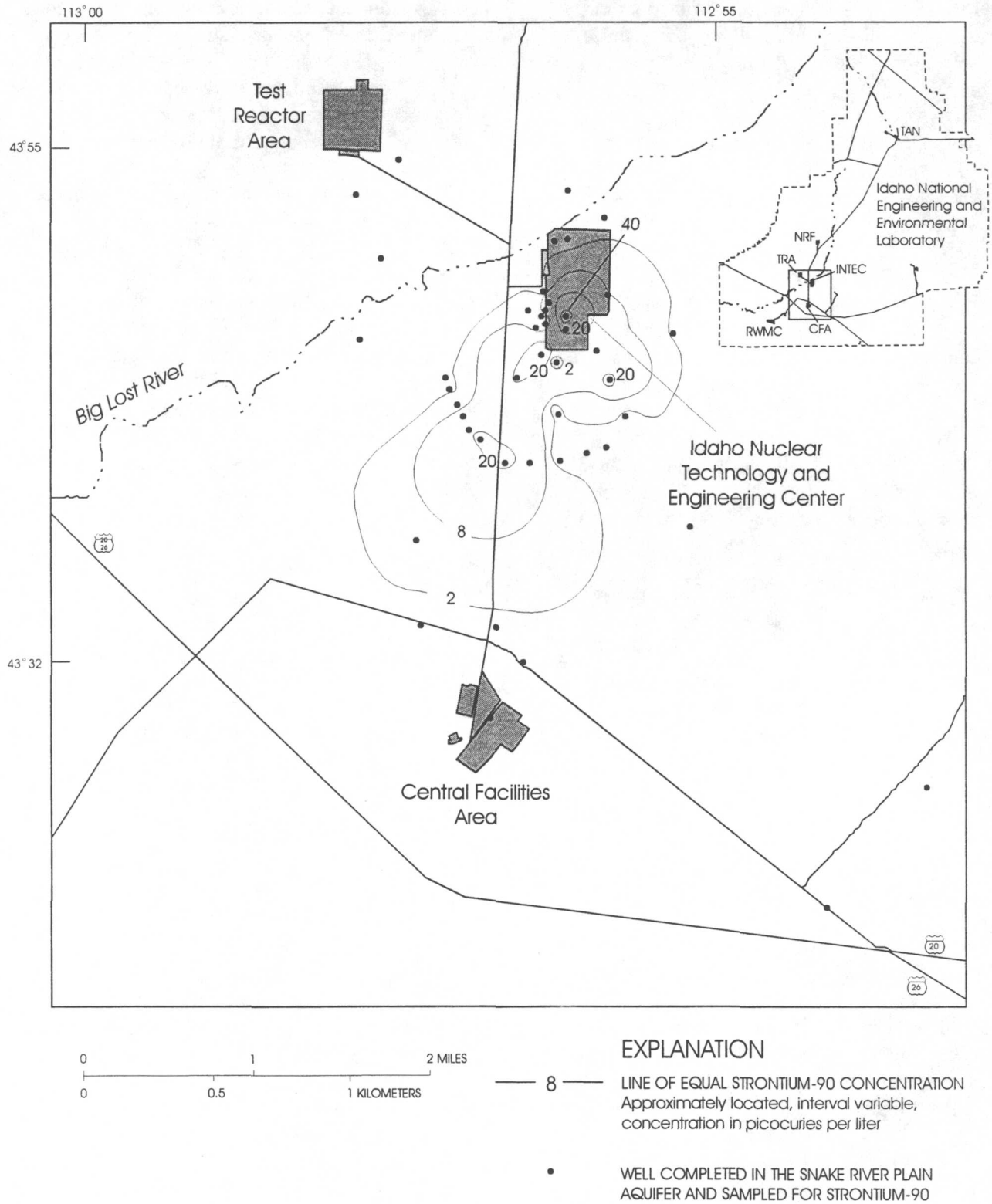


Figure 13. Distribution of strontium-90 in water from the Snake River Plain aquifer at the Idaho National Engineering and Environmental Laboratory, October 1998.

wastewater to the well before 1972. The TAN disposal well was turned over to a DOE contractor in 1988 as part of the Environmental Restoration Program. Samples were collected by the USGS in 1989 for special studies but no samples have been collected since December 1989. Water from the TAN disposal well contained 170±40 pCi/L of cobalt-60 in December 1989. During 1996–98, cobalt-60 concentrations in water from all wells sampled by the USGS at the INEEL were below the reporting level.

Cesium-137

From 1952 to 1998, about 138 Ci of cesium-137 in wastewater was discharged to the TRA radioactive-waste infiltration and evaporation ponds and about 23 Ci was discharged to the INTEC disposal well and infiltration ponds. During 1996–98, about 0.04 Ci was discharged to the TRA radioactive-waste evaporation pond and 0.0006 Ci was discharged to the INTEC infiltration ponds. The half-life of cesium-137 is 30.17 years (Walker and others, 1989, p. 34).

Concentrations of cesium-137 in water from wells 40 and 47 (fig. 5) exceeded the reporting levels through 1985 (Orr and Cecil, 1991, p. 35) but have been below the reporting level since 1985. The absence of detectable concentrations of cesium-137 is attributed to the discontinuation of wastewater discharge to the INTEC disposal well and to sorption processes in the unsaturated and perched ground-water zones.

Cesium-137 concentrations in water from the TAN disposal well (fig. 4) exceeded the reporting level because of the discharge of wastewater to the well before 1972. In December 1989, the concentration was 4,370±140 pCi/L (Bartholomay and others, 1995). No water samples have been collected by the USGS from the TAN disposal well since December 1989. During 1996–98, concentrations of cesium-137 in water from all wells sampled by the USGS at the INEEL were below the reporting level.

Plutonium

Monitoring of plutonium-238 and plutonium-239, -240 (undivided) in wastewater discharged to the Snake River Plain aquifer through the disposal well (fig. 5) at INTEC began in 1974. Before that time, alpha radioactivity from disintegration of plutonium was not separable from the monitored, undifferentiated alpha radioactivity. During 1974–95, about 0.26 Ci of plutonium was discharged to the disposal well and infiltration ponds at the INTEC (Bartholomay and others, 1997). During 1996–98, about 0.004 Ci of plutonium was discharged to infiltration ponds at the INTEC. The half-lives of plutonium-238, plutonium-239, and plutonium-240 are 87.7; 24,100; and 6,560 years, respectively (Walker and others, 1989, p. 46). Because of disposal of radioactive wastewater in the disposal well at INTEC, concentrations of plutonium isotopes in some samples from wells 40 and 47 (fig. 5) through January 1987 exceeded the reporting level (Orr and Cecil, 1991, p. 37). Concentrations in samples collected from these wells since 1987 have been below the reporting level.

Plutonium isotopes in water from the TAN disposal well (fig. 4) exceeded the reporting level because of disposal of radioactive wastewater before 1972. In December 1989, the concentration of plutonium-238 in the TAN disposal well was 0.26±0.04 pCi/L and the concentration of plutonium-239, -240 (undivided) was 0.71±0.06 pCi/L (Bartholomay and others, 1995). No water samples have been collected by the USGS from the TAN disposal well since December 1989. During 1996–98, concentrations in water from all wells sampled by the USGS at the INEEL were below the reporting level.

Americium-241

Americium-241 is a decay product of plutonium-241. Plutonium isotopes have been detected in wastewater discharged to the Snake River Plain aquifer at the INEEL and are in wastes buried at the RWMC. The half-life of americium-241 is 432.7 years (Walker and others, 1989, p. 46). Concentrations of americium-241 in water

samples collected between September 1972 and July 1982 from wells 87, 88, 89, and 90 at the RWMC (fig. 5) and in water samples collected through 1988 from the TAN disposal well (fig. 4) exceeded the reporting level (Orr and Cecil, 1991, p. 38–39). During 1992–95, the concentrations of americium-241 in one sample from each of two wells were at the reporting level: the concentration in water from well 37 was 0.09±0.03 pCi/L on October 2, 1992, and the concentration in water from well 120 was 0.06±0.02 pCi/L on April 20, 1993 (Bartholomay and others, 1997). During 1996–98, concentrations in all samples were below the reporting level.

Gross alpha- and beta-particle radioactivity

Gross alpha- and beta-particle radioactivity is a measure of the total radioactivity given off as alpha and beta particles during the radioactive decay process. Gross alpha and beta measurements are used to screen for radioactivity in the aquifer as a general indicator of ground-water contamination. Before 1994, gross alpha- and beta-particle radioactivity in water from three wells west and south of the INEEL (wells 8, 11, and 14, fig. 4) and four surface-water sites along the Big Lost River (fig. 1) was sampled. As part of the INEEL ground-water monitoring program adopted in 1994 (Sehlke and Bickford, 1993), the USGS expanded the number of wells at the INEEL used for sampling gross alpha- and gross beta-particle radioactivity.

During October 1998, water in 43 wells and 4 surface water sites were sampled for gross alpha- and gross-beta particle radioactivity. Concentrations of gross alpha-particle radioactivity were below the reporting level in all samples. Concentrations of gross beta-particle radioactivity in water from 7 of the 43 wells sampled in October 1998 were greater than the reporting level and ranged from 6±2 to 39±4 pCi/L. For comparison, background concentrations of gross beta-particle radioactivity in the Snake River Plain aquifer in Idaho generally range from 0 to about 8 pCi/L (Orr and others, 1991).

Chromium

Wastewater from TRA cooling-tower operations contained an estimated 24,000 lb of chromium that was discharged to an infiltration pond during 1952–64 and an estimated 31,000 lb that was discharged to an injection well during 1965–72 (Mann and Knobel, 1988, p. 7). In October 1972, chromium that was used as a corrosion inhibitor in cooling-tower operations was replaced by a polyphosphate. During 1971–83, about 265 lb of chromium was discharged to the disposal well at INTEC and 720 lb of chromate was discharged in wastewater at the Power Burst Facility (fig. 1) (Cassidy, 1984, p. 3). About 86 lbs of chromium was discharged to the INTEC infiltration ponds during 1992–95 (Bartholomay and others, 1997) and 44 lbs during 1996–98.

The MCL of 100 µg/L (U.S. Environmental Protection Agency, 1998) for total chromium in drinking water was exceeded in water from one well. The concentration of dissolved chromium in water from well 65, south of TRA (fig. 5), was 168 µg/L during October 1998. Other water samples contained from less than 14 to 26 µg/L of dissolved chromium during October 1998. Background concentrations of dissolved chromium in the Snake River Plain aquifer range from 2 to 3 µg/L (Orr and others, 1991, p. 41).

Sodium

During 1996–98, an estimated 1.3 million lb/yr of sodium in wastewater was discharged at the INEEL. About 708,000 lb/yr of sodium was discharged to the INTEC infiltration ponds; about 58,000 lb/yr was discharged to the TRA chemical-waste infiltration pond; about 524,000 lb/yr was discharged to the NRF industrial-waste ditch; and about 5,000 lb/yr was discharged at CFA (fig. 1). The total at TRA is the amount of sodium ion estimated from the sodium hydrate solution discharged.

The background sodium concentration in water from the Snake River Plain aquifer near the INEEL generally is less than 10 mg/L (Robertson and others, 1974, p. 155). In October 1998,

concentrations in water from most of the wells in the southern part of the INEEL were larger than 10 mg/L. Concentrations of dissolved sodium in water from wells near the INTEC have increased slightly or remained constant since disposal practices were changed in 1984 (table 4). Estimated discharge rates also have increased slightly at the INTEC since 1984, so the increase in concentrations in some wells may be attributed to this increase in discharge rates. During 1998, the largest concentration in water samples from wells at the INEEL was 96 mg/L in a sample from well 113 (table 4). In 1998, sodium concentrations in water from wells 88 and 120 (fig. 5), near the RWMC, contained 42 and 48 mg/L of sodium, respectively. Water from one well, MTR Test at the TRA (fig. 5), contained a sodium concentration of 42 mg/L.

Chloride

About 2.3 million lb/yr of chloride was discharged to infiltration ponds at the INEEL during 1996–98, which is an increase from the estimated 1.5 million lb/yr discharged during 1992–95 (Bartholomay and others, 1997, p. 36). Of the 2.3 million lb/yr discharged during 1996–98, about 1.17 million lb/yr was discharged to the INTEC infiltration ponds (fig. 3), which is about the same amount discharged during 1986–95 (Orr and Cecil, 1991, p. 40; Bartholomay and others, 1995, p. 31; Bartholomay and others, 1997, p. 36).

The background chloride concentration in water from the Snake River Plain aquifer at the INEEL is generally about 15 mg/L (Robertson and others, 1974, p. 150); the background chloride concentration near the INTEC is about 10 mg/L and, near the CFA, about 20 mg/L. In 1998, concentrations of dissolved chloride in most water samples from the INTEC and NRF (fig. 14) exceeded 20 mg/L. Chloride concentrations in water from wells near the INTEC have increased or remained constant since disposal practices were changed in 1984 (table 5). Concentrations in water from wells downgradient from the infiltration ponds correlate with discharge rates into the ponds if travel time is considered. For example, chloride concentrations in water from wells 57 and 37 were smallest in 1985, the year during which the smallest amount of chloride was discharged into the ponds (fig. 15). Concentrations in water from well 57 increased as discharge rates increased through 1993; concentrations then decreased through 1995, increased in 1996, and decreased again in 1997 and 1998. Concentrations in water from well 37 also correlate with discharge rates into ponds if longer travel time is considered (fig. 15). Chloride concentrations in water from well 59, near the INTEC infiltration ponds, were variable during 1984–98; concentrations were unusually large in October 1991 and 1995 (table 5). The larger concentrations probably were due to seepage down the well from the perched ground-water zone, which contained chloride concentrations of about 270 mg/L in 1991 and 1995 (Bartholomay and others, 1997). October 1998 chloride concentrations in water from wells 113 (fig. 5) and CFA-1 (fig. 4) were 220 and 108 mg/L, respectively (table 5).

At the TRA, the chloride concentration in water from well 65 was 18 mg/L. Chloride concentrations in water from all other wells completed in the Snake River Plain aquifer at the TRA were smaller than 15 mg/L. At the RWMC, chloride concentrations in water from wells 88, 89, and 120 were 84, 35, and 20 mg/L, respectively. Chloride concentrations in water from wells near the NRF slightly exceeded 20 mg/L, except the concentrations in well NRF-6 (fig. 2), which was 209 mg/L. This large concentration is attributed to the proximity of the well to the NRF industrial-waste ditch. The secondary MCL for chloride in drinking water is 250 mg/L (U.S. Environmental Protection Agency, 1998).

Sulfate

About 0.8 million lb/yr of sulfate in wastewater was discharged at the INEEL during 1996–98, which is a decrease from the 1.05 million lb/yr discharged during 1992–95 (Bartholomay and others, 1997). Of the 0.8 million lb/yr discharged during 1996–98, about 610,000 lb/yr was discharged to infiltration ponds at the TRA; 146,000 lb/yr was discharged to infiltration ponds at the INTEC; and 45,000 lb/yr was discharged to the NRF industrial-waste ditch. The background concentrations of sulfate in the Snake River Plain

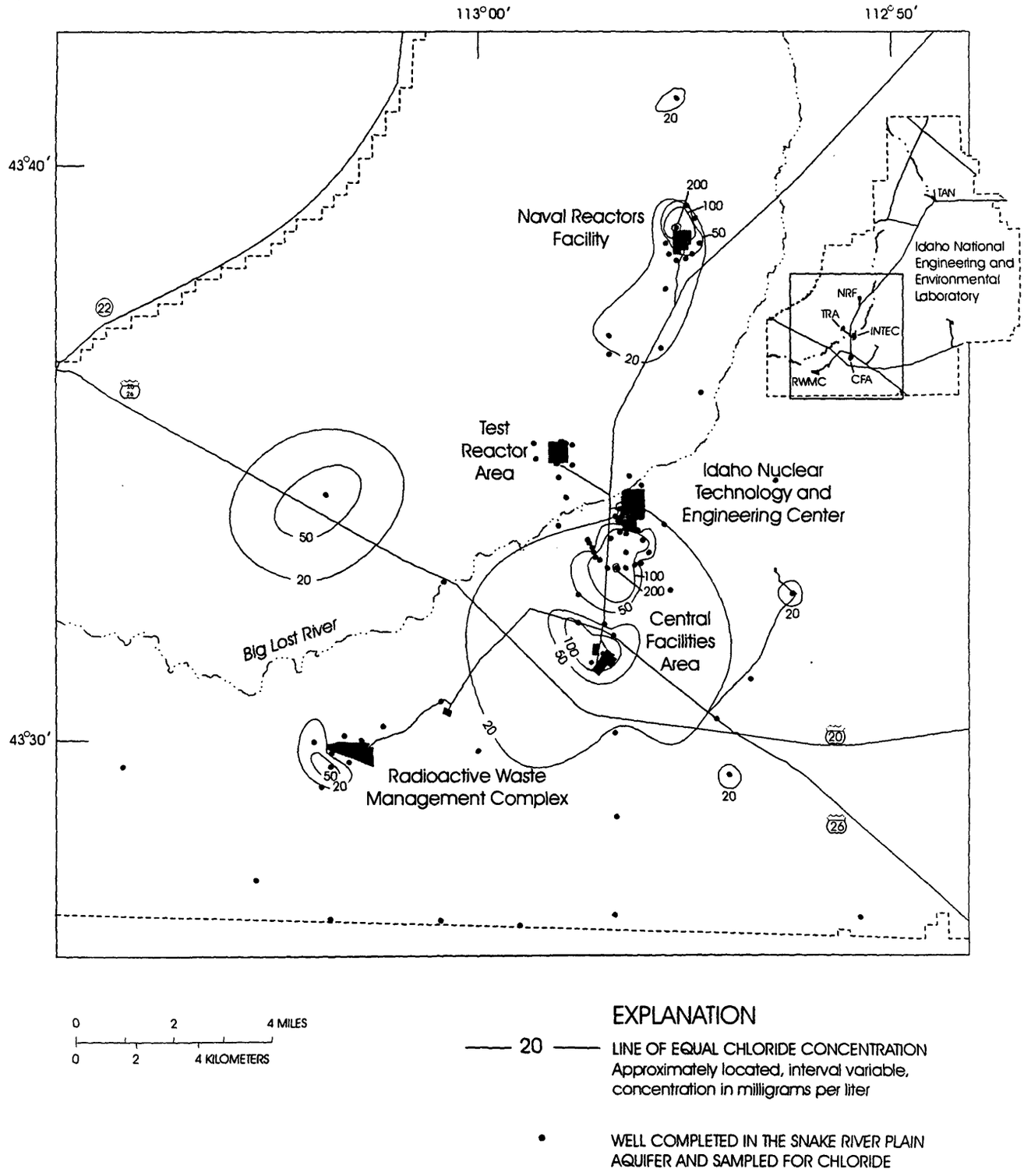
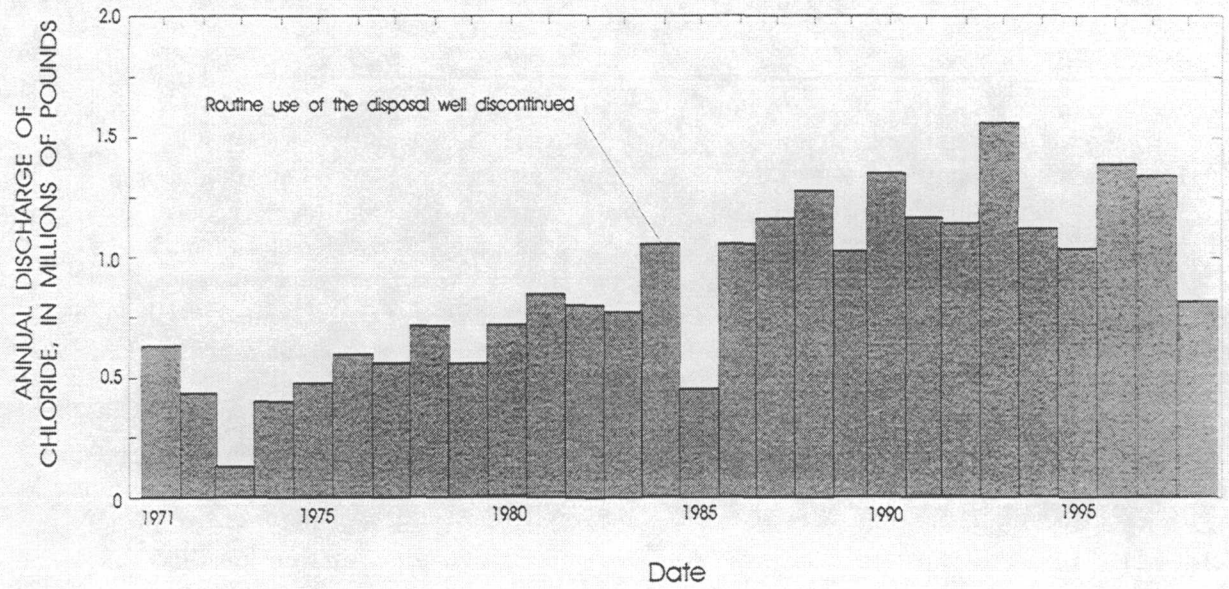


Figure 14. Distribution of chloride in water from the Snake River Plain aquifer at the Idaho National Engineering and Environmental Laboratory, October 1998.



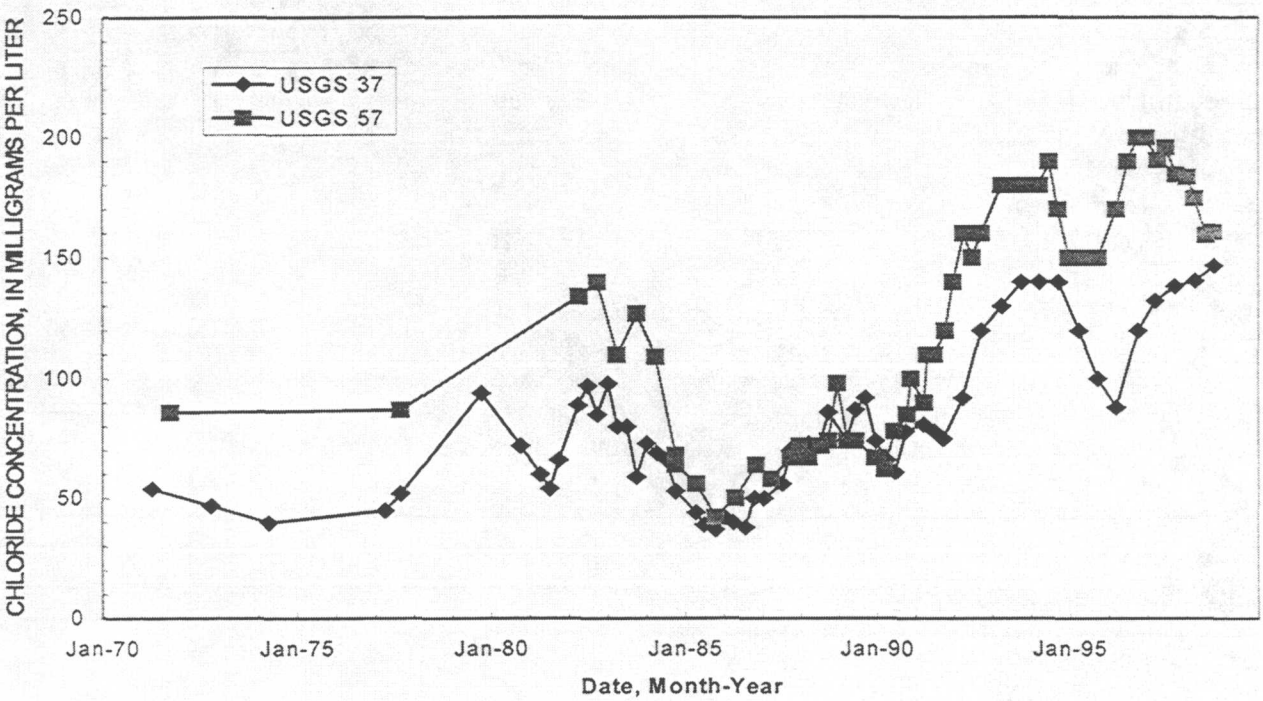


Figure 15. Amount of chloride discharged to the disposal well and the infiltration ponds, and the amount of chloride in water from two wells, Idaho Nuclear Technology and Engineering Center, 1971–98.

aquifer in the south-central part of the INEEL range from about 10 to 40 mg/L (Robertson and others, 1974, p. 72).

Because of the disposal history of sulfate at the various facilities, water-sample collection for dissolved sulfate analyses at several wells was added to the water-quality monitoring network in 1995. During 1998, sulfate concentrations in water from six wells near the NRF, two wells near the TRA, and one well near the RWMC were larger than background concentrations. Water collected from wells NRF-6, NRF-9, NRF-10, NRF-11, NRF-12, and NRF-13 (fig. 3) during November 1998 contained 145, 44, 41, 41, 52, and 82 mg/L, respectively. The large concentrations in water from these wells may be attributed to proximity of the wells to the NRF industrial-waste ditch. Water samples from MTR Test and well 65, sampled in October 1998 (fig. 5) contained 54 and 147 mg/L of sulfate, respectively. The larger-than-background concentrations in water from these wells probably are due to sulfate disposal at the TRA infiltration ponds. The October 1998 water sample from well 88 (fig. 5), near the RWMC, contained 59 mg/L of sulfate. The larger-than-background concentration in water from this well may be attributed to the well construction and/or waste disposal at the RWMC (Pittman and others, 1988, p. 57–61). The secondary MCL for sulfate in drinking water is 250 mg/L (U.S. Environmental Protection Agency, 1998).

Nitrate

Wastewater containing nitrate was injected into the Snake River Plain aquifer through the INTEC disposal well from 1952 to February 1984 and discharged to the INTEC infiltration ponds after February 1984 (Orr and Cecil, 1991). About 260,000 lb of nitrate was discharged to the INTEC infiltration ponds during 1996–98, of which 220,000 lb was discharged during February 1996. The average annual discharge rate during 1996–98 was about 86,700, which is about 50 percent of the disposal rate during 1986–88 and 30 percent of the rate during 1979–85. Concentrations of nitrate in ground water not affected by wastewater disposal from INEEL facilities generally are less than 5 mg/L as nitrate (Robertson and others, 1974, p. 73).

Concentrations of dissolved nitrite plus nitrate reported by the NWQL as nitrogen in milligrams per liter have been converted to nitrate in milligrams per liter in this report for comparison with nitrate concentrations presented in previous reports. Because nitrite analyses indicate that almost all the nitrite plus nitrate concentration is nitrate, concentrations will be called nitrate in this report. Nitrate concentrations have changed in response to disposal-rate changes and to the diversion of wastewater from the INTEC disposal well to infiltration ponds in 1984. In 1981, the maximum nitrate concentration was 62 mg/L in water from well 43 (Lewis and Jensen, 1985). By 1985, the concentrations in wells near INTEC ranged from less than 5 to 26.9 mg/L (Pittman and others, 1988, p. 61). By 1995, concentrations in wells near INTEC ranged from less than 5 to 49 mg/L. In 1998, nitrate concentrations in samples from wells 40, 43, 77, and CFA-1 (figs. 4 and 5) were 14, 31, 18, and 17 mg/L, respectively. The 1998 concentrations represent either a continuation of or a decrease in concentrations from those reported in 1995 (Bartholomay and others, 1997, p. 41). The decreases may be attributed to dilution by recharge from the Big Lost River and to long-term decreases in disposal.

In 1998, nitrate concentrations in water samples from wells 88, 89, and 119, near the RWMC, were 7.0, 8.7, and 5.7 mg/L, respectively. Historically, concentrations in water near the RWMC have slightly exceeded the regional background concentration of about 5 mg/L. At the TRA, water from well 65 contained 7.0 mg/L of nitrate. Water from several wells around the NRF contained concentrations of nitrate larger than 5 mg/L (fig. 16). All concentrations were less than the MCL for drinking water of 44 mg/L (as nitrate) (U.S. Environmental Protection Agency, 1998).

Fluoride

About 3,110 lb of fluoride was discharged to infiltration ponds at the INTEC during 1996–98. About 36,600 lb of fluoride was discharged at the

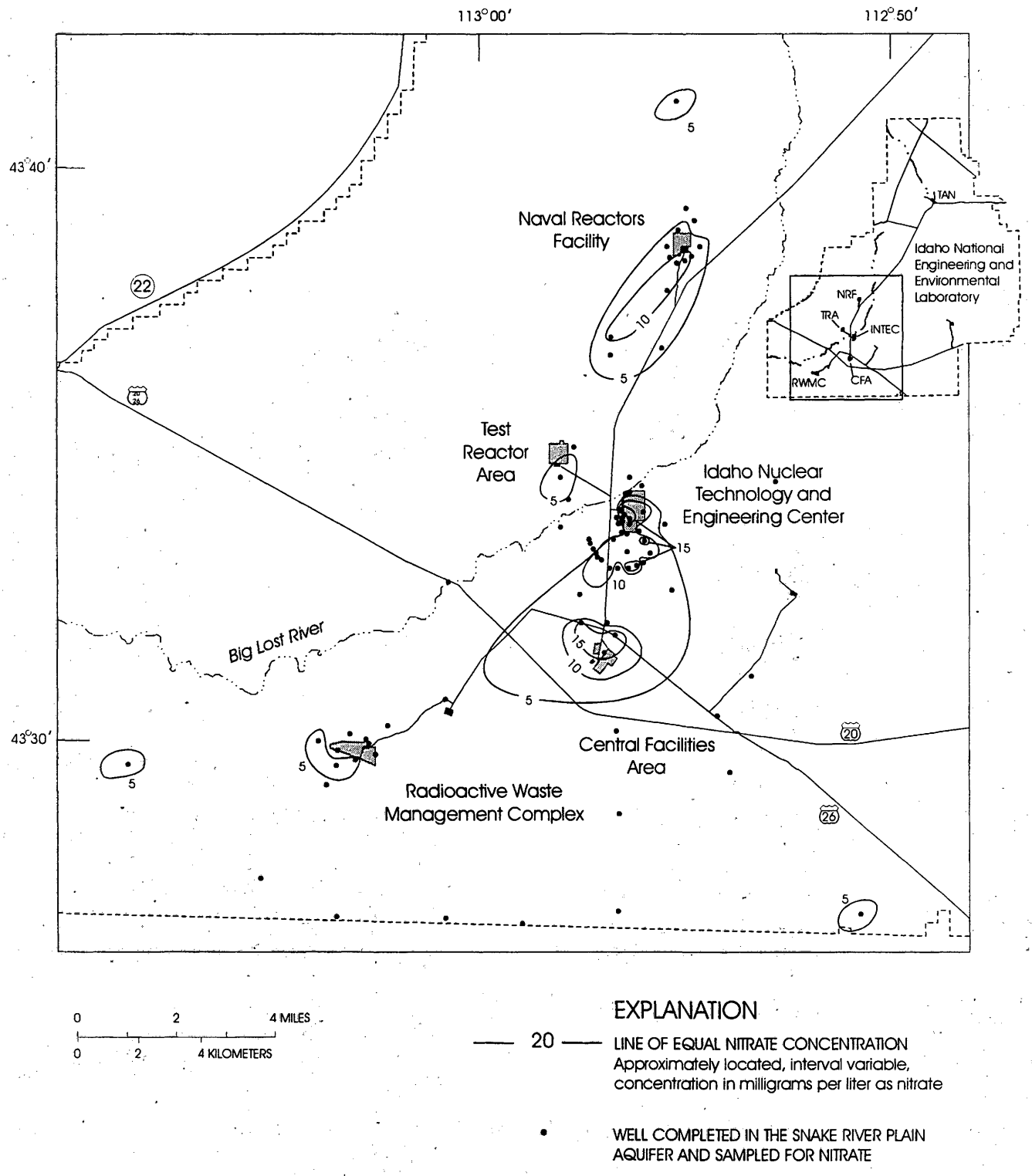


Figure 16. Distribution of nitrate in water from the Snake River Plain aquifer at the Idaho National Engineering and Environmental Laboratory, October 1998.

INTEC from 1971–95. The background concentrations of dissolved fluoride in the Snake River Plain aquifer in the southwestern part of the INEEL range from about 0.1 to 0.3 mg/L (Robertson and others, 1974, p. 75).

As part of the INEEL ground-water monitoring program adopted in 1994, the USGS began sampling for dissolved fluoride near the INTEC because fluoride is a constituent in wastewater discharged at the INTEC. During 1996–98, water samples from four wells were analyzed for fluoride; concentrations ranged from 0.2 to 0.3 mg/L. These concentrations are similar to background concentrations reported by Robertson and others (1974), which indicates that wastewater disposal has not affected fluoride concentrations in the Snake River Plain aquifer.

Trace Elements

As part of the INEEL ground-water monitoring program adopted in 1994 and several special sampling programs, water samples from several wells were collected and analyzed for a variety of dissolved trace elements during 1996–98. Trace elements sampled for during 1996–98 included aluminum, antimony, arsenic, barium, beryllium, cadmium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, uranium, vanadium, and zinc. The amount of each constituent in wastewater discharged from INEEL facilities was determined from record-to-date data from French and others (1999a). Some elements, such as strontium and uranium, are measured in discharges as radioactive isotopes, but may be seen or measured as stable isotopes. A summary of each trace element follows.

Aluminum.—About 117 lb of aluminum was discharged in wastewater at the INTEC during 1995–98. There were no other recorded discharges at the INEEL during 1971–98. During 1996–98, water samples from 10 wells completed in the Snake River Plain aquifer were analyzed for aluminum; concentrations ranged from 3 to 14 µg/L.

Antimony.—There are no recorded discharges of antimony in wastewater at the INEEL. During 1996–98, water samples from nine wells completed in the Snake River Plain aquifer were analyzed for antimony; concentrations of all samples were less than the minimum reporting level of 1 µg/L. The minimum reporting level for chemical constituents is the lowest measured concentration of a constituent that may be reliably reported using a given analytical method (Timme, 1995).

Arsenic.—About 11 lb of arsenic was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from 11 wells completed in the Snake River Plain aquifer were analyzed for arsenic; concentrations ranged from less than 1 to 4.2 µg/L.

Barium.—About 4,740 lb of barium was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for barium; concentrations ranged from 16 to 200 µg/L.

Beryllium.—Less than 1 lb of beryllium was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from 24 wells completed in the Snake River Plain aquifer were analyzed for beryllium; concentrations ranged from less than 0.5 to 1 µg/L.

Cadmium.—About 22 lb of cadmium was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for cadmium; concentrations ranged from less than 1 to 2 µg/L.

Cobalt.—There are no recorded discharges of cobalt in wastewater at the INEEL. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for cobalt; concentrations were less than the minimum reporting levels of 1 and 3 µg/L.

Copper.—About 81 lb of copper was discharged in wastewater at the INTEC during 1995–98. There were no other recorded discharges at the INEEL during 1971–98. During 1996–98,

water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for copper; concentrations ranged from less than the minimum reporting levels of 1 or 10 µg/L to 7.5 µg/L.

Iron.—About 752 lb of iron was discharged in wastewater at the INTEC during 1995–98. There were no other recorded discharges at the INEEL during 1971–98. During 1996–98, water samples from four wells completed in the Snake River Plain aquifer were analyzed for iron; concentrations ranged 4 to 9 µg/L.

Lead.—About 556 lb of lead was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for lead; concentrations ranged from less than the minimum reporting levels of 1 or 10 µg/L to 20 µg/L.

Lithium.—There are no recorded discharges of lithium in wastewater at the INEEL. During 1996–98, water samples from four wells completed in the Snake River Plain aquifer were analyzed for lithium; concentrations ranged from less than 4 to 25 µg/L.

Manganese.—About 44 lb of manganese was discharged in wastewater at the INTEC during 1995–98. There were no other recorded discharges at the INEEL during 1971–98. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for manganese; concentrations ranged from less than 1 to 5.1 µg/L.

Mercury.—About 141 lb of mercury was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from 11 wells completed in the Snake River Plain aquifer were analyzed for mercury; concentrations were less than 0.1 µg/L.

Molybdenum.—There are no recorded discharges of molybdenum in wastewater at the INEEL. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for molybdenum; concentrations ranged from less than the minimum reporting levels of 1 or 10 µg/L to 6 µg/L.

Nickel.—There are no recorded discharges of nickel in wastewater at the INEEL. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for nickel; concentrations ranged from less than the minimum reporting levels of 1 or 10 µg/L to 1.2 µg/L.

Selenium.—About 9 lb of selenium was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from six wells completed in the Snake River Plain aquifer were analyzed for selenium; concentrations ranged from 1 to 2.6 µg/L.

Silver.—About 190 lb of silver was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for silver; concentrations were less than 1 µg/L.

Strontium.—There are no recorded discharges of stable strontium isotopes in wastewater at the INEEL. During 1996–98, water samples from four wells completed in the Snake River Plain aquifer were analyzed for stable strontium; concentrations ranged from 160 to 450 µg/L.

Thallium.—There are no recorded discharges of thallium in wastewater at the INEEL. During 1996–98, water samples from 18 wells completed in the Snake River Plain aquifer were analyzed for thallium; concentrations ranged from less than 0.5 to 0.7 µg/L.

Uranium.—There are no recorded discharges of uranium in wastewater at the INEEL. During 1996–98, water samples from nine wells completed in the Snake River Plain aquifer were analyzed for uranium; concentrations ranged from 1 to 3 µg/L.

Vanadium.—There are no recorded discharges of vanadium in wastewater at the INEEL. During 1996–98, water samples from four wells completed in the Snake River Plain aquifer were analyzed for

vanadium; concentrations ranged from less than 6 to 8 µg/L.

Zinc—About 5,240 lb of zinc was discharged in wastewater at the INEEL during 1971–98. During 1996–98, water samples from 13 wells completed in the Snake River Plain aquifer were analyzed for zinc; concentrations ranged from less than the minimum reporting levels of 1 or 3 µg/L to 404 µg/L.

Purgeable Organic Compounds

Purgeable organic compounds (POC's) are present in the Snake River Plain aquifer because of waste-disposal practices at the INEEL. In 1987, water samples from 81 wells completed in the Snake River Plain aquifer were analyzed for 36 POC's as part of a reconnaissance sampling program (Mann and Knobel, 1987). Analyses of samples indicated that from 1 to 12 POC's were present in samples from 45 wells at concentrations above their reporting levels. In 1988 and 1989, water samples were collected from 38 wells as a continuation of the 1987 study (Mann, 1990). Water samples from 22 wells contained concentrations above the minimum reporting levels for 1 to 19 POC's, mainly carbon tetrachloride; 1,1,1- trichloroethane; and trichloroethylene. In 1990 and 1991, water samples were collected from 76 wells at or near the INEEL for various water-quality studies (Liszewski and Mann, 1992). Water samples from 31 wells completed in the Snake River Plain aquifer contained concentrations above the minimum reporting level for 1 to 14 POC's. During 1992–95, water samples were collected from 53 wells at or near the INEEL for various water-quality studies (Greene and Tucker, 1998). Water samples from 23 wells completed in the Snake River Plain aquifer contained concentrations above the minimum reporting level for 1 to 14 POC's. During 1996–98, water samples were collected from 44 wells at or near the INEEL for various water-quality studies. Water samples from 15 wells completed in the Snake River Plain aquifer contained concentrations above the minimum reporting level for 1 to 12 POC's.

A plume of 1,1,1-trichloroethane, a solvent used in industrial cleaning processes (Lucius and others, 1989, p. 450), has developed in the Snake River Plain aquifer near the INTEC because of waste-disposal practices (Bartholomay and others, 1995). Ten of the wells near INTEC that previously had water with concentrations of 1,1,1-trichloroethane above the minimum reporting level were sampled during 1992–95. Concentrations in water from 8 of the 10 wells remained above the minimum reporting level (Bartholomay and others, 1997). Three of the wells near INTEC that previously had water with concentrations of 1,1,1-trichloroethane above the minimum reporting level were sampled during 1996–98, and concentrations in water in all three of the wells were above the minimum reporting level. All concentrations were below the MCL for drinking water of 200 µg/L (U.S. Environmental Protection Agency, 1998).

During 1996–98, concentrations of POC's in water samples from several wells at or near the RWMC exceeded the reporting levels. For example, in October 1998, water from the RWMC Production well contained 4.5 µg/L of carbon tetrachloride, 0.8 µg/L of chloroform, 0.5 µg/L of 1,1,1-trichloroethane, 2.1 µg/L of trichloroethylene, and 0.18 µg/L of tetrachloroethylene. A plot of carbon tetrachloride concentrations for the RWMC production well (fig. 17) indicates that concentrations have increased with time. Water from well 87 contained concentrations above the reporting levels of carbon tetrachloride, 1,1,1-trichloroethylene, dichlorodifluoromethane, and trichloroethylene. Water from well 88 contained concentrations above the reporting levels of carbon tetrachloride; chloroform; 1,1,1- trichloroethane; trichloroethylene; and toluene. Water from well 90 contained concentrations above the reporting levels of carbon tetrachloride; chloroform; tetrachloroethylene; 1,1,1-trichloroethane; and trichloroethylene. Water from well 120 contained concentrations above the reporting levels of carbon tetrachloride; chloroform; tetrachloroethylene; 1,1,1-trichloroethylene; and trichloroethylene. A July 1998 sample from well RWMC M7S contained concentrations above the reporting levels of carbon tetrachloride; chloroform; 1,1,1-trichloroethane; trichloroethylene; dichlorodifluoromethane; and tetrachloroethylene.

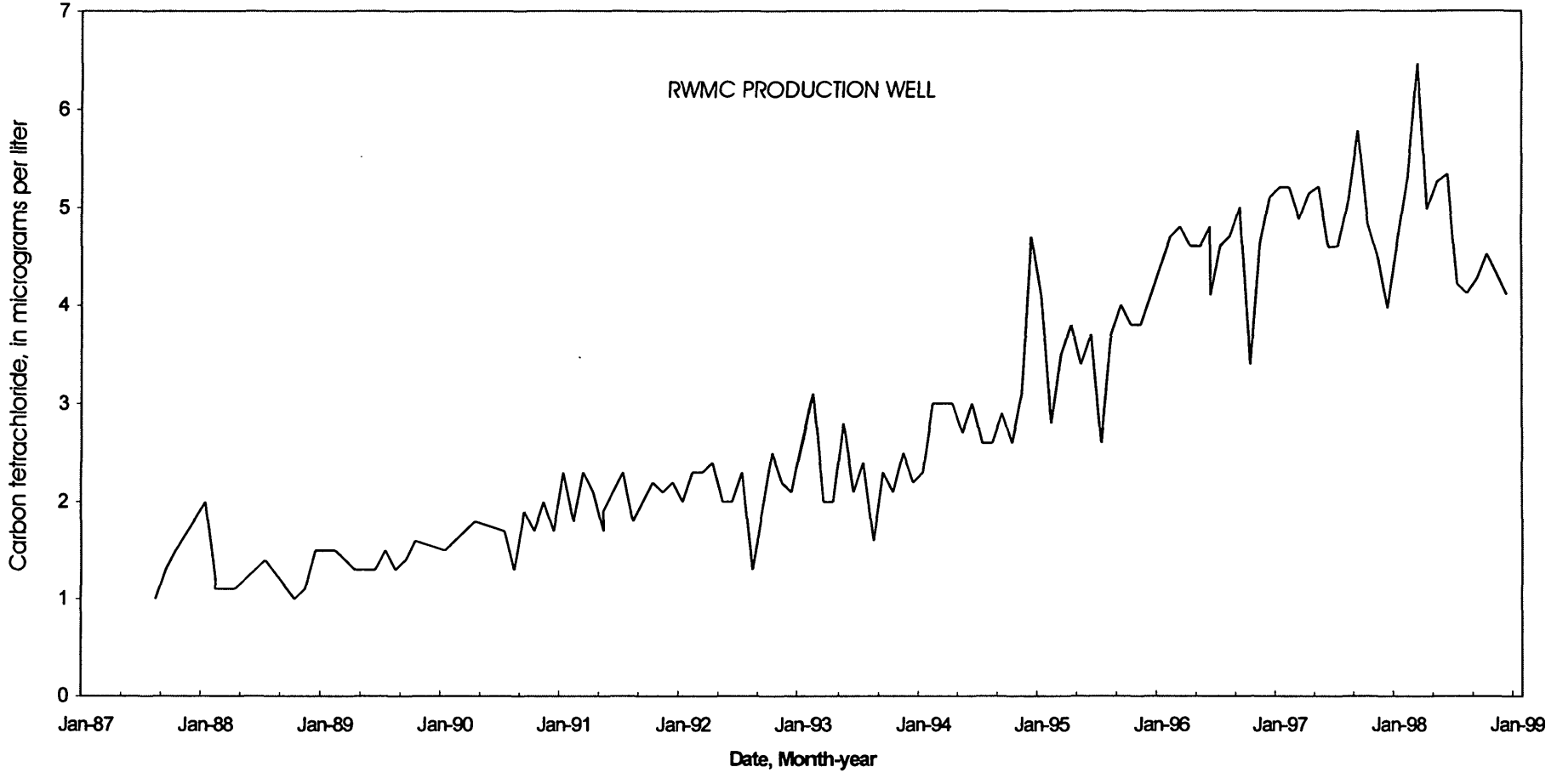


Figure 17. Carbon tetrachloride concentrations in the RWMC Production well, 1987–98.

The POC's are present because of waste-disposal practices at the RWMC.

During 1987–89, concentrations of 1 to 15 POC's in water from 10 wells near the TAN exceeded their reporting levels (Mann and Knobel, 1987; Mann, 1990). TAN wells were not sampled by the USGS for POC's during 1990–93 because the wells were not part of routine sampling. During 1994–95, six wells near the TAN were sampled as part of the INEEL ground-water monitoring program (Sehlke and Bickford, 1993). One sample from the TAN Expl. well contained 1.1 µg/L of isopropylbenzene. One sample from well ANP-9 contained 11 µg/L of toluene (Bartholomay and others, 1997). During 1996–98, five wells near TAN were sampled as part of the ground-water monitoring program. No POC concentrations exceeded their reporting levels. In addition, water from well USGS 24 was sampled in 1996 and concentrations of nine POC's exceeded their reporting levels. Two POC concentrations (trichloroethylene at 990 µg/L and tetrachloroethylene at 46 µg/L) exceeded their respective MCLs of 5 µg/L for drinking water.

Total Organic Carbon

Analyses of total organic carbon (TOC) are used to screen for organic compounds in the aquifer as a general indicator of ground-water contamination. As part of the INEEL ground-water monitoring program adopted in 1994, the USGS began sampling water at several wells at the INEEL for TOC. As part of another sampling program, the USGS also sampled water from 13 wells near the NRF for TOC. During October-November 1998, water samples from 51 wells completed in the Snake River Plain aquifer were analyzed for TOC; concentrations ranged from not detected to 3.0 mg/L.

Specific Conductance, Temperature, and pH

Specific conductance is a measure of the electrical conductivity of water and is proportional to the quantities of dissolved chemical constituents in the water. Dissolved chemical constituents, such as chloride, sodium, and sulfate, in wastewater discharged to disposal wells and infiltration ponds at INEEL facilities generally have increased the specific conductance of ground water. In 1998, the specific conductance of water from 129 wells at the INEEL ranged from 258 to 1,347 µS/cm; the median specific conductance was 411 µS/cm.

The increase in specific conductance attributed to wastewater discharged to the aquifer is apparent in ground water downgradient from INEEL facilities. A plume of increased specific conductance originated from the INTEC infiltration ponds and extended downgradient from the INTEC to the CFA (fig. 18). The specific conductance of water from several wells within this plume increased from about 500 µS/cm in 1985 (Pittman and others, 1988, p. 64) to more than 1,000 µS/cm in 1998; specific conductance of water from well 113 (fig. 5) was 1,085 µS/cm in 1998. Increases in specific conductance since 1985 can be attributed to the increase of chemical wastewater discharged to the INTEC infiltration ponds.

The specific conductance of water from several wells at the TRA exceeded 400 µS/cm in 1998. Specific conductance of water from well 65, downgradient from infiltration ponds at the TRA was 609 µS/cm. The specific conductance of water from wells near the NRF generally exceeded 500 µS/cm. Specific conductance of water from well NRF-6, near the industrial-waste ditch, was 1,347 µS/cm. Specific conductance of water from wells 88 and 120, near the RWMC, exceeded 400 µS/cm.

Water temperatures of 129 wells sampled in 1998 ranged from 8.5°C in well P&W 2 to 19.5°C in well USGS 7. The median temperature was 12.5°C. The pH ranged from 7.7 in wells USGS 4, 19, and 113 to 8.4 in well CPP-4; the median pH was 8.0.

SUMMARY

Radiochemical and chemical wastewater discharged since 1952 to infiltration ponds and disposal wells at the Idaho National Engineering

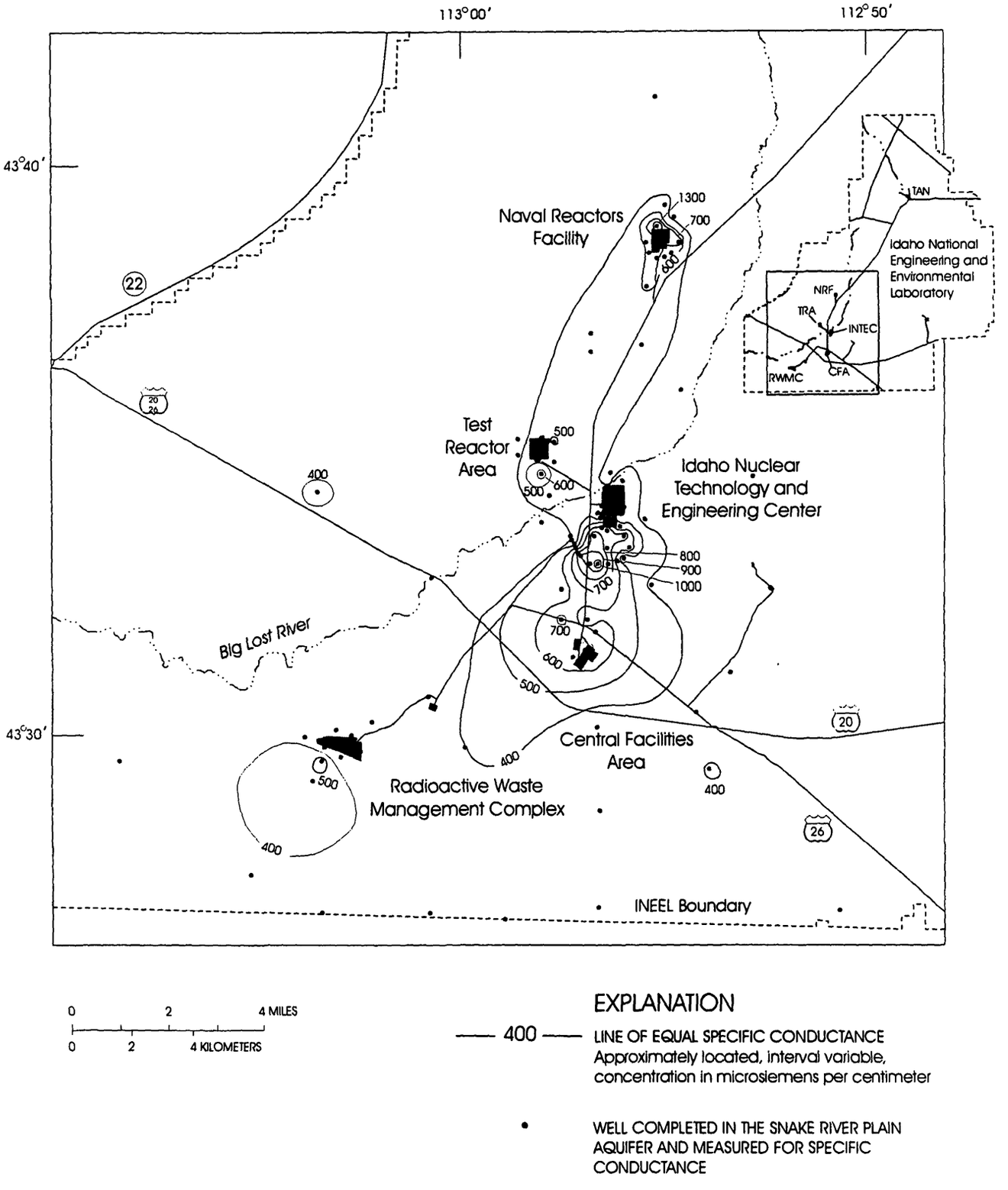


Figure 18. Distribution of specific conductance of water from the Snake River Plain aquifer at the Idaho National Engineering and Environmental Laboratory, October 1998.

and Environmental Laboratory (INEEL) has affected water quality in the Snake River Plain aquifer. The U.S. Geological Survey, in cooperation with the U.S. Department of Energy, maintains a monitoring network at the INEEL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the aquifer. This report presents an analysis of water-level and water-quality data collected from the Snake River Plain aquifer during 1996–98.

Water in the Snake River Plain aquifer moves principally through fractures and interflow zones in basalt, generally flows southwestward, and eventually discharges at springs along the Snake River. The aquifer is recharged principally from infiltration of irrigation water, infiltration of streamflow, and ground-water inflow from adjoining mountain drainage basins.

In 1998, the altitude of the water table in the Snake River Plain aquifer at the INEEL was about 4,600 ft above sea level in the northern part and about 4,420 ft above sea level in the southwestern part. Locally, the hydraulic gradient ranged from about 1 to 15 ft/mi and ground-water flow was to the south and southwest. From March–May 1995 to March–May 1998, water levels in INEEL wells increased; increases ranged from about 7 ft in wells in the west-central part of the INEEL to about 1 to 2 ft in wells in the northern part.

During 1996–98, no tritium was discharged to infiltration ponds at the INTEC. In October 1998, concentrations of tritium originating from the INTEC and TRA ranged from 0.29±0.06 to 18.7±0.8 pCi/mL. Near the southern boundary of the INEEL, tritium concentrations in water from wells 105 and 124 exceeded the reporting level in October 1998 because of lower detection limits used for analyses. Radioactive decay, decreased tritium disposal, dilution from recharge, and discontinuation of the use of the infiltration ponds at TRA and the disposal well at INTEC and subsequent wastewater discharge to infiltration ponds at INTEC contributed to decreased concentrations of tritium in ground water at the INEEL during 1996–98.

During 1996–98, about 0.03 Ci of strontium-90 was discharged to infiltration ponds at the INEEL. In October 1998, strontium-90 concentrations in ground water ranged from 2.1±0.6 to 41.1±1.5 pCi/L. During 1996–98, strontium-90 concentrations remained relatively constant or declined. The absence of a strontium-90 plume at the TRA probably can be attributed to discharge of radioactive wastewater only to TRA infiltration ponds and to sorption processes in the unsaturated and perched ground-water zones.

During 1996–98, the concentrations of cobalt-60, cesium-137, plutonium-238, plutonium-239,-240 (undivided), and americium-241 in water from all wells sampled at the INEEL were below the reporting level.

In 1998, several wells were sampled for dissolved chromium. The concentration of chromium in water from well 65 was 168 µg/L, which exceeded the MCL of 100 µg/L. Water samples from the other wells contained from less than 14 to 26 µg/L of dissolved chromium.

During 1996–98, an estimated 1.3 million lb/yr of sodium in wastewater was discharged at the INEEL principally to the infiltration ponds at INTEC. In October 1998, most of the wells in the southern part of the INEEL had concentrations larger than 10 mg/L. Sodium concentrations have increased or remained constant because of an increase in disposal rates since 1984. The largest sodium concentration in water from wells was 96 mg/L.

During 1996–98, about 2.3 million lb/yr of chloride in wastewater was discharged at the INEEL. In 1998, chloride concentrations in most water samples from the INTEC and NRF exceeded 20 mg/L. Chloride concentrations near the INTEC have increased or remained constant because of an increase in disposal rates since 1984. Chloride concentrations in water from wells 113 and CFA-1 were 220 and 108 mg/L, respectively. Chloride concentrations in water from wells near the TRA were less than 20 mg/L. Chloride concentrations in water from wells near the NRF slightly exceeded 20 mg/L, except the concentration in water from well NRF-6, which was 209 mg/L.

During 1996–98, about 0.8 million lb/yr of sulfate was discharged to infiltration ponds and an industrial-waste ditch at the INEEL. During 1998, sulfate concentrations in water from six wells near the NRF, two wells near the TRA, and one well near the RWMC exceeded 40 mg/L, the estimated background concentration of sulfate in the Snake River Plain aquifer at the INEEL.

During 1996–98, an average of 86,700 lb of nitrate was discharged annually to the INTEC infiltration ponds. Nitrate concentrations remained relatively constant or decreased during 1996–98 because of dilution by recharge water and a long-term decrease in disposal. Nitrate concentrations in water from wells 40, 43, 77, and CFA-1 were 14, 31, 18, and 17 mg/L, respectively, in 1998.

During 1996–98, about 3,110 lb of fluoride was discharged to the INTEC infiltration ponds. Concentrations of fluoride in water from wells near the INTEC ranged from 0.2 to 0.3 mg/L. These concentrations are similar to background concentrations for that area.

During 1996–98, concentrations of 1 to 12 different purgeable organic compounds were detected in water from wells at the INEEL. Concentrations of 1,1,1-trichloroethane were above the reporting level in water from all three wells sampled near the INTEC; and water from RWMC wells contained concentrations of 1,1,1-trichloroethane, carbon tetrachloride, chloroform, dichlorodifluoromethane, trichloroethylene, tetrachloroethylene, and toluene. During 1987–89, concentrations of 15 POC's were detected in water from wells near TAN. Of the six wells near TAN that were sampled in 1996–98, water from one well contained concentrations of nine different POC's.

SELECTED REFERENCES

Ackerman, D.J., 1991, Transmissivity of the Snake River Plain aquifer at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 91–4058 (DOE/ID–22097), 35 p.

Anderson, S.R., 1991, Stratigraphy of the unsaturated zone and uppermost part of the Snake River Plain aquifer at the Idaho Chemical Processing Plant and Test Reactors Area, Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 91–4010 (DOE/ID–22095), 71 p.

Anderson, S.R., Ackerman, D.J., Liszewski, M.J., and Freiburger, R.M., 1996, Stratigraphic data for wells at and near the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 96–248 (DOE/ID–22127), 27 p.

Anderson, S.R., Kuntz, M.A., and Davis, L.C., 1999, Geologic controls of hydraulic conductivity in the Snake River Plain aquifer at and near the Idaho National Engineering and Environmental Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 99–4033 (DOE/ID–22155), 38 p.

Barraclough, J.T., and Jensen, R.G., 1976, Hydrologic data for the Idaho National Engineering Laboratory site, Idaho, 1971 to 1973: U.S. Geological Survey Open-File Report 75–318 (IDO–22055), 52 p.

Barraclough, J.T., Lewis, B.D., and Jensen, R.G., 1981, Hydrologic conditions at the Idaho National Engineering Laboratory, Idaho, emphasis: 1974–1978: U.S. Geological Survey Water-Resources Investigations Open-File Report 81–526 (IDO–22060), 77 p.

Barraclough, J.T., Robertson, J.B., and Janzer, V.J., 1976, Hydrology of the solid waste burial ground, as related to the potential migration of radionuclides, Idaho National Engineering Laboratory, *with a section on* Drilling and sample analyses, by L.G. Saindon: U.S. Geological Survey Open-File Report 76–471 (IDO–22056), 183 p.

Barraclough, J.T., Teasdale, W.E., and Jensen, R.G., 1967, Hydrology of the National Reactor Testing Station, Idaho, 1965: U.S. Geological Survey Open-File Report (IDO–22048), 107 p.

Barraclough, J.T., Teasdale, W.E., Robertson, J.B., and Jensen, R.G., 1967, Hydrology of the National Reactor Testing Station, Idaho, 1966: U.S. Geological Survey Open-File Report (IDO–22049), 95 p.

Bartholomay, R.C., 1993, Concentrations of tritium and strontium-90 in water from selected wells at the Idaho National Engineering Laboratory after purging one, two, and three borehole volumes: U.S. Geological Survey Water-Resources Investigations Report 93–4201 (DOE/ID–22111), 21 p.

———1998, Distribution of selected radiochemical and chemical constituents in water from perched ground-water zones, Idaho National Engineering Laboratory, Idaho, 1992–95: U.S. Geological Survey Water-Resources Investigations Report 98–4026 (DOE/ID–22145), 59 p.

Bartholomay, R.C., Hill, G.H., and Randolph, R.B., 1999, Statistical comparison of gross alpha- and gross beta-particle activity in water analyzed using two different laboratory methods: 1999 41st Rocky Mountain Conference on Analytical Chemistry, Denver, Colo., Final program and abstracts, p. 132.

Bartholomay, R.C., Orr, B.R., Liszewski, M.J., and Jensen, R.G., 1995, Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, Snake River Plain aquifer, Idaho National Engineering Laboratory, Idaho, 1989 through 1991: U.S. Geological Survey Water-Resources Investigations Report 95–4175 (DOE/ID–22123), 47 p.

Bartholomay, R.C., Tucker, B.J., Ackerman, D.J., and Liszewski, M.J., 1997, Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, Snake River Plain aquifer, Idaho National Engineering Laboratory, Idaho, 1992 through 1995: U.S. Geological Survey Water-Resources Investigations Report 97–4086 (DOE/ID–22137), 57 p.

Bartholomay, R.C., and Williams, L.M., 1996, Evaluation of preservation methods for selected nutrients in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 96–4260 (DOE/ID–22131), 16 p.

Becker, B.H., Burgess, J.D., Holden, K.J., Jorgensen, D.K., Magnuson, S.O., and Sondrup, A.J., 1998, Interim risk assessment and contaminant screening for the waste area group 7 remedial investigation, Lockheed Martin Idaho Technologies Co. report, DOE/ID–10569, [variously paged].

Bennett, C.M., 1990, Streamflow losses and groundwater level changes along the Big Lost River at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 90–4067 (DOE/ID–22091), 49 p.

Brennan, T.S., Lehmann, A.K., O'Dell, I., and Tungate, A.M., 1997, Water resources data, Idaho, water year 1996—volume 1. Great Basin and Snake River Basin above King Hill: U.S. Geological Survey Water-Data Report ID–96–1, 448 p.

———1998, Water resources data, Idaho, water year 1997—volume 1. Great Basin and Snake River Basin above King Hill: U.S. Geological Survey Water-Data Report ID–97–1, 427 p.

———1999, Water resources data, Idaho, water year 1998—volume 1. Great Basin and Snake River Basin above King Hill: U.S. Geological Survey Water-Data Report ID–98–1, 380 p.

Bunde, R.L., Rosentreter, J.J., and Liszewski, M.J., 1998, Rate of strontium sorption and the effects of variable aqueous concentrations of sodium and potassium on strontium distribution coefficients of a surficial sediment at the Idaho National Engineering Laboratory, Idaho: Environmental Geology, v. 34(2/3), p. 135–142.

Bunde, R.L., Rosentreter, J.J., Liszewski, M.J., Hemming, C.H., and Welhan, J., 1997, Effects of calcium and magnesium on strontium distribution coefficients: Environmental Geology, v. 32, no. 3, p. 219–229.

Busenberg, Eurybiades, Plummer, L.N., Doughten, M.W., Widman, P.K., and Bartholomay, R.C., 2000, Chemical and isotopic composition and gas concentrations of ground and surface water from selected sites at and near the Idaho National Engineering and Environmental Laboratory, Idaho, 1994 through 1997: U.S. Geological Survey Open-File Report 00–81 (DOE/ID–22164), 51 p.

Cassidy, G.B., 1984, Idaho National Engineering Laboratory industrial waste management information for 1983 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10057 (83), 99 p.

Cecil, L.D., Knobel, L.L., Wegner, S.J., and Moore, L.L., 1989, Evaluation of field sampling and preservation methods for strontium-90 in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 89–4146 (DOE/ID–22083), 24 p.

Cecil, L.D., Orr, B.R., Norton, T., and Anderson, S.R., 1991, Formation of perched ground-water zones and concentrations of selected chemical constituents in water, Idaho National Engineering Laboratory, Idaho, 1986–88: U.S. Geological Survey Water-Resources Investigations Report 91–4166 (DOE/ID–22100), 53 p.

Claassen, H.C., 1982, Guidelines and techniques for obtaining water samples that accurately represent the water chemistry of an aquifer: U.S. Geological Survey Open-File Report 82–1024, 49 p.

Currie, L.A., 1984, Lower limit of detection-definition and elaboration of a proposed position for radiological effluent and environmental measurements: U.S. Nuclear Regulatory Commission NUREG/CR–4007, 139 p.

Energy Research and Development Administration, 1977, Waste management operations, Idaho National Engineering Laboratory, Idaho: Final Environmental Impact Statement, ERDA–1536, 719 p.

Faires, L.M., 1992, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—determinations of metals in water by inductively coupled plasma—mass spectrometry: U.S. Geological Survey Open-File Report 92–634, 28 p.

Fishman, M.J., ed., 1993, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—determination of inorganic and organic constituents in water and fluvial sediments: U.S. Geological Survey Open-File Report 93–125, 217 p.

Fishman, M.J., and Friedman, L.C., eds., 1989, Methods for determination of inorganic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A1, 545 p.

French, D.L., Lisee, D.J., and Taylor, K.A., 1997a, Idaho National Engineering and Environmental Laboratory nonradiological waste management information for 1996 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10057 (96), [variously paged].

———1997b, Radioactive waste management information for 1996 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10054 (96), [variously paged].

French, D.L., Tallman, R.E., and Taylor, K.A., 1998, Idaho National Engineering Laboratory nonradiological waste management information for 1997 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10057 (97), [variously paged].

———1999a, Idaho National Engineering and Environmental Laboratory nonradiological waste management information for 1998 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10057 (98), [variously paged].

———1999b, Radioactive waste management information for 1998 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10054 (98), [variously paged].

French, D.L., and Taylor, K.A., 1998, Radioactive waste information for 1997 and record-to-date: U.S. Department of Energy, Waste Management Programs Division, Idaho Operations Office Publication, DOE/ID–10054 (97), [variously paged].

Goerlitz, D.F., and Brown, Eugene, 1972, Methods for analysis of organic substances in water: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 40 p.

Greene, M.J., and Tucker, B.J., 1998, Purgeable organic compounds in water at or near the Idaho National Engineering Laboratory, Idaho, 1992–95: U.S. Geological Survey Open-File Report 98–51 (DOE/ID–22146), 21 p.

Jones, P.H., 1961, Hydrology of waste disposal, National Reactor Testing Station, Idaho, an interim report: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22042–USGS, 152 p.

Knobel, L.L., Bartholomay, R.C., and Orr, B.R., 1997, Preliminary delineation of natural geochemical reactions, Snake River Plain aquifer system, Idaho National Engineering Laboratory and vicinity, Idaho: U.S. Geological Survey Water-Resources Investigations Report 97–4093 (DOE/ID–22139), 52 p.

Knobel, L.L., and Mann, L.J., 1993, Sampling for purgeable organic compounds using positive-displacement piston and centrifugal submersible pumps—a comparative study: Ground Water Monitoring Review, Spring 1993, p. 142–148.

Lewis, B.D., and Jensen, R.G., 1985, Hydrologic conditions at the Idaho National Engineering Laboratory, Idaho, 1979–1981 update: U.S. Geological Survey Hydrologic Investigations Atlas HA–674, 2 sheets.

Liszewski, M.J., and Mann, L.J., 1992, Purgeable organic compounds in ground water at the Idaho National Engineering Laboratory, Idaho, 1990 and 1991: U.S. Geological Survey Open-File Report 92–174 (DOE/ID–22104), 19 p.

Lucius, J.E., Olhoeft, G.R., Hill, P.L., and Duke, S.K., 1989, Properties and hazards of 108 selected substances: U.S. Geological Survey Open-File Report 89–491, 538 p.

Mann, L.J., 1986, Hydraulic properties of rock units and chemical quality of water for INEL-1—a 10,365-foot deep test hole drilled at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations Report 86–4020 (DOE/ID–22070), 23 p.

———1989, Tritium concentrations in flow from selected springs that discharge to the Snake River, Twin Falls-Hagerman area, Idaho: U.S. Geological Survey Water-Resources Investigations Report 89–4156 (DOE/ID–22084), 20 p.

———1990, Purgeable organic compounds in ground water at the Idaho National Engineering Laboratory, Idaho—1988 and 1989: U.S. Geological Survey Open-File Report 90–367 (DOE/ID–22089), 17 p.

———1996, Quality assurance plan and field methods for quality of water activities, U.S. Geological Survey, Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 96–615 (DOE/ID–22132), 37 p.

Mann, L.J., and Beasley, T.M., 1994, Iodine-129 in the Snake River Plain aquifer at and near the Idaho National Engineering Laboratory, Idaho, 1990–91: U.S. Geological Survey Water-Resources Investigations Report 94–4053 (DOE/ID–22115), 27 p.

Mann, L.J., and Cecil, L.D., 1990, Tritium in ground water at the Idaho National Engineering Laboratory: U.S. Geological Survey Water-Resources Investigations Report 90–4090 (DOE/ID–22090), 35 p.

Mann, L.J., and Knobel, L.L., 1987, Purgeable organic compounds in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 87–766 (DOE/ID–22074), 23 p.

———1988, Concentrations of nine trace metals in ground water at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Open-File Report 88–332 (DOE/ID–22075), 17 p.

Mann, L.J., and Low, W.H., 1995, Tritium, stable isotopes and nitrogen in flow from selected springs that discharge to the Snake River, Twin Falls-Hagerman area, Idaho, 1990–93: U.S. Geological Survey Water-Resources Investigations Report 94–4247 (DOE/ID–22119), 21 p.

Morris, D.A., Barraclough, J.T., Chase, G.H., Teasdale, W.E., and Jensen, R.G., 1965, Hydrology of subsurface waste disposal, National Reactor Testing Station, Idaho, annual progress report, 1964: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22047–USGS, 186 p.

Morris, D.A., Barraclough, J.T., Hogenson, G.M., Shuter, Eugene, Teasdale, W.E., Ralston, D.A., and Jensen, R.G., 1964, Hydrology of subsurface waste disposal, National Reactor Testing Station, Idaho, annual progress report, 1963: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22046–USGS, 97 p.

Morris, D.A., Hogenson, G.M., Shuter, Eugene, and Teasdale, W.E., 1963, Hydrology of waste disposal, National Reactor Testing Station, Idaho, annual progress report, 1962: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22044–USGS, 99 p.

Nace, R.L., Voegeli, P.T., Jones, J.R., and Morris, Deutsch, 1975, Generalized geologic framework of the National Reactor Testing Station, Idaho: U.S. Geological Survey Professional Paper 725–B, 49 p.

Olmsted, F.H., 1962, Chemical and physical character of ground water in the National Reactor Testing Station, Idaho: U.S. Atomic Energy Commission, Idaho Operations Office Publication, IDO–22043–USGS, 142 p.

Orr, B.R., and Cecil, L.D., 1991, Hydrologic conditions and distribution of selected chemical constituents in water, Snake River Plain aquifer, Idaho National Engineering Laboratory, Idaho, 1986 to 1988: U.S. Geological Survey Water-Resources Investigations Report 91–4047 (DOE/ID–22096), 56 p.

Orr, B.R., Cecil, L.D., and Knobel, L.L., 1991, Background concentrations of selected radionuclides, organic compounds, and chemical constituents in ground water in the vicinity of the Idaho National Engineering Laboratory: U.S. Geological Survey Water-Resources Investigations Report 91–4015 (DOE/ID–22094), 52 p.

Pittman, J.R., Jensen, R.G., and Fischer, P.R., 1988, Hydrologic conditions at the Idaho National Engineering Laboratory, 1982 to 1985: U.S. Geological Survey Water-Resources Investigations Report 89–4008 (DOE/ID–22078), 73 p.

Robertson, J.B., Schoen, Robert, and Barraclough, J.T., 1974, The influence of liquid waste disposal on the geochemistry of water at the National Reactor Testing Station, Idaho, 1952-1970: U.S. Geological Survey Open-File Report (IDO–22053), 231 p.

Sehlke, G., and Bickford, F.E., 1993, Idaho National Engineering Laboratory ground-water monitoring plan: EG&G Idaho, Inc., and Golder Associates, Inc., DOE/ID–10441, vol. 1–2, [variously paged].

Stevens, H.H., Jr., Ficke, J.F., and Smoot, G.F., 1975, Water temperature—influential factors, field measurement, and data presentation: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. D1, 65 p.

Timme, P.J., 1995, National Water Quality Laboratory, 1995 services catalog: U.S. Geological Survey Open-File Report 95–352, 120 p.

Tucker, B.J., and Orr, B.R., 1998, Distribution of selected radiochemical and chemical constituents in perched ground water, Idaho National Engineering Laboratory, Idaho, 1989–91, U.S. Geological Survey Water-Resources Investigations Report 98–4028 (DOE/ID–22144), 62 p.

U.S. Environmental Protection Agency, 1998, Protection of environment-Code of Federal Regulations 40: Washington, D.C., Office of the Federal Register, National Archives and Records Administration, Parts 136 to 149, 808 p.

U.S. Geological Survey, 1985, National water summary, 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, 467 p.

Walker, E.H., 1964, Subsurface geology of the National Reactor Testing Station, Idaho: U.S. Geological Survey Bulletin 1133–E, 22 p.

Walker, F.W., Parrington, J.R., and Feiner, Frank, 1989, Nuclides and isotopes, chart of the nuclides (14th ed.): General Electric Company, Nuclear Energy Operations, 57 p.

Wegner, S.J., 1989, Selected quality assurance data for water samples collected by the U.S. Geological Survey, Idaho National Engineering Laboratory, 1980 to 1988: U.S. Geological Survey Water-Resources Investigations Report 89–4168 (DOE/ID–22085), 91 p.

Wershaw, R.L., Fishman, M.J., Grabbe, R.R., and Lowe, L.E., 1987, Methods for the determination of organic substances in water and fluvial sediments: U.S. Geological Survey Techniques of Water-Resources Investigations, book 5, chap. A3, 80 p.

Wilde, F.D., Radtke, D.B., Gibs, Jacob, and Iwatsubo, R.T., 1998, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations Report [variously paged].

Williams, L.M., 1996, Evaluation of quality assurance/quality control data collected by the U.S. Geological Survey for water-quality activities at the Idaho National Engineering Laboratory, Idaho, 1989 through 1993: U.S. Geological Survey Water-Resources Investigations Report 96–4148 (DOE/ID–22129), 115 p.

——1997, Evaluation of quality assurance/quality control data collected by the U.S. Geological Survey for water-quality activities at the Idaho National Engineering Laboratory, Idaho, 1994 through 1995: U.S. Geological Survey Water-Resources Investigations Report 97–4058 (DOE/ID–22136), 87 p.

Williams, L.M., Bartholomay, R.C., and Campbell, L.J., 1998, Evaluation of quality-assurance/quality control data collected by the U.S. Geological Survey from wells and springs between the southern boundary of the Idaho National Engineering and Environmental Laboratory and the Hagerman Area, Idaho, 1989 through 1995: U.S. Geological Survey Water-Resources Investigations Report 98–4206 (DOE/ID–22150), 83 p.

Wood, W.W., 1981, Guidelines for collection and field analysis of ground-water samples for selected unstable constituents: U.S. Geological Survey Techniques of Water-Resources Investigations, book 1, chap. D2, 24 p.

Table 1. Well location, construction, and sample-collection method and frequency, Snake River Plain aquifer, Idaho National Engineering and Environmental Laboratory

[Status of wells as of October 1998. Well identifier: see figures 4 and 5 for well locations. Sampling method: Tap, sampled from faucet; Pump, sampled from pumping well (pumping rate in gallons per minute); Sampling frequency: A, annual; S, semiannual; Q, quarterly]

Well identifier	Location		Well construction		Water-sample collection	
	Latitude	Longitude	Diameter (inches)	Depth (feet)	Method	Frequency
ANP-6	43°53'08"	112°45'41"	12	305	Pump (45)	A
ANP-9	43°48'56"	112°40'00"	12	322	Pump (20)	S
Arbor Test	43°35'09"	112°38'48"	16	790	Pump (20)	S
AREA II	43°22'23"	112°47'02"	16	877	Pump (18)	A
Atomic City	43°26'38"	112°48'41"	8	639	Tap	S
Badging Facility	43°30'42"	112°53'51"	8	644	Pump (35)	A
CFA-1	43°32'04"	112°56'20"	16	685	Pump (1,000)	Q
CFA-2	43°31'44"	112°56'35"	20	681	Pump (1,400)	Q
CFA LF 2-10	43°32'16"	112°56'33"	6	765	Pump (8.3)	S
CFA LF 3-9	43°32'16"	112°57'10"	4	500	Pump (7.5)	A
CFA LF 3-11	43°32'49"	112°56'55"	4	492	Well disabled	A
CPP-1	43°34'33"	112°56'02"	20	585	Pump (3,000)	S
CPP-2	43°34'32"	112°56'08"	16	605	Pump (3,000)	S
CPP-4	43°34'40"	112°55'44"	16	700	Pump (400)	S
CPP-5	43°34'40"	112°55'44"	16	721	Pump (200)	S
EBR-1	43°30'51"	113°00'26"	12	1,075	Pump (25)	S
Hwy 3	43°32'56"	113°00'25"	8	750	Tap	S
IET	43°51'53"	112°42'05"	20	324	Pump (46)	A
INEL-1-WS	43°37'16"	112°56'36"	8	595	Pump (30)	S
Leo Rogers	43°25'33"	112°50'49"	20	702	Pump (20)	A
MTR Test	43°35'20"	112°57'26"	8	588	Pump (26)	S
NPR Test	43°34'49"	112°52'31"	6	599	Pump (28)	S
PSTF	43°49'41"	112°45'42"	16	322	Pump (44)	S
P&W 2	43°54'19"	112°45'31"	10	386	Pump (35)	S
RWMC M3S	43°30'08"	113°02'18"	6	633	Pump (3.7)	A
RWMC M7S	43°30'23"	113°01'48"	6	638	Pump (4.1)	A
RWMC Production	43°30'02"	113°02'17"	16	683	Pump (200)	Q
Site 4	43°36'17"	112°54'20"	15	496	Pump (500)	S
Site 9	43°31'23"	112°53'01"	10	1,057	Pump (25)	A
Site 14	43°43'34"	112°46'31"	10	717	Pump (40)	S
Site 17	43°40'27"	112°57'57"	20	600	Pump (25)	A
Site 19	43°35'22"	112°58'21"	12	865	Pump (30)	A

Table 1. Well location, construction, and sample-collection method and frequency, Snake River Plain aquifer, Idaho National Engineering and Environmental Laboratory—*continued*

Well identifier	Location		Well construction		Water-sample collection	
	Latitude	Longitude	Diameter (inches)	Depth (feet)	Method	Frequency
SPERT-1	43°32'52"	112°52'03"	24	653	Pump (400)	S
TAN Expl.	43°50'38"	112°45'34"	12	550	Pump (42)	S
TRA 1	43°35'21"	112°57'38"	20	600	Pump (3,400)	A
TRA 3	43°35'22"	112°57'35"	20	602	Pump (3,800)	A
TRA 4	43°35'21"	112°57'42"	20	975	Pump (2,000)	A
TRA Disposal	43°35'06"	112°57'23"	12	1,267	Pump (25)	S
USGS 1	43°27'00"	112°47'08"	6	636	Pump (19)	S
USGS 2	43°33'20"	112°43'23"	5	704	Pump (16)	A
USGS 4	43°46'57"	112°28'22"	6	553	Pump (40)	S
USGS 5	43°35'43"	112°49'38"	6	500	Pump (5)	S
USGS 6	43°40'31"	112°45'37"	6	620	Pump (25)	A
USGS 7	43°49'15"	112°44'39"	4	1,200	Pump (45)	S
USGS 8	43°31'21"	113°11'58"	6	812	Pump (16)	S
USGS 9	43°27'40"	113°04'45"	8	655	Pump (19)	S
USGS 11	43°23'36"	113°06'42"	12	704	Pump (23)	S
USGS 12	43°41'26"	112°55'07"	10	560	Pump (32)	S
USGS 14	43°20'19"	112°55'07"	6	751	Pump (16)	S
USGS 15	43°42'34"	112°55'17"	10	640	Pump (40)	A
USGS 17	43°39'37"	112°51'54"	6	498	Pump (32)	S
USGS 18	43°45'40"	112°44'09"	4	329	Pump (30)	A
USGS 19	43°44'26"	112°57'57"	6	405	Pump (33)	S
USGS 20	43°32'53"	112°54'59"	6	676	Pump (30)	S
USGS 22	43°34'22"	113°03'17"	6	657	Pump (2.5)	S
USGS 23	43°40'55"	113°59'59"	6	467	Pump (25)	S
USGS 26	43°52'12"	112°39'40"	8	266	Pump (40)	S
USGS 27	43°48'51"	112°32'18"	8	312	Pump (20)	S
USGS 29	43°44'07"	113°28'51"	6	422	Pump (32)	A
USGS 31	43°46'25"	112°34'21"	8	428	Pump (40)	A
USGS 32	43°44'44"	112°32'21"	6	392	Pump (28)	A
USGS 34	43°33'34"	112°56'55"	10	700	Pump (30)	S
USGS 35	43°33'39"	112°56'58"	7	578	Pump (25)	S
USGS 36	43°33'30"	112°56'52"	6	567	Pump (25)	Q
USGS 37	43°33'26"	112°56'48"	8	573	Pump (25)	S
USGS 38	43°33'22"	112°56'43"	8	729	Pump (4)	S

Table 1. Well location, construction, and sample-collection method and frequency, Snake River Plain aquifer, Idaho National Engineering and Environmental Laboratory—*continued*

Well identifier	Location		Well construction		Water-sample collection	
	Latitude	Longitude	Diameter (inches)	Depth (feet)	Method	Frequency
USGS 39	43°33'43"	112°57'00"	6	572	Pump (25)	Q
USGS 40	43°34'11"	112°56'11"	6	483	Pump (8)	Q
USGS 41	43°34'09"	112°56'13"	6	674	Pump (25)	S
USGS 42	43°34'04"	112°56'13"	6	678	Pump (25)	S
USGS 43	43°34'15"	112°56'15"	6	676	Pump (6)	S
USGS 44	43°34'09"	112°56'21"	6	650	Pump (25)	S
USGS 45	43°34'02"	112°56'18"	6	651	Pump (25)	S
USGS 46	43°34'07"	112°56'15"	6	651	Pump (25)	S
USGS 47	43°34'07"	112°56'03"	6	652	Pump (8)	S
USGS 48	43°34'01"	112°56'03"	6	750	Pump (29)	S
USGS 51	43°33'50"	112°56'06"	6	659	Pump (4)	S
USGS 52	43°34'14"	112°55'42"	6	650	Pump (30)	S
USGS 57	43°33'44"	112°56'26"	6	732	Pump (30)	Q
USGS 58	43°35'00"	112°57'25"	6	503	Pump (26)	S
USGS 59	43°33'54"	112°55'47"	6	657	Pump (1)	S
USGS 65	43°34'47"	112°57'45"	6	498	Pump (8)	Q
USGS 67	43°33'44"	112°55'41"	6	698	Pump (8)	S
USGS 76	43°34'25"	112°57'32"	6	718	Pump (29)	S
USGS 77	43°33'15"	112°56'03"	6	610	Pump (25)	S
USGS 79	43°35'05"	112°58'19"	6	702	Pump (30)	S
USGS 82	43°34'01"	112°55'10"	8	700	Pump (25)	Q
USGS 83	43°30'23"	112°56'15"	6	752	Pump (28)	S
USGS 84	43°33'56"	112°57'42"	6	505	Pump (5)	S
USGS 85	43°32'46"	112°57'12"	6	637	Pump (23)	S
USGS 86	43°29'35"	113°08'00"	8	691	Pump (19)	S
USGS 87	43°30'13"	113°02'42"	6	673	Pump (2)	Q
USGS 88	43°29'40"	113°03'02"	6	662	Pump (2)	Q
USGS 89	43°30'05"	113°03'28"	6	646	Pump (5)	Q
USGS 90	43°29'54"	113°02'05"	6	626	Pump (4)	Q
USGS 97	43°38'07"	112°55'15"	4	510	Pump (27)	S
USGS 98	43°36'57"	112°56'36"	6	505	Pump (25)	S
USGS 99	43°37'05"	112°55'21"	6	450	Pump (25)	S
USGS 100	43°35'03"	112°40'07"	6	750	Pump (10)	S
USGS 101	43°32'55"	112°38'18"	6	865	Pump (13)	S

Table 1. Well location, construction, and sample-collection method and frequency, Snake River Plain aquifer, Idaho National Engineering and Environmental Laboratory—*continued*

Well identifier	Location		Well construction		Water-sample collection	
	Latitude	Longitude	Diameter (inches)	Depth (feet)	Method	Frequency
USGS 102	43°38'53"	112°55'16"	6	760	Pump (29)	A
USGS 103	43°27'14"	112°56'07"	8	445	Pump (21)	Q
USGS 104	43°28'56"	112°56'08"	8	700	Pump (26)	Q
USGS 105	43°27'03"	113°00'18"	8	800	Pump (24)	S
USGS 106	43°29'59"	112°59'31"	8	760	Pump (24)	S
USGS 107	43°29'42"	112°53'28"	8	690	Pump (30)	S
USGS 108	43°26'59"	112°58'26"	8	760	Pump (24)	S
USGS 109	43°27'01"	113°02'56"	6	800	Pump (22)	S
USGS 110A	43°27'17"	112°50'15"	10	644	Pump (24)	S
USGS 111	43°33'31"	112°56'05"	8	595	Pump (15)	S
USGS 112	43°33'14"	112°56'30"	8	563	Pump (30)	Q
USGS 113	43°33'14"	112°56'18"	6	564	Pump (25)	Q
USGS 114	43°33'18"	112°55'50"	6	562	Pump (10)	Q
USGS 115	43°32'20"	112°55'41"	6	581	Pump (5)	Q
USGS 116	43°33'31"	112°55'32"	6	580	Pump (20)	Q
USGS 117	43°29'55"	113°02'59"	8	655	Pump (12)	Q
USGS 119	43°29'45"	113°02'34"	8	705	Pump (3)	Q
USGS 120	43°29'19"	113°03'15"	8	705	Pump (27)	Q
USGS 121	43°34'50"	112°56'03"	8	475	Pump (8)	S
USGS 123	43°33'52"	112°56'14"	8	481	Pump (3)	S
USGS 124	43°23'07"	112°58'31"	4	800	Pump (19)	S
USGS 125	43°26'02"	113°05'28"	10	760	Pump (21)	S

Table 2. Tritium concentrations in water from selected wells at the Idaho National Engineering and Environmental Laboratory, 1980–98

[Location of wells shown on figures 4 and 5. Concentrations and associated uncertainties in picocuries per milliliter. Analytical uncertainties are reported as 1 times the sample standard deviation. NS, not sampled; --, no data, well drilled in 1984]

Well CFA-1		Well 38		Well 47	
Date	Concentration	Date	Concentration	Date	Concentration
10/21/80	41.0±0.6	10/17/80	87.8±1.1	10/13/80	27.9±0.6
10/13/81	35.6±0.6	10/08/81	77.5±0.8	10/08/81	27.9±0.6
10/11/82	33.1±0.6	10/07/82	74.1±0.8	10/07/82	15.3±0.4
10/06/83	31.5±0.6	10/13/83	70.9±0.9	10/17/83	73.0±0.9
10/12/84	33.8±1.2	10/09/84	66.7±0.9	10/23/84	14.0±0.5
10/25/85	32.4±0.8	10/28/85	55.8±1.7	10/29/85	12.0±0.6
10/31/86	34.8±1.1	11/18/86	59.5±1.7	10/29/86	5.8±0.4
10/15/87	32.1±1.0	10/16/87	65.9±1.9	10/26/87	3.5±0.4
10/28/88	27.3±0.7	11/07/88	53.2±1.1	9/30/88	3.5±0.3
10/26/89	22.0±0.6	10/31/89	40.2±0.9	10/19/89	5.0±0.3
10/15/90	17.2±0.5	10/05/90	31.9±0.8	10/31/90	7.5±0.4
10/10/91	21.1±0.6	10/03/91	26.3±0.7	10/24/91	6.2±0.3
10/08/92	16.4±0.5	10/14/92	21.3±0.6	10/21/92	10.8±0.4
10/93	NS	10/23/93	16.2±0.7	10/26/93	6.0±0.4
10/94	NS	10/14/94	15.1±0.7	10/19/94	9.9±0.5
10/11/95	13.4±0.6	10/12/95	13.0±0.6	10/16/95	7.6±0.4
10/16/96	17.8±0.8	10/25/96	11.8±0.6	10/21/96	13.6±0.7
10/21/97	14.2±0.6	10/09/97	8.2±0.4	10/14/97	9.7±0.5
10/19/98	12.6±0.6	10/19/98	7.9±0.4	10/28/98	4.6±0.3

Well 59		Well 77		Well 111	
Date	Concentration	Date	Concentration	Date	Concentration
10/24/80	31.5±0.6	10/13/80	93.7±1.1		--
10/06/81	29.7±0.6	10/05/81	79.9±0.8		--
10/06/82	25.2±0.4	9/30/82	81.5±0.8		--
10/13/83	59.7±0.9	10/04/83	63.5±0.9		--
10/10/84	14.1±0.5	10/09/84	70.5±0.9		--
10/30/85	42.0±1.3	10/29/85	46.3±1.4	11/05/85	29.5±1.0
11/14/86	16.7±0.7	11/13/86	70.0±1.7	10/27/86	49.2±1.4
10/06/87	3.6±0.4	10/20/87	60.2±1.7	9/25/87	57.5±1.7
10/21/88	3.3±0.3	11/06/88	50.5±1.0	10/04/88	37.6±0.8
10/23/89	2.4±0.2	10/30/89	41.2±0.9	10/04/89	29.4±0.7
10/12/90	6.7±0.3	10/25/90	40.7±0.9	9/24/90	32.9±0.8
10/21/91	19.3±0.6	10/09/91	41.7±1.0	10/25/91	18.3±0.6
10/23/92	5.6±0.6	10/09/92	36.8±0.9	10/09/92	16.0±0.5
10/25/93	3.4±0.3	10/23/93	31.5±1.2	10/21/93	13.0±0.6
11/01/94	3.5±0.3	10/07/94	28.7±1.1	10/13/94	10.5±0.5
10/23/95	13.0±0.6	10/24/95	25.1±1.0	10/26/95	7.0±0.4
10/29/96	3.1±0.3	10/17/96	24.0±1.0	10/17/96	8.2±0.5
10/22/97	2.5±0.2	10/16/97	18.2±0.7	10/28/97	7.8±0.4
10/27/98	1.9±0.2	10/13/98	18.2±0.7	10/26/98	6.4±0.3

Table 3. Strontium-90 concentrations in water from selected wells at the Idaho National Engineering and Environmental Laboratory, 1980–98

[Location of wells shown on figures 4 and 5. Concentrations and associated uncertainties in picocuries per liter. Analytical uncertainties are reported as 1 times the sample standard deviation. QA, quality assurance replicate; --, no data, well drilled in 1984]

Well 36		Well 37		Well 38		Well 45	
Date	Concentration	Date	Concentration	Date	Concentration	Date	Concentration
10/17/80	17±2	10/13/80	22±3	10/17/80	22±3	10/24/80	23±3
10/08/81	24±2	10/07/81	25±3	10/08/81	28±3	10/06/81	71±5
10/07/82	10±2	10/07/82	30±3	10/07/82	27±3	10/06/82	79±5
10/13/83	15±2	10/10/83	26±3	10/13/83	12±2	10/12/83	37±3
10/09/84	32±4	10/10/84	17±2	10/09/84	26±4	10/09/84	2±2
10/28/85	40±4	10/28/85	18±3	10/28/85	14±2	10/29/85	6±2
11/18/86	10±2	10/27/86	21±2	11/18/86	13±2	11/14/86	5±2
10/16/87	33±3	10/05/87	17±2	10/16/87	13±2	10/20/87	2.8±1.4
11/07/88	16±2	10/07/88	14±2	11/07/88	32±3	11/06/88	0±2
10/31/89	25±3	9/29/89	16±2	10/31/89	9±2	11/02/89	0.4±1.6
10/25/90	17±2	10/17/90	14±2	10/05/90	22±3	10/26/90	14±2
10/08/91	14±3	10/07/91	-3±2	10/03/91	9±3	10/09/91	16±2
10/28/92	16±2	10/02/92	11±2	10/14/92	27±3	11/13/92	1.1±2.0
10/20/93	14±3	10/21/93	20±3	10/23/93	25±3	11/01/93	8±2
10/13/94	14±2	10/07/94	13±2	10/14/94	27±3	10/17/94	2.2±1.6
10/11/95	8.7±1.0	10/11/95	0.3±1.1	10/12/95	23.5±1.4	10/11/95	1.6±0.9
10/23/96	11.8±1.0	10/24/96	9.1±1	10/25/96	26±1.4	10/11/95	12±2 QA
10/07/97	13.4±1.1	10/08/97	9.9±1.2	10/09/97	22±2	10/29/96	1.9±1
10/15/98	12.9±0.8	10/15/98	13.4±1	10/19/98	20.7±1.1	10/16/97	1.1±0.8
						10/14/98	2.1±0.6

Well 47		Well 57		Well 113	
Date	Concentration	Date	Concentration	Date	Concentration
10/13/80	107±6	10/24/80	88±5		
10/08/81	79±5	10/05/81	93±6		--
10/07/82	60±4	10/06/82	90±5		--
10/17/83	130±7	10/13/83	83±5		--
10/23/84	61±4	10/10/84	66±5		--
10/29/85	63±5	10/29/85	74±5	11/01/85	30±3
10/29/86	56±4	11/14/86	42±3	10/27/86	27±3
10/26/87	54±3	10/09/87	49±3	10/02/87	28±3
9/30/88	48±3	10/05/88	41±3	9/27/88	27±3
10/19/89	59±4	12/22/89	45±4	10/06/89	20±2
10/31/90	51±4	10/29/90	41±4	10/03/90	16±3
10/24/91	55±4	10/24/91	40±4	10/08/91	23±2
10/21/92	56±4	10/06/92	41±4	10/22/92	16±2
10/26/93	54±4	10/12/93	36±3	10/23/93	13±3
10/19/94	55±4	10/03/94	27±3	10/17/94	14±2
10/16/95	76±3	10/11/95	29.2±1.5	10/17/95	14.1±1.0
10/16/95	47±2 QA	10/18/96	30.5±1.5	10/18/96	14.8±1.1
10/21/96	58±2	10/14/97	18.5±1.6	10/16/97	13±1.5
10/14/97	41.8±1.6	10/06/98	20.8±1.1	10/15/98	12.2±0.9
10/28/98	41.1±1.5				
10/28/98	43.9±1.6QA				

Table 4. Sodium concentrations in water from selected wells at the Idaho National Engineering and Environmental Laboratory, 1981–98

[Location of wells shown on figures 4 and 5. Concentrations and associated uncertainties in milligrams per liter. NS, not sampled; --, no data, well drilled in 1984]

Well CFA-1		Well 37		Well 40		Well 47	
Date	Concentration	Date	Concentration	Date	Concentration	Date	Concentration
10/13/81	21	10/07/81	34	10/12/81	94	10/08/81	21
10/11/82	16	10/07/82	30	10/07/82	69	10/07/82	15
10/06/83	10	10/10/83	37	10/10/83	46	10/17/83	52
10/12/84	14	10/10/84	34	10/16/84	33	10/23/84	22
10/25/85	15	10/28/85	31	10/29/85	18	10/29/85	18
10/31/86	22	10/27/86	28	10/30/86	15	10/29/86	12
10/15/87	26	10/05/87	33	10/13/87	13	10/26/87	11
10/28/88	15	10/07/88	19	11/09/88	11	9/30/88	12
10/26/89	26	9/89	NS	10/18/89	12	10/19/89	13
10/15/90	17	10/17/90	32	10/16/90	14	10/31/90	15
10/10/91	26	10/07/91	31	10/29/91	16	10/24/91	14
10/08/92	26	10/02/92	38	11/17/92	16	10/21/92	18
10/93	NS	10/21/93	45	10/08/93	16	10/26/93	15
10/94	NS	10/07/94	46	10/18/94	15	10/19/94	19
10/11/95	30	10/11/95	41	10/19/95	20	10/16/95	17
10/16/96	18	10/24/96	42	10/17/96	15	10/21/96	22
10/21/97	24	10/08/97	48	10/20/97	11	10/14/97	19
10/19/98	27	10/15/98	50	10/07/98	12	10/28/98	15

Well 57		Well 59		Well 111		Well 113	
Date	Concentration	Date	Concentration	Date	Concentration	Date	Concentration
10/81	NS	10/06/81	19				
10/06/82	51	10/06/82	17		--		--
10/13/83	24	10/13/83	28		--		--
10/10/84	45	10/10/84	17		--		--
10/29/85	36	10/30/85	45	11/05/85	15	11/01/85	41
11/14/86	28	11/14/86	37	10/27/86	25	10/27/86	43
10/09/87	31	10/06/87	12	9/25/87	27	10/02/87	49
10/05/88	27	10/21/88	5	10/04/88	28	9/27/88	41
12/22/89	29	10/23/89	12	10/89	NS	10/89	NS
10/29/90	38	10/12/90	21	9/24/90	33	10/03/90	71
10/24/91	42	10/21/91	75	10/25/91	22	10/08/91	64
10/06/92	59	10/23/92	36	10/09/92	28	10/22/92	81
10/12/93	72	10/25/93	23	10/21/93	33	10/23/93	87
10/03/94	69	11/01/94	25	10/13/94	32	10/17/94	90
10/11/95	62	10/23/95	65	10/26/95	23	10/17/95	79
10/18/96	78	10/29/96	38	10/17/96	39	10/18/96	93
10/14/97	78	10/22/97	36	10/28/97	40	10/16/97	94
10/06/98	69	10/27/98	14	10/26/98	39	10/15/98	96

Table 5. Chloride concentrations in water from selected wells at the Idaho National Engineering and Environmental Laboratory, 1980–98

[Location of wells shown on figures 4 and 5. Concentrations in milligrams per liter. NS, not sampled; --, no data, well drilled in 1984]

Well CFA-1		Well 37		Well 40		Well 47	
Date	Concentration	Date	Concentration	Date	Concentration	Date	Concentration
10/21/80	80	10/13/80	72	10/13/80	210	10/13/80	54
10/13/81	82	10/07/81	66	10/12/81	150	10/08/81	48
10/11/82	86	10/07/82	85	10/07/82	150	10/07/82	32
10/06/83	78	10/10/83	59	10/10/83	150	10/17/83	160
10/12/84	53	10/10/84	53	10/16/84	44	10/23/84	27
10/25/85	51	10/28/85	37	10/29/85	23	10/29/85	21
10/31/86	78	10/27/86	50	10/30/86	23	10/29/86	23
10/15/87	83	10/05/87	70	10/13/87	24	10/26/87	23
10/28/88	86	10/07/88	86	11/09/88	23	9/30/88	23
10/26/89	93	9/29/89	92	10/18/89	23	10/19/89	24
10/15/90	86	10/17/90	78	10/16/90	27	10/31/90	31
10/10/91	100	10/07/91	75	10/29/91	31	10/24/91	30
10/08/92	100	10/02/92	120	11/17/92	29	10/21/92	36
10/93	NS	10/21/93	140	10/08/93	30	10/26/93	31
10/94	NS	10/07/94	140	10/18/94	30	10/19/94	38
10/11/95	100	10/11/95	100	10/19/95	37	10/16/95	35
10/16/96	70	10/24/96	120	10/17/96	27	10/21/96	44
10/21/97	100	10/08/97	138	10/20/97	21	10/14/97	38
10/19/98	108	10/15/98	147	10/07/98	19	10/28/98	26

Well 57		Well 59		Well 111		Well 113	
Date	Concentration	Date	Concentration	Date	Concentration	Date	Concentration
10/24/80	80	10/24/80	37				
10/81	118	10/06/81	37		--		--
10/06/82	140	10/06/82	47		--		--
10/13/83	130	10/13/83	60		--		--
10/10/84	64	10/10/84	28		--		--
10/29/85	42	10/30/85	40	11/05/85	50	11/01/85	67
11/14/86	64	11/14/86	35	10/27/86	100	10/27/86	110
10/09/87	67	10/06/87	23	9/24/87	120	10/02/87	150
10/05/88	74	10/21/88	24	10/04/88	120	9/27/88	160
12/22/89	67	10/23/89	22	10/04/89	120	10/06/89	160
10/29/90	85	10/12/90	44	9/24/90	140	10/03/90	180
10/24/91	120	10/21/91	190	10/25/91	110	10/08/91	170
10/06/92	160	10/23/92	67	10/09/92	130	10/22/92	200
10/12/93	180	10/25/93	44	10/21/93	140	10/23/93	220
10/03/94	170	11/01/94	47	10/13/94	130	10/17/94	210
10/11/95	150	10/23/95	150	10/26/95	100	10/17/95	190
10/18/96	200	10/29/96	75	10/17/96	160	10/18/96	230
10/14/97	185	10/22/97	71	10/28/97	159	10/16/97	238
10/06/98	161	10/27/98	29	10/26/98	145	10/15/98	220