HYDROLOGIC CONDITIONS AND DISTRIBUTION OF SELECTED CHEMICAL CONSTITUENTS IN WATER, SNAKE RIVER PLAIN AQUIFER, IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO, 1986 TO 1988

By Brennon R. Orr and L. DeWayne Cecil

U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS REPORT 91-4047

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

Idaho Falls, Idaho
March 1991

U.S. DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATED UNITS

Multiply	By	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
acre	0.4047	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)	0.1646	meter per kilometer
cubic foot per second per mile ((ft^3/s)/mi)	0.01760	cubic meter per second per kilometer
pound (lb)	0.4536	kilogram
curie (Ci)	3.7×10^{10}	becquerel
picocurie per milliliter (pCi/mL)	0.037	becquerel per milliliter
picocurie per liter (pCi/L)	0.037	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 both the 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).

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ABSTRACT

Detectable concentrations of radionuclide- and chemical-waste constituents in water from the Snake River Plain aquifer at the Idaho National Engineering Laboratory decreased during 1986-88. Decreased radionuclide concentrations are attributed to reduced rates of radionuclide-waste disposal, sorption processes, radioactive decay, dilution from recharge, and changes in waste-disposal practices.

Tritium concentrations in aquifer water decreased as much as 39 pCi/mL (picocuries per milliliter) during 1986-88 and ranged from 0.7±0.2 to 61.6±1.1 pCi/mL in 1988. Strontium-90 concentrations decreased as much as 33 pCi/L (picocuries per liter) during 1986-88 and ranged from 8±2 to 48±3 pCi/L in 1988. Cobalt-60 and cesium-137 concentrations exceeded the reporting level in water from only one well during 1986-88.

In 1988, concentrations of plutonium-238 and plutonium-239, -240 (undivided) in water from the Test Area North disposal well were 0.19±0.05 pCi/L and 0.96±0.08 pCi/L, respectively. The concentration of plutonium-238 in well CFA-1 was 0.11±0.03 pCi/L in 1987. In subsequent samples, concentrations were less than the reporting level.

Sodium, chloride, and nitrate plumes originating from the Idaho Chemical Processing Plant decreased in size since use of the ICPP disposal well was discontinued in 1984. During 1986-88, the approximate areal extent of the sodium plume decreased from 6.8 to 2.5 square miles, the chloride plume decreased from 17 to 5.2 square miles, and the nitrate plume decreased from 14 to 5 square miles. In 1987, water from wells 65 and 89 contained

280 and 50 μg/L, respectively, of chromium; other water samples contained from less than 1 to 30 μg/L.

INTRODUCTION

The INEL (Idaho National Engineering Laboratory), 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. INEL facilities are used in the development of peacetime atomic-energy applications, nuclear safety research, defense programs, and advanced energy concepts. Liquid radionuclide and chemical wastes generated at these facilities have been discharged to onsite infiltration ponds and disposal wells since 1952. Liquid-waste disposal has resulted in detectable concentrations of several waste constituents in water in the Snake River Plain aquifer underlying the INEL.

The U.S. Department of Energy requires information about the mobility of dilute radionuclide- and chemical-waste constituents in the Snake River Plain aquifer. Waste-constituent mobility is, in part, determined 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 in cooperation with the U.S. Department of Energy's Idaho Operations Office.

Purpose and Scope

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

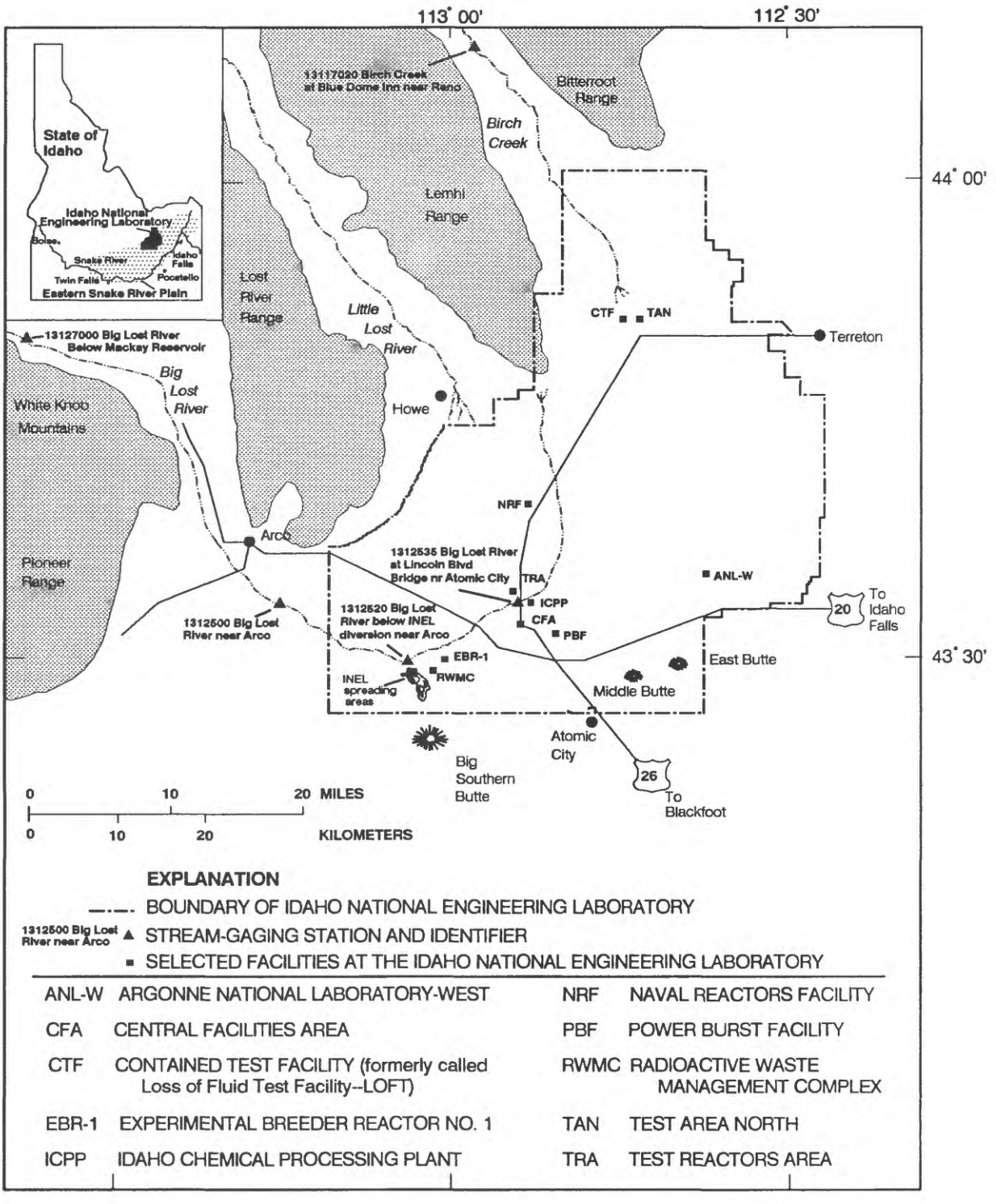

Figure 1.--Location of the Idaho National Engineering Laboratory.

This report presents an analysis of water-level and water-quality data collected from the Snake River Plain aquifer during 1986-88 as part of the continuing hydrogeologic investigation at the INEL. The report describes the distribution and concentration of selected radionuclide and chemical constituents in ground water from disposal of wastes at the INEL. An analysis of water-level and water-quality data collected during 1986-88 from perched ground-water zones in unsaturated rocks overlying the Snake River Plain aquifer will be presented in a separate report (L.D. Cecil, written commun., 1991).

Acknowledgments

The U.S. Department of Energy's RESL (Radiological and Environmental Sciences Laboratory) provided radionuclide analyses of water samples. Technical staff at the RESL are under the supervision of T.F. Gesell, Director, and D.B. Martin, Chief, Analytical Chemistry Branch.

Ground-Water Monitoring Networks

Ground-water monitoring networks are maintained at the INEL 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 a series of wells from which periodic water-level and water-quality data are obtained. Data from the monitoring networks are on file at the Geological Survey's INEL Project Office.

Water-level monitoring network.--The INEL 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 were monitored during 1986-88 in 120 wells. Water levels were measured continuously in 7 wells, monthly in 5 wells, quarterly in 55 wells, semiannually in 28 wells, and annually in

25 wells. The location of observation wells and the frequency of water-level measurements are shown on 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 from nearby surface-water sites and from wells in perched ground-water zones is sampled to document the chemical quality of water that recharges the aquifer. Numerous water samples are collected near areas of detailed study, such as TRA (Test Reactors Area), ICPP (Idaho Chemical Processing Plant), RWMC (Radioactive Waste Management Complex), and TAN (Test Area North).

The type, frequency, and depth of ground-water sampling generally depend on the information needed in a specific area. Water samples 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, total chromium, sodium, chloride, nitrate, specific conductance, and 27 other chemical constituents or physical properties. During 1986-88, 1,107 water samples were collected for radionuclide and chemical analyses. The location of wells that constituted the water-quality monitoring network for the Snake River Plain aquifer at the INEL during 1986-88 and frequency of sample collection are shown in figures 4 and 5 and in table 1.

Guidelines for Interpreting Analytical Results

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).

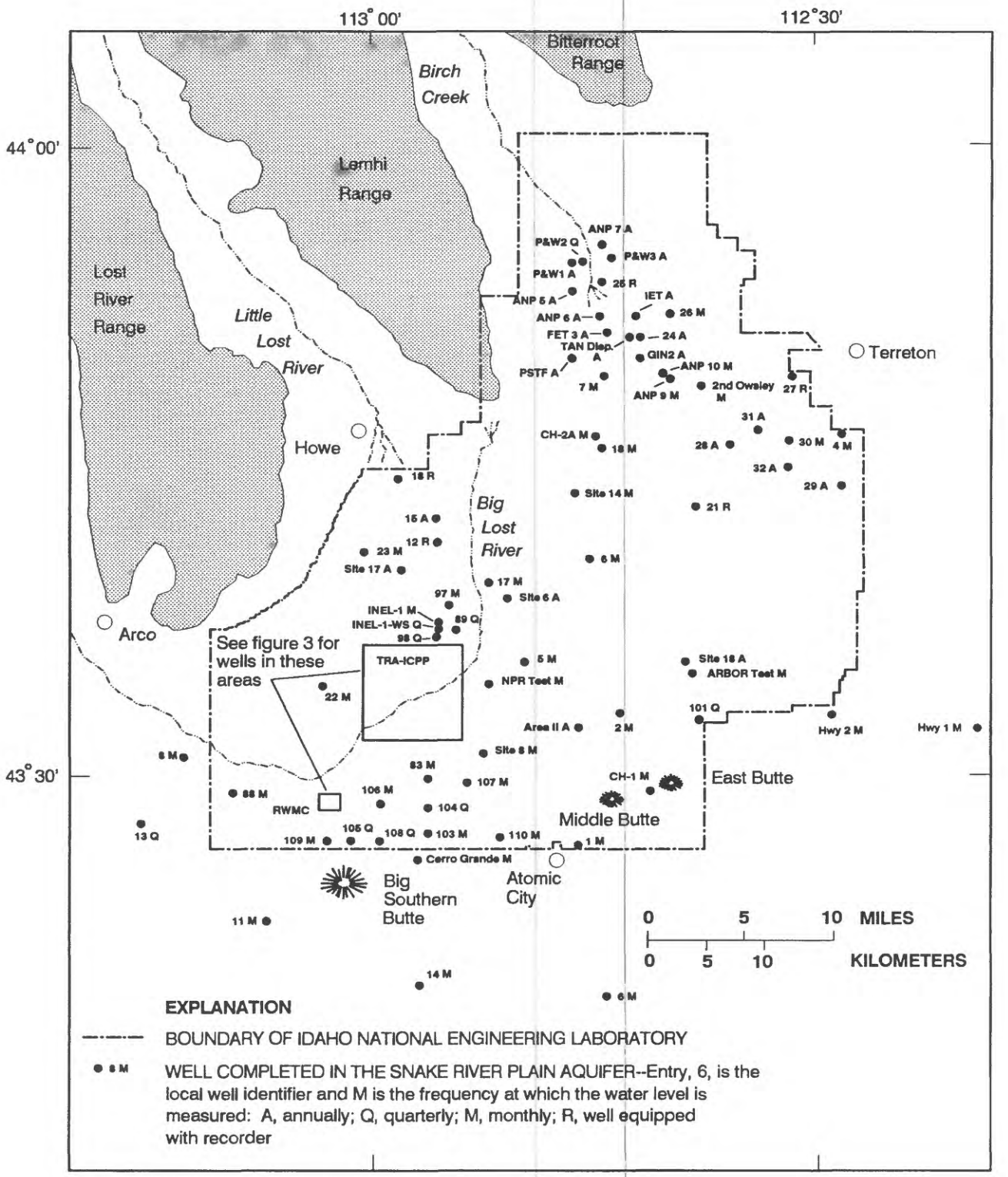

Figure 2.--Location of wells and the frequency of water-level measurements, Snake River Plain aquifer, Idaho National Engineering Laboratory and vicinity.

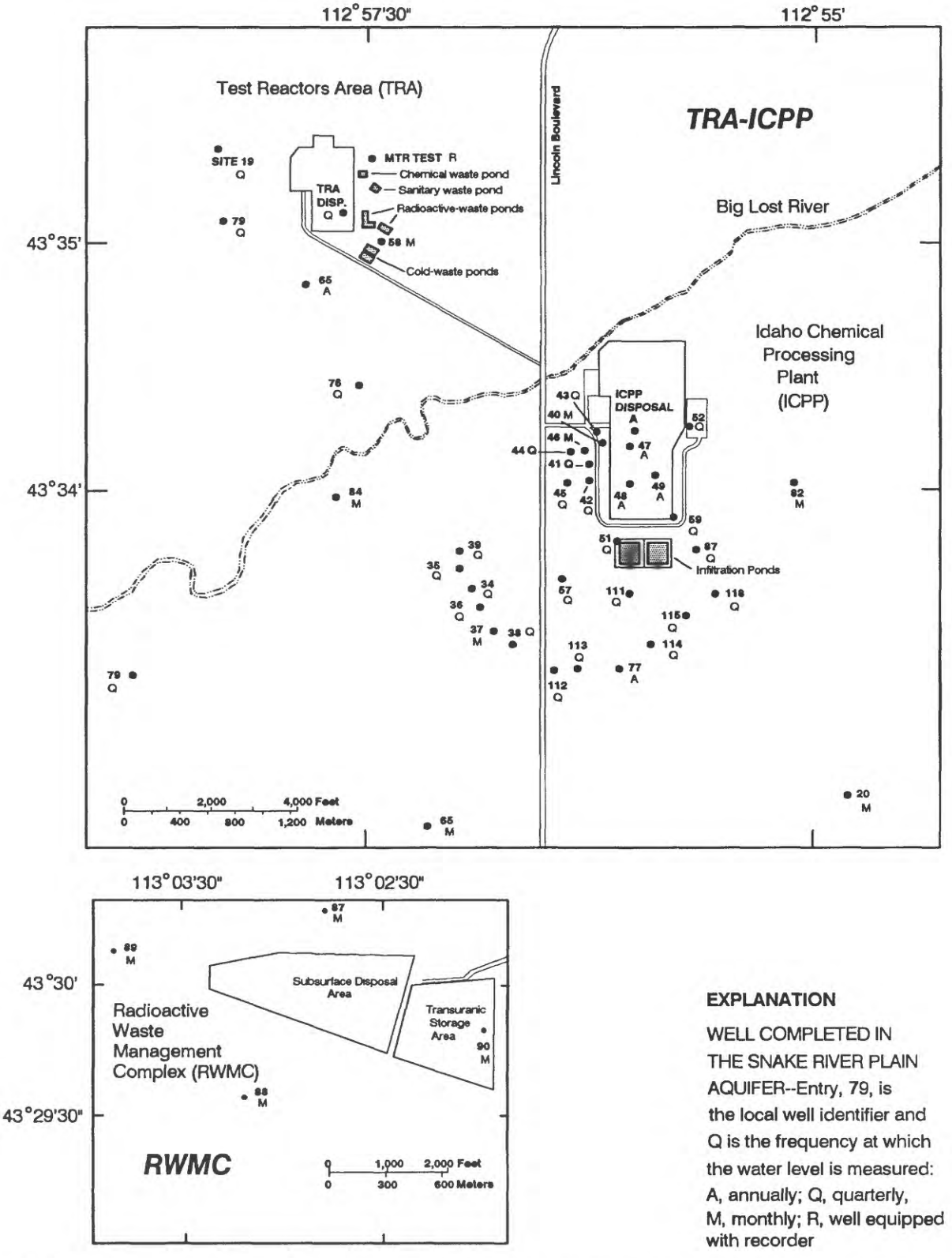

Figure 3.--Location of wells and the frequency of water-level measurements, Snake River Plain aquifer, Test Reactors Area, Idaho Chemical Processing Plant, and Radioactive Waste Management Complex.

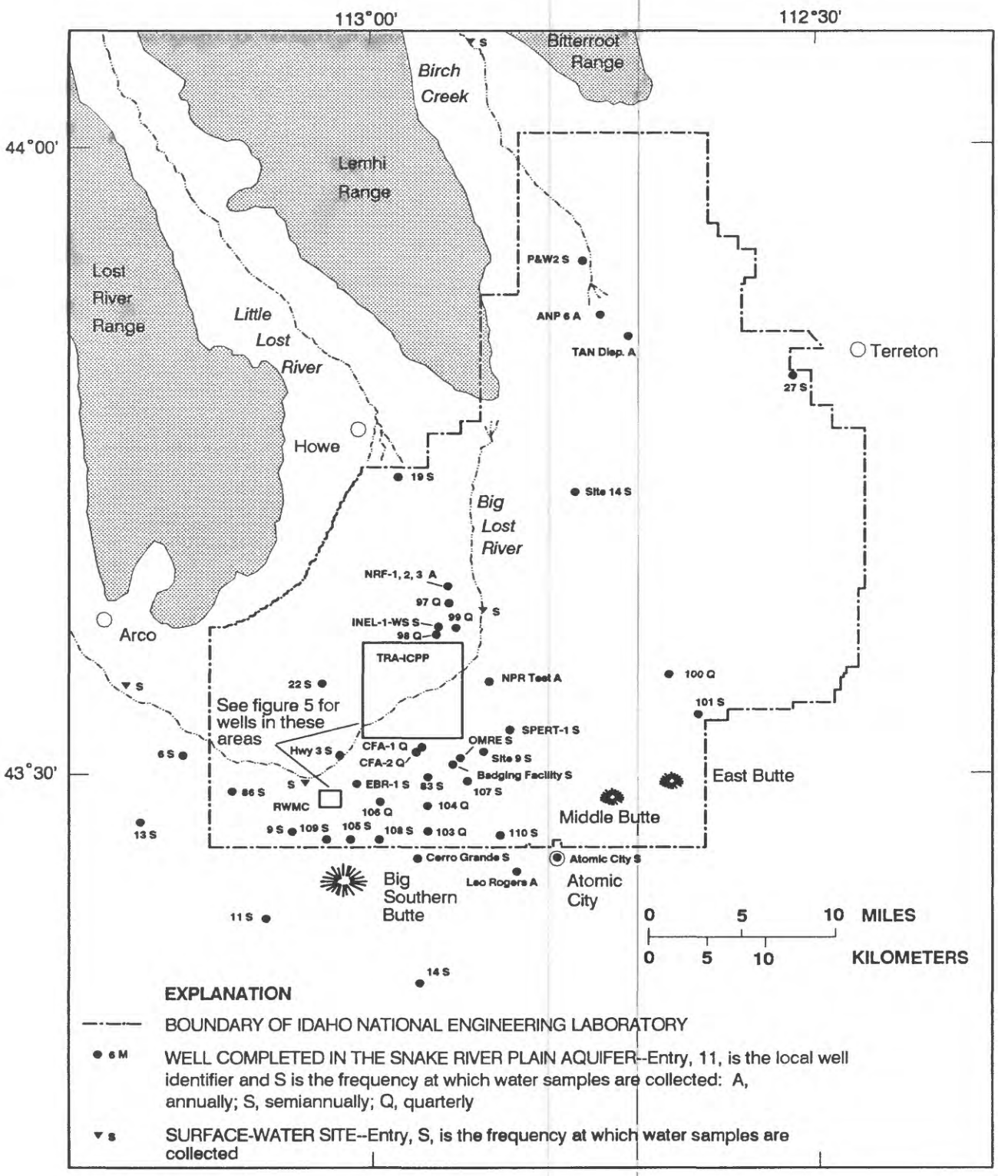

Figure 4.--Location of wells and the frequency of water-sample collections, Snake River Plain aquifer, Idaho National Engineering Laboratory and vicinity.

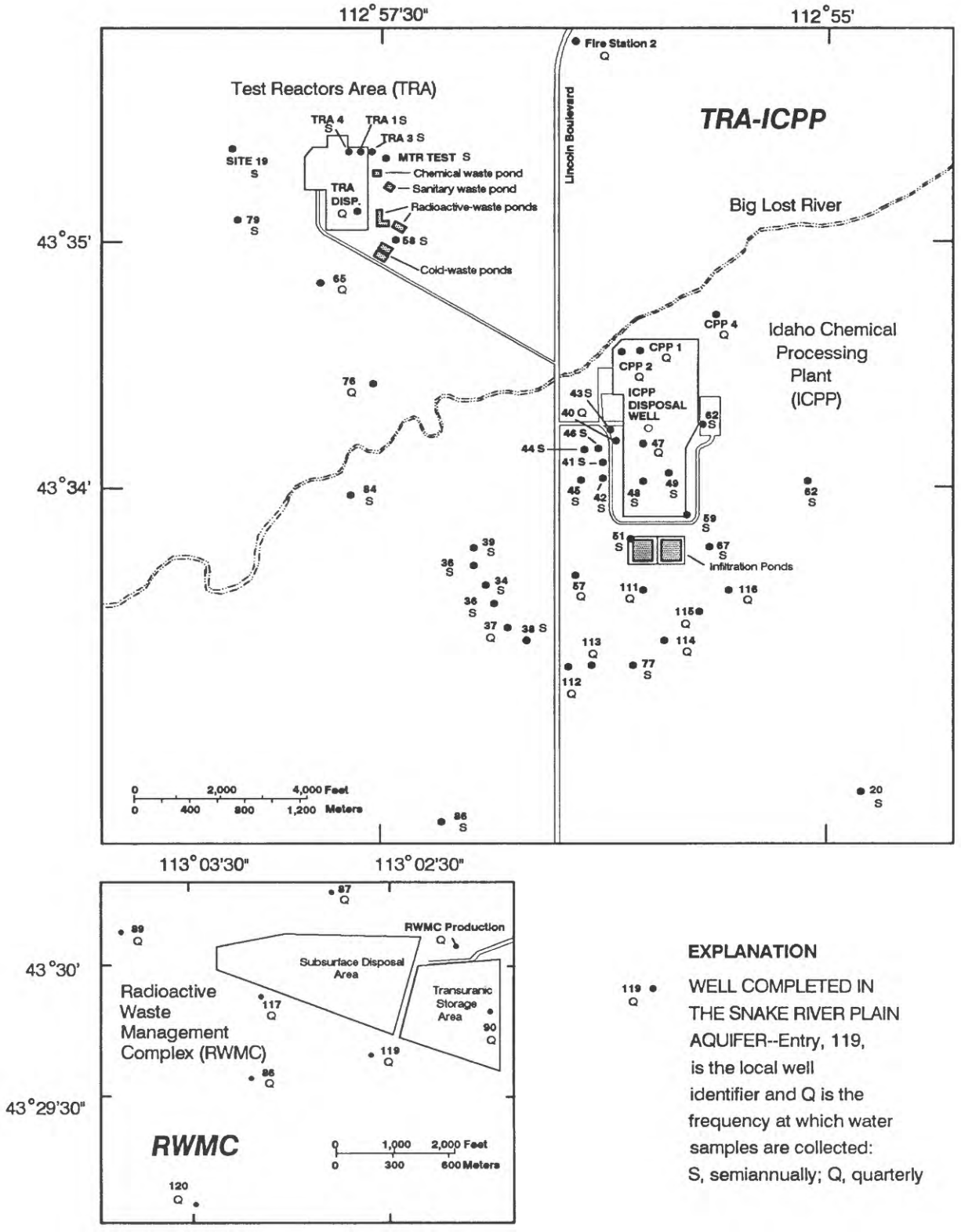

Figure 5.--Location of wells and frequency of water-sample collections, Snake River Plain aquifer, Test Reactors Area, Idaho Chemical Processing Plant, and Radioactive Waste Management Complex.

Table 1.--Monitoring-well locations and sample-collection method and frequency, Snake River Plain aquifer, Idaho National Engineering Laboratory.

[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); Thief--sampled with a thief sampler (depth, in feet, at which samples were collected); Bail--sampled with a bailer (depth, in feet, at which samples were collected). Sampling frequency: Q--quarterly; S--semiannual; A--annual.]

Well identifier	Location		Well diameter (inches)	Well depth (feet)	Water-sample Collection method	Water-sample Collection frequency
	Latitude	Longitude				
ANP 6	43°51'52"	112°44'31"		301	Pump (40)	A
Atomic City	43°26'38"	112°48'41"			Tap	S
Badging Facility	43°30'42"	112°53'51"	8	644	Pump (35)	S
Cerro Grande	43°26'18"	112°55'55"	6	567	Thief (560)	S
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
CPP-1	43°34'33"	112°56'02"	20	585	Pump (3,000)	Q
CPP-2	43°34'32"	112°56'08"	16	605	Pump (3,000)	Q
CPP-4	43°34'40"	112°55'44"	16	700	Pump (400)	Q
EBR-1	43°30'51"	113°00'26"	12	1,075	Pump (1,000)	S
Fire Station 2	43°35'48"	112°56'23"	16	518	Pump (400)	Q
Hwy 3	43°32'56"	113°00'25"			Tap	S
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	A
MTR Test	43°35'20"	112°57'26"	8	588	Pump (26)	S
NPR Test	43°34'49"	112°52'31"	6	600	Pump (26)	A
NRF-1	43°38'59"	112°54'54"			Pump	A
NRF-2	43°38'54"	112°54'54"			Pump	A
NRF-3	43°38'58"	112°54'55"			Pump	A
OMRE	43°31'16"	112°53'47"	14	943	Pump	S
P&W 2	43°54'19"	112°45'31"	10	386	Pump (35)	S
RWMC Production	43°30'02"	113°02'17"	16	683	Pump (200)	Q
Site 9	43°31'23"	112°53'01"			Thief (700)	S

Table 1.--Monitoring-well locations and sample-collection method and frequency, Snake River Plain aquifer, Idaho National Engineering Laboratory--continued

Well identifier	Location		Well		Water-sample Collection	
	Latitude	Longitude	diameter (inches)	depth (feet)	method	frequency
Site 14	43°43'34"	112°46'31"	10	717	Pump (11)	S
Site 19	43°35'22"	112°58'21"	12	865	Pump (25)	S
SPERT-1	43°32'52"	112°52'03"	24	653	Pump (400)	S
TAN Disp	43°50'53"	112°42'32"			Pump (20)	S
TRA 1	43°35'21"	112°57'38"	20	600	Pump (3,400)	S
TRA 3	43°35'22"	112°57'35"	20	602	Pump (3,800)	S
TRA 4	43°35'21"	112°57'42"	20	975	Pump (2,000)	S
TRA Disposal	43°35'06"	112°57'23"	12	1,267	Pump (25)	Q
USGS 8	43°31'21"	113°11'58"			Thief (790)	S
USGS 9	43°27'40"	113°04)45"	8	655	Pump (19)	S
USGS 11	43°23'36"	113°06)42"			Thief (690)	S
USGS 13	43°27'31"	113°14)39"			Thief (1,000)	S
USGS 14	43°20'19"	112°56)32"			Thief (740)	S
USGS 19	43°44'26"	112°57)57"			Thief (295)	S
USGS 20	43°32'53"	112°54)59"			Thief (530)	S
USGS 22	43°34'22"	113°03)17"			Thief (640)	S
USGS 27	43°48'51"	112°32)18"			Thief (255)	S
USGS 34	43°33'34"	112°56)55"			Thief (580)	S
USGS 35	43°33'39"	112°56)58"			Thief (520)	S
USGS 36	43°33'30"	112°56)52"			Thief (540)	S
USGS 37	43°33'26"	112°56)48"	8	573	Pump (8)	Q
USGS 38	43°33'22"	112°56)43"			Thief (540)	S
USGS 39	43°30'42"	112°53)51"			Thief (500)	S
USGS 40	43°34'11"	112°56)11"	6	679	Pump (8)	Q

Table 1.--Monitoring-well locations and sample-collection method and frequency, Snake River Plain aquifer, Idaho National Engineering Laboratory--continued

Well identifier	Location		Well		Water-sample Collection	
	Latitude	Longitude	diameter (inches)	depth (feet)	method	frequency
USGS 41	43°34'09"	112°56)13"			Thief (500)	S
USGS 42	43°34'04"	112°56)13"			Thief (500)	S
USGS 43	43°34'15"	112°56)15"	6	676	Pump (8)	S
USGS 44	43°34'09"	112°56)21"			Thief (500)	S
USGS 45	43°34'02"	112°56'18"			Thief (500)	S
USGS 46	43°34'07"	112°56'15"			Thief (500)	S
USGS 47	43°34'07"	112°56'03"	6	652	Pump (6)	Q
USGS 48	43°34'01"	112°56'03"			Thief (520)	S
USGS 49	43°34'03"	112°55'54"			Bailer-460)	S
USGS 51	43°33'50"	112°56'06"	6	659	Pump (6)	S
USGS 52	43°34'14"	112°55'42"			Thief (500)	S
USGS 57	43°33'44"	112°56'26"	6	732	Pump (5)	Q
USGS 58	43°35'00"	112°57'25"	6	503	Pump (25)	S
USGS 59	43°33'54"	112°55'47"	6	657	Pump (6)	S
USGS 65	43°34'37"	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 (25)	Q
USGS 77	43°33'15"	112°56'03"	6	610	Thief (540)	S
USGS 79	43°35'05"	112°58'19"	6	702	Thief (550)	S
USGS 82	43°34'01"	112°55'10"	8	700	Pump (6)	S
USGS 83	43°30'23"	112°56'15"	6	752	Pump (6)	S
USGS 84	43°33'56"	112°57'42"			Bail (490)	S
USGS 85	43°32'46"	112°57'12"	6	637	Thief (570)	S
USGS 86	43°29'35"	113°08'00"	8	691	Pump (19)	S

Table 1.--Monitoring-well locations and sample-collection method and frequency, Snake River Plain aquifer, Idaho National Engineering Laboratory--continued

Well identifier	Location		Well diameter (inches)	Well depth (feet)	Water-sample Collection method	Water-sample Collection frequency
	Latitude	Longitude				
USGS 87	43°30'13"	113°02'42"	6	673	Pump (3)	Q
USGS 88	43°29'40"	113°03'02"	6	662	Pump (5)	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)	Q
USGS 98	43°36'57"	112°56)36"	6	505	Pump (18)	Q
USGS 99	43°37'05"	112°55)21"	6	450	Pump (25)	Q
USGS 100	43°35'03"	112°40)07"	6	750	Pump (18)	Q
USGS 101	43°32'55"	112°38)18"	6	865	Pump (9)	S
USGS 103	43°27'14"	112°56)07"	8	760	Pump (21)	Q
USGS 104	43°28'56"	112°56)08"	8	700	Pump (16)	Q
USGS 105	43°27'03"	113°00)18"	8	800	Pump (19)	S
USGS 106	43°29'59"	112°59)31"	8	760	Pump (22)	Q
USGS 107	43°29'42"	112°53)28"	8	690	Pump (5)	S
USGS 108	43°26'59"	112°58)26"	8	760	Pump (20)	S
USGS 109	43°27'01"	113°02)56"	6	800	Pump (16)	S
USGS 110	43°27'17"	112°50)15"	8	780	Pump (5)	S
USGS 111	43°33'31"	112°56)05"	8	595	Pump (15)	Q
USGS 112	43°33'14"	112°56)30"	8	563	Pump (25)	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 (15)	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 (5)	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 (20)	Q

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

In the laboratory, instrument signals must exceed a critical level before the qualitative decision can be made as to whether the radionuclide was detected. Radionuclide concentrations that equal 1.6s meet this criterion; at 1.6s, there is a 95-percent probability that the correct conclusion--not detected--will be made. Given a large number of samples, as many as 5 percent of the samples with measured concentrations larger than or equal to 1.6s, 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. Radionuclide 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.

Waste Disposal Sites at the INEL

Liquid-waste disposal sites at INEL facilities have been the principal sources of radionuclide- and chemical-waste constituents in water from the Snake River Plain aquifer at the INEL. In the past, liquid-waste disposal sites at the INEL have included infiltration ponds and ditches, drain fields, and disposal wells. From 1986 to 1988, liquid-waste disposal was accomplished using infiltration ponds and drain fields. Waste materials buried at the RWMC also are a source of some waste constituents in ground water. Radionuclide waste-disposal data presented in this report were obtained from a series of radioactive waste management information reports (Litteer, 1987b and 1988b; Litteer and Reagan, 1989b). Chemical waste-disposal data were obtained from a series of industrial waste-management information reports (Litteer, 1987a and 1988a; Litteer and Reagan, 1989a). The radionuclide and chemical-waste disposal data are collected by contractors at each facility.

Test Reactors Area.--During 1986-88, approximately 259 million gal/year

of wastewater were discharged to infiltration ponds at the TRA (fig. 3). From 1982 to 1985, 276 million gal/year of wastewater were discharged to these infiltration ponds (Pittman and others, 1988). Liquid low-level radioactive, chemical, and sanitary wastes were discharged to infiltration ponds. Cooling-tower wastes were discharged to an infiltration pond from 1952 to 1964; to the Snake River Plain aquifer through a 1,275-ft-deep disposal well from 1964 until March 1982; and into two nonradioactive-waste infiltration ponds from 1982 to the present. The TRA disposal well has been used as an observation well since 1985.

The average annual discharge to the radioactive-waste infiltration ponds was about 151 million gal during 1960-88. The volume of wastewater and the curies of tritium discharged to the radioactive-waste infiltration ponds during this period are shown on figure 6. Discharge to the infiltration ponds was 20.5 million gal in 1985 and 18.3 million gal in 1988. The average annual discharge for 1986-88 was 20.7 million gal and was much less than the long-term average annual discharge of 151 million gal.

In 1986-88, about 97 percent of the radioactivity in wastewater disposed at the TRA was attributed to tritium. In comparison, about 10 percent of the radioactivity in wastewater disposed in 1974-79 was attributed to tritium (Pittman and others, 1988, p. 22), about 50 percent was attributed in 1980, and about 90 percent was attributed in 1981-85.

In 1976, the Department of Energy 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. At the end of 1988, the contractor was in the first year of the final phase of this reduction program (R.N. Beatty, EG&G Idaho, Inc., oral commun., 1990). The decrease in volume of radioactive wastewater disposed at the TRA may be a result of this program.

An infiltration pond has been used for liquid chemical-waste disposal from an ion-exchange system at the TRA since 1962. The average annual discharge to the chemical-waste infiltration pond was about 21 million gal for the period 1962-88. Discharge to the infiltration pond decreased from

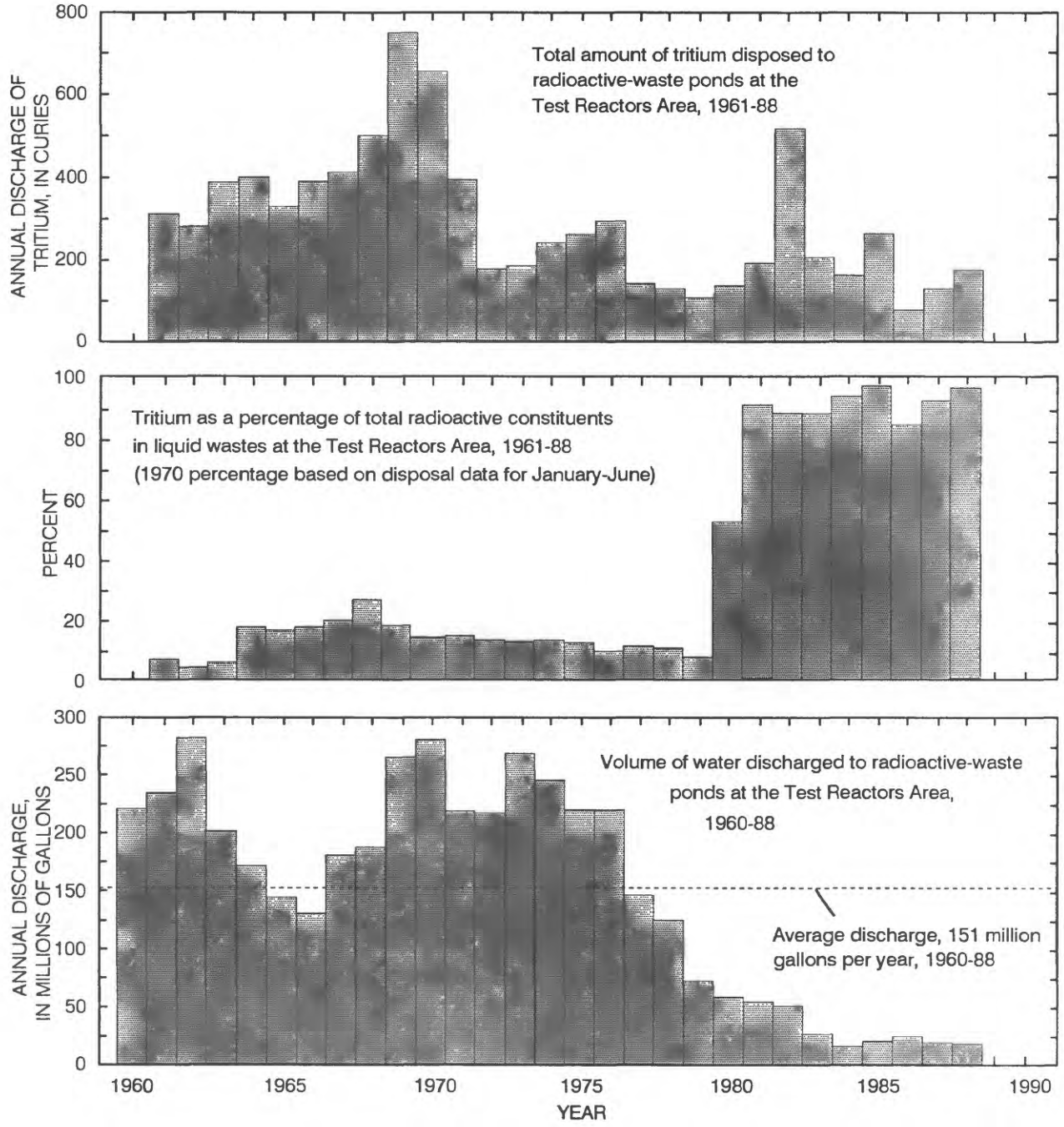

Figure 6.--Quantities of tritium disposed, tritium as a percentage of total radioactive constituents in liquid wastes, and volume of water discharged to the radioactive-waste infiltration ponds at the Test Reactors Area, 1960-88.

about 6 million gal in 1985 to 4.2 million gal in 1988. The average annual discharge for 1986-88 was 5.4 million gal, 26 percent of the long-term average annual discharge of 21 million gal. Sulfate and sodium were the predominant constituents in the chemical wastewater. During 1986-88, average annual amounts of about 507,000 lb of sulfate and 183,000 lb of sodium were discharged to TRA infiltration ponds. The average annual concentrations of sulfate and sodium in the wastewater during 1986-88 were about 11,000 and 4,100 mg/L, respectively.

A deep disposal well was used from 1964 to March 1982 to inject non-radioactive wastewater from cooling-tower operations at the TRA into the Snake River Plain aquifer. Since March 1982, this wastewater has been discharged to two infiltration ponds (fig. 3). The average annual discharge to the well and the infiltration ponds was about 230 million gal during 1964-88 and about 225 million gal during 1986-88. This wastewater contained an average annual amount of about 469,000 lb of sulfate and 32,000 lb of other chemicals during 1986-88.

About 7.6 million gal/year of sewage effluent were discharged to an infiltration pond at the TRA during 1986-88. This sewage effluent contained an average annual amount of about 430 lb of chloride and 630 lb of hypochlorite.

Idaho Chemical Processing Plant.--From 1953 to February 1984, the ICPP discharged most of its low-level radioactive, chemical, and sanitary wastewater into the Snake River Plain aquifer through a 600-ft deep disposal well. The average discharge of wastewater to the well was about 363 million gal/year (Pittman and others, 1988, p. 24). Two infiltration ponds presently are being used for wastewater disposal. The first pond was completed in February 1984 and the second pond was put into service in October 1985. The volumes of wastewater discharged to the well and infiltration ponds during 1961-88 are shown on figure 7. The total annual discharge to the well and ponds ranged from 260 million gal in 1963 to 600 million gal in 1987 and averaged about 400 million gal/year. The average discharge during 1986-88 was about 580 million gal/year.

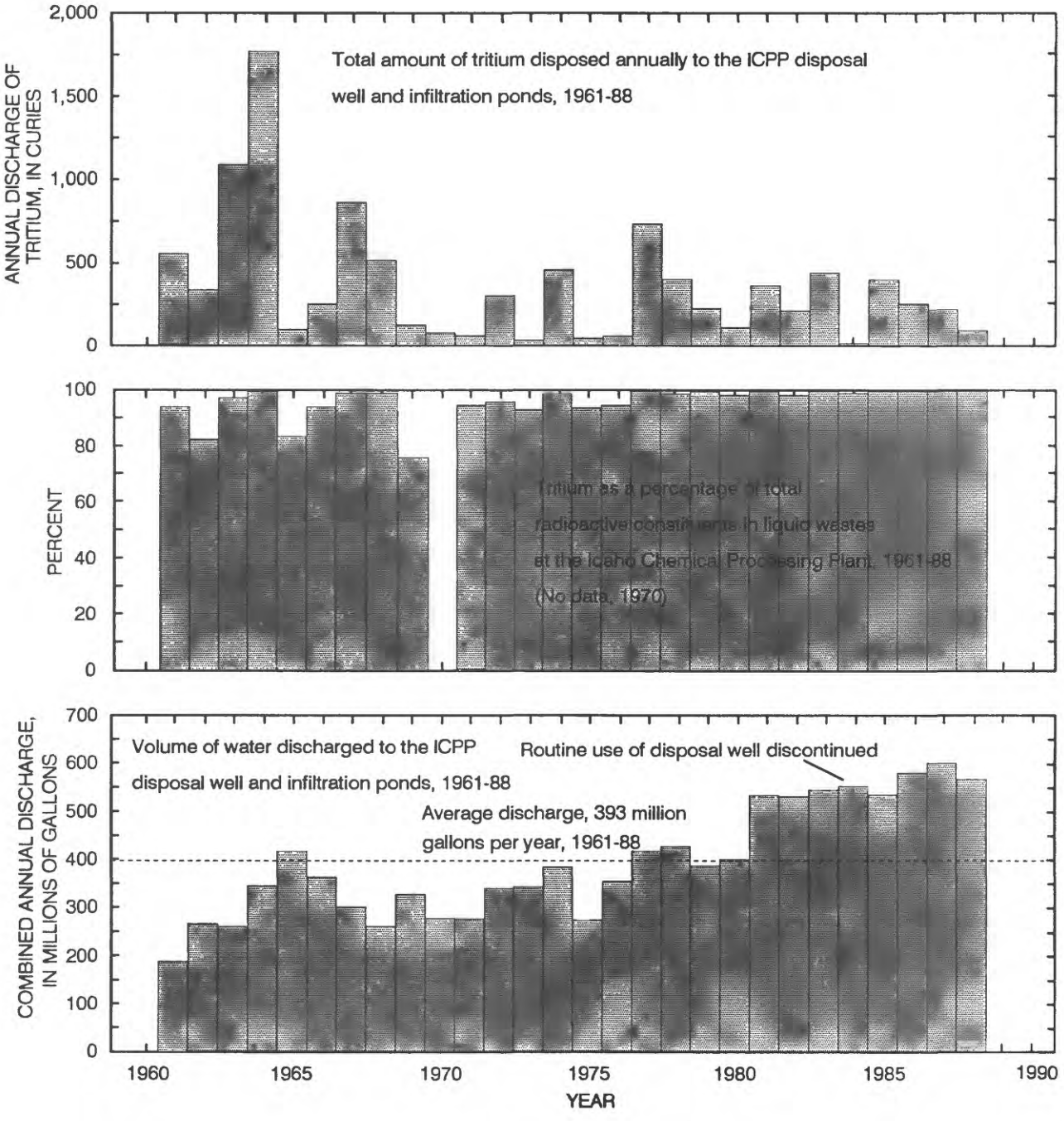

Figure 7.--Quantities of tritium disposed, tritium as a percentage of total radioactive constituents in liquid wastes, and volume of water discharged to the disposal well and infiltration ponds at the Idaho Chemical Processing Plant, 1961-88.

Most of the radioactivity in wastewater discharged to the infiltration ponds at the ICPP is attributed to tritium. Tritium has accounted for more than 90 percent of the radioactivity in wastewater disposed at the ICPP since 1975 (fig. 7). During 1986-88, tritium accounted for 99.8 percent of the total radioactivity in wastewater. During 1982-85, 1,088 Ci of tritium were contained in wastewater at the ICPP for an average annual amount of 272 Ci (Pittman and others, 1988, p. 27). During 1986-88, 556 Ci of tritium were disposed for an average annual amount of 185 Ci.

Chloride, fluoride, nitrate, and sulfate were the predominant non-radioactive constituents in wastewater discharged to the ICPP infiltration ponds. Average annual amounts of about 1,178,000 lb of chloride, 2,255 lb of fluoride, 160,400 lb of nitrate, and 227,000 lb of sulfate were contained in ICPP wastewater during 1986-88. An average annual volume of 8.5 million gal of sewage effluent were discharged to a sanitary-waste infiltration pond at the ICPP during 1986-88.

Naval Reactors Facility.--Wastewater at the NRF is discharged to a 3-mi long industrial-waste ditch and sewage ponds. During 1986-88, about 36 million gal/year of wastewater were discharged to the industrial-waste ditch. Disposal rates decreased about 39 percent from 1982-85 when 93 million gal/year were discharged (Pittman and others, 1988, p. 25). Another 36 million gal/year of sewage effluent also were discharged to sewage ponds.

Chloride, sulfate, and sodium were the predominant chemical constituents in wastewater discharged to the industrial-waste ditch. About 84,000 lb of chloride, 73,000 lb of sulfate, and 52,000 lb of sodium were disposed annually during 1986-88. These amounts reflected disposal-rate decreases of 34 percent for chloride, 77 percent for sulfate, and 42 percent for sodium from the average annual amounts disposed during 1982-85. Amounts of other chemicals comprising the remainder of constituents in the wastewater averaged about 19,000 lb/year.

Radioactive Waste Management Complex.--Solid and liquid radionuclide and chemical wastes have been buried in trenches and pits at the SDA (Subsurface Disposal Area) at the RWMC since 1952. Prior to 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. These constituents include transuranic wastes, disposed to trenches until 1970, and other radionuclide and chemical constituents and organic compounds.

About 550 Ci of plutonium-238, 21,000 Ci of plutonium-239, 4,900 Ci of plutonium-240, and 165,000 Ci of plutonium-241 were buried in the SDA during 1954-70 (Barraclough and others, 1976, p. 11). Organic compounds also have been buried. An estimated 88,400 gal of organic waste were disposed prior to 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, volumes of low-level radioactive, chemical, and sanitary wastewater were discharged at TAN into the Snake River Plain aquifer through a 310-ft-deep disposal well. 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 disposed at TAN prior to 1959. During 1959-88, about 61 Ci of radioactivity were discharged in wastewater to the disposal well and infiltration pond. Of this amount, approximately 20 Ci were 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). Use of the evaporator was phased out in 1969.

During 1986-88, the average volume of radioactive wastewater discharged to the infiltration pond at TAN was about 20.8 million gal/year. The average rate of disposal of radioactivity in this wastewater was 0.012 Ci/year.

An average of approximately 31.5 million gal/year of chemical wastes and 12 million gal/year of sewage wastes were discharged to the infiltration pond during 1986-88. The predominant constituents included chloride and sodium. Average annual amounts of 13,000 lb of chloride and 9,100 lb of

sodium were disposed. The average annual amount of all other chemical constituents in the effluent was about 2,100 lb.

Central Facilities Area.--An average annual volume of about 100 million gal of liquid wastes is discharged to the sewage plant tile drain field at the CFA. Most radionuclide wastes discharged to this drain field are derived from pumpage of production well CFA-1 (fig. 4) which obtains water from within the ICPP contaminant plume in the Snake River Plain aquifer. Most of the radioactivity in wastewater disposed at the CFA is attributed to tritium. During 1986-88, tritium accounted for 99.7 percent of the total radioactivity in wastewater disposed at the CFA and averaged about 2 Ci/year.

Chloride and sodium are the predominant constituents in chemical and laundry wastes discharged to the drain field at the CFA. During 1986-88, average annual amounts of about 41,000 lb of chloride and 25,000 lb of sodium were contained in wastewater discharged to the drain field. The average annual amount of all other chemicals in the effluent was about 21,000 lb.

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).

Surface water

Recharge to the Snake River Plain aquifer is principally from infiltration of applied irrigation water, infiltration of streamflow, and from alluvial ground-water inflow from adjoining mountain drainage basins. Some recharge may be from direct infiltration of precipitation, although the small annual precipitation on the plain (8 in. at the INEL), evapotranspira-

tion, and the great depth to water (in places exceeding 900 ft) probably minimize this source of recharge.

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 INEL (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. Since 1958, excess runoff has been diverted to spreading areas in the southwestern part of the INEL where much of the water rapidly infiltrates to the aquifer. Other surface drainages that provide recharge to the Snake River Plain aquifer at the INEL include Birch Creek and the Little Lost River (fig. 1).

The average streamflow in the Big Lost River below Mackay Reservoir for the 72-year period of record (water years 1905, 1913-14, and 1920-88) was 227,500 acre-ft/year (Harenberg and others, 1989, p. 233). Streamflow in the Big Lost River below Mackay Reservoir declined from 326,500 acre-ft during the 1986 water year (144 percent of average flow) to 141,300 acre-ft during the 1988 water year (62 percent of average flow) (fig. 8). Streamflow in the Big Lost River near Arco declined from 145,200 acre-ft during the 1986 water year to 4,930 acre-ft during water year 1988. Combined streamflow in the Big Lost River below the INEL diversion near Arco and the INEL diversion at its head near Arco was 127,950 acre-ft during the 1986 water year and zero in the 1988 water year.

Recharge to the Snake River Plain aquifer is substantial downstream from Arco due to infiltration of streamflow from the Big Lost River channel, diversion areas, sinks, and playas. Measured infiltration losses at various discharges ranged from 1 to 28 $(ft^3/s)/mi$ (Bennett, 1990, p. 1). Channel infiltration losses from Arco to the diversion to the INEL spreading areas (fig. 8) declined from 16,971 acre-ft in the 1986 water year to 2,112 acre-ft in the 1988 water year (Bennett, 1990, p. 46). Recharge from the INEL diversion areas declined from 42,743 acre-ft in water year 1986 to zero in water year 1988 (Bennett, 1990, p. 42). Channel infiltration losses from the INEL diversion to Lincoln Boulevard declined from 16,412 acre-ft in water year 1986 to zero in water year 1988 (Bennett, 1990, p. 48) and losses

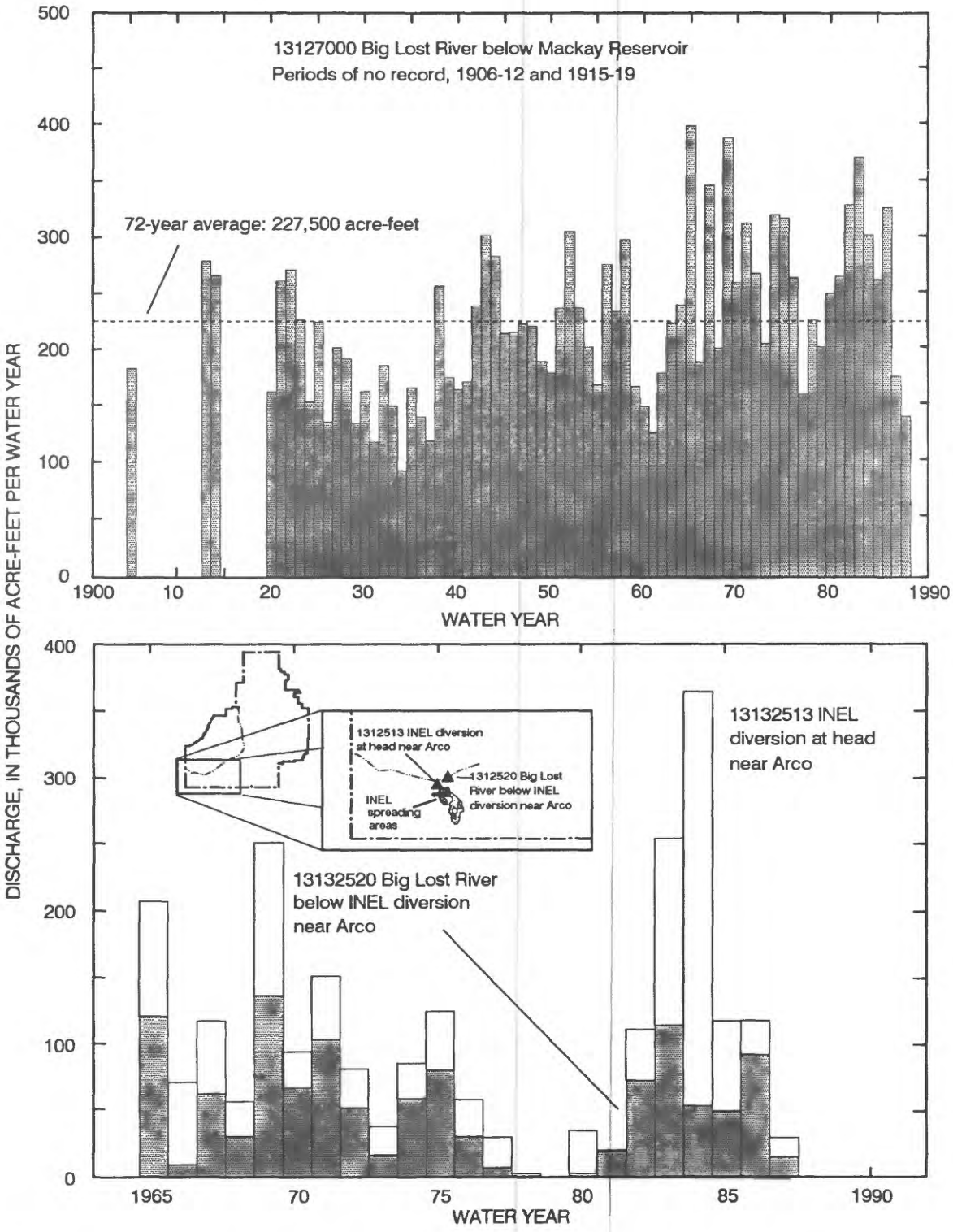

Figure 8.--Discharge of the Big Lost River below Mackay Reservoir (water years 1903, 1913-14, and 1920-88), Big Lost River below the INEL diversion, and the INEL diversion at head near Arco (water years 1965-88).

from Lincoln Boulevard to terminal playas declined from 72,224 acre-ft to zero during the same period (Bennett, 1990, p. 45).

Ground Water

Water in the Snake River Plain aquifer moves principally through fractures and interflow zones in the basalt. A significant proportion of ground water moves through the upper 800 ft of saturated rocks (Mann, 1986, p. 21). Hydraulic conductivity of basalt in the upper 800 ft of the aquifer generally is 1 to 100 ft/day. Hydraulic conductivity of underlying rocks is several orders of magnitude smaller. The effective base of the Snake River Plain aquifer at the INEL probably ranges from about 850 to 1,220 ft below land surface.

Depth to water in wells completed in the Snake River Plain aquifer ranges from about 200 ft at the northern part of the INEL to more than 900 ft in the southeastern part. In July 1988, the altitude of the water table was about 4,590 ft above sea level near TAN (fig. 9) and about 4,420 ft above sea level near the RWMC. Water flowed southward and southwestward beneath the INEL at an average hydraulic gradient of about 4 ft/mi (fig. 9). Locally, however, the hydraulic gradient ranged from about 1 to 15 ft/mi. From July 1985 to July 1988, water-level changes in INEL wells ranged from a 26.8-ft decline near the RWMC to a 4.3-ft rise north of TAN (fig. 10). Water levels generally declined in the southern two-thirds of the INEL during that time and rose in the northern one-third.

Water levels monitored in wells 12, 17, 23 (fig. 2) and well 20 (fig. 3) provide an indication of water-level changes in the Snake River Plain aquifer at different distances from the Big Lost River. Water levels in these wells fluctuated in response to streamflow during 1950-88 (fig. 11). Long-term water-level fluctuations ranged from 10 ft in well 20 to about 22 ft in well 12. Water levels in these wells declined during 1986-88, in response to decreases in streamflow in the Big Lost River.

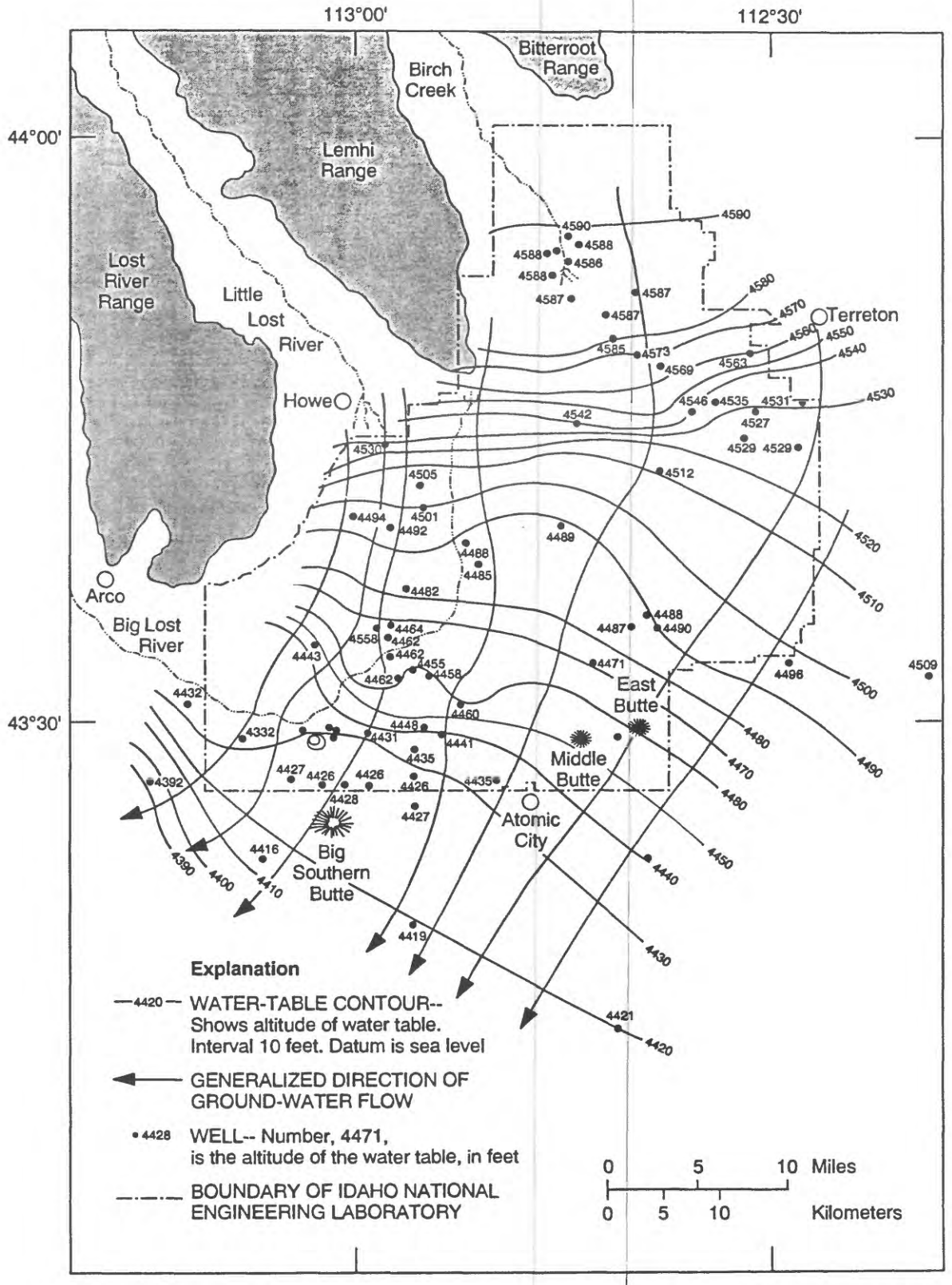

Figure 9.--Altitude of the water table, Snake River Plain aquifer, and general direction of ground-water movement, July 1988.

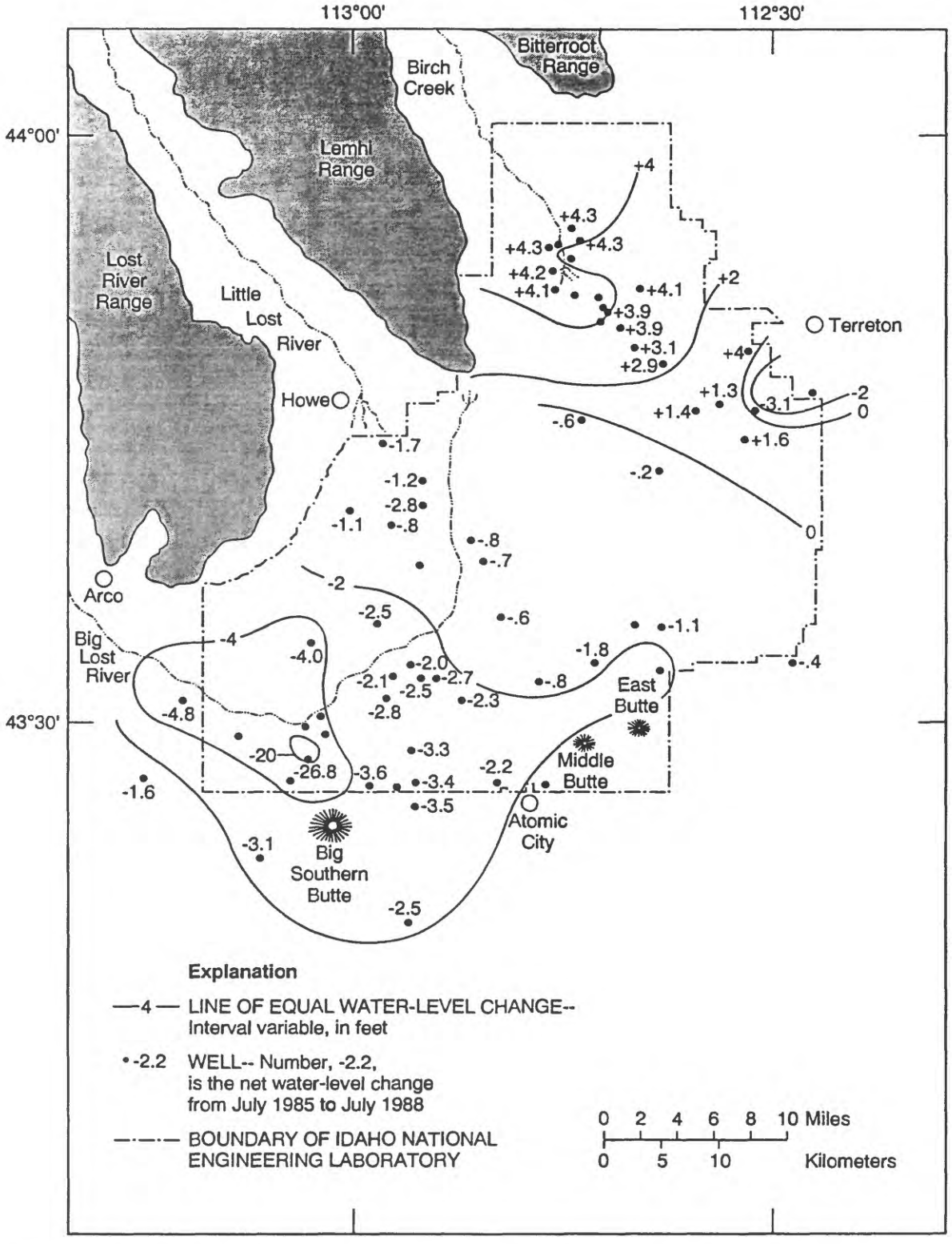

Figure 10.--Generalized ground-water level change for the Snake River Plain aquifer in the vicinity of the Idaho National Engineering Laboratory, July 1985 to July 1988.

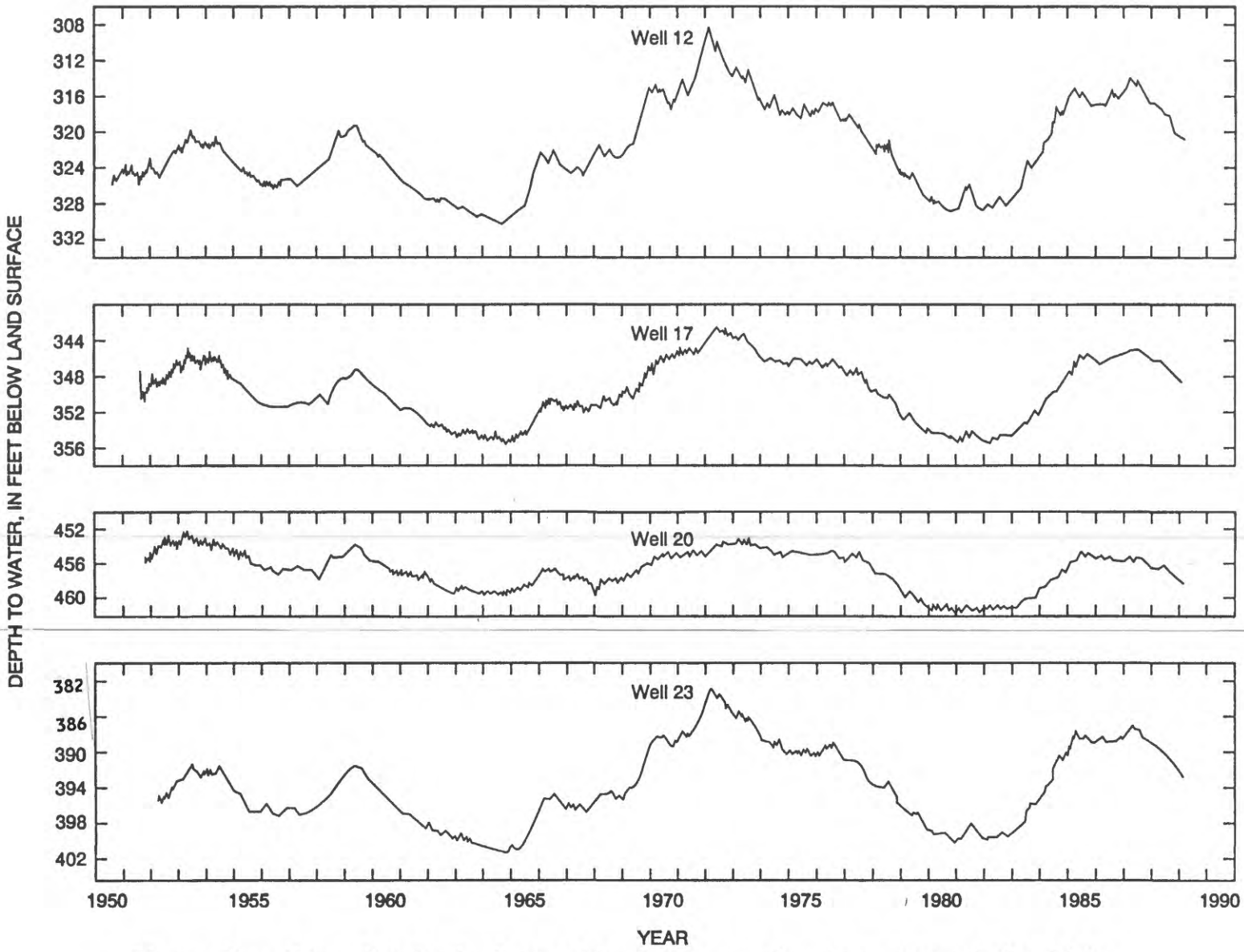

Figure 11.--Water levels in four wells in the southwestern part of the Idaho National Engineering Laboratory, 1950-88.

Ground water moves southwestward from the INEL and is eventually discharged to springs along the Snake River downstream from Twin Falls, 100 mi southwest of the INEL. Approximately 4.3 million acre-ft of ground water were discharged to these springs in 1988 (Mann, 1989, p. 2).

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

Contaminant plumes of radionuclide and chemical constituents in the Snake River Plain aquifer at the INEL are attributed to waste-disposal practices. The areas 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. Radionuclide and chemical constituents detected in ground water at the INEL include tritium, strontium-90, cobalt-60, cesium-137, plutonium-238, plutonium-239, -240 (undivided), americium-241, total chromium, sodium, chloride, and nitrate. In 1987, 12 purgeable organic compounds were detected locally in ground water at the INEL (Mann and Knobel, 1987, p. 10). Concentrations of these compounds during 1988-89 are documented in a report by Mann (1990).

Tritium

A tritium plume has developed in the Snake River Plain aquifer since the 1950's from disposal of liquid wastes at the INEL. Tritium has a half-life of 12.26 years. The principal sources of tritium in the aquifer have been the injection of liquid wastes through the disposal well at the ICPP and discharge of wastewater to the infiltration ponds at the ICPP and TRA. About 30,900 Ci of tritium have been discharged to the well and ponds since 1952. Routine use of the disposal well was terminated in February 1984; subsequently, most liquid radionuclide wastes have been discharged to the infiltration ponds. During 1986-88, approximately 555 Ci of tritium were discharged to the ponds at the ICPP, and approximately 377 Ci were discharged to the ponds at the TRA.

Table 2.--Tritium concentrations in water from selected wells at the Idaho National Engineering Laboratory, 1980-88

[Concentrations and associated uncertainties in picocuries per milliliter; location of wells shown on figure 3; --, no data, well drilled in 1984]

Well 47		Well 111		Well 38	
Date	Concentration	Date	Concentration	Date	Concentration
10/13/80	27.9±0.6		--	10/17/80	87.8±1.1
10/29/81	27.9±0.6		--	10/08/81	77.5±0.8
10/07/82	15.3±4.0		--	10/07/82	74.1±0.8
10/17/83	73.0±0.9		--	10/13/83	70.9±0.9
10/23/84	14.0±0.5		--	10/09/84	66.7±0.9
10/29/85	12.0±0.5	11/05/85	29.5±0.8	10/28/85	55.8±1.2
10/29/86	5.8±0.4	10/27/86	49.2±1.1	11/18/86	59.5±0.9
10/26/87	3.5±0.4	09/25/87	57.5±1.2	10/16/87	65.9±1.3
09/30/88	3.5±0.2	10/04/88	37.6±0.8	11/07/88	45.0±5.0

Well 77		Well CFA-1	
Date	Concentration	Date	Concentration
10/13/80	93.0±1.0	10/21/80	41.0±0.6
10/05/81	79.9±0.8	10/13/81	35.6±0.6
09/30/82	81.5±0.8	10/11/82	33.1±0.6
10/04/83	63.5±0.9	10/06/83	31.5±0.6
10/09/84	70.5±0.9	10/12/84	33.8±0.7
10/22/85	46.3±1.0	10/25/85	32.4±0.8
11/13/86	70.0±0.9	10/31/86	34.8±0.9
10/20/87	60.2±1.2	10/15/87	32.1±0.8
11/06/88	50.5±0.9	10/28/88	27.3±0.6

Tritium concentrations in water from the Snake River Plain aquifer decreased by as much as 39 pCi/mL during 1986-88. By October 1988, tritium concentrations ranged from 0.7±0.2 to 61.6±1.1 pCi/mL and the tritium plume extended southwestward in the general direction of ground-water flow (fig. 12). The size of the plume in which tritium concentrations exceeded 0.5 pCi/mL decreased from about 51 mi^2 in October 1985 to about 45 mi^2 in October 1988. The area of the plume containing tritium concentrations in excess of the maximum contaminant level of 20 pCi/mL (U.S. Environmental Protection Agency, 1989, p. 551) decreased from 4.4 to 2.8 mi^2. A water sample from well 65 (fig. 5), near the TRA, contained 61.6±1.1 pCi/mL of tritium. Water from well 77, south of the ICPP, contained 50.5±0.9 pCi/mL (table 2). Tritium concentrations in water from wells 103, 105, and 108,

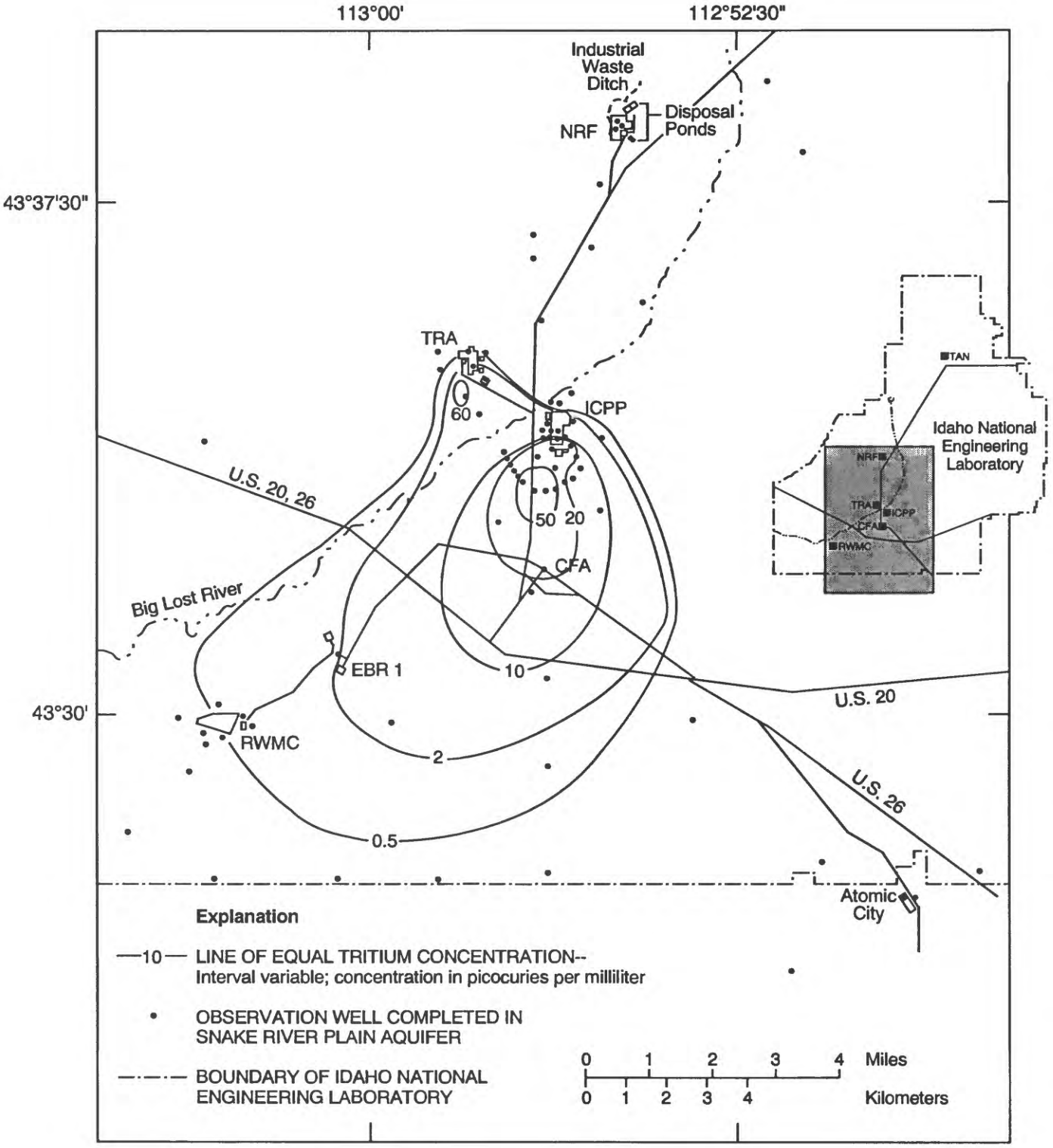

Figure 12.--Distribution of tritium in water from the Snake River Plain aquifer at the Idaho National Engineering Laboratory, October 1988.

near the southern boundary of the INEL (fig. 4), exceeded the reporting level during 1983-85 (Pittman and others, 1988, p. 51; Mann and Cecil, 1990, p. 27). Since 1985, tritium concentrations in water from these wells have been less than the reporting level.

Tritium concentrations in wells 47, 38, and CFA-1 generally decreased during 1980-88 (table 2) in response to a decreased rate of tritium disposal from the ICPP. Concentrations in water from well 111, near the ICPP infiltration ponds, have fluctuated, possibly in response to the diversion of liquid wastes to the infiltration ponds in 1984.

Radioactive-decay processes, overall reduction in tritium disposal rates, dilution from recharge, and changes in disposal methods have contributed to reduced concentrations of tritium and the decreased size of the tritium plume in ground water at the INEL. Of the total of 30,900 Ci of tritium disposed to the aquifer from 1952 to 1988, only about 10,200 Ci remain after radioactive decay (Mann and Cecil, 1990, p. 30). The average combined rate of tritium disposal at the TRA and ICPP during 1962-88 was 645 Ci/year. The average disposal rate was 424 Ci/year (66 percent of the long-term average) during 1979-88 and was 352 Ci/year (55 percent of the long-term average) during 1984-88. Reduction in tritium concentrations also may be attributed to dilution by recharge from the Big Lost River near the ICPP and TRA during 1981-87. Finally, the discontinuation of the use of the ICPP disposal well and subsequent discharge to infiltration ponds may have attenuated and diffused tritium concentrations in the aquifer.

Strontium-90

A total of 21 Ci of strontium-90 were in wastewater injected directly to the aquifer through the ICPP disposal well and discharged to infiltration ponds at the ICPP and TRA prior to 1986 for an average annual discharge rate of about 0.6 Ci. In 1984, general use of the ICPP disposal well was discontinued, and the ICPP infiltration ponds were used for disposal of liquid wastes. Approximately 0.13 Ci of strontium-90 was discharged to the ICPP infiltration ponds during 1986-88 and 0.13 Ci was discharged to the TRA

radioactive-waste infiltration ponds. The combined average annual disposal rate during 1986-88 was about 0.09 Ci.

A plume of strontium-90, with a half-life of 28.6 years, has formed in the aquifer principally in response to discharge of strontium-90 to the ICPP disposal well. The maximum contaminant level is 8 pCi/L (U.S. Environmental Protection Agency, A89, p. 551). In October 1985, the size of the strontium-90 plume where concentrations exceeded 6 pCi/L was about 2 mi^2 (Pittman and others, 1988, p. 53); the concentrations of strontium-90 in wells 57 and 47 were 74±5 and 63±5 pCi/L, respectively (table 3). Strontium-90 concentrations decreased as much as 33 pCi/L during 1986-88. By October 1988, strontium-90 concentrations ranged from 8±2 to 48±3 pCi/L, and the area of the strontium-90 plume had decreased to approximately 0.8 mi^2 (fig. 13). The strontium-90 concentrations in wells 57 and 47, both within the plume, decreased to 41±3 and 48±3 pCi/L, respectively (table 3).

Table 3.--Strontium-90 concentrations in water from selected wells at the Idaho National Engineering Laboratory, 1981-88

[Concentrations and associated uncertainties in picocuries per liter; location of wells shown on figure 3.]

Well 47		Well 57		Well 38	
Date	Concentration	Date	Concentration	Date	Concentration
10/08/81	79±5	10/05/81	93±6	10/08/81	28±3
10/07/82	60±4	10/06/82	90±5	10/07/82	27±3
10/17/83	130±7	10/13/83	83±5	10/13/83	12±2
10/23/84	61±4	10/10/84	66±6	10/09/84	26±4
10/29/85	63±5	10/29/85	74±5	10/28/85	14±2
10/29/86	56±4	11/14/86	42±3	11/18/86	13±2
10/26/87	54±3	10/09/87	49±3	10/16/87	13±2
09/30/88	48±3	10/05/88	41±3	11/07/88	32±3

Concentrations of strontium-90 generally decreased during 1981-88 in water from wells near the ICPP (table 3). Fluctuating concentrations in well 38 probably are attributed to collection of water samples with a thief sampler. Other wells were sampled using dedicated submersible pumps.

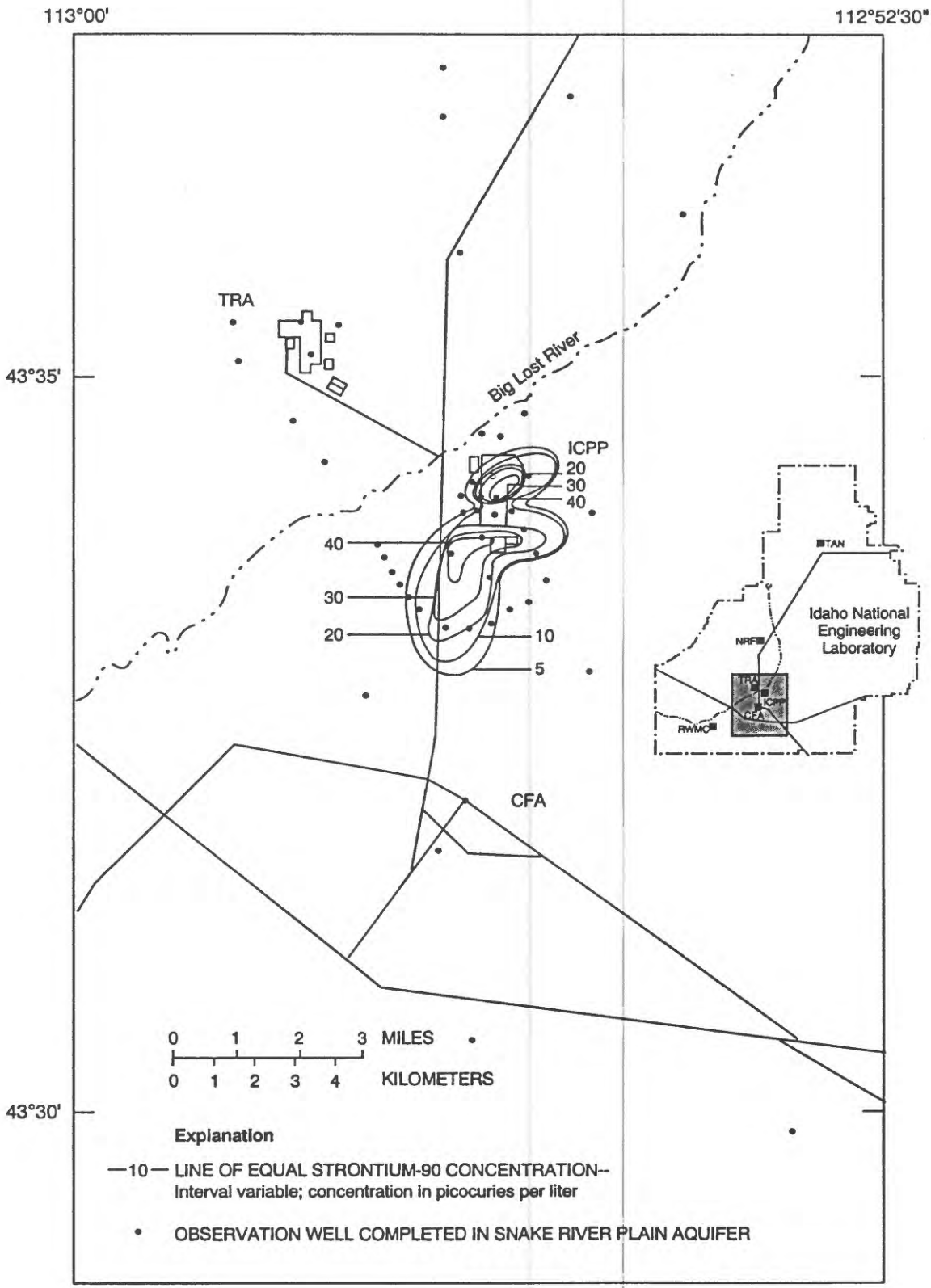

Figure 13.--Distribution of strontium-90 in water from the Snake River Plain aquifer at the Idaho National Engineering Laboratory, October 1988.

The reduced areal extent and concentration of strontium-90 by 1988 in ground water beneath the ICPP principally occurred in response to the diversion of liquid radionuclide wastes from the disposal well to the infiltration ponds. Processes of radioactive decay, diffusion, dispersion, and dilution from natural recharge also contributed to the reduction in strontium-90 concentrations. The absence of a strontium-90 plume at the TRA can be attributed to discharge of liquid radionuclide wastes only to TRA infiltration ponds and to sorption processes in the unsaturated zone and perched ground-water zones between the land surface and the Snake River Plain aquifer.

Cobalt-60

Since 1951, about 434 Ci of cobalt-60 were discharged to the TRA radioactive-waste infiltration ponds. During 1986-88, about 6.5 Ci of cobalt-60 were discharged to the ponds. The average disposal rate prior to 1974 was 20 Ci/year; from 1974 to 1988, the average disposal rate was 2.3 Ci/year. The half-life of cobalt-60 is 5.26 years.

Cobalt-60 concentrations exceeded the reporting level through 1985 in water from well 65 (fig. 5), south of the TRA. During 1986-88, cobalt-60 was not detected in water from well 65. The reduction in discharge of cobalt-60 to the TRA radioactive-waste infiltration ponds is in part responsible for the absence of detectable concentrations of cobalt-60 in ground water near the TRA during 1986-88. Other factors that probably contribute to the absence of cobalt-60 include radioactive decay and sorption processes in the unsaturated and perched ground-water zones.

Cobalt-60 concentrations in the TAN disposal well (fig. 4) exceeded the reporting level as a result of the discharge of liquid radioactive wastes to the well prior to 1972. Water from the TAN disposal well contained 890±9 pCi/L of cobalt-60 in October 1987. Cobalt-60 was not detected in water from any other wells completed in the Snake River Plain aquifer at the INEL during 1986-88.

Cesium-137

From 1952 to 1988, about 138 Ci of cesium-137 were discharged to the TRA radioactive-waste infiltration ponds and about 23 Ci were discharged to the ICPP disposal well and infiltration ponds. During 1986-88, approximately 0.7 Ci was discharged to the TRA radioactive-waste infiltration ponds and 0.3 Ci was discharged to the ICPP infiltration ponds. The half-life of cesium-137 is 30.23 years.

Prior to 1986, cesium-137 had not been detected in water from the Snake River Plain aquifer at the TRA but had been detected in ground water near the ICPP (Lewis and Jensen, 1984, p. 49; Pittman and others, 1988, p. 53). During 1982-85, maximum concentrations of cesium-137 in wells 40 and 47 (fig. 5) were 237±45 and 200±50 pCi/L, respectively. During 1986-88, no cesium-137 concentrations were detected in those wells. The absence of detectable concentrations of cesium-137 is attributed to the discontinuation of liquid-waste discharge to the ICPP disposal well and to sorption processes in the unsaturated and perched ground-water zones.

Cesium-137 concentrations have been detected in water from the TAN disposal well as a result of discharge of liquid radioactive wastes to the well prior to 1972. The concentration of cesium-137 in water from the TAN disposal well was 3,800±160 pCi/L in April 1986. In January 1988, the concentration was 3,060±120 pCi/L. Cesium-137 was not detected in water from any other wells completed in the Snake River Plain aquifer at the INEL during 1988.

Plutonium

Monitoring of quantities of plutonium-238 and plutonium-239, -240 (undivided) discharged to the Snake River Plain aquifer through the ICPP disposal well began in 1974. Prior to that time, alpha activity from disintegration of plutonium was not separable from the monitored, undifferentiated alpha activity. About 0.15 Ci of plutonium-238 and 0.05 Ci of plutonium-239, -240 (undivided) were discharged to the ICPP well during 1974-85.

During 1986-88, approximately 0.06 Ci of plutonium was discharged to infiltration ponds at the ICPP. The half-lives of plutonium-238, plutonium-239, and plutonium-240 are 86.4, 24,360, and 6,580 years, respectively.

Prior to 1986, concentrations of plutonium isotopes exceeded the reporting level in water from wells 40 and 47 (fig. 5) near the ICPP (Pittman and others, 1988, p. 54). Both wells are near the ICPP disposal well. In July 1985, the concentration of plutonium-238 in well 40 was 0.27±0.05 pCi/L. In August 1986, the concentration was 0.12±0.03 pCi/L; plutonium-238 was not detected in subsequent samples. In January 1987, the concentration of plutonium-239, -240 (undivided) in water from well 40 was 5.5±0.4 pCi/L. Concentrations of plutonium-239, -240 (undivided) in prior and subsequent samples were less than the reporting level. In October 1983, the concentration of plutonium-238 in well 47 was 0.50±0.06 pCi/L. Plutonium-238 concentrations were less than the reporting level in subsequent water samples.

Plutonium isotopes have been detected in water from the TAN disposal well (fig. 4) as a result of disposal of liquid radioactive wastes prior to 1972. The concentration of plutonium-238 in the TAN disposal well in 1987 was 1.22±0.09 pCi/L and the concentration of plutonium-239, -240 (undivided) was 5.0±0.2 pCi/L. Concentrations of plutonium-238 and plutonium-239, -240 (undivided) were 0.19±0.05 pCi/L and 0.96±0.08 pCi/L, respectively during 1988.

The concentration of plutonium-238 in water from well CFA-1 was 0.11±0.03 pCi/L in 1987 (Knobel and Mann, 1988, p. 21). In subsequent samples, the concentration of plutonium-238 was less than the reporting level. Plutonium isotopes were not detected in water samples from other wells completed in the Snake River Plain aquifer during October 1988, (Knobel and Mann, 1988, p. 34-36).

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 INEL and are in wastes buried at the RWMC. Between September 1972 and January 1988, concentrations of americium-241 exceeded the reporting level in water from wells 87, 88, 89, and 90 at the RWMC (fig. 5), and from the TAN disposal well. The half-life of americium-241 is 432 years.

Between October 1972 and September 1973, four water samples obtained from well 87 using a thief sampler contained concentrations of americium-241 that exceeded the reporting level. Concentrations ranged from 0.04±0.01 to 0.30±0.02 pCi/L; the median concentration was 0.12±0.02 pCi/L. In October 1974, a dedicated submersible pump was installed in well 87 to ensure that water representative of the aquifer was collected rather than water affected by wellbore storage. After that date, americium-241 was not detected in water samples collected from well 87.

Between April 1973 and July 1978, eight water samples obtained from well 88 using a thief sampler contained detectable concentrations of americium-241. Concentrations ranged from 0.02±0.006 to 0.13±0.02 pCi/L; the median concentration was 0.06±0.02 pCi/L. From August 1975, when a dedicated submersible pump was installed in well 88, to July 1982, americium-241 was detected once (July 1982). During 1986-88, americium-241 was not detected in water samples collected from well 88.

Between October 1972 and December 1974, eight water samples obtained from well 89 using a thief sampler contained concentrations of americium-241 that exceeded the reporting level. Concentrations ranged from 0.027±0.002 to 5±1 pCi/L; the median concentration was 0.12±0.02 pCi/L. After August 1975, when a dedicated submersible pump was installed, americium-241 was not detected in water samples collected from well 89.

Between September 1972 and July 1975, eight water samples obtained from well 90 using a thief sampler contained detectable concentrations of americium-241. Concentrations ranged from 0.03±0.01 to 1.50±0.40 pCi/L; the median concentration was 0.13±0.02 pCi/L. From August 1975, when a dedicated submersible pump was installed, to April 1981, three samples contained

detectable concentrations of americium-241. During 1986-88, americium-241 was not detected in water samples collected from well 90.

Americium-241 has been detected in water from the TAN disposal well (fig. 4), probably as a result of disposal of liquid radioactive wastes prior to 1972. The concentration of americium-241 in the TAN disposal well was 0.21±0.04 pCi/L in 1987 and 0.10±0.03 pCi/L in 1988.

Total Chromium

Wastewater from TRA cooling-tower operations contained an estimated 24,000 lb of chromium that were discharged to an infiltration pond during 1952-64 and an estimated 31,000 lb that were discharged to an injection well during 1965-72 (Mann and Knobel, 1988, p. 7-10). In October 1972, chromium was replaced by a polyphosphate as a corrosion inhibitor in cooling-tower operations. During 1971-83, approximately 260 lb of chromium were discharged to the ICPP disposal well and 719 lb of chromate were discharged in liquid waste at the PBF (Power Burst Facility) (Cassidy, 1984, p. 3). No chromium disposal was reported at the INEL during 1984-88.

In 1987, water samples from 81 wells were analyzed for total chromium as part of a reconnaissance-level sampling program at the INEL (Mann and Knobel, 1988, p. 1). The maximum contaminant level of 50 µg/L (U.S. Environmental Protection Agency, 1989, p. 547) was exceeded in water from well 65 (fig. 5), which had a concentration of 280 µg/L (Mann and Knobel, 1988, p. 12-17). The concentration in well 89 was at the maximum contaminant level. Other water samples contained from less than 1 to 30 µg/L of chromium.

Total chromium concentrations were monitored in water from 24 wells in 1988 as part of the regular monitoring program. Chromium concentrations of 210 and 30 µg/L were detected in wells 65 and 84, respectively.

Sodium

An estimated 3.2 million lb of sodium were disposed in liquid wastes at the INEL during 1986-88. About 2.2 million lb of sodium are estimated to have been discharged to the ICPP infiltration ponds. This estimation is based on chloride disposal at that facility. Approximately 552,000 lb of sodium were discharged to infiltration ponds at the TRA and approximately 156,000 lb were discharged to the NRF industrial-waste ditch.

The background sodium concentration in water from the Snake River Plain aquifer near the INEL generally is less than 10 mg/L (Robertson and others, 1974, p. 155). The extent of a sodium plume in the vicinity of the ICPP in October 1988 is shown on figure 14. The ICPP plume decreased in size from 6.8 mi^2 in 1985 to approximately 2.5 mi^2 in 1988. The maximum concentration of sodium in water from the aquifer was 56 mg/L at well 112 (fig. 5).

Sodium concentrations in water from several wells near the RWMC exceeded 10 mg/L in 1988. Water from well 88 contained 52 mg/L of sodium. There was no definable sodium plume at the TRA. Water from two wells at the TRA contained sodium concentrations of 10 mg/L.

In 1988, sodium concentrations in water from NRF wells 1, 2, and 3 (fig. 4) were 114, 16, and 14 mg/L, respectively, similar to those in previous years. Sodium concentrations in water from well NRF 2 were as large as 47 mg/L in 1982, but no long-term concentration trend is apparent. Some fluctuation may occur in response to changes in discharge rates to the NRF industrial-waste ditch. Sodium disposal decreased from about 86,300 lb in 1986 (Litteer, 1987a, p. 70) to about 14,800 lb in 1988 (Litteer and Reagan, 1989a, p. NRF-5).

Chloride

Approximately 3,960,000 lb of chloride were discharged to infiltration ponds at the INEL during 1986-88. Of this amount, approximately 3,520,000 lb were discharged to the ICPP infiltration ponds (fig. 3). Chloride

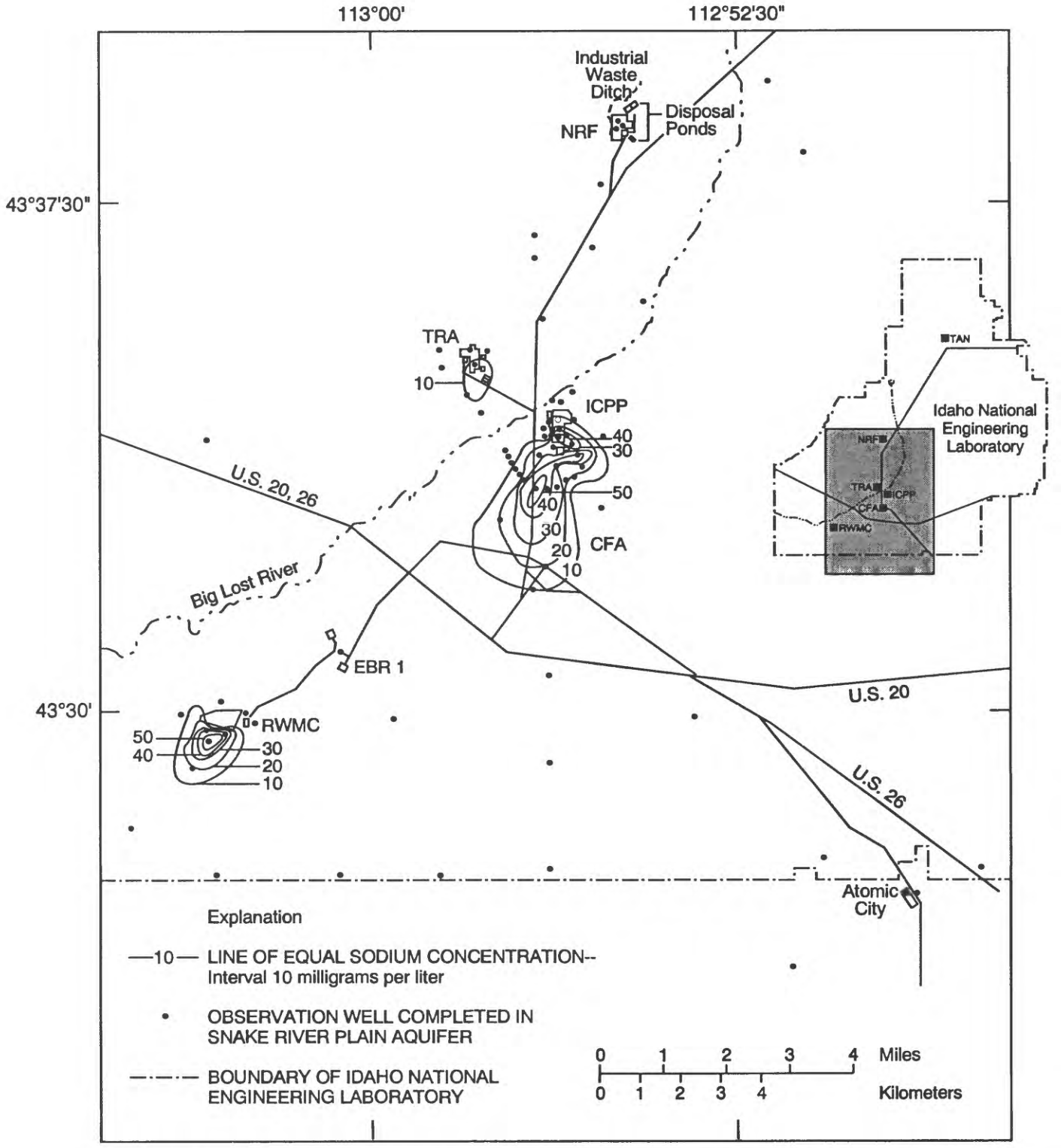

Figure 14.--Distribution of sodium in water from the Snake River Plain aquifer at the Idaho National Engineering Laboratory, October 1988.

disposal to the subsurface has resulted in detectable increases in chloride concentrations in water from the Snake River Plain aquifer.

In 1988, chloride concentrations in ground water exceeded 20 mg/L at the ICPP, TRA, RWMC, and NRF (fig. 15). At the ICPP, the size of the chloride plume with concentrations exceeding 20 mg/L decreased in extent during 1986-88. In 1984, the area of the chloride plume extended south of Highway 20 (Pittman and others, 1988, p. 59) and was about 17 mi^2 in size. By 1988, the plume had decreased in size to about 9.5 mi^2 and did not extend as far south as Highway 20. Chloride concentrations in wells 113 (fig. 5) and CFA-1 (fig. 4) were 160 and 86 mg/L, respectively. At the TRA, the chloride concentration in water from well 65 was 21 mg/L. Chloride concentrations in other wells completed in the Snake River Plain aquifer at the TRA were less than 20 mg/L.

At the RWMC, chloride concentrations in wells 88, 89, and 120 were 94, 38, and 28 mg/L, respectively. Chloride concentrations in ground water near the NRF slightly exceeded 20 mg/L, except for the INEL-1 water-supply well (fig. 4), in which the chloride concentration was 135 mg/L. Chloride concentrations in water from NRF well 2 declined from 100 mg/L in October 1984 to 37 mg/L in March 1988. The secondary maximum contaminant level for chloride is 250 mg/L (U.S. Environmental Protection Agency, 1989, p. 656).

Nitrate

Concentrations of nitrate in ground water not influenced by wastewater disposal from INEL facilities generally are less than 5 mg/L (Robertson, and others, 1974, p. 73). Wastewater containing nitrate was injected to the Snake River Plain aquifer through the ICPP disposal well from 1952 to February 1984 and to the ICPP infiltration ponds after February 1984. An average of 164,000 lb of nitrate was discharged annually to the ICPP infiltration ponds during 1986-88. This rate of disposal was about 60 percent of the disposal rate during 1982-85 and 55 percent of the rate during 1979-81.

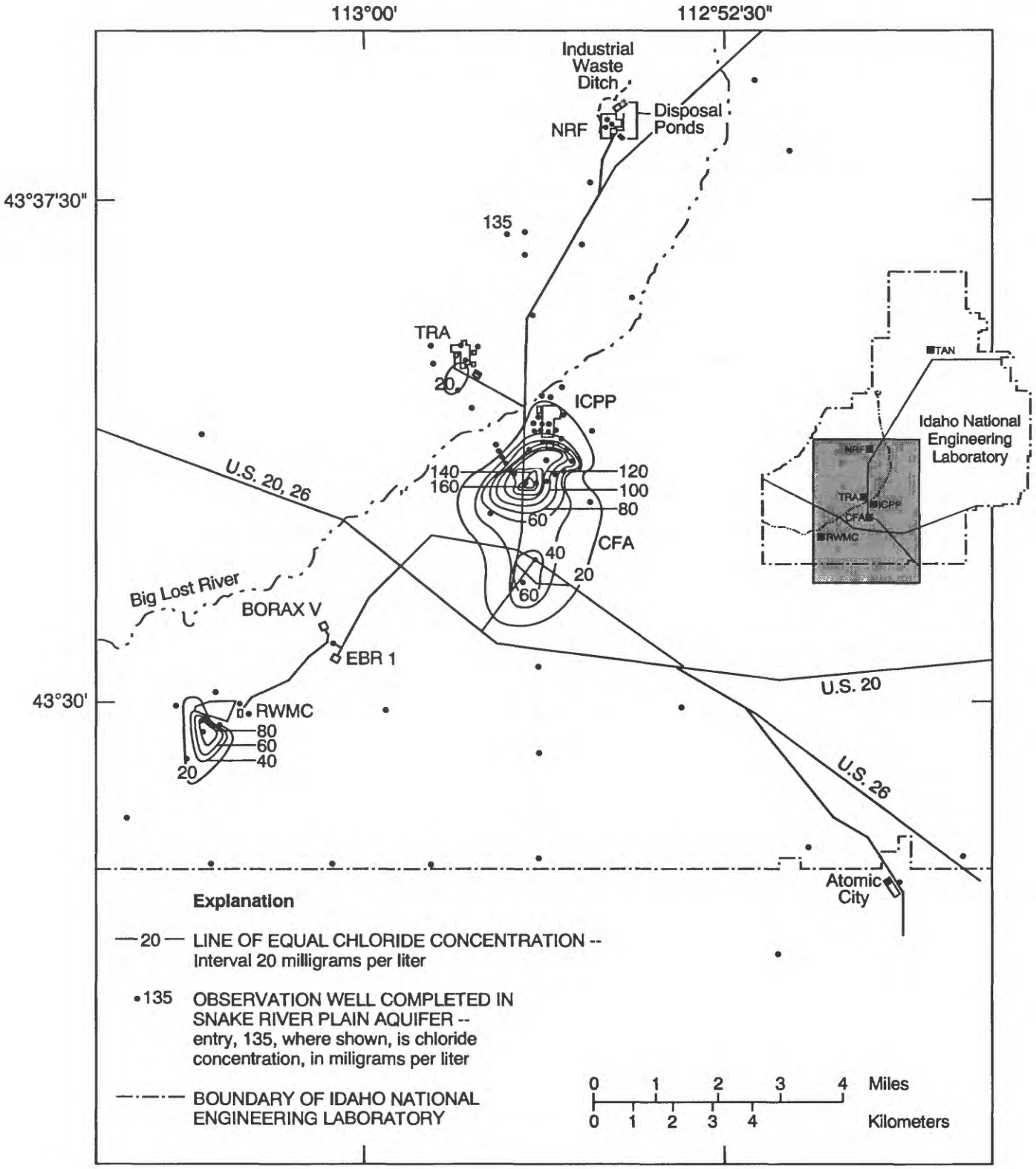

Figure 15.--Distribution of chloride in water from the Snake River Plain aquifer at the Idaho National Engineering Laboratory, October 1988.

Nitrate concentrations reported by the U.S. Geological Survey's National Water Quality Laboratory as N (nitrogen) are presented in this report as NO_3 (nitrate) for comparison with nitrate concentrations presented in previous reports. Changes in nitrate concentrations, and the size and configuration of the nitrate plume have occurred in response to disposal-rate changes and to the diversion of liquid wastes from the ICPP disposal well to infiltration ponds in 1984. In 1981, the size of the ICPP nitrate plume where concentrations exceeded 5 mg/L was about 10 mi^2; the maximum concentration was 62 mg/L in water from well 43 (Lewis and Jensen, 1984, p. 58). By 1984, the size had increased to about 14 mi^2 and concentrations ranged from less than 5 to 26.9 mg/L (Pittman and others, 1988, p. 61). By 1988, the nitrate plume had decreased in size to approximately 5 mi^2 (fig. 16). Nitrate concentrations in wells 67, 77, and CFA-1 (figs. 4 and 5) were 24, 23, and 20 mg/L, respectively. Nitrate concentrations declined during 1986-88 in response to reduced disposal rates.

In 1988, nitrate concentrations in water from wells 88 and 89, near the RWMC, were 7.5 and 8.0 mg/L, respectively. Historically, concentrations in the vicinity of the RWMC have slightly exceeded the regional background concentration of about 5 mg/L. At the TRA, water from wells 65, 76, and the TRA disposal well contained 6.6, 5.3, and 5.3 mg/L of nitrate, respectively. Water from well 97, south of the NRF, contained 8.0 mg/L. Concentrations of nitrate in water from the Snake River Plain aquifer at the INEL did not exceed the drinking water standard of 45 mg/L (as nitrate) (U.S. Environmental Protection Agency, 1989, p. 547).

Lead and Mercury

Prior to 1984, approximately 340 lb of lead and 150 lb of mercury were disposed in wastewater, principally at the ICPP. During 1986-88, no discharge of lead or mercury was reported in wastewater to infiltration ponds at the INEL.

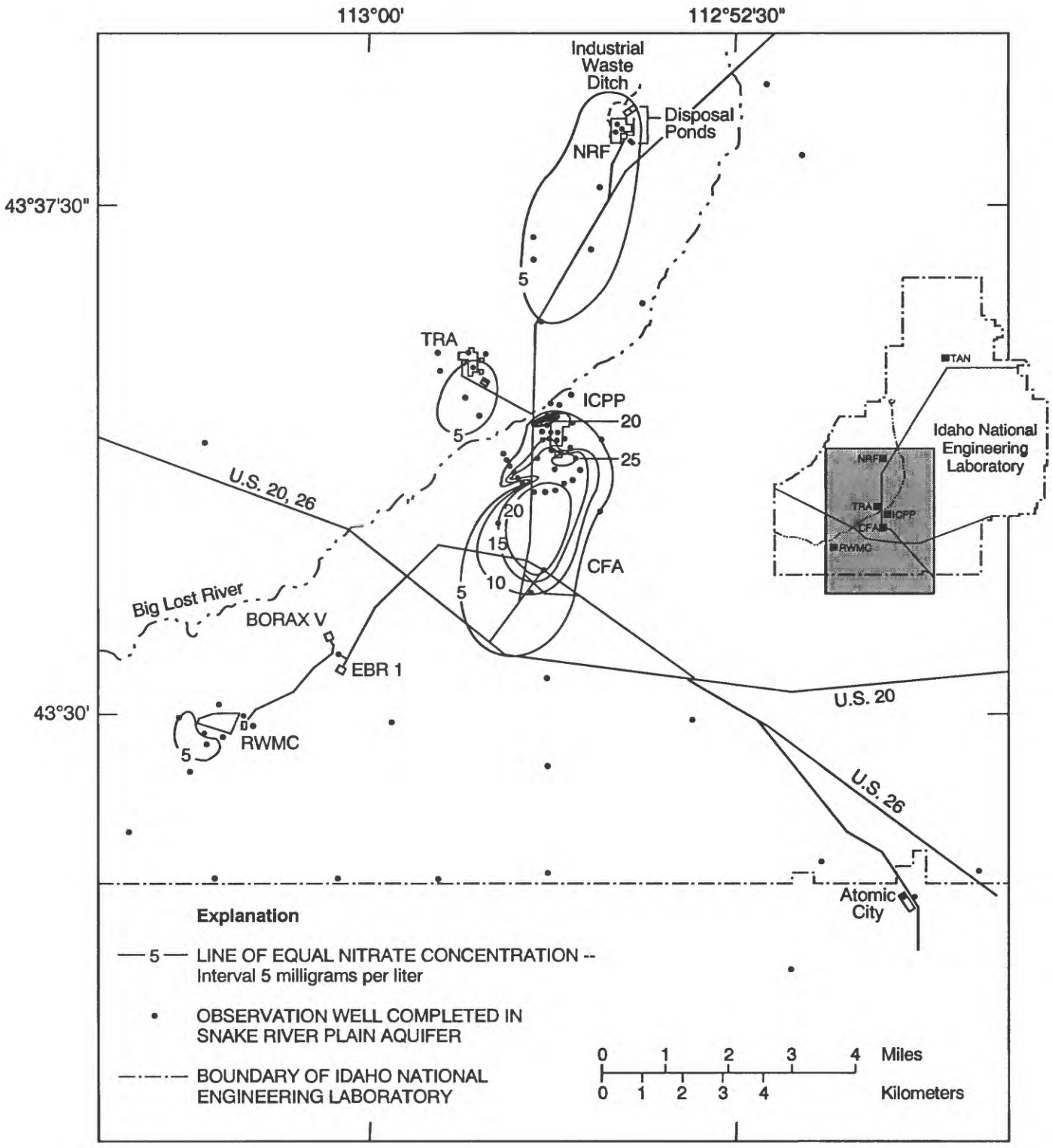

Figure 16.--Distribution of nitrate in water from the Snake River Plain aquifer at the Idaho National Engineering Laboratory, October 1988.

In October 1987, water samples from 81 wells completed in the Snake River Plain aquifer were analyzed for lead as part of a reconnaissance-level sampling program (Mann and Knobel, 1988, p. 12-17). Water from 77 wells contained less than the analytical method detection limit of 5 µg/L and water from 1 well contained less than the analytical method detection limit of 10 µg/L for that sample. Lead concentrations in water from wells 47, 67, and 76 (fig. 5) were 6, 9, and 7 µg/L, respectively, and were less than the maximum contaminant level of 50 µg/L (U.S. Environmental Protection Agency, 1989, p. 547).

As part of the same sampling program, water from 81 wells completed in the aquifer was analyzed for mercury. Water from 70 wells contained less than 0.1 µg/L. The maximum mercury concentration was 0.4 µg/L in water from well 47. Mercury concentrations in the remaining 10 wells ranged from 0.1 to 0.3 µg/L; the maximum contaminant level for mercury is 2 µg/L (U.S. Environmental Protection Agency, 1989, p. 547).

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. Dissolved chemical constituents in liquid wastes discharged to disposal wells and infiltration ponds at INEL facilities generally increase specific conductance in ground water. In 1988, the specific conductance of water from 89 wells at the INEL ranged from 178 to 860 µS/cm; the median specific conductance was 410 µS/cm.

The increase in specific conductance attributed to liquid wastes discharged to the aquifer is apparent in ground water downgradient from INEL facilities. In October 1988, the area near the ICPP, TRA, and NRF, in which the specific conductance of water from wells exceeded 400 µS/cm, was about 25 mi^2 (fig. 17), approximately the same as in 1985. A plume of increased specific conductance originated from the ICPP infiltration ponds, extending downgradient from the ICPP to the CFA. The conductance in several wells within this plume increased from about 500 µS/cm in 1985 (Pittman and

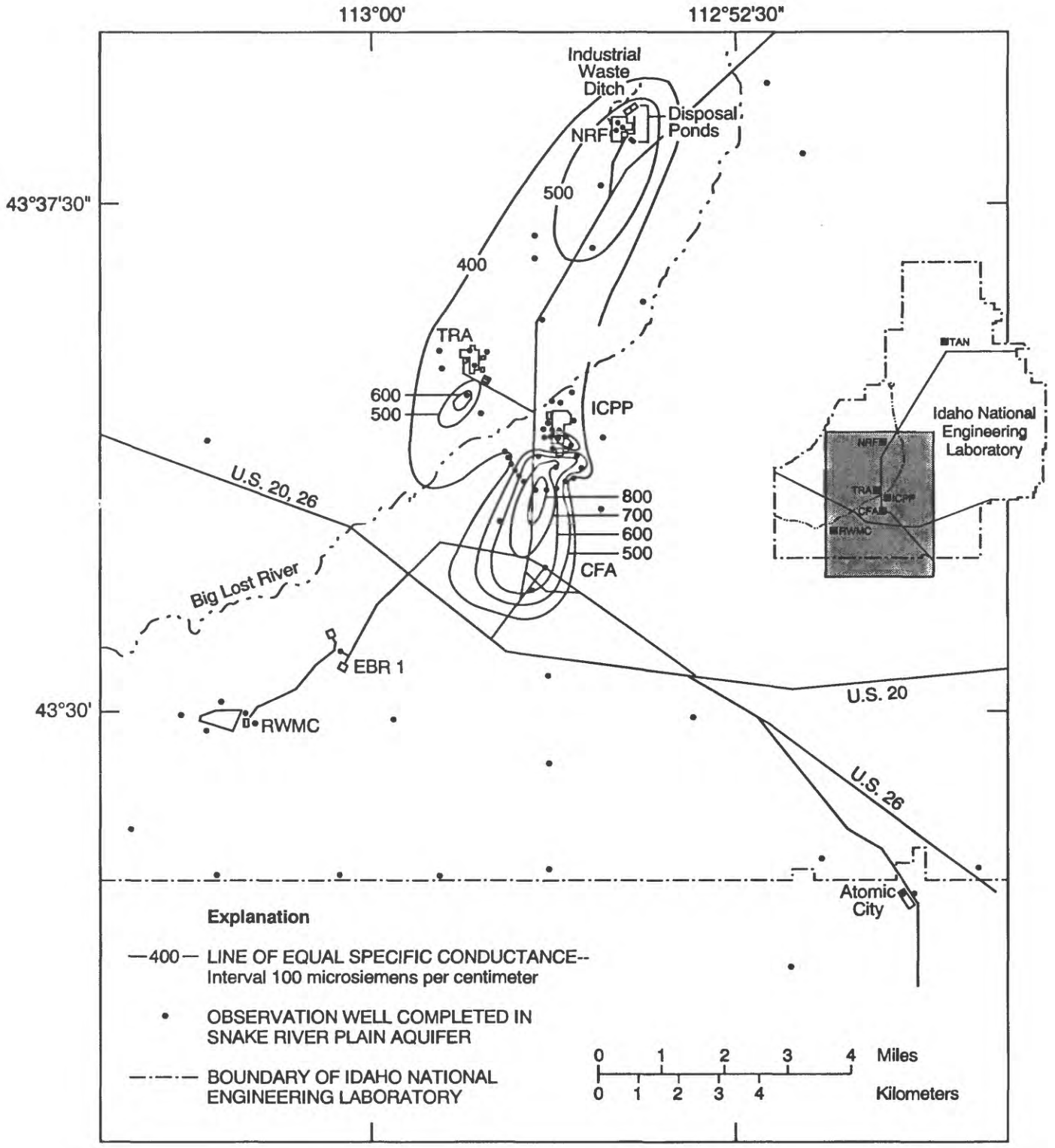

Figure 17.--Distribution of specific conductance of water from the Snake River Plain aquifer at the Idaho National Engineering Laboratory, October 1988.

others, 1988, p. 64) to more than 700 μS/cm in 1988. Well 113 (fig. 5) contained water with a conductance of 860 μS/cm. Increases in conductance probably can be attributed to the diversion of liquid wastes to ICPP infiltration ponds in 1984.

The specific conductance of water from several wells at the TRA exceeded 400 μS/cm in 1988. Water from well 65, downgradient from infiltration ponds at the TRA, had a conductance of 600 μS/cm. The specific conductance of water from wells near the NRF generally exceeded 500 μS/cm. Supply wells NRF 1, 2, and 3, and monitoring wells 97 and 99 contained water with conductances exceeding 500 μS/cm. Near the RWMC, wells 88 and 120 contained water with specific conductance exceeding 400 μS/cm.

Water temperatures from 89 samples collected in 1988 ranged from 10 °C in well 86 to 18 °C in well EBR-1. The median temperature was 13.5 °C. The pH ranged from 7.7 in well 19 to 9.6 in well 49; the median pH was 8.01.

SUMMARY

Recharge to the Snake River Plain aquifer from streamflow infiltration declined during 1986-88. Flow in the Big Lost River at the INEL diversion declined from 127,950 acre-ft in 1986 to zero in 1988. Recharge from the INEL diversion areas declined from 42,743 acre-ft in 1986 to zero in 1988. Channel infiltration losses from the INEL diversion to Lincoln Boulevard declined from 16,412 acre-ft in 1986 to zero in 1988; losses from Lincoln Boulevard to terminal playas declined from 72,224 acre-ft in 1986 to zero in 1988.

In 1988, the altitude of the water table in the Snake River Plain aquifer was about 4,590 ft above sea level near TAN and about 4,430 ft above sea level near the RWMC. Locally, the hydraulic gradient ranged from about 1 to 15 ft/mi and flow was to the south and southwest. From July 1985 to July 1988, water-level changes in INEL wells ranged from a decline of 26.8 ft near the RWMC to a rise of 4.3 ft north of TAN. During that time, water

levels generally declined across the southern two-thirds of the INEL and rose in the northern one-third.

During 1986-88, approximately 555 Ci of tritium were discharged to infiltration ponds at the ICPP and approximately 377 Ci were discharged to radioactive-waste infiltration ponds at the TRA. A tritium plume originating from the ICPP and TRA decreased from 51 mi^2 in 1985 to approximately 45 mi^2 in 1988. The area of the plume containing tritium concentrations in excess of 20 pCi/mL decreased from 4.4 to 2.8 mi^2. Tritium concentrations in wells 65 and 77 were 61.6±1.1 and 50.5±0.9 pCi/mL, respectively. Tritium concentrations exceeded the reporting level during 1983-85 in water from wells 103, 105, and 108, near the southern boundary of the INEL, but have been less than the reporting level since 1985. Radioactive decay, decreased tritium disposal, dilution from natural recharge, and discontinuation of the use of the ICPP disposal well, and subsequent liquid-waste discharge to infiltration ponds contributed to reduced concentrations of tritium in ground water at the INEL during 1986-88.

Approximately 0.13 Ci of strontium-90 was discharged to the ICPP infiltration ponds during 1986-88. An additional 0.13 Ci was discharged to the TRA radioactive-waste infiltration ponds. The area of the strontium-90 plume at the ICPP decreased from approximately 2 mi^2 in 1985 to approximately 0.8 mi^2 in 1988; strontium-90 concentrations ranged from 8±2 to 48±3 pCi/L. The reduced areal extent and concentration of strontium-90 in the aquifer by 1988 probably resulted from changes in waste-disposal practices, radioactive decay, diffusion, dispersion, and changes in natural recharge. The absence of a strontium-90 plume at the TRA can be attributed to disposal of liquid radionuclide wastes only to TRA infiltration ponds and to sorption processes in the unsaturated and perched ground-water zones.

During 1986-88, about 6.5 Ci of cobalt-60 were discharged to TRA radioactive-waste infiltration ponds. In 1985, cobalt-60 was detected in water from well 65, south of the TRA, but concentrations in subsequent samples were less than the reporting level. The reduction in discharge of cobalt-60 to the TRA radioactive-waste infiltration ponds, radioactive decay, and sorption processes in the unsaturated zone are responsible for

the absence of detectable concentrations of cobalt-60 in ground water near the TRA during 1986-88. Water from the TAN disposal well contained 890±9 pCi/L of cobalt-60 in October 1987. Cobalt-60 was not detected during 1986-88 in water from any other wells completed in the Snake River Plain aquifer at the INEL.

During 1986-88, approximately 0.7 Ci of cesium-137 was discharged to the TRA radioactive-waste ponds and 0.3 Ci was discharged to the ICPP infiltration ponds. Before 1986, cesium-137 had been detected in ground water near the ICPP but had not been detected near the TRA. During 1986-88, cesium-137 was not detected in water from wells that previously had detectable concentrations. The absence of detectable concentrations of cesium-137 can be attributed to changes in ICPP waste-disposal practices and to sorption processes in the unsaturated and perched ground-water zones. The concentration of cesium-137 in water from the TAN disposal well was 3,800±160 pCi/L in April 1986 and 3,060±120 pCi/L in January 1988. Concentrations of cesium-137 were not detected in water from other wells completed in the Snake River Plain aquifer.

During 1986-88, approximately 0.06 Ci of plutonium was discharged to infiltration ponds at the ICPP. In July 1985, the concentration of plutonium-238 in water from well 40 was 0.27±0.05 pCi/L; in August 1986, the concentration was 0.12±0.03 pCi/L. Plutonium-238 was not detected in subsequent samples. In January 1987, the concentration of plutonium-239, -240 (undivided) in water from well 40 was 5.5±0.4 pCi/L. Plutonium-239, -240 (undivided) was not detected in prior and subsequent samples. In 1988, the concentrations of plutonium-238 and plutonium-239, -240 (undivided) in the TAN disposal well were 0.19±0.05 pCi/L and 0.96±0.08 pCi/L, respectively. The concentration of plutonium-238 in well CFA-1 was 0.11±0.03 pCi/L in 1987. In subsequent samples, the concentration of plutonium-238 was less than the reporting level. During October 1988, plutonium isotopes were not detected in water samples from other wells completed in the Snake River Plain aquifer. The concentration of americium-241, a decay product of plutonium-241, in the TAN disposal well was 0.21±0.04 pCi/L in 1987 and 0.10±0.03 pCi/L in 1988.

No chromium disposal was reported at the INEL during 1986-88. In 1987, water samples from 81 wells were sampled for total chromium. The maximum contaminant level of 50 μg/L was exceeded in water from well 65, which had a concentration of 280 μg/L. The concentration in water from well 89 was 50 μg/L. Water samples from 79 other wells contained from less than 1 to 30 μg/L. In 1988, total chromium concentrations of 210 and 30 μg/L were detected in wells 65 and 84, respectively.

An estimated 3.2 million lb of sodium were disposed in liquid wastes at the INEL during 1986-88, principally to ICPP infiltration ponds. The sodium plume originating from the ICPP decreased in size from 6.8 mi^2 in 1985 to approximately 2.5 mi^2 in 1988. The maximum sodium concentration in water from wells was 56 mg/L.

Approximately 3.96 million lb of chloride were discharged in wastewater during 1986-88. In 1988, chloride concentrations exceeding 20 mg/L were detected in ground water at the ICPP, TRA, RWMC, and NRF. The ICPP chloride plume, which was 17 mi^2 in 1985, decreased to approximately 9.5 mi^2 in 1988. Chloride concentrations in water from wells 113 and CFA-1 were 160 and 86 mg/L, respectively. Chloride concentrations in water from aquifer wells at the TRA generally were less than 20 mg/L. Chloride concentrations in ground water near the NRF slightly exceeded 20 mg/L, except for the INEL-1 water-supply well, in which the chloride concentration was 135 mg/L.

An average of 164,000 lb of nitrate was discharged annually to the ICPP infiltration ponds during 1986-88. Nitrate concentrations declined during 1986-88 in response to reduced disposal rates. The nitrate plume extending south of the ICPP decreased from about 14 mi^2 in 1985 to about 5 mi^2 in 1988. Nitrate concentrations in wells 67, 77, and CFA-1 were 24, 23, and 20 mg/L, respectively, in 1988.

Approximately 340 lb of lead and 150 lb of mercury were reportedly discharged in liquid wastes at the INEL prior to 1984, principally at the ICPP. During 1986-88, no lead or mercury were reported discharged in wastewater. In 1987, lead concentrations in water samples from 77 wells were less than 5 μg/L; water from 1 well contained less than 10 μg/L. Lead

concentrations in water from wells 47, 67, and 76 were 6, 9, and 7 μg/L, respectively, all less than the maximum contaminant level of 50 μg/L. Also, in 1987, mercury concentrations in water from 70 wells were less than 0.1 μg/L. The mercury concentration in well 47 was 0.4 μg/L. Mercury concentrations in the remaining wells ranged from 0.1 to 0.3 μg/L.

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