DOE/ID-22242

Prepared in cooperation with the U.S. Department of Energy

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Scientific Investigations Report 2017–5021

U.S. Department of the Interior
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Cover: Photograph showing U.S. Geological Survey Idaho National Laboratory Project Office scientist collecting a water sample at well USGS 87. (Photograph by Roy Bartholomay, U.S. Geological Survey, April 13, 2015.)

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RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

Suggested citation:
Bartholomay, R.C., Maimer, N.V., Rattray, G.W., and Fisher, J.C., 2017, An update of hydrologic conditions and distribution of selected constituents in water, eastern Snake River Plain aquifer and perched groundwater zones, Idaho National Laboratory, Idaho, emphasis 2012–15: U.S. Geological Survey Scientific Investigations Report 2017–5021 (DOE/ID-22242), 87 p., https://doi.org/10.3133/sir20175021.

ISSN 2328-0328 (online)

Contents

Contents

Figures

Figures

Figures

Tables

Tables

Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter
million gallons (Mgal)	3,785	cubic meter (m^3)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [(ft^3/s)/mi^2]	0.01093	cubic meter per second per square kilometer [(m^3/s)/km^2]
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Mass	
pound, avoirdupois (lb)	0.4536	kilogram (kg)
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

International System of Units to U.S. customary units

Multiply	By	To obtain
	Volume	
liter (L)	33.82	ounce, fluid (fl. oz)
liter (L)	2.113	pint (pt)
liter (L)	1.057	quart (qt)
liter (L)	0.2642	gallon (gal)
	Radioactivity	
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)

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

$$°F = (1.8 \times °C) + 32.$$

Datums

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1927 (NAD 27).

Altitude, as used in this report, refers to distance above the vertical datum.

Supplemental Information

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

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

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

Activities for radioactive constituents in water are given in picocuries per liter (pCi/L).

Abbreviations

ATR Complex	Advanced Test Reactor Complex (formerly RTC, Reactor Technology Complex; and TRA, Test Reactors Facility)
CFA	Central Facilities Area
Ci	Curie
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
ESRP	eastern Snake River Plain
ICPP	Idaho Chemical Processing Plant
INEL	Idaho National Engineering Laboratory (1974–97)
INEEL	Idaho National Engineering and Environmental Laboratory (1997–2005)
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LRL	laboratory reporting level
LT-MDL	long-term method detection level
MCL	maximum contaminant level
MDL	method detection limit
MRL	minimum reporting level
MLMS	multilevel monitoring system
NAD	normalized absolute difference
NRF	Naval Reactors Facility

Abbreviations

NRTS	National Reactor Testing Station (1949–74)
NWIS	National Water Information System
NWQL	National Water Quality Laboratory (USGS)
PBF	Power Burst Facility
ppm	parts per million
QA	quality assurance
RESL	Radiological and Environmental Sciences Laboratory (DOE)
RSD	relative standard deviation
RWMC	Radioactive Waste Management Complex
RWMC PROD	RWMC Production Well
s	sample standard deviation
SDA	Subsurface Disposal Area
TAN	Test Area North
TRA DISP	Test Reactor Area disposal well
TSF	Technical Support Facility
TOC	total organic carbon
USGS	U.S. Geological Survey
VOC	volatile organic compound

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Abstract

Since 1952, wastewater discharged to infiltration ponds (also called percolation ponds) and disposal wells at the Idaho National Laboratory (INL) has affected water quality in the eastern Snake River Plain (ESRP) aquifer and perched groundwater zones underlying the INL. The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, maintains groundwater-monitoring networks at the INL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the aquifer and in perched groundwater zones. This report presents an analysis of water-level and water-quality data collected from the ESRP aquifer, multilevel monitoring system (MLMS) wells in the ESRP aquifer, and perched groundwater wells in the USGS groundwater monitoring networks during 2012–15.

From March–May 2011 to March–May 2015, water levels in wells completed in the ESRP aquifer declined in all wells at the INL. Water-level declines were largest in the northern part of the INL and smallest in the southwestern part.

Detectable concentrations of radiochemical constituents in water samples from wells or MLMS equipped wells in the ESRP aquifer at the INL generally decreased or remained constant during 2012–15. Decreases in concentrations were attributed to radioactive decay, changes in waste-disposal methods, and dilution from recharge and underflow.

In 2015, concentrations of tritium in groundwater from 49 of 118 ESRP aquifer wells were greater than or equal to the reporting level and ranged from 230±50 to 5,760±120 picocuries per liter. Tritium concentrations from one or more discrete zones from nine wells equipped with MLMS were greater than or equal to reporting levels in water samples collected at various depths. Tritium concentrations in deep perched groundwater at the Advanced Test Reactor Complex (ATR Complex) equaled or exceeded the reporting level in 13 wells during at least one sampling event during 2012–15, and concentrations ranged from 210±60 to 28,100±900 pCi/L.

Concentrations of strontium-90 in water from 18 of 67 ESRP aquifer wells sampled during April or October 2015 exceeded the reporting level. Strontium-90 was not detected in the ESRP aquifer beneath the ATR Complex. During at least one sampling event during 2012–15, concentrations of strontium-90 in water from 12 wells completed in deep perched groundwater at the ATR Complex equaled or exceeded the reporting levels and concentrations ranged from 1.8±0.6 to 73.6±2 pCi/L.

During 2012–15, concentrations of cesium-137 were less than the reporting level in all but eight ESRP aquifer wells, and concentrations of plutonium-238, plutonium-239, -240 (undivided), and americium-241 were less than the reporting level in water samples from all ESRP aquifer wells and all zones in wells equipped with MLMS.

In April 2009, the dissolved chromium concentration in water from one ESRP aquifer well, USGS 65, south of ATR Complex equaled the maximum contaminant level (MCL) of 100 µg/L. In April 2015, the concentration of chromium in water from that well had decreased to 72.8 µg/L, much less than the MCL. Concentrations in water samples from 62 other ESRP aquifer wells sampled ranged from <0.6 to 25.4 µg/L. During 2012–15, dissolved chromium was detected in water from all wells completed in deep perched groundwater at the ATR Complex, and concentrations ranged from 4.41 to 37 µg/L.

In 2015, concentrations of sodium in water from most ESRP aquifer wells in the southern part of the INL were greater than the western tributary background concentration of 8.3 milligrams per liter (mg/L). After the new percolation ponds were put into service in 2002 southwest of the Idaho Nuclear Technology and Engineering Center (INTEC), concentrations of sodium in water samples from the Rifle Range well increased steadily until 2008, when concentrations generally began decreasing. The increases and decreases were attributed to disposal variability in the new percolation ponds.

Concentrations of sodium in most wells equipped with MLMS generally varied little with depth. During 2012–15, dissolved sodium concentrations in water from 18 wells completed in deep perched groundwater at the ATR Complex ranged from 7.09 to 33.4 mg/L.

In 2015, concentrations of chloride in most water samples from ESRP aquifer wells south of the INTEC and at the Central Facilities Area exceeded the background concentrations. Chloride concentrations in water from wells south of the INTEC have generally decreased because of discontinued chloride disposal to the old percolation ponds since 2002 when discharge of wastewater was discontinued. After the new percolation ponds were put into service in 2002 southwest of the INTEC, concentrations of chloride in water samples from one well rose steadily until 2008 then began decreasing. Most of the concentrations in 11 MLMS wells are less than or near background concentrations for western tributary water at the INL. The zones from wells with greater than background concentrations represent influence from wastewater disposal. During 2012–15, dissolved chloride concentrations in deep perched groundwater from 18 wells at the ATR Complex ranged from 4.16 to 78.1 mg/L.

In 2015, sulfate concentrations in water samples from ESRP aquifer wells in the south-central part of the INL that exceeded the background concentration of sulfate ranged from 22 to 162 mg/L. The greater-than-background concentrations in water from these wells probably resulted from sulfate disposal at the ATR Complex infiltration ponds or the old INTEC percolation ponds. In 2015, sulfate concentrations in water samples from wells near the Radioactive Waste Management Complex (RWMC) were mostly greater than background concentrations and could have resulted from well construction techniques and (or) waste disposal at the RWMC or the ATR Complex. The vertical distribution of sulfate concentrations in multilevel monitoring wells near the southern boundary of the INL was generally consistent with depth and ranged between 17 and 28 mg/L. The maximum dissolved sulfate concentration in shallow perched groundwater near the ATR Complex was 175 mg/L in well CWP 3 in April 2012. During 2012–15, dissolved sulfate concentrations in water from 18 wells completed in deep perched groundwater at the ATR Complex ranged from 18.8 to 638 mg/L.

In 2015, concentrations of nitrate in water from most ESRP aquifer wells at and near the INTEC exceeded the western tributary background concentration of 0.655 mg/L. Concentrations of nitrate in wells southwest of INTEC and farther away from the influence of disposal areas and the Big Lost River show a general decrease in nitrate concentration through time. Two wells south of INTEC show increasing trends that could be the result of wastewater beneath the INTEC tank farm being mobilized to the aquifer.

During 2012–15, water samples from several ESRP aquifer wells were collected and analyzed for volatile organic compounds (VOCs). Eighteen VOCs were detected. At least 1 and up to 7 VOCs were detected in water samples from 14 wells. The primary VOCs detected include carbon tetrachloride, trichloromethane, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. In 2015, concentrations for all VOCs were less than their respective MCL for drinking water, except carbon tetrachloride in water from two wells, trichloroethene in three wells and vinyl chloride in one well.

During 2012–15, variability and bias were evaluated from 54 replicate and 33 blank quality-assurance samples. Results from replicate analyses were investigated to evaluate sample variability. Constituents with acceptable reproducibility were major ions, nutrients, and VOCs. All radiochemical constituents and trace metals had acceptable reproducibility except for gross alpha- and beta-particle radioactivity, cesium-137, antimony, cobalt, iron and manganese. The samples that did not meet reproducibility criteria all had very small concentrations. Bias from sample contamination was evaluated from equipment, field, container, and source-solution blanks. Some of the constituents were found at small concentrations near reporting levels, but analyses indicate that no sample bias was likely for any of the sample periods.

Introduction

The Idaho National Laboratory (INL), operated by the U.S. Department of Energy (DOE), encompasses about 890 mi^2 of the eastern Snake River Plain (ESRP) in southeastern Idaho (fig. 1). The INL was established in 1949 to develop atomic energy, nuclear safety research, defense programs, environmental research, and advanced energy concepts. Wastewater disposal sites at the Test Area North (TAN), the Naval Reactors Facility (NRF), the Advanced Test Reactor Complex (ATR Complex), and the Idaho Nuclear Technology and Engineering Center (INTEC) (fig. 1) have contributed radioactive- and chemical-waste contaminants to the ESRP aquifer since 1952. These sites incorporated various wastewater disposal methods, including lined evaporation ponds, unlined percolation (infiltration) ponds and ditches, drain fields, and injection wells. Waste materials buried in shallow pits and trenches in the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC) also have contributed contaminants to groundwater.

Wastewater disposal has resulted in detectable concentrations of several waste constituents in water from the ESRP aquifer underlying the INL. Disposal of wastewater to infiltration ponds and infiltration of surface water at waste-burial sites resulted in the formation of perched groundwater in basalts and in sedimentary interbeds that overlie the ESRP aquifer (Cecil and others, 1991). Perched groundwater is an integral part of the pathway for waste-constituent migration to the aquifer.

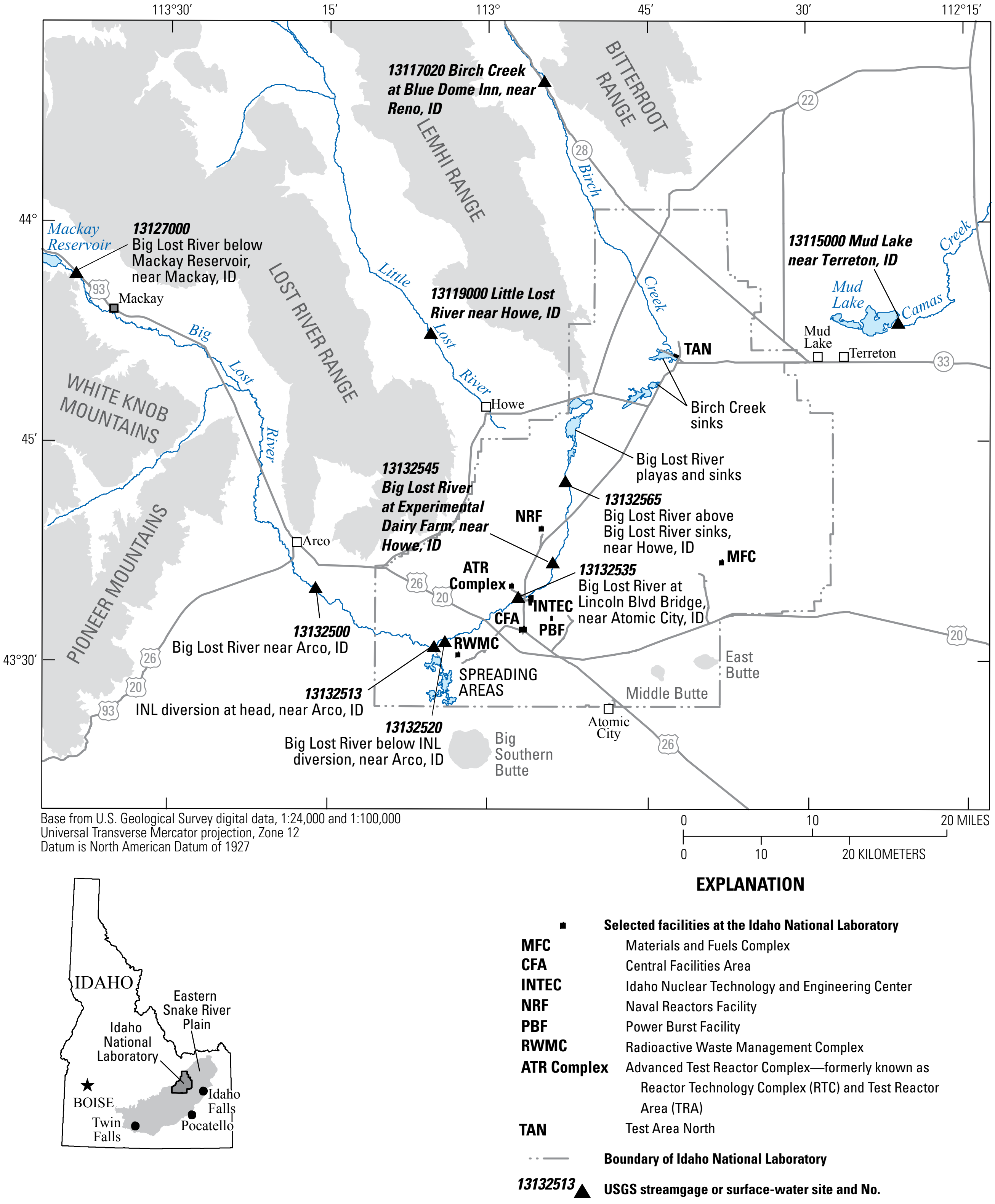


Figure 1. Location of the Idaho National Laboratory, surface-water streamgages, and selected facilities, eastern Snake River Plain, southeastern Idaho.

The DOE requires information about the mobility of radiochemical- and chemical-waste constituents in the ESRP aquifer and in perched groundwater above the aquifer so they can assess the effect of INL facility operations on water quality and to aid in remediation activities. Waste-constituent mobility is determined, in part, by (1) the rate and direction of groundwater 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 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 INL. The purpose of the resulting study was to characterize these resources before the development of nuclear-reactor testing facilities. Since that time, the USGS has maintained water-level and water-quality monitoring networks at the INL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the ESRP aquifer and in perched groundwater.

Most of the wells in the USGS monitoring network were constructed as open boreholes and are open to the aquifer through their entire depth below the water table. Beginning in 2005, the USGS and the INL contractor collaborated to instrument two wells (Middle 2050A and Middle 2051) with multilevel monitoring systems (MLMS) to collect water samples for analysis in order to describe the vertical distribution of constituents in the ESRP aquifer. The USGS expanded the program during 2006–12 to include nine additional wells (USGS 103, 105, 108, 131A, 132, 133, 134, 135, and 137A).

This report presents an analysis of water-level and water-quality data collected from wells in the USGS groundwater monitoring networks during 2012–15 as part of the continuing hydrogeologic investigations conducted by the USGS at the INL. This report describes the distribution and concentration of selected radiochemical and chemical constituents in groundwater and perched groundwater at the INL, the vertical distribution of selected constituents from samples collected with MLMS, and the changes in the regional water levels from 2011 through 2015. The report also summarizes the history of waste disposal at the ATR Complex (formerly known as the Test Reactor Area [TRA]), INTEC; (formerly known as the Idaho Chemical Processing Plant, ICPP), RWMC, TAN, NRF, and the Central Facilities Area (CFA).

Previous Investigations

Hydrologic conditions and the distribution of selected wastewater constituents in groundwater and perched groundwater are discussed in a series of reports describing the INL. Table 1 summarizes selected previous investigations on the geology, hydrology, and water characteristics at and near the INL, and periods included in those investigations. Numerous previous investigations on the hydrology and geology at the INL have been conducted by INL contractors, State agencies, and the USGS. A list of all the reports published by the USGS on project work completed at the INL can be found at http://id.water.usgs.gov/INL/Pubs/B.html.

Table 1. Summary of selected previous investigations on geology, hydrology, and water characteristics of groundwater and perched groundwater, Idaho National Laboratory, Idaho, 1961–2015.

[**Summary:** ATRC, Advanced Test Reactor Complex; ICPP, Idaho Chemical Processing Plant; INEL, Idaho National Engineering Laboratory; INEEL, Idaho National Engineering and Environmental Laboratory; INL, Idaho National Laboratory; INTEC, Idaho Nuclear Technology and Engineering Center; NRTS, National Reactor Testing Station; RWMC, Radioactive Waste Management Complex]

Reference	Investigation period	Summary
		Groundwater
Jones (1961)		Hydrology of waste disposal at the NRTS, Idaho.
Olmsted (1962)		Chemical and physical character of ground water at the NRTS, Idaho.
Morris and others (1963, 1964, 1965)		Hydrology of waste disposal at the NRTS, Idaho.
Barraclough and others (1967a)	1965	Hydrology of the NRTS, Idaho.
Barraclough and others (1967b)	1966	Hydrology of the NRTS, Idaho.
Nace and others (1975)		Generalized geologic framework of the NRTS, Idaho.
Robertson and others (1974)		Effects of waste disposal on the geochemistry of ground water at the NRTS, Idaho.
Barraclough and others (1976)		Hydrology of the solid waste burial ground (now the RWMC).
Barracough and Jensen (1976)	1971–73	Hydrologic data for the INEL, Idaho.
Barraclough and others (1981)	1974–78	Hydrologic conditions for the INEL, Idaho.
Lewis and Jensen (1985)	1979–81	Hydrologic conditions for the INEL, Idaho.
Pittman and others (1988)	1982–85	Hydrologic conditions for the INEL, Idaho.
Orr and Cecil (1991)	1986–88	Hydrologic conditions and distribution of selected chemical constituents in water at the INEL, Idaho.
Bartholomay and others (1995)	1989–91	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, INEL, Idaho.
Bartholomay and others (1997)	1992–95	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, INEL, Idaho.
Bartholomay and others (2000)	1996–98	Hydrologic conditions and distribution of selected constituents in water, INEEL, Idaho.
Davis (2006b)	1999–2001	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in water, INL, Idaho.
Ackerman and others (2006)		Conceptual model of groundwater flow in the eastern Snake River Plain aquifer, INL, with implications for contaminant transport.
Davis (2008)	2002–05	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Bartholomay and Twining (2010)	2006–08	Vertical distribution of selected constituents in water from wells equipped with Westbay® Insruments packer sampling systems.
Davis and others (2013)	2009–11	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Bartholomay and others (2015)	2009–13	Vertical distribution of selected constituents in water from wells equipped with Westbay® Instruments packer sampling systems.
Davis and others (2015)	1981–2012	Water quality trends for wells indfluenced by waterwater disposal at the INL.
Bartholomay and Twining (2015)	1949–2014	Hydrologic influences on water level changes in groundwater wells at the INL.

Table 1. Summary of selected previous investigations on geology, hydrology, and water characteristics of groundwater and perched groundwater, Idaho National Laboratory, Idaho, 1961–2015.—Continued

Reference	Investigation period	Summary
		Perched groundwater
Barraclough and others (1967a)	1965	Extent of perched ground water and distribution of selected wastewater constituents in perched ground water at the ATRC.
Barraclough and others (1967b)	1966	Extent of perched ground water and distribution of selected wastewater constituents in perched ground water at the ATRC.
Robertson and others (1974)		Analysis of perched ground water and conditions related to the disposal of wastewater to the subsurface at the INEL.
Barraclough and Jensen (1976)		Extent of perched ground water and distribution of selected wastewater constituents in perched ground water at the ATRC.
Robertson (1977)		Numerical model simulating flow and transport of chemical and radionuclide constituents through perched water at the ATRC.
Barraclough and others (1981)	1974–78	Hydrologic conditions for the INEL, Idaho.
Lewis and Jensen (1985)	1979–81	Hydrologic conditions for the INEL, Idaho.
Pittman and others (1988)	1982–85	Hydrologic conditions for the INEL, Idaho.
Hull (1989)		Conceptual model that described migration pathways for wastewater and constituents from the radioactive-waste infiltration ponds at the ATRC.
Anderson and Lewis (1989)		Correlation of drill cores and geophysical logs to describe a sequence of basalt flows and sedimentary interbeds in the unsaturated zones underlying the RWMC.
Anderson (1991)		Correlation of drill cores and geophysical logs to describe a sequence of basalt flows and sedimentary interbeds in the unsaturated zones underlying the ARTC and INTEC.
Ackerman (1991)		Analyzed data from 43 aquifer tests conducted in 22 wells to estimate transmissivity of basalts and sedimentary interbeds containing perched ground water beneath the ATRC and INTEC.
Cecil and others (1991)	1986–88	Mechanisms for formation of perched water at the ATRC, ICPP, and RWMC, INEL, Idaho; distribution of chemical and radiochemical constituents in perched water at the ATRC, ICPP and RWMC.
Tucker and Orr (1998)		Hydrologic conditions and distribution of selected radiochemical and chemical constituents in perched ground water, INEL, Idaho.
Bartholomay (1998)	1992–95	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in perched ground water, INEL, Idaho.
Orr (1999)		Transient numerical simulation to evaluate a conceptual model of flow through perched water beneathe wastewater infiltration ponds at the ATRC.
Bartholomay and Tucker (2000)	1996–98	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in perched ground water, INEEL, Idaho.
Davis (2006a)	1999–2001	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in perched ground water, INL, Idaho.
Davis (2008)	2002–05	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched ground water, INL, Idaho.
Davis (2010)	2006–08	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched ground water, INL, Idaho.
Davis and others (2013)	2009–11	Hydrologic conditions and distribution of selected radiochemical and chemical constituents in groundwater and perched groundwater, INL, Idaho.
Davis and others (2015)	1981–2012	Water quality trends for wells influenced by waterwater disposal at the INL.

Groundwater Monitoring Networks

The USGS maintains groundwater monitoring networks at the INL to characterize the occurrence, movement, and quality of water, and to delineate waste-constituent plumes in the ESRP aquifer and perched groundwater zones. Periodic water-level and water-quality data are obtained from these networks. Additionally, data are collected from MLMS to describe the vertical distribution of selected constituents. Data from these monitoring networks are available through the USGS National Water Information System (NWIS) Web site at http://waterdata.usgs.gov/id/nwis/nwis.

Water-Level Monitoring Network

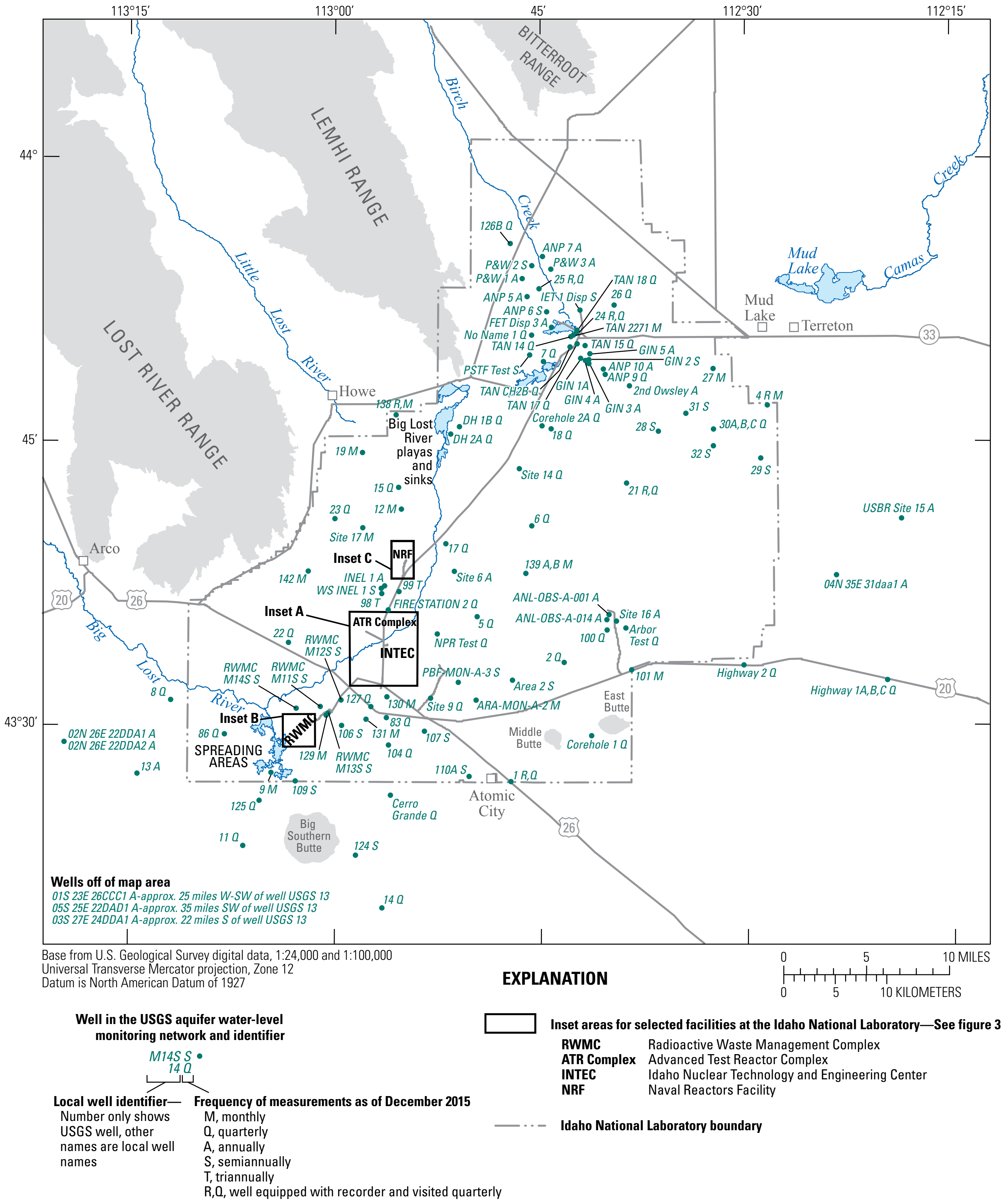
The USGS aquifer water-level monitoring network was designed to determine hydraulic-gradient changes that affect the rate and direction of groundwater and waste-constituent movement in the ESRP aquifer, to identify sources of recharge to the aquifer, and to measure the effects of recharge. During 2005–12, 11 wells were equipped with MLMS that allow pressure and temperature measurements to be acquired at isolated depths in each of the wells. This multilevel monitoring provided data that were used to describe the vertical distribution of pressure and temperature gradients in addition to the spatial distribution information previously gathered from open boreholes. A continuous monitoring well was installed in USGS 138 in 2012 to provide additional water-level information in the northwestern corner of the INL. A dual piezometer well (USGS 139) was completed in 2014 to provide additional water-level information in the central part of the INL. As of December 2015, water levels were monitored in 177 aquifer wells. Water levels were measured annually in 51 wells, semiannually in 46 wells, triannually in 3 wells, quarterly in 55 wells, monthly in 16 wells, and continuously recorded in 6 aquifer wells. Figures 2 and 3 show the locations of aquifer wells and the frequency of water-level measurements as of December 2015.

The USGS perched groundwater-level monitoring network was designed so that the extent and volume of perched groundwater in storage could be estimated. Perched groundwater occurs at the INL because unique features of the basalt layers and sedimentary interbeds in the unsaturated zones above the regional aquifer system that lie beneath some of the facilities provide a mechanism for the development of zones that hold water for a long time (Cecil and others, 1991, p. 17). As of December 2015, water levels in 29 wells (fig. 4) were monitored. At the ATR Complex, the network included 9 wells to monitor shallow perched groundwater levels and 18 wells to monitor deep perched groundwater levels. Shallow perched groundwater is considered to be water perched in surficial sediment deposits, and deep perched groundwater is water perched at greater depth. Perching mechanisms are attributed to contrasting hydraulic properties between sedimentary interbeds and basalts or between low-permeability basalt-flow interiors and overlying fractured basalt. Southwest of the INTEC, the network included one well (ICPP-MON-V-200) to monitor perched groundwater levels around the INTEC percolation ponds. Perched groundwater at the RWMC was measured in well USGS 92. Well locations and frequency of water-level measurements as of December 2015 are shown in figure 4.

Water-Quality Monitoring Network

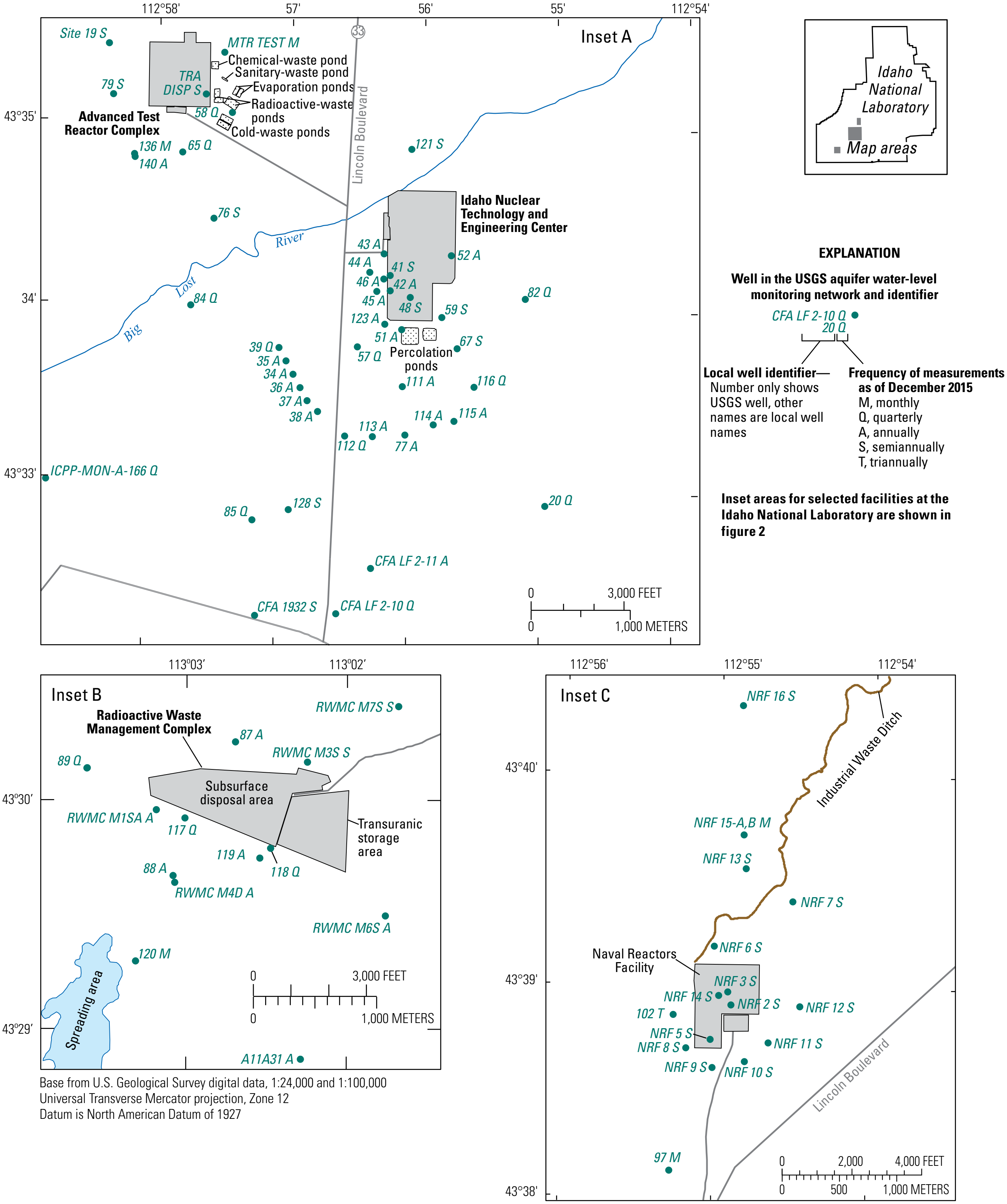
The radiochemical and chemical character of groundwater and perched groundwater in the ESRP aquifer was determined from analyses of water samples collected as part of a comprehensive sampling program to identify contaminant concentrations and to define patterns of waste migration in the aquifer and perched groundwater zones. Water samples were collected annually and analyzed to identify trends in water quality from wells that penetrate the aquifer at various depths and with differing well completions (openhole, screened, or equipped with MLMS). Numerous water samples were collected from aquifer and perched groundwater wells near areas of detailed study, such as the ATR Complex, INTEC, RWMC, TAN, and CFA. Water samples from the NRF were collected and analyzed as part of a separate study, and the results are available on the USGS NWIS Web page at http://waterdata.usgs.gov/id/nwis/nwis.

Beginning in 2005, the USGS and the INL contractor collaborated to equip two wells (Middle 2050A and Middle 2051; figs. 5 and 6) with MLMS to collect water samples for analysis in order to describe the vertical distribution of constituents in the ESRP aquifer. The USGS expanded the program from 2006 to 2012 to equip nine additional wells (USGS 103, 105, 108, 131A, 132, 133, 134, 135, and 137A; figs. 5 and 6). North Wind, Inc. (2006), Fisher and Twining (2011), and Twining and Fisher (2012; 2015) give detailed descriptions of the installation of each well. Water chemistry, vertical hydraulic head, and water temperature data were collected from the MLMS during 2005–15 (Bartholomay and Twining, 2010; Fisher and Twining, 2011; Twining and Fisher, 2012, 2015; Bartholomay and others, 2015).



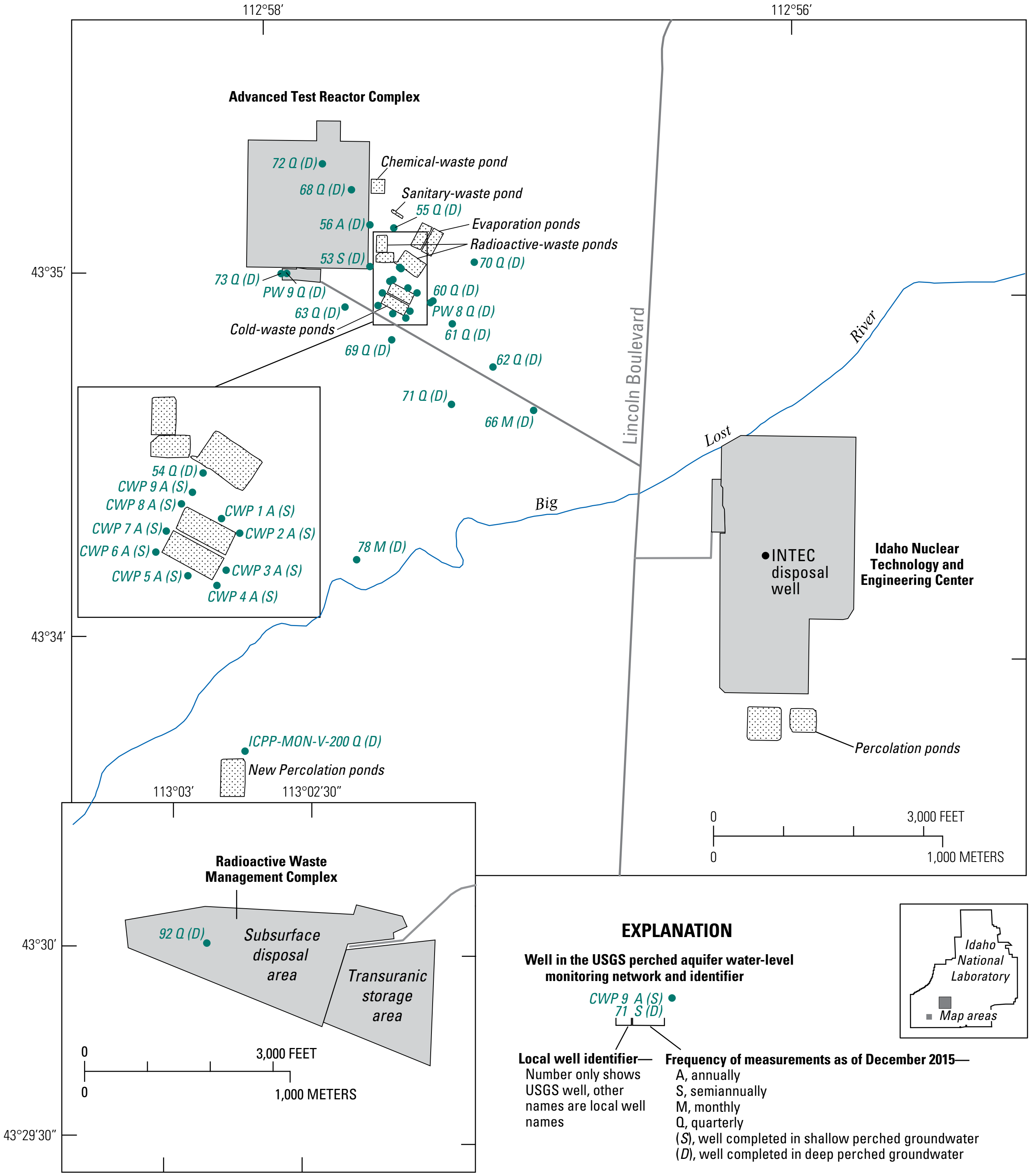
Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 2. Location of wells in the U.S. Geological Survey aquifer water-level monitoring network at and near the Idaho National Laboratory (INL), Idaho, and frequency of water-level measurements, as of December 2015.



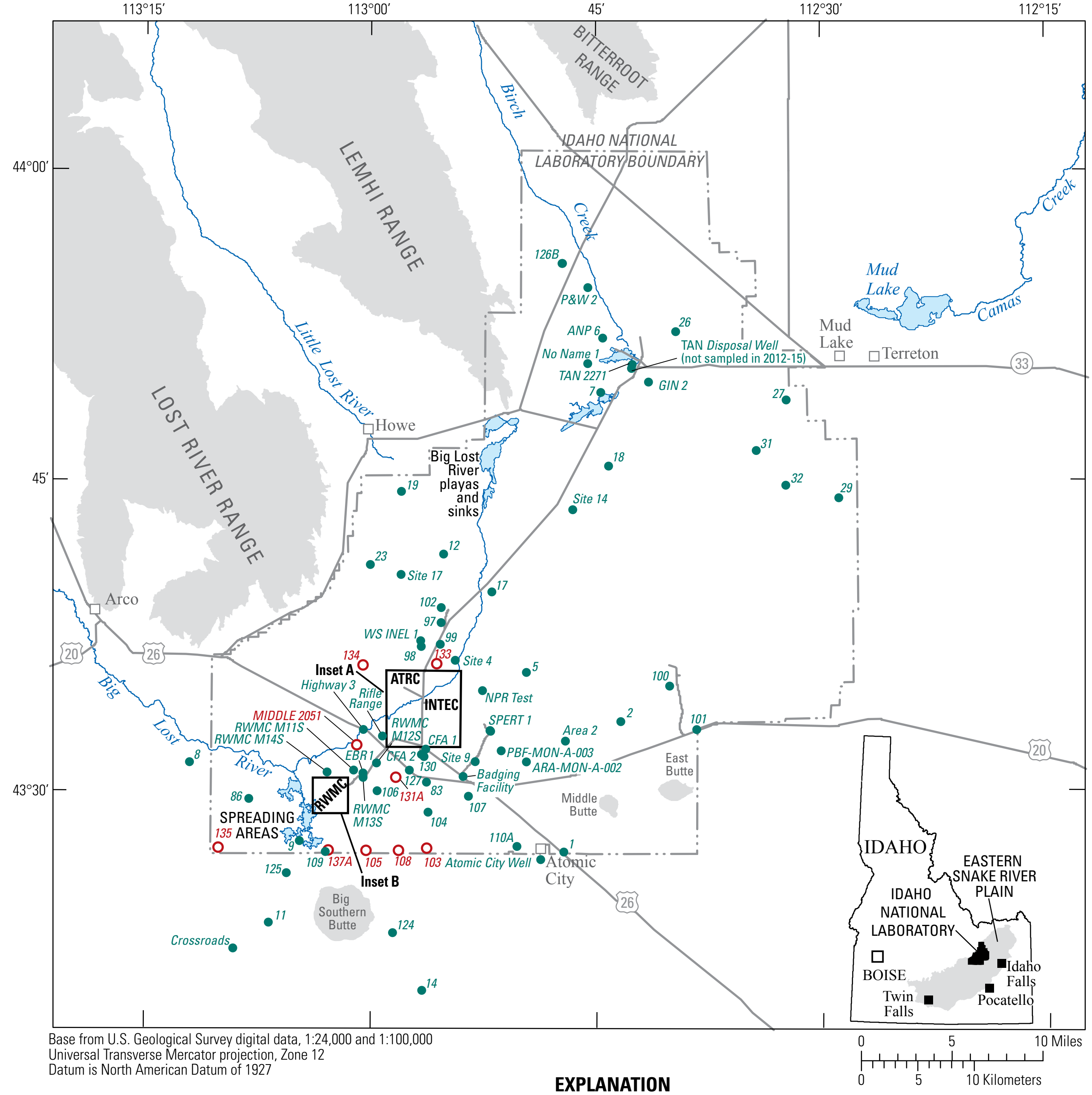
Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 3. Location of wells in the U.S. Geological Survey aquifer water-level monitoring network at the Advanced Test Reactor Complex (ATR Complex), Idaho Nuclear Technology and Engineering Center (INTEC), Radioactive Waste Management Complex (RWMC), and Naval Reactors Facility (NRF), Idaho National Laboratory (INL), Idaho, and frequency of water-level measurements, as of December 2015.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 4. Location of wells in the U.S. Geological Survey perched groundwater-level monitoring network at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, and frequency of water-level measurements, as of December 2015.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

EXPLANATION

Well in the USGS aquifer water-quality monitoring network and identifier

M14S ●
14

Local well identifier—Number only shows USGS well, other names are local well names

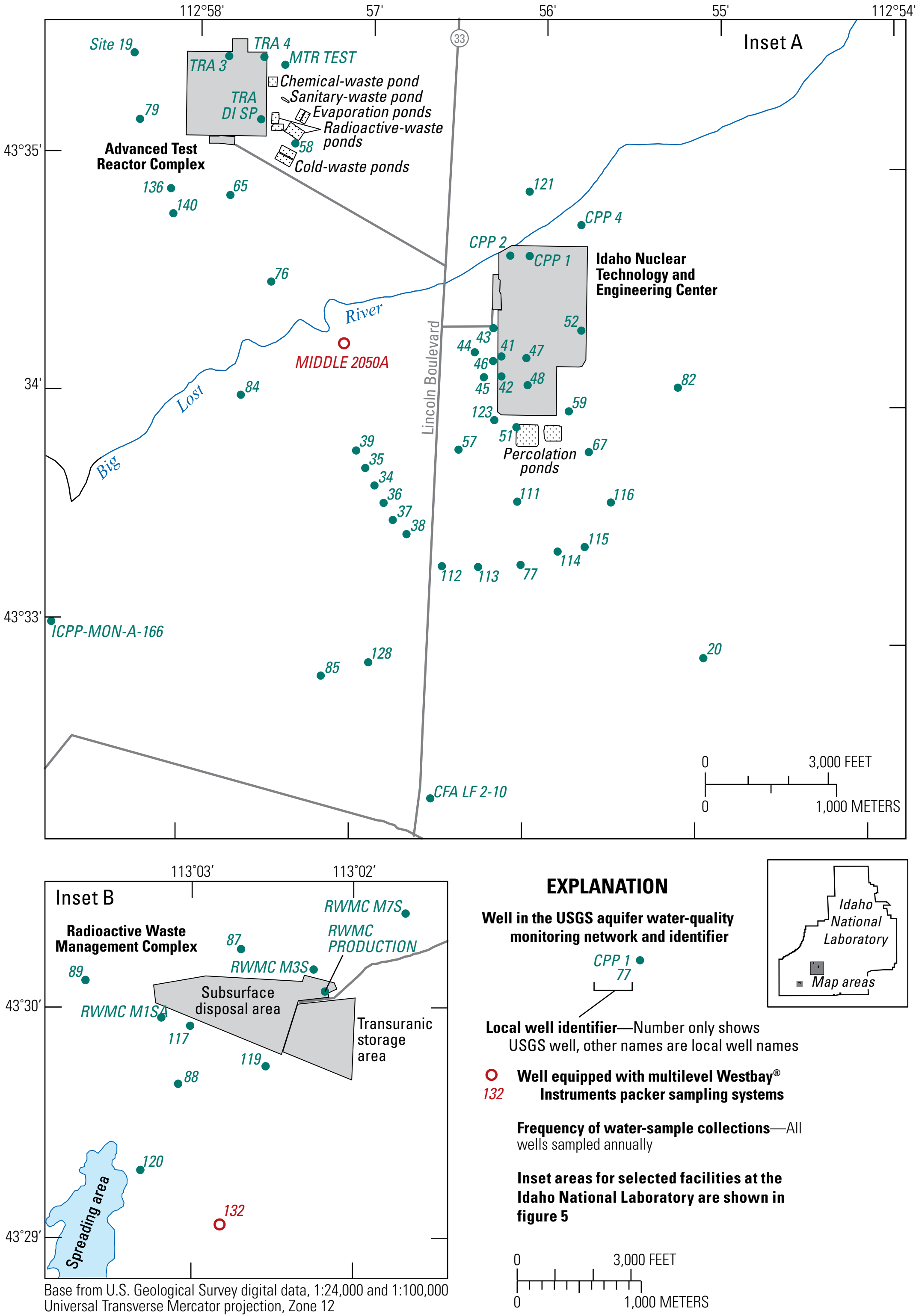
103 ○ **Well equipped with multilevel Westbay® Instruments packer monitor system**

Frequency of water-sample collections—All wells sampled annually

▭ **Inset areas for selected facilities at the Idaho National Laboratory—See figure 6**

RWMC	Radioactive Waste Management Complex
ATR Complex	Advanced Test Reactor Complex
INTEC	Idaho Nuclear Technology and Engineering Center
TAN	Test Area North

Figure 5. Location of wells in the U.S. Geological Survey aquifer water-quality monitoring network, Idaho National Laboratory and vicinity, Idaho, December 2015.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 6. Location of wells in the U.S. Geological Survey aquifer water-quality monitoring network at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho.

The type and depth of groundwater sampling generally depend on the information needed in a specific area. Water samples were routinely collected and analyzed for some combination of concentrations of tritium, strontium-90, cesium-137, plutonium-238, plutonium-239, -240 (undivided), americium-241, gross alpha- and beta-particle radioactivity, chromium, sodium, chloride, sulfate, nutrients including nitrite plus nitrate (as nitrogen [N]), nitrite (as N), orthophosphate (as phosphorus), ammonia (as N), volatile organic compounds (VOCs), and measurements of specific conductance, pH, and temperature. Additionally, as part of the INL groundwater monitoring program adopted in 1994 (Sehlke and Bickford, 1993), water samples from several wells also were analyzed for fluoride and an extensive suite of trace elements. When a new well is drilled by the USGS at the INL, samples are collected and analyzed for all constituents previously listed, together with a full suite of cations and anions and carbon, deuterium, oxygen, and uranium isotopes. A schedule listing the constituents that are typically analyzed is provided in a report by Bartholomay and others (2014, appendix A). The location and construction of wells, and the water sample collection method in the aquifer water-quality monitoring network as of December 2015, are shown in figures 5 and 6, and in table 2. Two new MLMS-equipped wells USGS 131A and 137A (Twining and Fisher, 2015) well USGS 140 (Twining and others, 2014), and well TAN 2271 (Twining and others, 2016) were completed during 2012–15. Well location and construction of wells in the USGS water-quality monitoring network for perched groundwater beneath INL facilities as of December 2015 are shown in figure 7 and table 3. All wells were scheduled to be sampled annually.

Table 2. Construction of wells in the U.S. Geological Survey aquifer water-quality monitoring network and water sample-collection method, eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, as of December 2015.

[All wells are sampled annually. **Well name:** Well locations are shown in figures 5 and 6. **Diameter:** //, hole diameter is not required for borehole volume calculations with multilevel thief samplers. **Sample-collection method:** Pump, sampled from pumping well (pumping rate in gallons per minute); Tap, sampled from faucet; Westbay® Instruments, sampled with multilevel thief sampler. **Abbreviations:** No., number; USGS, U.S. Geological Survey]

Well No. or name	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
ANP 6	435152112443101	10	295	Pump (25)
ARA-MON-A-002	433054112492102	6	620	Pump (15)
Area 2	433223112470201	16	877	Pump (18)
Atomic City	432638112484101	8	639	Tap
Badging Facility	433042112535101	8	644	Pump (35)
CFA 1	433204112562001	16	639	Pump (1,000)
CFA 2	433144112563501	16	681	Pump (1,400)
CFA LF 2-10	433216112563301	6	716	Pump (8.3)
CPP 1	433433112560201	16	586	Pump (3,000)
CPP 2	433432112560801	16	605	Pump (3,000)
CPP 4	433440112554401	16	700	Pump (400)
Crossroads	432128113092701	8	796	Pump (35)
GIN 2	434949112413401	2	381	Pump (2)
Highway 3	433256113002501	8	750	Pump (18)
ICPP-MON-A-166	433300112583301	6	527	Pump (3)
Middle 2050A-517 ft	433409112570515	//	539	Westbay® Instruments installed 2005
Middle 2051-749 ft	433217113004909	//	771	Westbay® Instruments installed 2005
Middle 2051-827 ft	433217113004906	//	876	Westbay® Instruments installed 2005
Middle 2051-1091 ft	433217113004903	//	1,128	Westbay® Instruments installed 2005
Middle 2051-1141 ft	433217113004901	//	1,177	Westbay® Instruments installed 2005
MTR Test	433520112572601	8	588	Pump (26)
No name 1	435038112453401	12	500	Pump (42)
NPR test	433449112523101	6	600	Pump (28)
PBF-MON-A-003	433203112514201	5	575	Pump (10)
P&W 2	435419112453101	10	378	Pump (35)
Rifle range	433243112591101	5	620	Pump (25)
RWMC M1SA	432956113030901	6	638	Pump (6)
RWMC M3S	433008113021801	6	633	Pump (6)
RWMC M7S	433023113014801	6	628	Pump (5)
RWMC M11S	433058113010401	6	624	Pump (12)
RWMC M12S	433118112593401	6	572	Pump (6)

Table 2. Construction of wells in the U.S. Geological Survey aquifer water-quality monitoring network and water sample-collection method, eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, as of December 2015.—Continued

Well No. or name	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
RWMC M13S	433037113002701	6	643	Pump (6)
RWMC M14S	433052113025001	6	635	Pump (14)
RWMC PROD	433002113021701	10, 14	685	Pump (200)
Site 4	433617112542001	8	495	Pump (500)
Site 9	433123112530101	10	1,057	Pump (30)
Site 14	434334112463101	8, 12	717	Pump (36)
Site 17	434027112575701	15	600	Pump (30)
Site 19	433522112582101	8, 10	860	Pump (15)
SPERT-1	433252112520301	14	653	Pump (400)
TAN 2271	435053112423101	10	282	Pump (4)
TRA 3	433522112573501	20	602	Pump (3,800)
TRA 4	433521112574201	16, 18	965	Pump (2,000)
TRA DISP	433506112572301	6, 8	1,267	Pump (25)
USGS 1	432700112470801	5	630	Pump (22)
USGS 2	433320112432301	5	699	Pump (16)
USGS 5	433543112493801	6	494	Pump (5)
USGS 7	434915112443901	4, 6	903	Pump (45)
USGS 8	433121113115801	6	812	Pump (15)
USGS 9	432740113044501	6	654	Pump (15)
USGS 11	432336113064201	6	704	Pump (23)
USGS 12	434126112550701	10	563	Pump (35)
USGS 14	432019112563201	5	752	Pump (16)
USGS 17	433937112515401	5, 6	498	Pump (15)
USGS 18	434540112440901	4	329	Pump (30)
USGS 19	434426112575701	6	399	Pump (17)
USGS 20	433253112545901	6	658	Pump (18)
USGS 23	434055112595901	5, 6	458	Pump (25)
USGS 26	435212112394001	6	266	Pump (20)
USGS 27	434851112321801	6	312	Pump (20)
USGS 29	434407112285101	6	426	Pump (30)
USGS 31	434625112342101	8, 10	428	Pump (40)
USGS 32	434444112322101	5.5, 6	392	Pump (35)
USGS 34	433334112565501	10	700	Pump (30)
USGS 35	433339112565801	7	579	Pump (25)
USGS 36	433330112565201	6	567	Pump (25)
USGS 37	433326112564801	6	572	Pump (25)
USGS 38	433322112564301	4	724	Pump (18)
USGS 39	433343112570001	8	492	Pump (25)
USGS 41	433409112561301	6	666	Pump (25)
USGS 42	433404112561301	6	678	Pump (25)
USGS 43	433415112561501	6	564	Pump (6)
USGS 44	433409112562101	6	650	Pump (25)
USGS 45	433402112561801	6	651	Pump (25)
USGS 46	433407112561501	6	651	Pump (25)
USGS 47	433407112560301	6	651	Pump (8)
USGS 48	433401112560301	6	750	Pump (29)
USGS 51	433350112560601	6	647	Pump (4)
USGS 52	433414112554201	6	602	Pump (30)
USGS 57	433344112562601	6	582	Pump (30)
USGS 58	433500112572502	6	503	Pump (26)
USGS 59	433354112554701	6	587	Pump (18)
USGS 65	433447112574501	4	498	Pump (8)
USGS 67	433344112554101	4, 6	694	Pump (8)
USGS 76	433425112573201	6	718	Pump (29)

Table 2. Construction of wells in the U.S. Geological Survey aquifer water-quality monitoring network and water sample-collection method, eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, as of December 2015.—Continued

Well No. or name	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
USGS 77	433315112560301	6	586	Pump (25)
USGS 79	433505112581901	6	702	Pump (30)
USGS 82	433401112551001	6	693	Pump (25)
USGS 83	433023112561501	6	752	Pump (20)
USGS 84	433356112574201	6	505	Pump (20)
USGS 85	433246112571201	6	614	Pump (23)
USGS 86	432935113080001	8	691	Pump (19)
USGS 87	433013113024201	4	673	Pump (2)
USGS 88	432940113030201	4	663	Pump (8)
USGS 89	433005113032801	6	637	Pump (2)
USGS 97	433807112551501	4	510	Pump (27)
USGS 98	433657112563601	4	508	Pump (25)
USGS 99	433705112552101	4	440	Pump (25)
USGS 100	433503112400701	6	750	Pump (10)
USGS 101	433255112381801	4, 6	842	Pump (12)
USGS 102	433853112551601	6	445	Pump (30)
USGS 103-993 ft	432714112560712	//	1,014	Westbay® Instruments installed 2007
USGS 103-1087 ft	432714112560708	//	1,098	Westbay® Instruments installed 2007
USGS 103-1210 ft	432714112560704	//	1,240	Westbay® Instruments installed 2007
USGS 103-1258 ft	432714112560702	//	1,279	Westbay® Instruments installed 2007
USGS 104	432856112560801	8	700	Pump (26)
USGS 105-851 ft	432703113001815	//	862	Westbay® Instruments installed 2008
USGS 105-952 ft	432703113001811	//	982	Westbay® Instruments installed 2008
USGS 105-1072 ft	432703113001807	//	1,102	Westbay® Instruments installed 2008
USGS 106	432959112593101	8	760	Pump (24)
USGS 107	432942112532801	8	690	Pump (30)
USGS 108-888 ft	432659112582610	//	904	Westbay® Instruments installed 2010
USGS 108-1029 ft	432659112582606	//	1,060	Westbay® Instruments installed 2010
USGS 108-1172 ft	432659112582602	//	1,194	Westbay® Instruments installed 2010
USGS 109	432701113025601	4	800	Pump (22)
USGS 110A	432717112501502	6	644	Pump (6)
USGS 111	433331112560501	8	560	Pump (12)
USGS 112	433314112563001	8	507	Pump (12)
USGS 113	433314112561801	6	556	Pump (15)
USGS 114	433318112555001	6	560	Pump (10)
USGS 115	433320112554101	6	581	Pump (5)
USGS 116	433331112553201	6	572	Pump (20)
USGS 117	432955113025901	6.5	655	Pump (12)
USGS 119	432945113023401	6.5	705	Pump (15)
USGS 120	432919113031501	6.5	705	Pump (18)
USGS 121	433450112560301	6	475	Pump (10)
USGS 123	433352112561401	6	515	Pump (12)
USGS 124	432307112583101	4	800	Pump (20)
USGS 125	432602113052801	5	774	Pump (18)
USGS 126B	435529112471401	6	472	Pump (10)
USGS 127	433058112572201	6	596	Pump (25)
USGS 128	433250112565601	4.5	615	Pump (23)
USGS 130	433130112562801	4.5	636	Pump (25)
USGS 131A-616 ft	433036112581815	//	632	Westbay® Instruments installed 2012
USGS 131A-812 ft	433036112581810	//	842	Westbay® Instruments installed 2012
USGS 131A-981 ft	433036112581806	//	1,058	Westbay® Instruments installed 2012
USGS 131A-1,137 ft	433036112581803	//	1,157	Westbay® Instruments installed 2012
USGS 132-765 ft	432906113025018	//	787	Westbay® Instruments installed 2006

Table 2. Construction of wells in the U.S. Geological Survey aquifer water-quality monitoring network and water sample-collection method, eastern Snake River Plain aquifer, Idaho National Laboratory, Idaho, as of December 2015.—Continued

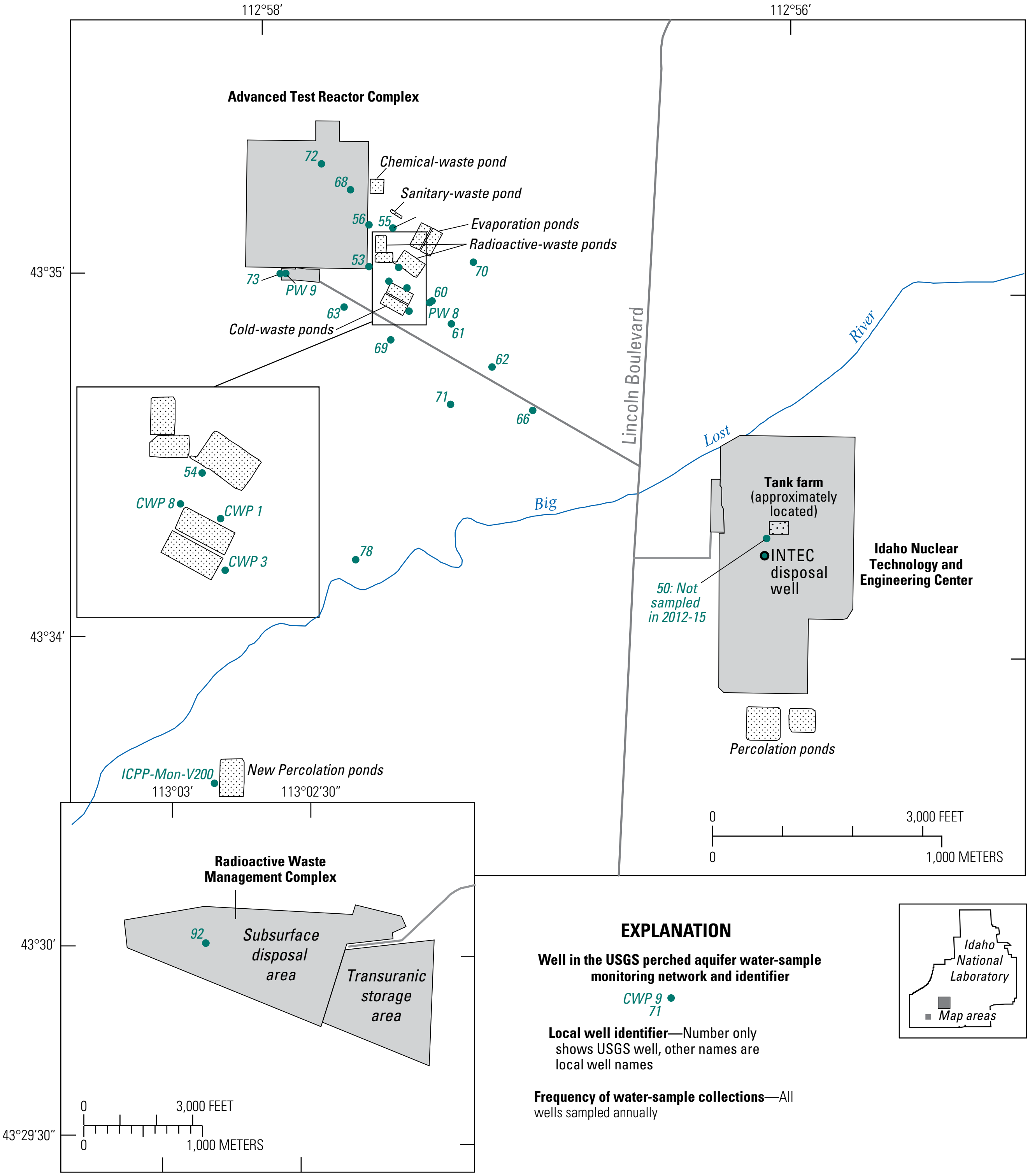
Well No. or name	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
USGS 133-469 ft	433605112554312	//	480	Westbay® Instruments installed 2006
USGS 134-578 ft	433611112595819	//	590	Westbay® Instruments installed 2006
USGS 134-646 ft	433611112595815	//	652	Westbay® Instruments installed 2006
USGS 135-837 ft	432753113093609	//	861	Westbay® Instruments installed 2008
USGS 136	433447112581501	6	560	Pump (21)
USGS 137A-662	432701113025807	//	718	Westbay® Instruments installed 2012
USGS 137A-747	432701113025805	//	784	Westbay® Instruments installed 2012
USGS 137A-841	432701113025803	//	862	Westbay® Instruments installed 2012
USGS 137A-876	432701113025801	//	895	Westbay® Instruments installed 2012
USGS 140	433441112581201	6	546	Pump (24)
WS INEL1	433716112563601	6	490	Pump (30)

Table 3. Construction of wells in the U.S. Geological Survey perched groundwater-quality monitoring network and water sample-collection method at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, as of December 2015.

[All wells sampled annually. **Well No.:** Well locations are shown in figure 7. **Sample-collection method**: Bail, sample collected with a bailer (sample collection depth in feet below land surface); Pump, sample collected with a pump (pumping rate in gallons per minute). **Abbreviation:** USGS, U.S. Geological Survey]

Well No.	USGS site No.	Well construction		Sample-collection method
		Diameter (inches)	Depth (feet)	
CWP 1	433459112572601	6	58	Bail (55)
CWP 3	433455112572501	6	55	Bail (50)
CWP 8	433500112573001	6	64	Bail (58)
ICPP-Mon-V-200	433321112581501	4	127	Pump (1.5)
PW 8	433456112572001	6	166	Pump (8)
PW 9	433500112575401	6	200	Pump (5)
USGS 53	433503112573401	6	71	Bail
USGS 54	433503112572801	6	82	Pump (4)
USGS 55	433508112573001	6	81	Pump (1)
USGS 56	433509112573501	6	105	Bail (74)
USGS 60	433456112571901	6	117	Pump (6)
USGS 61	433453112571601	4	123	Pump (6)
USGS 62	433446112570701	8	165	Pump (5)
USGS 63	433455112574001	10	109	Pump (5)
USGS 66	433436112564801	4	202	Bail (195)
USGS 68	433516112573901	10	128	Pump (1)
USGS 69	433450112573001	4	115	Pump (5)
USGS 70	433504112571001	8	100	Pump (6)
USGS 71	433439112571501	5	171	Bail (165)
USGS 72	433519112574601	4	174	Bail (148)
USGS 73	433502112575401	6	127	Bail (125)[1]
USGS 78	433413112573501	7	204	Bail (165)
USGS 92	433000113025301	3.5	214	Bail (213)

[1] Well had a pump in it until 2014 when the pump gave out, so the pump was pulled and the well was bailed starting in 2015.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 7. Location of wells in the U.S. Geological Survey perched groundwater-quality monitoring network at the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, as of December 2015.

Waste-Disposal Sites at the Idaho National Laboratory

Wastewater disposal at INL facilities (fig. 1) has been the principal source of radioactive- and chemical-waste constituents in water from the ESRP aquifer and in perched groundwater zones at and near the INL. In the past, wastewater disposal sites included infiltration ponds (percolation ponds) and ditches, evaporation ponds, drain fields, and disposal wells. Currently (2016), wastewater is being discharged to infiltration ponds, evaporation ponds, and ditches at the INL; and the effluent is sampled and analyzed by the INL contractor for radionuclides and various other constituents prior to discharge. Solid and liquid wastes buried at the RWMC (fig. 1) also are sources of some constituents in groundwater.

Contractors at each INL facility collected and reported concentrations of radioactive- and chemical-waste-disposal data from 1976 to 1998 (French and others, 1999a, 1999b); however, prior to 1976 and since 1999, no formal program has been in place to compile annual amounts of constituents discharged at each facility (Richard Kauffman, U.S. Department of Energy, oral commun., 2005). Highlights of the waste disposal history at INL facilities are summarized here; a more comprehensive summary of waste disposal at the INL from 1952 through 1998 can be found in Bartholomay and others (2000).

Advanced Test Reactor Complex

Since 1952, low-level radioactive, chemical, and sanitary wastewater has been discharged to infiltration and lined evaporation ponds located east of the ATR Complex (fig. 3). Nonradioactive cooling-tower wastewater was discharged to radioactive-waste infiltration ponds from 1952 to 1964, to the ESRP aquifer through a 1,267-ft-deep disposal well (TRA DISP, fig. 3) from 1964 until March 1982, and into two cold-waste infiltration ponds from 1982 to the present (2016). A more complete summary of potential groundwater contamination sources at the ATR Complex is found in U.S. Department of Energy (2011a, table 4-1).

In 1976, the DOE contractor at the ATR Complex began a three-phase program to reduce radioactivity in wastewater. The first phase was 1976–80, and the second phase was 1981–87. The contractor finished the final phase of the program in 1993. In August 1993, the radioactive-waste infiltration ponds at the ATR Complex were replaced with lined evaporation ponds. The evaporation ponds were designed to prevent radioactive wastewater from entering the aquifer.

During 1961–79, less than 25 percent of radioactivity in wastewater discharged was attributed to tritium; most other radioactivity consisted of radionuclides with half-lives of about several weeks, as well as small amounts of strontium-90, cesium-137, and cobalt-60 (Barraclough and others, 1981). In 1980, about 50 percent of radioactivity was attributed to tritium, and during 1981–93, more than 90 percent was attributed to tritium (Bartholomay and others, 1997, fig. 6). Overall, approximately 8,920 curies (Ci) of tritium were discharged to the radioactive-waste infiltration ponds between 1952 and 1993.

A chemical-waste infiltration pond was used for disposal of chemical wastewater from an ion-exchange system at the ATR Complex (fig. 3) from 1962 to 1999. The average annual discharge to this pond was about 17.5 million gallons (Mgal) during 1962–98. Sulfate and sodium hydrate were the predominant constituents in the chemical wastewater (Bartholomay and others, 2000). In 1999, the chemical-waste infiltration pond was closed and covered with a protective cap (S.M. Stoller Corporation, 2002a).

From 1964 to March 1982, the TRA disposal well (TRA DISP, fig. 3) was used to inject nonradioactive wastewater from cooling-tower operations at the ATR Complex into the ESRP aquifer and also was used to discharge some radioactive wastewater from reactor operations (U.S. Department of Energy, 2011a). Since March 1982, wastewater from cooling-tower operations has been discharged to two cold-waste infiltration ponds (fig. 3). The TRA disposal well has been used as an observation well since 1982. Prior to 1964, well USGS 53 (fig. 4) also was used intermittently to discharge wastewater into the perched groundwater system (U.S. Department of Energy, 2011b) and has been used as an observation well since 1964.

Large quantities of chromate-contaminated wastewater were injected directly into the ESRP aquifer or infiltrated through the unsaturated zone beneath the radioactive-waste infiltration ponds (fig. 3). Between 1952 and 1972, an estimated 17,790 lb of chromium was discharged to the radioactive-waste infiltration ponds and 31,131 lb of chromium was discharged to the TRA disposal well. Other contaminants discharged at the ATR Complex such as those associated with sanitary sewage in the sanitary waste pond (fig. 3) included nitrate, phosphate, and chloride (U.S. Department of Energy, 2011a).

Idaho Nuclear Technology and Engineering Center

From 1952 to February 1984, the INTEC discharged most low-level radioactive, chemical, and sanitary wastewater into the ESRP aquifer through a 600-ft-deep disposal well (INTEC Disposal Well, fig. 4). Two percolation ponds (also called infiltration ponds) were used for wastewater disposal from 1984 through August 25, 2002 (fig. 4). The first pond was completed in February 1984 and the second pond was completed in October 1985. On August 26, 2002, the “old” percolation ponds were taken out of service and wastewater was discharged to the “new” percolation ponds about 2 mi southwest of INTEC (fig. 4). The new percolation ponds were designed to be a rapid infiltration system, and each pond can accommodate as much as 3 Mgal/d of continuous discharge (S.M. Stoller Corporation, 2004).

Tritium has accounted for most of the radioactivity in wastewater discharged to the disposal well and old percolation ponds at the INTEC (Davis, 2008, fig. 9). During 1953–2000, a total of about 21,135 Ci of tritium was discharged at the INTEC (Mann and Cecil, 1990; Davis, 2008). Other radionuclides discharged at INTEC included strontium-90, cesium-137, iodine-129, plutonium isotopes, uranium isotopes, neptunium-237, americium-241, and technetium-99 (U.S. Department of Energy, 2011a). In 1972, about 18,100 Ci of strontium-90, 19,100 Ci of cesium-137, and 18,900 gallons of sodium bearing waste were released to soil at the INTEC tank farm during a failed transfer between two underground storage tanks (fig. 7) (Cahn and others, 2006). This accounts for about 88 percent (approximately 15,900 Ci) of the source of strontium-90 to groundwater at the INTEC tank farm (fig. 7). Three other locations at the INTEC tank farm are the source of the remaining 12 percent of strontium-90 (Cahn and others, 2006).

Historically, chloride, fluoride, nitrate, sodium, and sulfate were the predominant chemical constituents in wastewater discharged at the INTEC (Pittman and others, 1988; Orr and Cecil, 1991; Bartholomay and others, 1995, 1997, 2000). Mercury also has been listed as a constituent that potentially could affect groundwater quality (U.S. Department of Energy, 2011a).

Naval Reactors Facility

Wastewater at the NRF is discharged to a 1.65-mi-long industrial-waste ditch and sewage ponds (fig. 3). The waste ditch was first used in 1953 to dispose of non-radioactive, non-sewage industrial wastewater. Chloride, sulfate, and sodium have been the predominant chemical constituents in wastewater discharged to the ditch throughout its history of operation (Lewis and Jensen, 1985; Pittman and others, 1988; Orr and Cecil, 1991; Bartholomay and others, 1995, 1997, 2000).

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 include transuranic wastes, other radiochemical and inorganic chemical constituents, and organic compounds. The transuranic wastes were buried in trenches until 1970, and stored above ground at the RWMC after 1970. Only low-level mixed waste has been buried at the RWMC since 1970. 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 17,100 Ci of plutonium-238, 64,900 Ci of plutonium-239, 17,100 Ci of plutonium-240, and 183,000 Ci of americium-241 were buried in the SDA during 1952–99 (Holdren and others, 2002, table 4-1). An estimated 88,400 gal of organic waste was buried before 1970 (Mann and Knobel, 1987, p. 1). These buried organic 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, organic, and sanitary wastewater was discharged at TAN (fig. 1) into the ESRP aquifer through a 310-ft-deep disposal well (TAN Disposal Well, fig. 5). In 1972, the disposal well was replaced by a 35-acre infiltration pond. Records are not available to indicate the amount of radioactivity in wastewater discharged at TAN before 1959. During 1959–93, about 61 Ci of radioactivity in wastewater were discharged to the disposal well and infiltration pond. It is estimated that as little as 350 gal to as much as 35,000 gal of trichloroethylene (TCE) were disposed of in the disposal well (U.S. Department of Energy, 2011a). Based on information available through 1998, radioactive wastewater has not been discharged since 1993 (Bartholomay and others, 2000). The principal contaminants at TAN from use of the disposal well include several volatile organic compounds (including TCE, tetrachloroethylene, *cis*-dichloroethene, *trans*-1,2-dichloroethene, and vinyl chloride) and several radionuclides (strontium-90, cesium-137, tritium, and uranium-234) (U.S. Department of Energy, 2011a).

Chemical wastewater containing predominantly chloride and sodium was discharged to the infiltration pond at the Technical Support Facility (TSF) near TAN during 1971–2007. Some low-level radioactive waste containing approximately 0.039 Ci of strontium-90 also was released to the pond during 1972–85 (U.S. Department of Energy, 2011a). A closure plan for the pond was submitted to the Idaho Department of Environmental Quality in November 2007, and wastewater discharge to the pond ceased on November 29, 2007. All activities proposed in the plan were completed by February 2008 (S.M. Stoller Corporation, 2009).

Central Facilities Area

About 65 Ci of radioactivity in about 1,500 Mgal of wastewater were discharged to the sewage-plant tile drain field at the CFA (fig. 1) during 1952–93. Most radioactive wastes discharged to this drain field were from aquifer water pumped from well CFA 1 (fig. 5), which obtains water from within the INTEC contaminant plume in the ESRP aquifer. Most radioactivity in wastewater discharged at the CFA was attributed to tritium.

Chloride and sodium were the predominant chemical constituents in wastewater at the CFA (Lewis and Jensen, 1984; Pittman and others, 1988; Orr and Cecil, 1991; Bartholomay and others, 1995, 1997, 2000). Nitrate in the southern part of the CFA has been attributed to wastewater disposal at the former CFA mercury pond (U.S. Department of Energy, 2011b).

Hydrologic Conditions

The ESRP 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 ESRP aquifer is primarily from infiltration of applied irrigation water, infiltration of streamflow, groundwater inflow from adjoining mountain drainage basins, and infiltration of precipitation.

Surface Water

The Big Lost River drains more than 1,400 mi^2 of mountainous area that includes parts of the Lost River Range and the Pioneer Mountains west of the INL (fig. 1). Surface water flow along the Big Lost River infiltrates to the ESRP aquifer through the river channel and at sinks and playas at its terminus (fig. 1). When flow in the Big Lost River exceeds 250 ft^3/s in the river channel, excess streamflow is diverted to spreading areas, where it rapidly infiltrates into the spreading areas. This excess streamflow has been diverted since 1965 to spreading areas in the southwestern part of the INL to prevent potential flooding at the INL facilities (Bennett, 1990, p. 15). Other surface drainages that provide recharge to the ESRP aquifer at the INL include Birch Creek, the Little Lost River, and Camas Creek (fig. 1).

The average streamflow recorded at USGS streamgage 13127000, Big Lost River below Mackay Reservoir near Mackay, Idaho (fig. 1) for complete water years (October 1–September 30) 1905–2015 was 216,700 acre-ft/yr (fig. 8). Streamflow at streamgages at and downstream of streamgage 13127000 (fig. 1) for water years 2012–15 are shown in table 4 and figure 8. Most of the flow between Mackay Reservoir and Arco, Idaho, is diverted for irrigation and groundwater recharge; therefore, flow only reaches the INL during wet years or when heavy rainfall or rapid snowmelt warrant brief periods of high discharge out of Mackay Reservoir.

Recharge to the ESRP aquifer downstream of Arco, Idaho (fig. 1), is substantial during wet years because of streamflow infiltration from the Big Lost River channel, diversion areas, sinks, and playas. For example, infiltration losses at various discharges measured during 1951–85 ranged from 1 (ft^3/s)/mi in the river channel to 28 (ft^3/s)/mi in the sinks (Bennett, 1990, p. 24–26). Bennett (1990) considered streamflow losses to evapotranspiration minor as compared to infiltration losses. However, infiltration can be zero in years when there is little or no flow in the Big Lost River channel at or downstream of streamgage 13132500 (fig. 1), as was the case during 2002–04 (Davis, 2008, table 4); during 2008 (Davis, 2010, table 4); and during 2013–15 (table 4).

Table 4. Average annual streamflow at U.S. Geological Survey streamgages along the Big Lost River, Idaho, water years 2012–15.

[**USGS streamgage:** Streamgage locations are shown in figure 1. **Streamflow:** Data are from U.S. Geological Survey, National Water Information System (2016). **Abbreviations:** INL, Idaho National Laboratory; WY, water year; USGS, U.S. Geological Survey]

USGS streamgage No. and name		Streamflow (acre-feet)			
		WY 2012	WY 2013	WY 2014	WY 2015
13127000	Big Lost River below Mackay Reservoir, near Mackay, Idaho	218,300	160,900	118,200	147,200
13132500	Big Lost River near Arco, Idaho	16,300	310	0	0
13132513	INL diversion at head, near Arco, Idaho	0	0	0	0
13132520	Big Lost River below the INL diversion, near Arco, Idaho	6,100	0	0	0
13132535	Big Lost River at Lincoln Blvd. Bridge, near Atomic City, Idaho	1,950	0	0	0
13132565	Big Lost River above Big Lost River Sinks, near Howe, Idaho	1,090	0	0	0

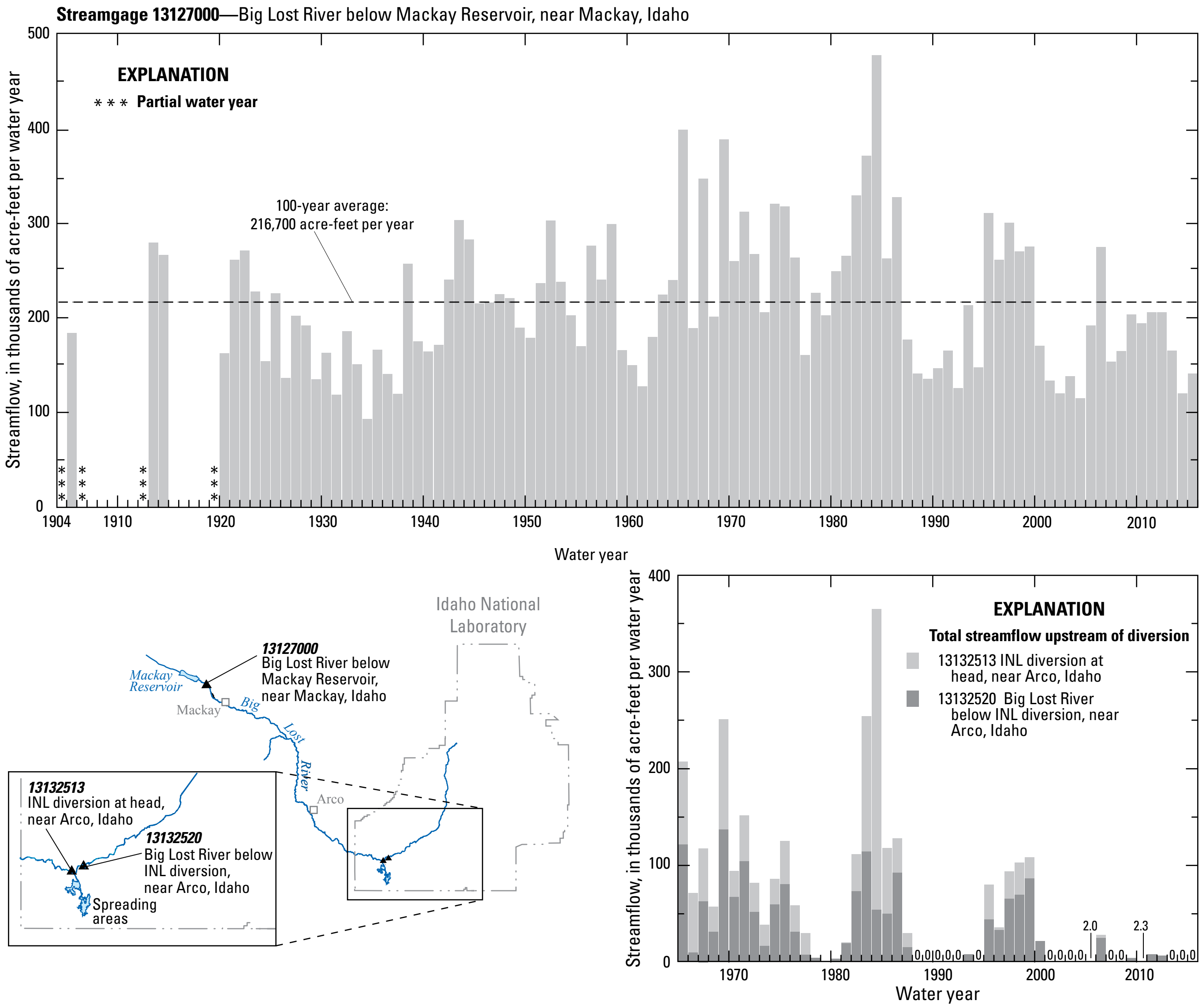
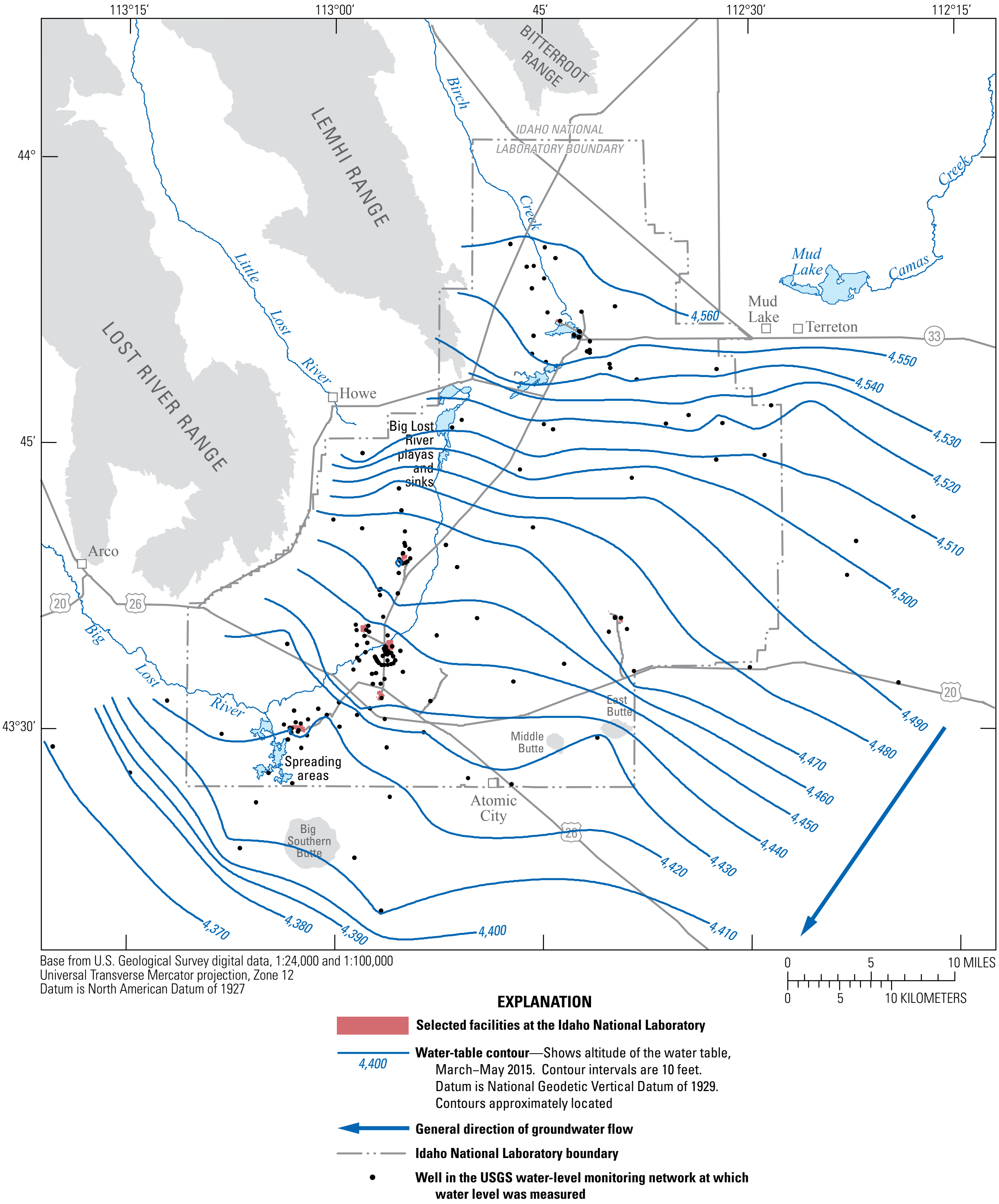


Figure 8. Streamflow at streamgages along the Big Lost River, Idaho.

Groundwater

Water in the ESRP aquifer primarily moves through interflow and fracture zones in the basalt. A large proportion of groundwater moves through the upper 200–800 ft of basaltic rocks (Mann, 1986, p. 21). Ackerman (1991, p. 30) and Bartholomay and others (1997) reported a range of transmissivity of basalt in the upper part of the aquifer of 1.1–760,000 ft^2/d. Anderson and others (1999) reported a range of hydraulic conductivity at the INL of 0.01–32,000 ft/d. The hydraulic conductivity of rocks underlying the aquifer ranges from 0.002 to 0.03 ft/d (Mann, 1986, p. 21). The effective base of the ESRP aquifer was measured in different wells from about 815 to 1,710 ft below land surface in the western half of the INL (Anderson and others, 1996, table 3). Wells in the eastern half of the INL do not penetrate the base of the aquifer, so the effective base of the aquifer has only been estimated from surface-based electrical-resistivity surveys (Ackerman and others, 2010, fig. 6).

Depth to water in wells completed in the ESRP aquifer ranges from about 225 ft in the northern part of the INL to more than 900 ft in the southeastern part. During March–May 2015, the altitude of the water table was about 4,560 ft in the northern part of the INL and about 4,410 ft in the southwestern part (fig. 9). Water flowed south and southwestward beneath the INL (fig. 9) at an average hydraulic gradient of about 4 ft/mi.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 9. Altitude of the water table in the eastern Snake River Plain aquifer at and near the Idaho National Laboratory, Idaho, March–May 2015.

Water levels in wells declined 3.92 to 5.03 ft in the northern part of the INL from March–May 2011 (Davis and others, 2013) to March–May 2015 (fig. 10). In the central and eastern parts of the INL, water levels declined from about 1 to 2.5 ft during March to May 2011–15 (fig. 10). In the southwestern part of the INL, water levels generally declined by approximately 0.5–2 ft during March to May 2011–15. Water level declines near wells along the Big Lost River can be attributed to no flow in the river during the last 3 years of the study period (table 4).

Water levels monitored in wells USGS 12, 17, and 23 (fig. 2), and 20 (fig. 3) show long-term water-level changes in the ESRP aquifer in the central part of the INL in response to infiltration of streamflow (fig. 11). Long-term water-level fluctuations were about 20 ft in well USGS 20, 30 ft in well USGS 17, 35 ft in well USGS 23, and 40 ft in well USGS 12. Water levels in these wells declined during 2012–15.

Groundwater moves southwestward from the INL and eventually discharges to springs along the Snake River near Twin Falls, Idaho, about 100 mi southwest of the INL. Discharge from the springs estimated by methods given by Kjelstrom (1995, table 6) was about 3.45 million acre-ft/yr for water year 2015, up slightly from the estimate of 3.13 million acre-ft/yr for water year 2011. Historically, the discharge to these springs has ranged from 2.97 million acre-ft/yr in 1904 to 4.94 million acre-ft/yr in 1951 (Daniel J. Ackerman, U.S. Geological Survey, written commun., 2007).

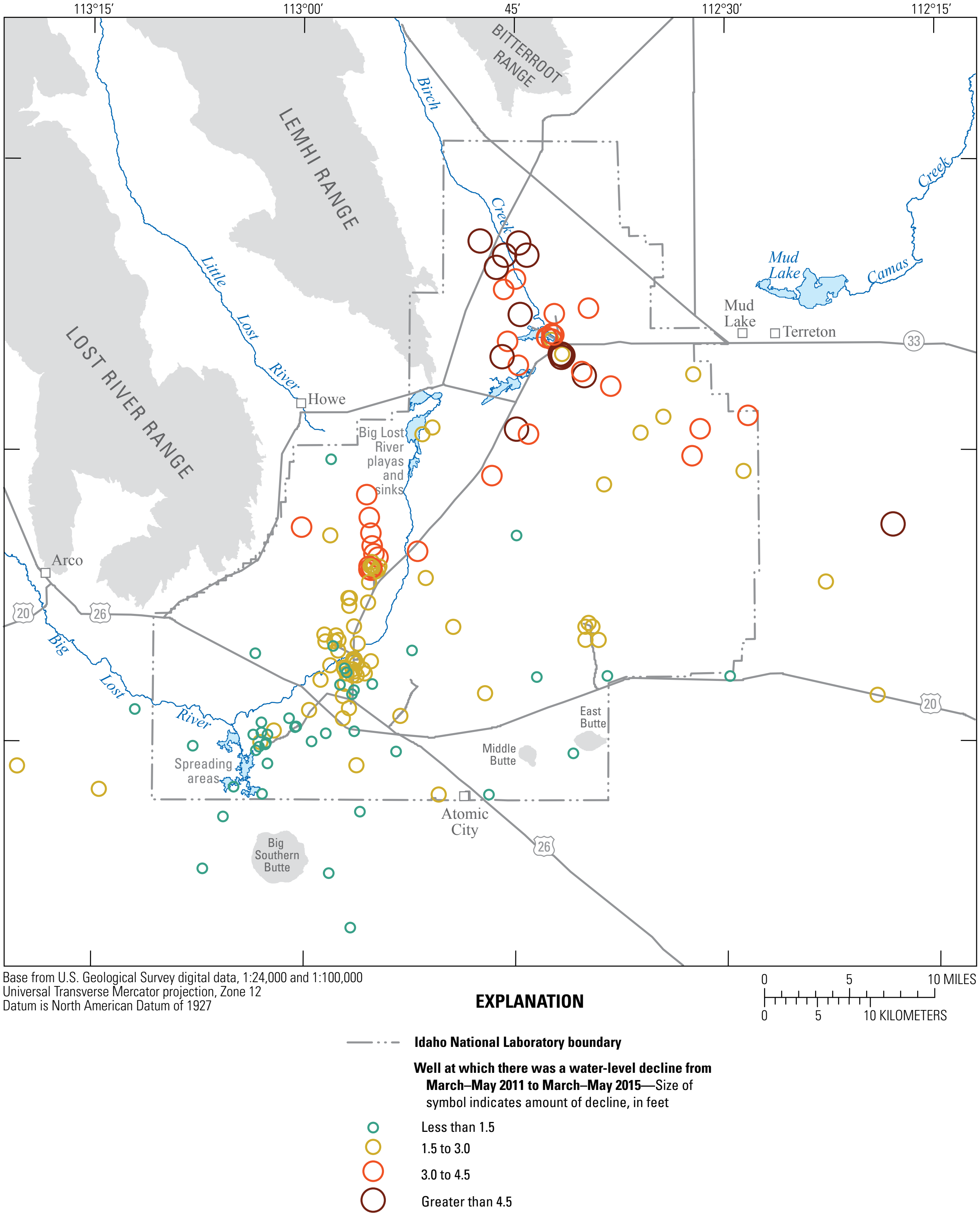
Perched Groundwater

Disposal of wastewater to infiltration ponds and infiltration of surface water at waste-burial sites at the INL has resulted in the formation of perched groundwater in basalts and in sedimentary interbeds that overlie the ESRP aquifer (Cecil and others, 1991). Perched groundwater has formed in a complex sequence of basalt flow and sedimentary interbeds beneath the ATR Complex, the INTEC, and the RWMC. Perched groundwater also has been detected beneath infiltration ponds and ditches at other facilities at the INL in the past, but is not discussed in this report.

Anderson and Lewis (1989) and Anderson (1991) correlated geophysical logs to describe the stratigraphic sequences in which perched groundwater has formed at the ATR Complex, the INTEC, and the RWMC. Although the subsurface stratigraphy, geohydrologic characteristics, and waste disposal practices at each of these areas differs, the features controlling the formation of perched groundwater at these sites are similar (Cecil and others, 1991). Sedimentary interbeds in the subsurface may have smaller vertical hydraulic conductivities than overlying basalt flows, and alteration between basalt flows may contribute to reduced vertical hydraulic conductivity in the interflow rubble zones (Perkins and Winfield, 2007). Dense, unfractured basalt flows may have a decreased vertical hydraulic conductivity and may inhibit downward flow, and sedimentary or chemical infilling of fractures in basalt may reduce vertical hydraulic conductivity by limiting the interconnectivity of fractures reducing the water transmitting capability of the basalts (Cecil and others, 1991). Any combination of these factors may disrupt the downward vertical movement of water and contribute to the formation of perched groundwater zones.

At the ATR Complex, deep and shallow perched groundwater zones have formed in response to disposal of wastewater to infiltration ponds (Tucker and Orr, 1998). South of the INTEC, perched groundwater zones formed previously in response to wastewater disposal to the old percolation ponds, but have dried up since the ponds were taken out of use in 2002 (fig. 4). Perched groundwater also has been detected in other areas at the INTEC and may be attributed to leaking pipelines, leach fields, damaged casing in the upper part of the INTEC disposal well, other infiltration ponds, or landscape irrigation (Tucker and Orr, 1998). Perched groundwater also is present beneath the new percolation ponds (fig. 4) that were put in service during 2002. Perched groundwater beneath the RWMC formed from infiltration of snowmelt and rain, and recharge from the Big Lost River and INL spreading areas. This perched groundwater contains constituents leached from buried radioactive and organic-chemical wastes. Perched groundwater beneath wastewater infiltration ponds and buried waste is an integral part of the pathway for waste-constituent migration to the ESRP aquifer. The extent of perched groundwater is affected by the waste-disposal practices.

During March–May 2015, water levels in most deep perched groundwater wells around the ATR Complex rose since the March–May 2011 reporting period. Water-level rises ranged from 1.27 ft in well USGS 62 to 17.3 ft in USGS 66 (fig. 12). Water-level rises may be attributed to variable recharge from ponds still in use or possible water leaks around the ATR Complex. Decreases in the deep perched zone occurred in wells PW-8, USGS 72, and USGS 78 near the ATR Complex, along with a decline in the perched zone near the new INTEC infiltration pond (ICPP-MON-V-200) and at RWMC (USGS 92) (fig. 12). The declines in wells USGS 78 and 92 are probably due to no flow in the Big Lost River during 2013 through 2015. During March–May 2015, water levels completed in shallow perched groundwater wells rose and declined near the cold waste ponds (fig. 12); this is probably due to variability in the amount of wastewater discharged to the ponds.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 10. Generalized decline in groundwater levels in the eastern Snake River Plain aquifer at and near Idaho National Laboratory (INL), Idaho, March–May 2011 to March–May 2015.

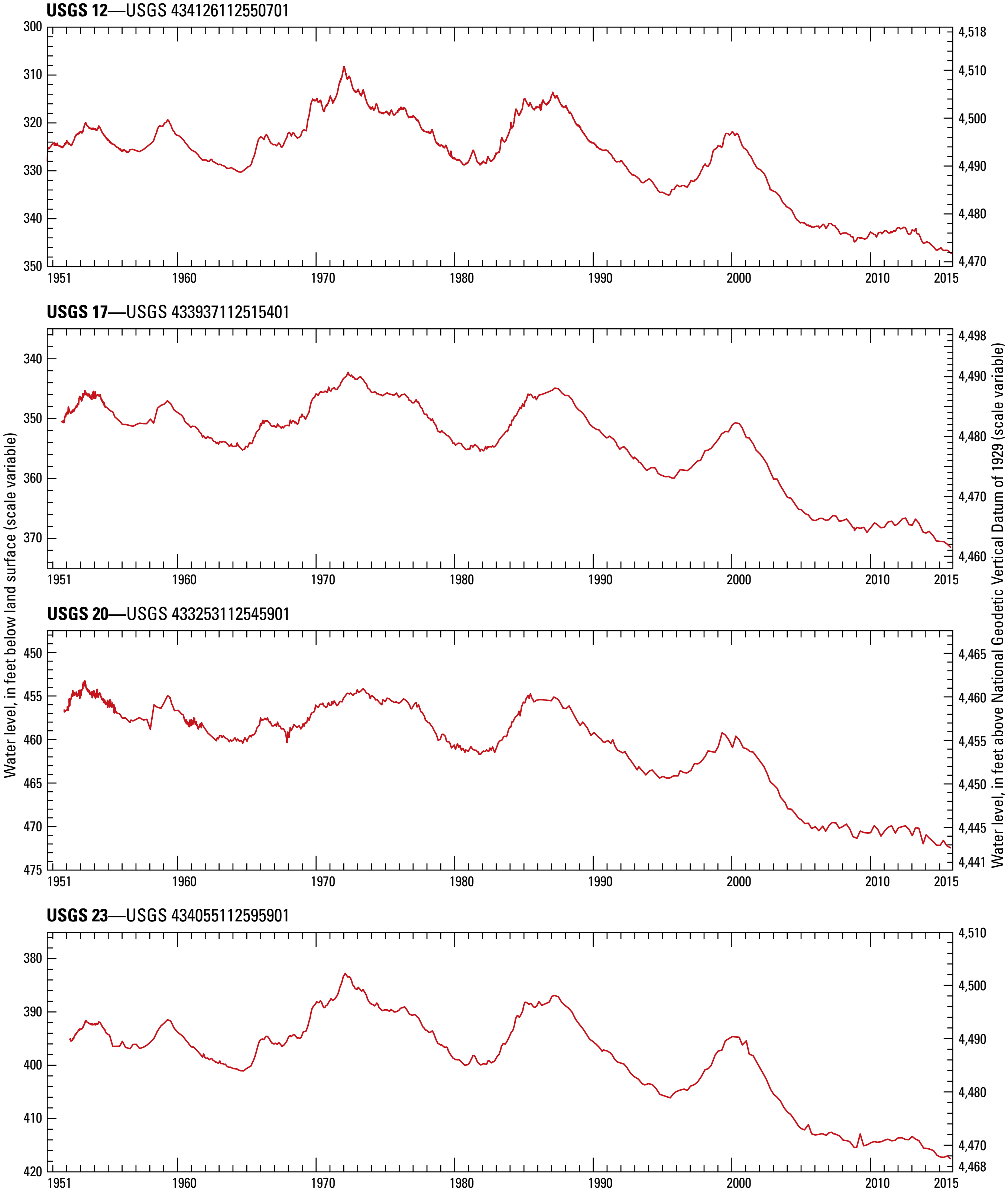
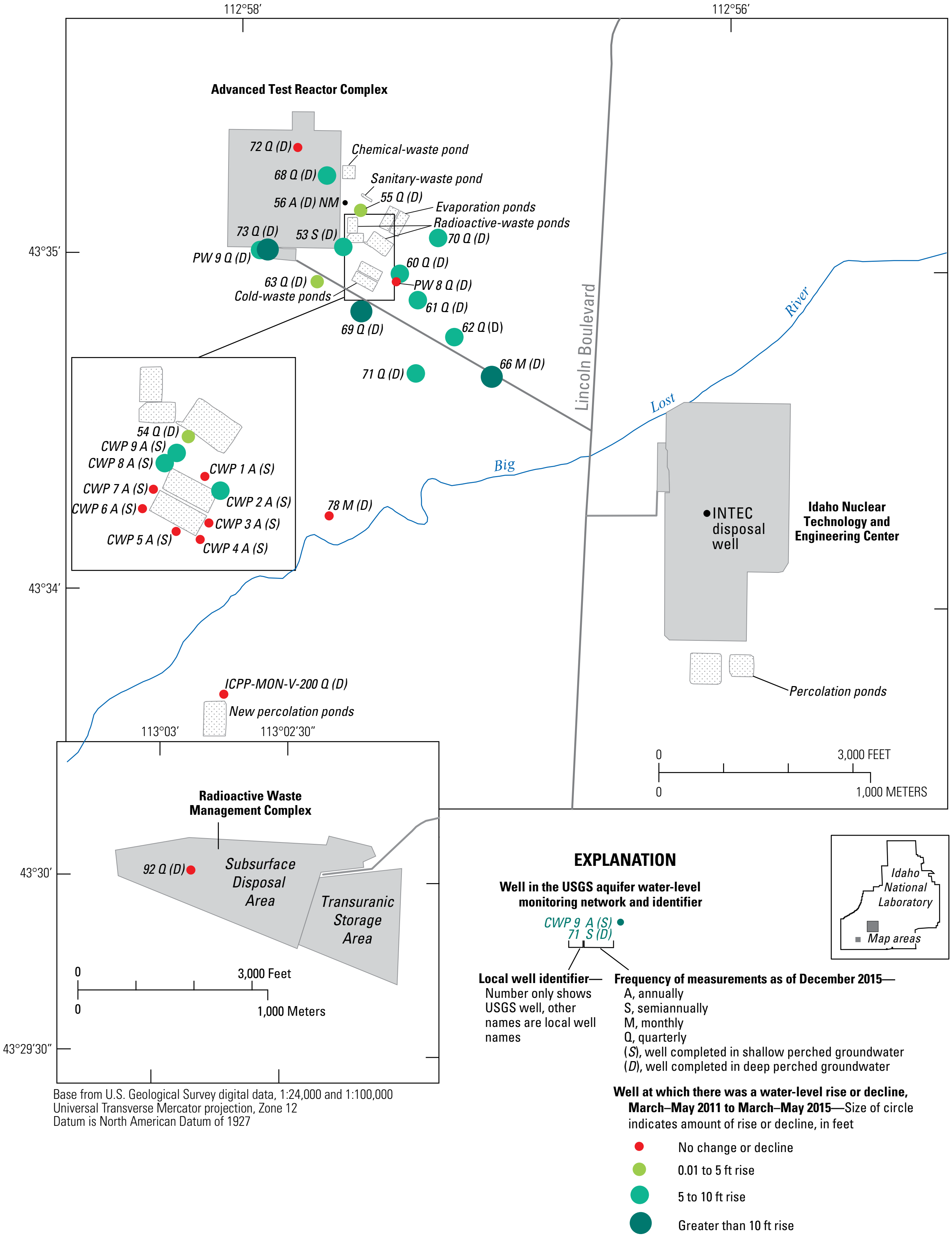


Figure 11. Water levels in four U.S. Geological Survey (USGS) wells 12, 17, 20, 23 in the central part of the Idaho National Laboratory, Idaho, 1952–2015.



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 12. Generalized rise or decline in perched groundwater levels at and near Idaho National Laboratory (INL), Idaho, March–May 2011 to March–May 2015.

Methods and Quality Assurance of Water Sample Analyses

Water samples were analyzed for radiochemical constituents at the DOE Radiological and Environmental Sciences Laboratory (RESL) at the INL and for chemical constituents at the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado. Until 2008, water samples analyzed by the RESL were entered into the USGS National Water Information System (NWIS) database with an uncertainty of 2***s***, where ***s*** is the sample standard deviation. Beginning in 2008 because of a USGS policy change, data were entered into the NWIS database with an uncertainty of 1***s***. Analytical uncertainties in this report are reported as 1***s*** for consistency with conventions used in previous USGS reports.

Methods used to sample and analyze for selected constituents generally follow the guidelines established by the USGS (Goerlitz and Brown, 1972; Stevens and others, 1975; Wood, 1976; Claassen, 1982; Wershaw and others, 1987; Fishman and Friedman, 1989; Faires, 1993; Fishman, 1993; U.S. Geological Survey, variously dated). Water samples were collected according to a quality-assurance plan for water-quality activities done by personnel at the USGS INL Project Office. The plan was finalized in June 1989 and revised in March 1992, in 1996 (Mann, 1996), in 2003 (Bartholomay and others, 2003), in 2008 (Knobel and others, 2008) and in 2014 (Bartholomay and others, 2014).

For the 11 wells equipped with dedicated MLMS, water samples were collected using pre-cleaned, stainless-steel thief sampling bottles which were lowered to the zone to be sampled, connected to the sampling port, and filled with formation water. The stainless-steel bottles were then raised to the surface and emptied into a pre-cleaned container; the water was then processed to fill appropriate bottles for analyses. Field measurements also were taken from the pre-cleaned container and are available for each well at http://waterdata.usgs.gov/id/nwis/nwis.

Field processing of water samples differed depending on the constituents for which analyses were requested. Water samples analyzed by the NWQL were placed in containers and preserved in accordance with laboratory requirements specified by Timme (1995) and Bartholomay and others (2014, appendix A). Containers and preservatives used for this study were supplied by the NWQL and were processed using a rigorous quality-control procedure (Pritt, 1989, p. 75) to minimize sample contamination. The process for water samples requiring filtration consisted of filtering the water through a disposable 0.45µm- filter cartridge that had been pre-rinsed with at least 1 L of deionized water. Water samples analyzed by the RESL were placed in containers and were preserved in accordance with laboratory requirements specified by Bodnar and Percival (1982) and Bartholomay and others (2014, appendix A).

Guidelines for Interpreting Results of Radiochemical Analyses

Concentrations of radionuclides are reported with an estimated sample standard deviation, ***s***, which 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 greater than the signal observed for the blank before a 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 a correct decision can be made for detection or nondetection of the radionuclide. The first aspect of the problem is a qualitative decision based on an observed signal and a definite criterion for detection. The second aspect of the problem is an estimation of the detection capabilities of a given measurement process.

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

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

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

The critical level and minimum detectable concentrations are based on counting statistics alone and do not include systematic or random errors inherent in laboratory procedures. The values 1.6*s* and 3*s* vary slightly with background or blank counts, with the number of gross counts for individual analyses, and for different radionuclides.

In this report, radionuclide concentrations less than 3*s* are considered to be less than a "reporting level." The critical level, minimum detectable concentration, and reporting level aid the reader to interpret analytical results and do not represent absolute concentrations of radioactivity, which may or may not have been detected. Analytical uncertainties in this report are reported as 1*s* for consistency with conventions used in previous reports.

Guidelines for Interpreting Results of Chemical Analyses

Historically, the NWQL has used a minimum reporting level (MRL) to report nondetected concentrations or concentrations less than the MRL. The MRL for chemical constituents is the lowest measured concentration of a constituent (the "less than" value reported by NWQL) that may be reliably reported using a given analytical method (Timme, 1995). However, NWQL determined that establishment of MRLs often was inconsistent, undefined, undocumented, and subjective (Childress and others, 1999). Therefore, in 1998, NWQL implemented new reporting procedures for some analytical methods based on long-term method detection levels (LT-MDLs). Childress and others (1999, p. 16) explained the new reporting procedures used by NWQL as:

> "The USGS National Water Quality Laboratory collects quality-control data on a continuing basis to evaluate selected analytical methods to determine long-term method detection levels (LTMDLs) and laboratory reporting levels (LRLs). These values are re-evaluated each year on the basis of the most recent quality control data and, consequently, may change from year to year.
>
> This reporting procedure limits the occurrence of false positive error. The chance of falsely reporting a concentration greater than the LT-MDL for a water sample in which the analyte is not present is 1 percent or less. Application of the LRL limits the occurrence of false negative error. The chance of falsely reporting a non-detection for a water sample in which the analyte is present at a concentration equal to or greater than the LRL is 1 percent or less. Accordingly, concentrations are reported as less than the LRL for water samples in which the analyte was either not detected or did not pass identification. Analytes that are detected at concentrations between the LT-MDL and LRL and that pass identification criteria are estimated. Estimated concentrations will be noted with a remark code of "E." These data should be used with the understanding that their uncertainty is greater than that of data reported without the "E" remark code."

USGS Office of Water Quality Technical Memorandum 2010.07 (U.S. Geological Survey, 2010) outlines changes to data reporting by the NWQL for the inorganic and organic constituents that became effective October 1, 2010. Starting in October 2010, the reporting level was set at the LT-MDL concentration and concentrations less than the LT-MDL were reported as less than the LT-MDL for inorganic constituents. Results less than the LT-MDL for organic constituents are given a "t" qualifier code. The LRL convention as previously described is still used for organic constituents. Results between the LT-MDL and two times the LT-MDL (formerly the LRL for inorganic constituents) that were formerly reported with an "E" are now given an "n" qualifier code. Results for inorganic and organic constituents less than the lowest calibration standard are given a "b" qualifier code.

USGS National Water Quality Laboratory Technical Memorandum 15.02 (U.S. Geological Survey, 2015) outlines changes to data reporting by the NWQL for the inorganic and organic constituents that became effective for data collected in 2015. Starting in 2015, concentrations of inorganic and organic constituents are reported with reference to reporting limits determined using detection and quantitation calculation (DQCALC) software and are reported as detection limits from DQCALC (DLDQC) for inorganic constituents and MRL for organic constituents. The DLDQC is one of four new report level codes adopted by the NWQL to replace the long-term method detection limit (U.S. Geological Survey, 2015). DLDQC is described as the lowest concentration that with 90 percent confidence will be exceeded no more than 1 percent of the time when a blank sample is measured (≤1 percent false positive risk.) (U.S. Geological Survey, 2015, p. 11). DQCALC is a Microsoft© Excel-based software package used to compute a method detection estimate (Standard Practice D7510-10; American Standards for Testing and Materials International, 2010). A more detailed explanation of the DQCALC procedures is available in U.S. Geological Survey (2015).

Evaluation of Quality-Assurance Samples

Investigations to determine variability and bias for individual constituents were summarized by Wegner (1989), Williams (1996, 1997), and Rattray (2012, 2014). Additional quality-assurance (QA) studies by USGS INL Project Office personnel include:

- An evaluation of field sampling and preservation methods for strontium-90 (Cecil and others, 1989);
- A study comparing pump types used for sampling VOCs (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 effects of various preservation types on nutrient concentrations (Bartholomay and Williams, 1996);
- An analysis of two analytical methods to determine gross alpha- and beta-particle activity (Bartholomay and others, 1999);
- An evaluation of well-purging effects on water-quality results (Knobel, 2006);
- An evaluation of 2009–11 QA data for routine sampling (Davis and others, 2013); and
- An evaluation of the 2006–08 and 2009–13 MLMS QA data (Bartholomay and Twining, 2010; Bartholomay and others, 2015).

During 2012–15, variability and bias was evaluated from 54 replicate and 33 blank QA samples. Constituents analyzed from these samples included the constituents identified in section, “Water-Quality Monitoring Network.”

Variability

Results from replicate analyses were investigated to evaluate sample variability. Replicates consisted of two water samples, an environmental sample and a replicate sample, with the replicate sample collected immediately after collection of the environmental sample. Replicates were submitted blind to the analytical laboratories, ensuring that the laboratories did not know the source of the water or that the samples were replicates.

Sample variability was evaluated by calculating the reproducibility and reliability of individual constituents (Rattray, 2012, 2014). Reproducibility (the closeness of agreement between individual measurements) was calculated as normalized absolute difference (NAD) for radiochemical and stable isotope constituents (measurements that include analytical uncertainties) and relative standard deviation (RSD) for inorganic and organic constituents (measurements that do not include analytical uncertainties). Reliability (the error associated with a measurement) was calculated as a pooled RSD for each constituent. Equations for calculating the NAD and pooled RSD are presented in Rattray (2012, 2014).

Reproducibility

Reproducibility of constituent measurements was considered acceptable if (Rattray, 2012, p. 10):

- The NAD was less than or equal to 1.96;
- The RSD was less than 14 percent (this corresponds to a relative percent difference of less than 20 percent);
- Both measurements were censored and (or) estimated because they were less than the reporting level for that analysis; or
- One measurement was censored or estimated and the other measurement was within one detection limit of the larger of the estimated value or the reporting level, or the measurements were within one detection limit of each other. For results reported using the LRL as the reporting level, the detection limit was the LT-MDL (one-half of the LRL). For results reported using the MRL as the reporting level, the detection limit was approximated as one-half of the MRL. For results reported using the DLDQC as the reporting level, the detection limit is the DLDQC value.

If the percentage of replicates with acceptable reproducibility for a constituent was greater than or equal to 90 percent, then the reproducibility for that constituent was considered acceptable for 2012–15.

Constituents with acceptable reproducibility were major ions (100 percent), nutrients (97–100 percent), and volatile organic compounds (90–100 percent). All radiochemical constituents (91–100 percent) and trace metals had acceptable reproducibility (91–100 percent) except for gross alpha-particle radioactivity (88 percent), gross beta-particle radioactivity (83 percent), cesium-137 (83 percent), antimony (50 percent), cobalt (50 percent), iron (0 percent), and manganese (50 percent). The radiochemical and trace metal constituents with low reproducibility were primarily from samples collected with thief sampling bottles, which may indicate a non-random error in samples collected with these bottles. However, all radiochemical and trace metal constituents with low reproducibility had concentrations that were less than seven times the method detection limit (MDL), LRL, LT-MDL, or DLDQC, and this low reproducibility was a function of the small concentrations. The overall high reproducibility of the replicate samples indicates that the associated environmental samples probably also have high reproducibility.

Reliability

Reliability and RSDs are generally a function of concentration, where reliability increases and RSDs decrease with increasing concentration. Because pooled RSDs should be calculated from samples with similar variability, reliability was estimated for discrete concentration ranges, of an order of magnitude or less, that had a similar range of RSDs (Rattray, 2012, p. 11).

Table 5 shows pooled RSDs for discrete concentration ranges for each constituent. RSDs were calculated for radiochemicals in order to calculate pooled RSDs, if both concentrations from a replicate sample pair equaled or exceeded the MDL and the reporting level of 3*s*. Pooled RSDs were less than or equal to 12 percent for all constituents, and their concentration ranges except for the 2–4 pCi/L concentration range for strontium-90 (20 percent), gross beta-particle radioactivity (19 percent), antimony (21 percent), and cobalt (73 percent). The large pooled RSDs and low reliability for the 2–4 pCi/L concentration range of strontium-90, gross beta-particle radioactivity, antimony, and cobalt were the result of small measured concentrations that were less than seven times the MDL, LRL, LT-MDL, or DLDQC. The overall small pooled RSDs for QA samples indicates that the associated environmental samples probably have high reliability.

Table 5. Ranges of concentrations, number of replicates with calculated relative standard deviations, and pooled relative standard deviations for radiochemical, inorganic, and organic constituents, Idaho National Laboratory, Idaho, 2012–15.

[Data are from U.S. Geological Survey (2016). **Constituent:** f, filtered; N, nitrogen; P, phosphorus; RSD, relative standard deviation; uf, unfiltered. **Abbreviations:** mg/L, milligram per liter; pCi/L, picocurie per liter; µg/L, microgram per liter]

Constituent	Concentration range	Number of replicates with calculated RSDs	Pooled RSD (percent)
Tritium (pCi/L)	200–2,000	14	12
	2,000–20,000	5	3.9
	20,000–30,000	1	1.3
Strontium-90 (pCi/L)	2–4	2	20
	8–30	5	5.4
	30–40	2	1.4
Gross-beta radioactivity (pCi/L)	2–6	10	19
Calcium (mg/L)	40–50	1	2.1
Magnesium (mg/L)	10–20	1	0.1
Sodium (mg/L)	6–40	49	2.2
Potassium (mg/L)	2–3	1	4.6
Chloride (mg/L)	2–20	39	0.8
	20–170	14	0.4
Sulfate (mg/L)	10–80	39	0.5
	100–240	6	0.6
Fluoride (mg/L)	0.2–0.3	51	1.3
Bromide (µg/L)	30–40	1	2.0
Silica (mg/L)	20–30	1	7.4
Ammonia (µg/L as N)	10–20	5	2.4
Nitrite (µg/L as N)	1–10	4	1.3
Nitrate (mg/L as N)	0.2–1.0	20	5.1
	1.0–4	18	0.8
Orthophosphate (µg/L as P)	8–40	37	3.0
	200–300	1	0.5
Aluminum (µg/L)	3–5	2	1.2
Antimony (µg/L)	0.06 –0.20	2	21
Arsenic (f) (µg/L)	1–4	2	1.3
Arsenic (uf) (µg/L)	0.5–0.7	1	3.8
Barium (u) (µg/L)	10–30	2	8.1
Barium (uf) (µg/L)	140–150	1	0.2
Boron (µg/L)	10–20	1	8.3
Cadmium (µg/L)	0.08–0.10	1	11
Chromium (f) (µg/L)	0.7–7.0	21	4.9
	7–40	13	3.0
Chromium (uf) (µg/L)	1–2	1	0.1
Cobalt (µg/L)	0.08–0.30	1	73
Lead (µg/L)	2–3	1	4.1
Lithium (µg/L)	3–4	1	0.5
Manganese (µg/L)	2–3	1	1.6
Molybdenum (µg/L)	2–4	2	1.3
Nickel (µg/L)	0.3–0.6	2	1.5
Selenium (f) (µg/L)	1–2	1	1.2
Selenium (uf) (µg/L)	1–2	1	2.0
Strontium (µg/L)	200–300	1	0.1
Tungsten (µg/L)	6–7	1	1.3
Uranium (µg/L)	1–2	2	0.5
Vanadium (µg/L)	3–4	1	0.5
Zinc (µg/L)	5–6	1	4.8
Tetrachloromethane (µg/L)	3–4	1	1.1
Trichloromethane (µg/L)	0.2–0.3	1	0.3
Toluene (µg/L)	0.3–0.4	1	4.3
Tetrachloroethene (µg/L)	0.1–0.2	1	1.5
Styrene (µg/L)	0.4–0.6	1	2.4
1,1-Dichloroethene (µg/L)	0.0–0.10	3	4.2
1,1-Trichloroethane (µg/L)	0.015–0.15	4	3.1
Trichloroethene (µg/L)	0.01–0.08	2	4.2
Trichloroethene (µg/L)	0.7–0.8	1	0.7

The pooled RSDs in table 5 are very similar to pooled RSDs determined from QA samples from 2009–11 (Davis and others, 2013, table 5), which demonstrates a consistency in reliability over time. A few constituents had noticeably different pooled RSDs when compared to 2009–11, for example, the pooled RSDs for both ammonia and aluminum showed a significant decrease while the pooled RSD for cobalt showed a significant increase for the 2012–15 datasets.

Bias

Bias from sample contamination was evaluated from equipment, field, and source solution blanks. Other sources of bias associated with field samples, such as matrix interference and sample degradation, were not evaluated. However, the NWQL and the RESL evaluate laboratory bias (including sample contamination, matrix interference, and sample degradation) with analysis of blank samples and reference materials. Equipment and field blanks were collected at field sites, and deionized water source-solution blanks were collected at the USGS Idaho Water Science Center, Idaho Falls Field Office. The equipment, field, and source solution blanks were collected as described by Rattray (2012, p. 7).

Equipment blanks were collected to identify bias of environmental samples due to inadequate cleaning of portable sampling equipment (thief samplers and stainless-steel sampling pipes). Inadequate cleaning of thief samplers and sampling pipes may cause cross-contamination between sample sites.

Equipment blanks include bias from sources other than the equipment, such as field collection and processing, sample storage and shipping, and laboratory processing and analysis. Consequently, field and source solution blanks were collected to determine whether bias identified in equipment blanks may be from sources other than the equipment. Field blanks were collected to identify all potential sources of bias in the equipment blanks except for bias from the equipment. Source-solution blanks were collected to identify bias in the deionized water source solution collected from the USGS Idaho Water Science Center, Idaho Falls Field Office.

Bias was evaluated from results of 9 equipment (6 sampling pipes and 3 thief samplers) blanks, 13 field blanks, and 11 source-solution blanks. Concentrations in blank samples were considered detected if (1) radiochemical constituents were greater than or equal to 3***s*** (the minimum detectable concentration) or the MDL and (2) inorganic and organic constituents exceeded their reporting level.

Numerous radiochemical, inorganic, and organic constituents were analyzed in equipment, field, and source solution blanks, but with the exception of detections of gross alpha radioactivity in two field blanks, all constituents detected in blank samples were less than or equal to three times the MDL for radiochemical constituents and less than or equal to the corresponding reporting level for inorganic and organic constituents. These small concentrations in blank samples indicate that, except for gross alpha radioactivity, there probably was no bias in environmental samples.

Gross alpha radioactivity was detected at activities of 29±7 and 23±5 pCi/L in field blanks collected on June 21, 2012, and April 17, 2013. These activities were about 8–10 times the MDL of 3 pCi/L for gross alpha radioactivity (Bartholomay and others, 2014). Gross alpha radioactivity was measured in four other field blanks, collected between July 10, 2013, and June 23, 2015, six equipment blanks, and five source solution blanks, but was not detected in any of these other blanks. Consequently, the source of the gross alpha radioactivity in the two field blanks could not be identified, but was not from the source solution. Inspection of gross alpha radioactivity analyses for environmental samples collected during June 2012 and April 2013 showed a single detection, 14±4 pCi/L, for the 44 analyses of gross alpha radioactivity. These results indicate that no bias of gross alpha radioactivity occurred during the June 2012 and April 2013 sampling events.

Selected Physical Properties of Water and Radiochemical and Chemical Constituents in the Eastern Snake River Plain Aquifer

Physical properties of water measured during sampling events included specific conductance, temperature, and pH. Contaminant plumes of radiochemical and chemical constituents in the ESRP aquifer at the INL are attributed to waste-disposal practices. Areal distribution of the plumes was interpreted from analyses of water samples collected from a three-dimensional flow system. Concentrations of these constituents represent water samples collected during April or October 2015 from wells completed at various depths in the aquifer and with differing well completions; for example, single and multiple screened intervals and open boreholes. No attempt was made to determine the vertical extent and distribution of these plumes. However, beginning in 2005, selected wells were instrumented with dedicated MLMS. During 2015, water samples were collected from selected zones from 11 wells with dedicated MLMS that allow for some description of the vertical distribution of selected constituents in the aquifer. Radiochemical and chemical constituents analyzed for in groundwater samples collected from wells at the INL during 2012–15 include tritium, strontium-90, cesium-137, plutonium-238, plutonium-239, -240 (undivided), americium-241, gross alpha- and beta-particle radioactivity, chromium and other trace elements, sodium, chloride, sulfate, nitrate (as N), fluoride, and VOCs.

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 INL facilities generally have increased the specific conductance of groundwater through time.

In 2015, the specific conductance of water from 127 wells that sample the ESRP aquifer ranged from 222 to 1,800 µS/cm; the highest value was in water from well NRF 6 located adjacent to the industrial waste ditch near the NRF (fig. 3). Specific conductance measurements for water from most wells around the NRF area were about 600 µS/cm (fig. 13).

The background specific conductance of water in the ESRP aquifer was about 300–325 µS/cm in the INTEC area in 1962 (Robertson and others, 1974, p. 159). A plume of increased specific conductance originated from the INTEC disposal well and old percolation ponds (fig. 6) and extended downgradient from the INTEC to the CFA (fig. 13). The specific conductance of water from several wells in 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 (Bartholomay and others, 2000, p. 37) and has decreased since then to 801 µS/cm in 2015 (fig. 13).

The specific conductance of water from several wells at the ATR Complex exceeded 400 µS/cm in 2015 (fig. 13). The maximum specific conductance measurement was from water from well USGS 65 (fig. 6), downgradient of the infiltration ponds at the ATR Complex. Well USGS 65 had a measurement of 606 µS/cm in April 2015, about the same value as in April 2011.

At the CFA, the specific conductance of water from well CFA 1 increased slightly from 586 µS/cm in 2011 to 612 µS/cm in April 2015; and in well CFA 2, the measurements decreased from 864 µS/cm in 2011 to 812 µS/cm in 2015. The largest specific conductance measurement in wells near CFA was in USGS 130 at 821 µS/cm.

Near the RWMC, the maximum specific conductance measured was in water from well USGS 88, at 639 µS/cm in October 2015, slightly larger than the measurement of 586 µS/cm in October 2011. Water from most other wells near the RWMC had measurements of about 250–400 µS/cm (fig. 13).

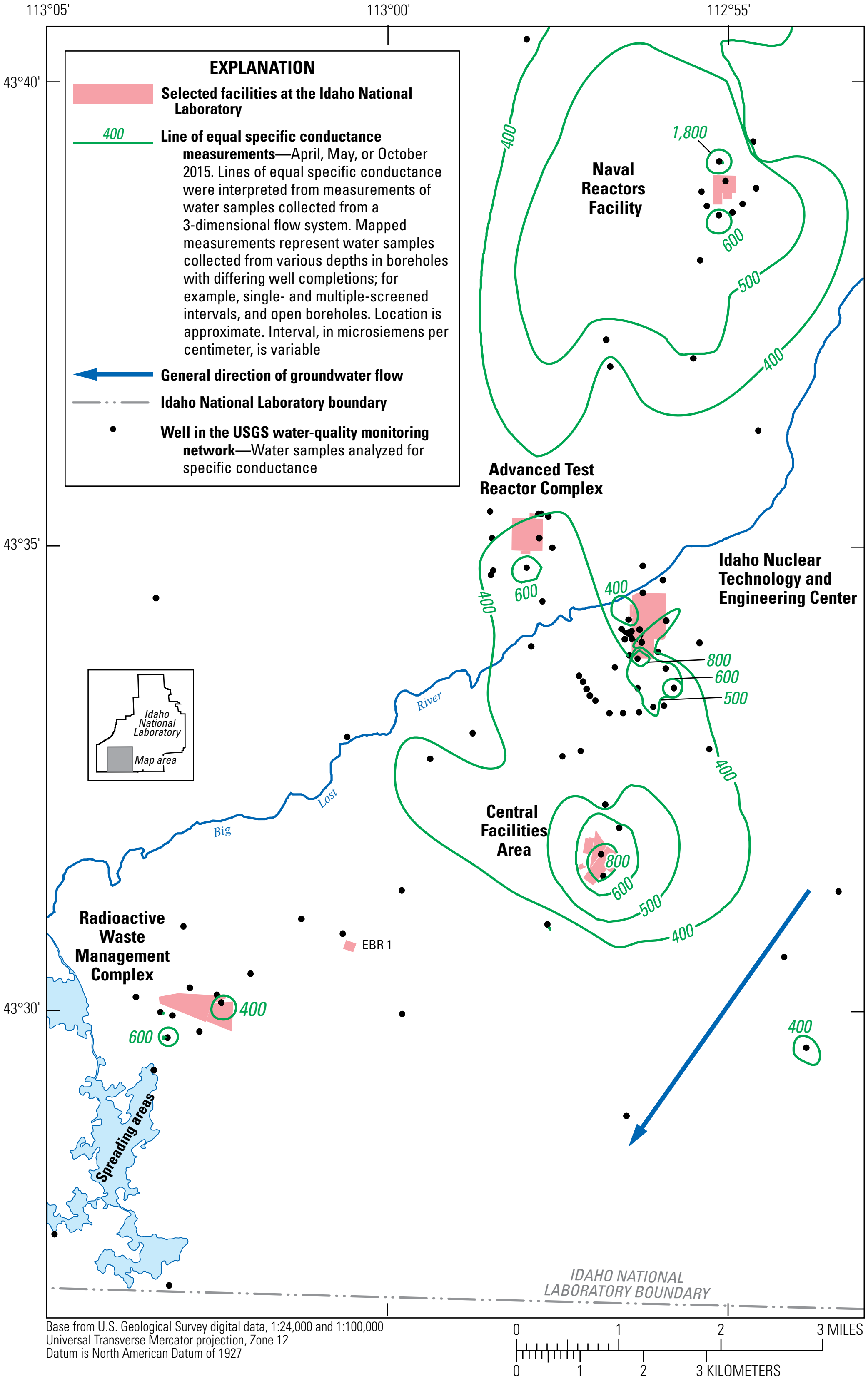
Water temperature of 127 wells measured in 2015 ranged from 9.8 °C in well P&W 2 located in the northern end of the INL to 18.7 in well USGS 7 also located in the northern part of the INL. The median water temperature was 12.8. In 2015, the pH for the 127 wells measured ranged from 6.7 in well CFA-2 to 9.1 in well USGS 119 with a median of 7.9. Water temperature and pH measurements were similar to what they have been in the past for the ESRP aquifer.

Tritium

A tritium plume has developed in the ESRP aquifer from discharge of wastewater at the INL since the 1950s. Tritium has a half-life of 12.3 years (Walker and others, 1989, p. 20). The MCL for tritium is 20,000 pCi/L (U.S. Environmental Protection Agency, 2015). About 31,810 Ci of tritium (Davis, 2006b) was discharged to wells and ponds at the INL from 1952 through 2000; no records are available since 2000. The primary sources of tritium in the aquifer have been the injection of wastewater through the disposal well at INTEC and the discharge of wastewater to percolation ponds at the INTEC and ATR Complex (fig. 4). Routine use of the disposal well at the INTEC ended in February 1984; subsequently, radioactive wastewater was discharged to the old percolation ponds until 1993 when discharge of low- and intermediate-level radioactive waste solutions ceased with the installation of the Liquid Effluent Treatment and Disposal Facility (U.S. Department of Energy, 2011a). Radioactive wastewater was discharged to the radioactive-waste ponds at the ATR Complex until 1993; since then, tritium at the ATR Complex has been discharged to lined evaporation ponds, which theoretically should prevent migration to the aquifer. Concentrations of tritium in water samples collected in 2015 from 49 of 118 aquifer wells exceeded the reporting level and ranged from 230±50 to 5,760±120 pCi/L. The tritium plume extended south-southwestward in the general direction of groundwater flow (fig. 14). Since 1997, tritium concentrations in water samples collected by the USGS from the ESRP aquifer have not exceeded the MCL.

Long-term radioactive-decay processes and an overall decrease in tritium disposal rates since the 1960s (Davis, 2008) contributed to decreased concentrations of tritium in water from most wells at the INL during 2012–15. Tritium concentrations in water from several wells at and south-southwest of the INTEC decreased during 2012–15 (fig. 15). The greatest decrease in tritium concentrations in wells south of the INTEC disposal well was in well USGS 114, which decreased from 7,000±260 pCi/L in October 2011 to 5,760+/-120 pCi/L in October 2015 (fig. 15). Concentrations of tritium in well CFA 1 (figs. 5 and 15) at CFA decreased from 5,300±210 pCi/L in April 2011 to 3,380±110 pCi/L in April 2015. The overall decrease in tritium concentrations in water from wells at and south-southwest of the INTEC likely is the result of discontinued discharge of tritium in wastewater since the early 1990s, along with dilution, dispersion, and radioactive decay.

Tritium concentrations in water from well USGS 59, near the old INTEC percolation ponds (figs. 6 and 15), have decreased since 1980, but were unusually high in October 1983, 1985, 1991, and 1995, and in 2002 (fig. 15). The higher concentrations in 1983 and 1985 correlate with higher annual discharge rates of tritium; however, annual discharge of tritium was low in 1991 and 1995 (Davis, 2008, fig. 9).



Base from U.S. Geological Survey digital data, 1:24,000 and 1:100,000
Universal Transverse Mercator projection, Zone 12
Datum is North American Datum of 1927

Figure 13. Distribution of specific conductance of water from wells at and near the Advanced Test Reactor Complex, Naval Reactors Facility, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, April, May, or October 2015.

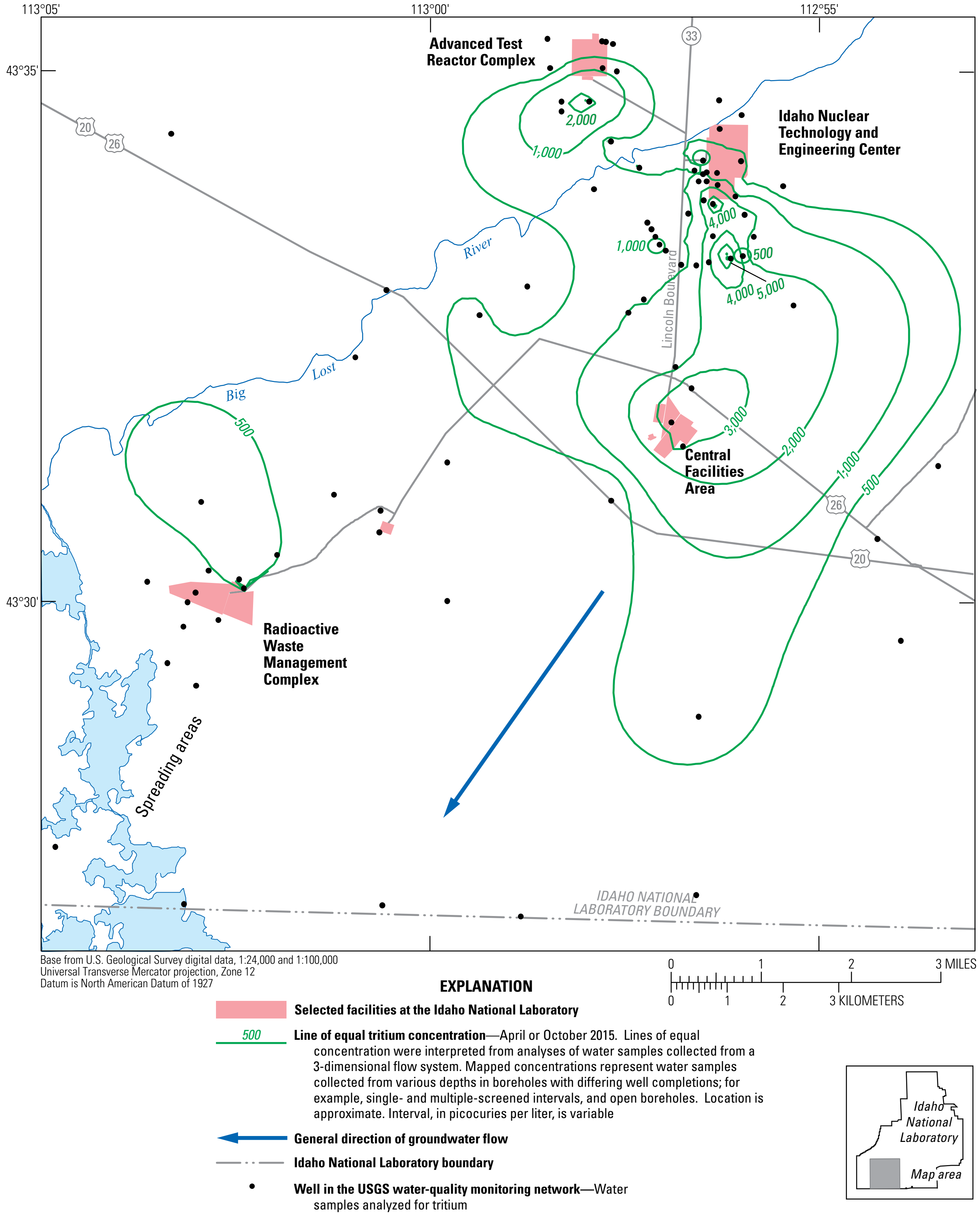
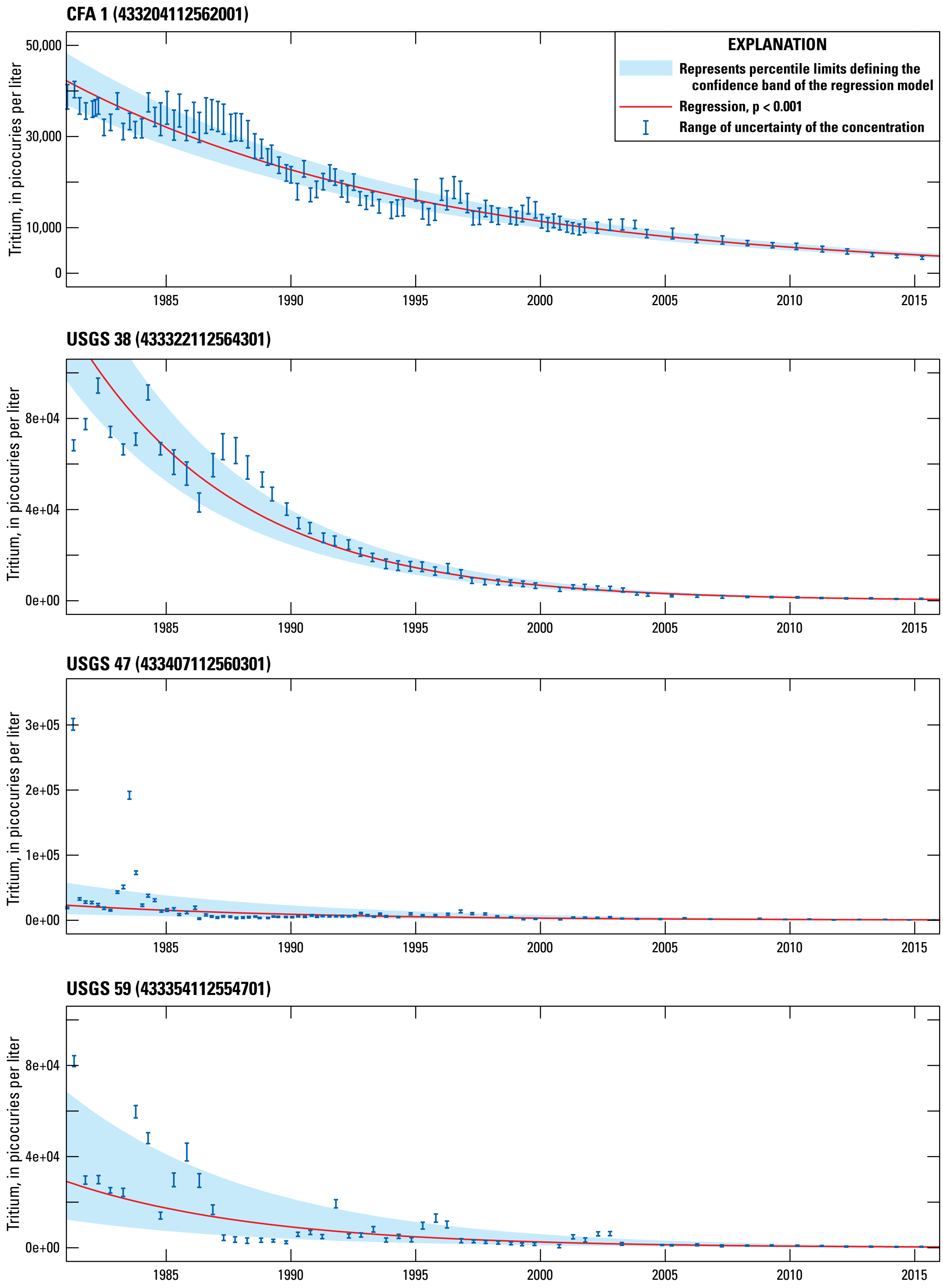


Figure 14. Distribution of tritium in water from wells at and near the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex at the Idaho National Laboratory, Idaho, April or October 2015.


CFA 1 (433204112562001)

USGS 38 (433322112564301)

USGS 47 (433407112560301)

USGS 59 (433354112554701)

Figure 15. Tritium concentrations in water from seven wells at and near the Central Facilities Areas, Idaho Nuclear Technology and Engineering Center, and Radioactive Waste Management Complex, 1980–2015. Locations of wells are shown in figures 5 and 6.

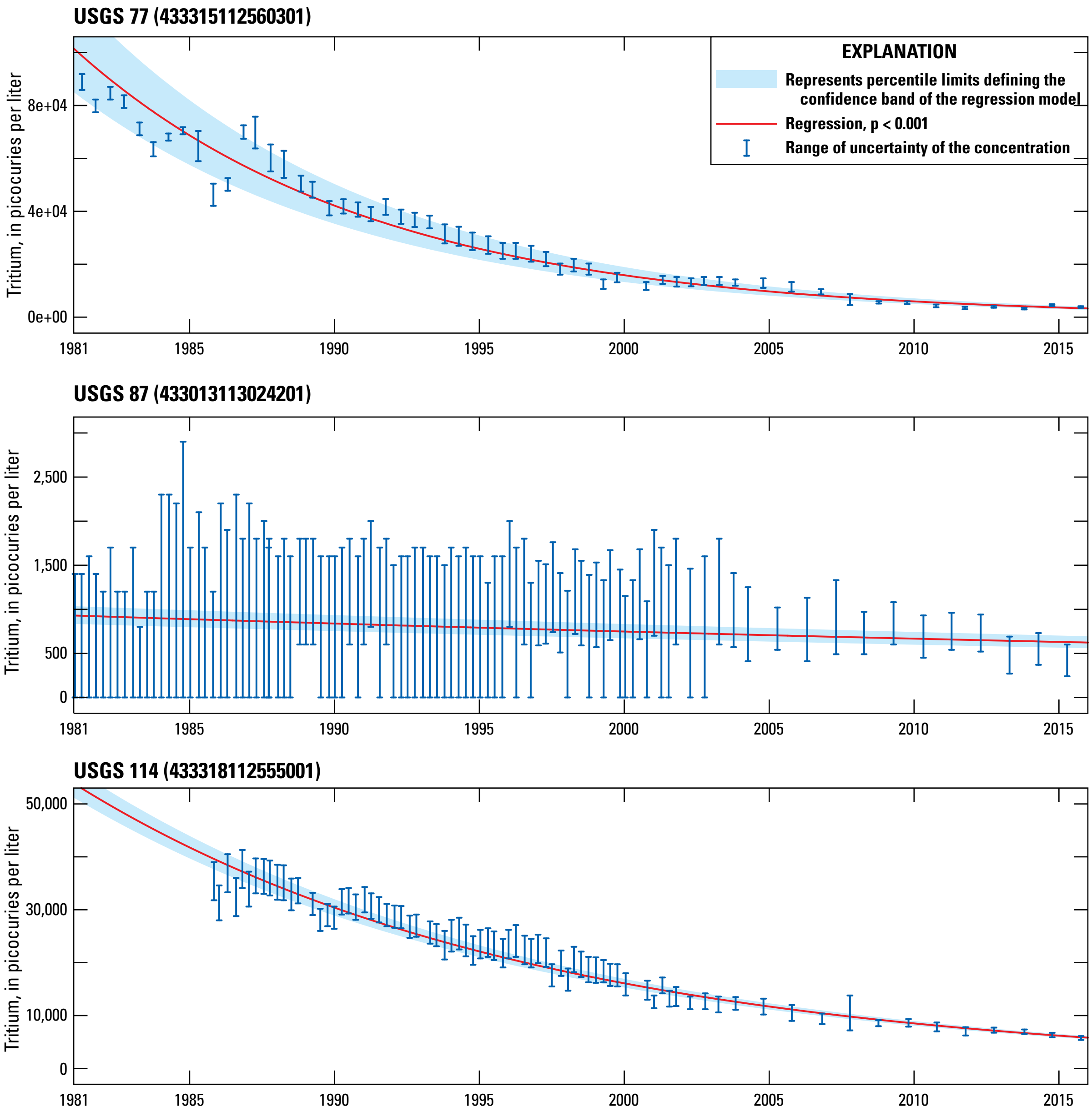


Figure 15.—Continued

In 1986, perched groundwater was detected outside the casing in well USGS 59. Following modifications to the well to prevent seepage of water into the well, a video log showed that some water from the perched groundwater zone was still seeping into the well. The higher concentrations in 1991, 1995, and 2002 probably resulted from seepage from a perched groundwater zone. The high concentrations also correlate with the use of the old east percolation pond and with disposal of tritium to the ponds. The low concentrations in water from well USGS 59 in 1989, 1993, 1994, and 1996–2000 correlate with years in which little or no tritium was discharged to the old percolation ponds (Davis, 2008, fig. 9). The slight increase in tritium concentrations in wells USGS 38, 47, 59, 77, and 114 between 2000 and 2001 (fig. 15), could have resulted from disposal of 0.03 Ci of tritium (S.M. Stoller Corporation, 2002b) to the old INTEC percolation ponds and from the lack of dilution by groundwater recharge because of no streamflow in the Big Lost River during 2001 (Davis, 2008). The steep decrease in concentrations from 2003 to 2015 (fig. 15) occur after the old percolation ponds were taken out of service and replaced with the new percolation ponds about 2 mi southwest of the INTEC.

A water-quality trend report examining data through 2012 (Davis and others, 2015) showed one well near RWMC (USGS 87) had an increasing trend, and the trend was attributed to water from upgradient disposal still contributing to the water concentration. The additional data collected through 2015 now indicates a statistically significant decreasing trend (fig. 15), which indicates concentrations should continue to decrease into the future if the source is from upgradient disposal.

Tritium concentrations in water from several wells (fig. 5) in and near the tritium plume (USGS 127, RWMC M11S, RWMC M13S, USGS 119 and USGS 117) (fig. 14) have been consistently less than the reporting level through time. Additionally, two wells that were discontinued from the sample program in 2012 (well USGS 83, which penetrates about 250 ft of the ESRP aquifer; and well EBR 1, which penetrates about 490 ft of the aquifer) also historically showed tritium concentrations less that the reporting level, and Mann and Cecil (1990, p. 18) speculated that tritium was not present in these two wells because of dilution from deeper water. The wells without tritium are completed in the upper part of the aquifer, and although the lack of tritium is not fully understood, it likely can be attributed to the nature of the basalt stratigraphy present at these locations.

Prior to 1999, concentrations of tritium in water from wells near the southern boundary of the INL (USGS 1, 103, 105, 108, 109, 110A) (fig. 5) varied between exceeding and not exceeding the reporting levels (Pittman and others, 1988; Mann and Cecil, 1990; Bartholomay and others, 1997, 2000). During 1999–2005, concentrations of tritium in water from these wells and all wells sampled south of the INL boundary were less than the reporting level (Davis, 2008). During 2006–11, some of the wells with MLMS showed concentrations in some zones above the reporting level (Davis and others, 2013, p. 37) while all other wells along the southern boundary and south of the INL had concentrations less than the reporting level. Water from wells USGS 1, all three zones sampled from the MLMS in USGS 108, 109, 110A, the one zone sampled from USGS 135, and all wells south of the INL boundary had tritium concentrations less than the reporting level during 2012–15. Tritium concentrations in the three sampling zones from USGS 105 (851, 952, and 1,072 ft BLS) sampled during 2012–15 had tritium concentrations that exceeded the reporting level in all three zones during at least two sampling events from 2012 to 2015, with the largest concentration of 460 +/-60 pCi/L occurring in zone 8 (952 ft BLS) in June 2014 (table 6). During 2012–15, water was sampled from the MLMS installed in well USGS 103 from the four deepest zones; these zones all showed concentrations above the reporting level in the past (Bartholomay and Twining, 2010; Bartholomay and others, 2015). Tritium concentrations exceeded the reporting level in all four zones during at least one sampling event from 2012 to 2015, with the largest concentration of 380 ±70 pCi/L occurring in zone 6 (1,087 ft BLS) during June 2012 (table 6). Water samples were collected from four zones in MLMS well USGS 137A completed near the southern boundary and all but one sample (July 2013 sample from zone 4,747 ft BLS; 250±50 pCi/L, table 6) had concentrations less than the reporting level.

Water from various depths in six other MLMS-equipped wells, which were not located along the southern boundary (figs. 5 and 6; table 6), was sampled and analyzed for tritium during 2012–15. Tritium concentrations in water from wells USGS 134 and Middle 2050A did not exceed the reporting level in any of the zones sampled during 2012–15. Other results showed that tritium concentrations in water from one or more zones in wells USGS 132, 133, Middle 2051, and USGS 131A exceeded the reporting level during 2012–15. Tritium concentrations that exceed the reporting levels are attributed to wastewater disposal at the INTEC and ATR Complex (Bartholomay and Twining, 2010; Bartholomay and others, 2015). Bartholomay and Twining (2010) and Bartholomay and others (2015) give a comprehensive analysis of the vertical variation in tritium concentrations for the 11 MLMS wells and possible sources of the tritium for the different zones in each well.

Table 6. Concentrations of selected constituents in water sampled at multiple depths in 11 wells equipped with multilevel monitoring systems, 2012–15.

[Analytical uncertainties are reported as 1 times the sample standard deviation. Concentrations equal to or greater than 3 times the sample standard deviation are considered greater than the reporting level and are **bold**. **Well No.:** Well locations are shown in figures 5 and 6. **Abbreviations:** ft BLS, feet below land surface; mg/L, milligram per liter; pCi/L, picocuries per liter; µg/L, microgram per liter; USGS, U.S. Geological Survey. **Symbol:** ±, plus or minus]

Well No. or name	Sampling port depth (ft BLS)	Date	Tritium (pCi/L)	Chromium (µg/L)	Chloride (mg/L)
USGS 103	993	06-25-12	120±60	6.61	13.3
	993	06-25-13	**240±50**	6.64	12.6
	993	07-09-14	130±50	5.81	12.8
	993	06-16-15	100±50	5.48	12.5
	1,087	06-25-12	**380±70**	6.32	14.6
	1,087	06-25-13	**280±50**	6.19	14.1
	1,087	07-09-14	**200±50**	5.75	14.3
	1,087	06-16-15	**150±50**	5.59	14.4
	1,210	06-25-12	150±60	5.73	14.6
	1,210	06-25-13	**250±50**	5.93	14.0
	1,210	07-09-14	**230±60**	5.47	14.2
	1,210	06-16-15	**150±50**	5.39	14.4
	1,258	06-25-12	**220±60**	5.77	14.5
	1,258	06-25-13	**260±50**	6.05	14.0
	1,258	07-08-14	**190±50**	5.34	14.3
	1,258	06-16-15	**160±50**	5.26	14.6
USGS 105	851	06-28-12	**190±60**	7.10	12.1
	851	06-27-13	**190±50**	7.45	11.7
	851	06-25-14	90±50	7.10	11.9
	851	06-17-15	110±50	7.70	12.0
	952	06-28-12	120±60	7.60	13.0
	952	06-27-13	**190±50**	8.15	12.4
	952	06-25-14	**460±60**	6.64	12.6
	952	06-17-15	**150±50**	7.13	12.7
	1,072	06-28-12	**240±60**	8.00	13.2
	1,072	06-27-13	**320±50**	7.94	12.4
	1,072	06-25-14	**200±50**	7.26	12.6
	1,072	06-17-15	**180±50**	7.30	12.7
USGS 108	809	06-25-14	30±50	5.65	16.2
	809	06-18-15	30±50	6.20	16.2
	888	06-26-12	10±60	6.41	16.7
	888	06-26-13	20±40	5.42	16.6
	1,029	06-26-12	60±60	6.41	17.4
	1,029	06-26-13	60±40	5.29	17.4
	1,172	06-26-12	40±60	6.12	17.1
	1,172	06-26-13	120±50	5.88	17.1
	1,172	06-24-14	70±50	5.15	17.2
	1,172	06-18-15	-10±50	5.38	17.1

Table 6. Concentrations of selected constituents in water sampled at multiple depths in 11 wells equipped with multilevel monitoring systems, 2012–15.—Continued

Well No. or name	Sampling port depth (ft BLS)	Date	Tritium (pCi/L)	Chromium (µg/L)	Chloride (mg/L)
USGS 131A	616	10-29-12	**940±70**	6.06	16.1
	616	07-17-13	**1,010±60**	10.5	16.1
	616	06-19-14	**860±70**	9.24	16.5
	616	06-15-15	**850±60**	9.16	17.1
	812	10-29-12	**1,590±90**	10.6	26.0
	812	07-16-13	**1,550±70**	10.8	26.2
	812	06-19-14	**1,290±70**	9.52	26.2
	812	06-15-15	**1,160±70**	8.98	26.4
	981	10-29-12	150±60	5.35	13.5
	981	07-16-13	**170±50**	5.31	12.9
	981	06-19-14	**150±50**	4.65	13.0
	981	06-15-15	110±50	4.72	13.3
	1,137	10-24-12	140±60	5.20	14.0
	1,137	07-16-13	**200±50**	5.22	13.2
	1,137	06-19-14	40±50	4.51	13.3
	1,137	06-15-15	50±50	4.75	13.6
USGS 132	765	06-19-12	170±60	7.80	11.4
	765	06-19-13	**300±50**	7.94	11.2
	765	06-17-14	**360±60**	6.85	10.9
	765	06-09-15	**150±50**	7.67	10.8
USGS 133	469	06-21-12	-60±60	5.84	12.1
	469	06-24-13	60±40	6.44	11.6
	469	06-17-14	**360±60**	6.35	11.9
	469	06-09-15	-12.3±48.1	7.81	11.7
USGS 134	579	06-16-14	-70±50	6.45	9.59
	579	06-08-15	-80±50	5.50	9.47
	707	06-18-12	-50±60	5.53	7.54
	707	07-10-13	0±40	6.35	7.28
USGS 135	837	06-21-12	-70±60	2.56	6.88
	837	06-24-13	40±40	2.40	6.67
	837	06-23-14	-11.4±50.4	2.30	6.73
	837	06-11-15	-60±50	2.73	6.67
USGS 137A	662	10-24-12	100±50	6.65	14.3
	662	07-15-13	140±50	6.91	13.7
	662	07-10-14	10±50	6.14	14.2
	662	06-22-15	20±50	6.36	13.7
	747	10-23-12	130±60	6.57	12.4
	747	07-15-13	**250±50**	6.44	12.0
	747	07-10-14	40±50	5.92	12.4
	747	06-22-15	10±50	5.54	12.1
	841	10-23-12	100±60	6.13	11.5
	841	07-15-13	100±40	6.20	11.0
	841	07-09-14	130±50	5.59	11.1
	841	06-22-15	-50±50	6.01	11.1
	876	10-23-12	140±60	6.19	11.9
	876	07-15-13	110±50	5.97	11.0
	876	07-09-14	60±50	5.75	11.1
	876	06-22-15	-40±50	5.28	11.1

Table 6. Concentrations of selected constituents in water sampled at multiple depths in 11 wells equipped with multilevel monitoring systems, 2012–15.—Continued

Well No. or name	Sampling port depth (ft BLS)	Date	Tritium (pCi/L)	Chromium (μg/L)	Chloride (mg/L)
Middle 2050A	517	06-19-12	20±60	1.55	5.51
	517	07-10-13	80±40	6.95	12.7
	517	06-26-14	40±50	7.06	12.5
	517	06-23-15	-20±50	7.22	12.3
Middle 2051	749	06-20-12	**280±60**	6.43	10.9
	749	06-20-13	**340±50**	6.23	10.7
	749	06-10-15	**200±50**	6.68	10.5
	827	06-20-12	**520±70**	7.12	11.3
	827	06-20-13	**400±50**	7.34	11.1
	827	06-18-14	**590±60**	6.17	11.0
	1,091	06-20-12	120 ± 60	6.52	12.2
	1,091	06-20-13	**200±50**	6.26	12.0
	1,091	06-18-14	**250±60**	5.64	11.7
	1,091	06-10-15	**200±50**	6.64	11.5
	1,141	06-20-12	120 ±60	6.82	12.1
	1,141	06-20-13	**210±50**	6.45	11.9

Strontium-90

A strontium-90 plume developed in the ESRP aquifer from wastewater disposal at the INL. Strontium-90 has a half-life of 29.1 years (Walker and others, 1989, p. 29). The MCL for strontium-90 in drinking water is 8 pCi/L (U.S. Environmental Protection Agency, 2015).

During 1952–98, about 24 Ci of strontium-90 was in wastewater that was injected directly into the aquifer through the disposal well and was discharged to the old percolation ponds at the INTEC (Bartholomay and others, 2000). 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 1972, about 18,100 Ci of strontium-90 was leaked at the INTEC tank farm (fig. 7) (Cahn and others, 2006). During 1952–1998, about 93 Ci of strontium-90 also was discharged to radioactive-waste infiltration and evaporation ponds at the ATR Complex. During 2000, 0.21 Ci of strontium-90/yttrium-90 was discharged at the ATR Complex (S.M. Stoller Corporation, 2002b, table 6-2). Data are not available for strontium-90 discharged at either the INTEC or the ATR Complex during 2001–15, but the amount is believed to be zero.

During April or October 2015, water from 66 aquifer wells was sampled for strontium-90 throughout the INL. Concentrations of strontium-90 in water from 18 aquifer wells exceeded the reporting level. Concentrations of strontium-90 greater than the reporting level ranged from 2.2±0.7 pCi/L in water from well USGS 45 to 539±12 pCi/L in water from well TAN 2271; the largest concentration near INTEC was in well USGS 47 at 17.6±0.9 pCi/L. The area of the strontium-90 plume near the INTEC extended south-southwestward in the general direction of groundwater flow (fig. 16). The concentrations of strontium-90 in water from wells near and southwest of INTEC have fluctuated and generally exceeded the reporting level since 1981; however, all wells have shown an overall decrease in strontium-90 concentration (fig. 17). Before 1989, strontium-90 concentrations in most wells had been decreasing likely because of factors including radioactive decay, diffusion, dispersion, changes in disposal methods, and dilution from natural recharge (Orr and Cecil, 1991, p. 35).

MLMS equipped wells USGS 137A and 131A southwest of CFA (fig. 5) were sampled for strontium-90 in September 2012 and 2013 (Bartholomay and others, 2015, table 7). None of the water from any zones sampled contained concentrations of strontium-90 exceeding the reporting level.

Strontium-90 has not been detected in the ESRP aquifer beneath the ATR Complex partly because of the exclusive use of waste-disposal ponds and lined evaporation ponds rather than the disposal well for radioactive-wastewater disposal at that facility. Sorption processes in sediments in the unsaturated zone beneath the radioactive waste-disposal pond have minimized or prevented strontium-90 migration to the aquifer at the ATR Complex. Additionally, the stratigraphy beneath the ATR Complex includes more sedimentary interbeds than the stratigraphy beneath the INTEC (Anderson, 1991, p. 22–28).

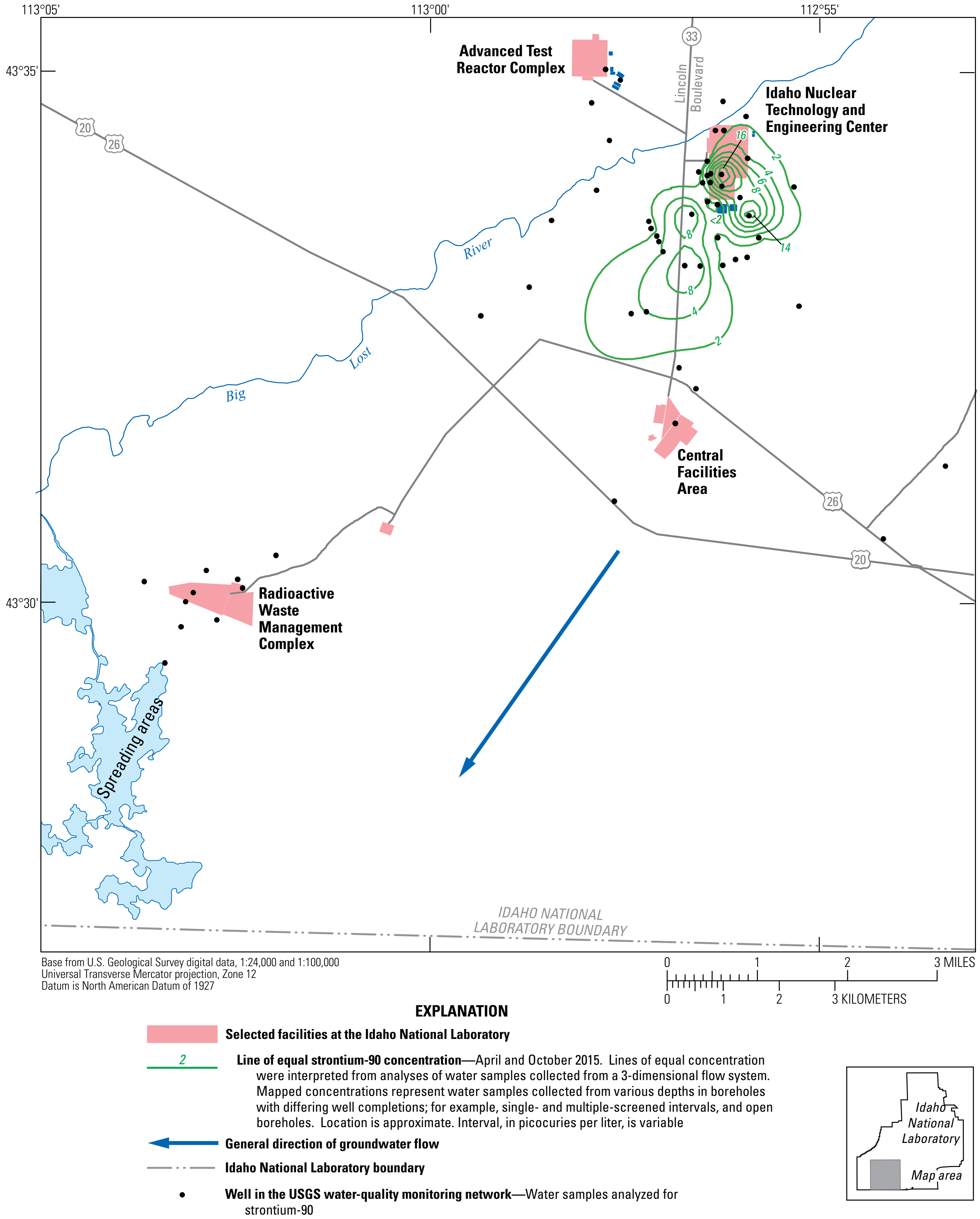
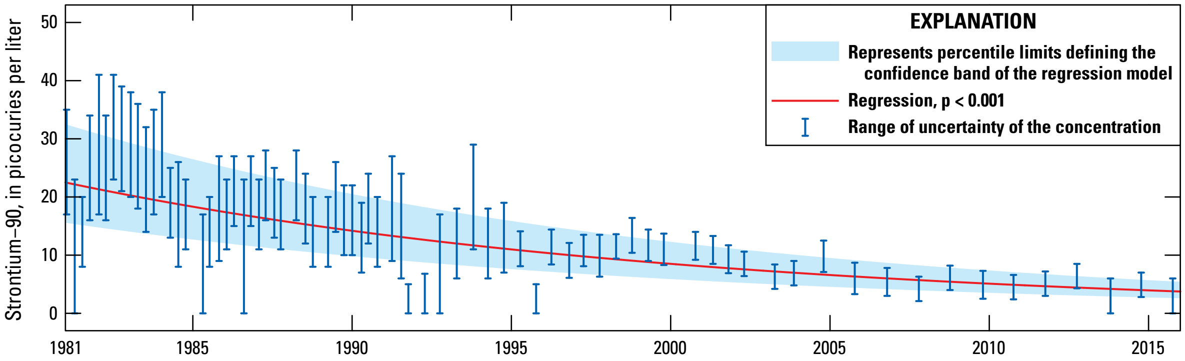
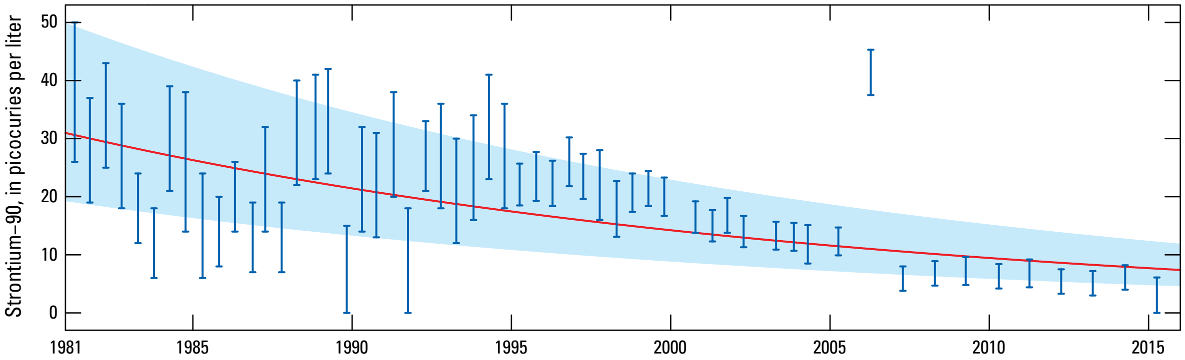


Figure 16. Distribution of strontium-90 in water from wells at and near the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, April or October 2015.

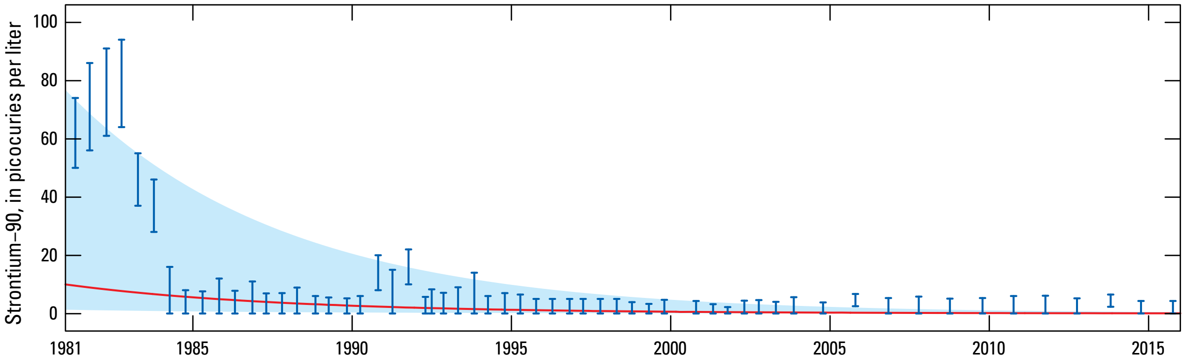
USGS 37 (433326112564801)



USGS 38 (433322112564301)



USGS 45 (433402112561801)



USGS 47 (433407112560301)

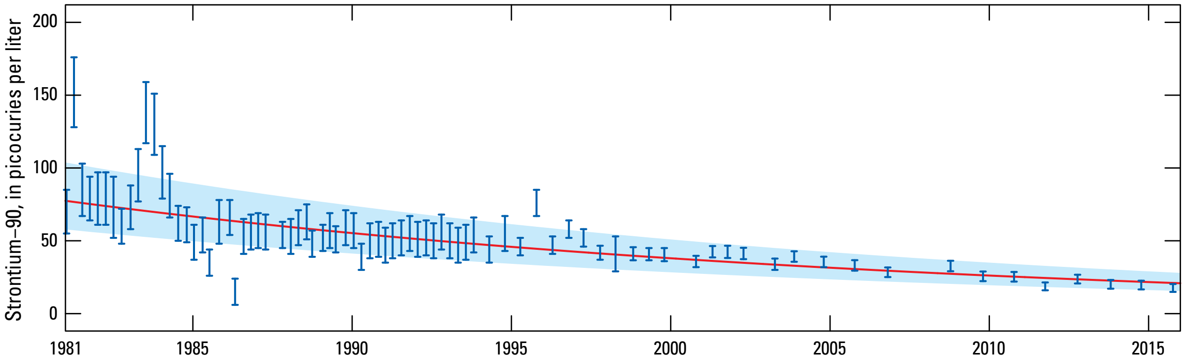
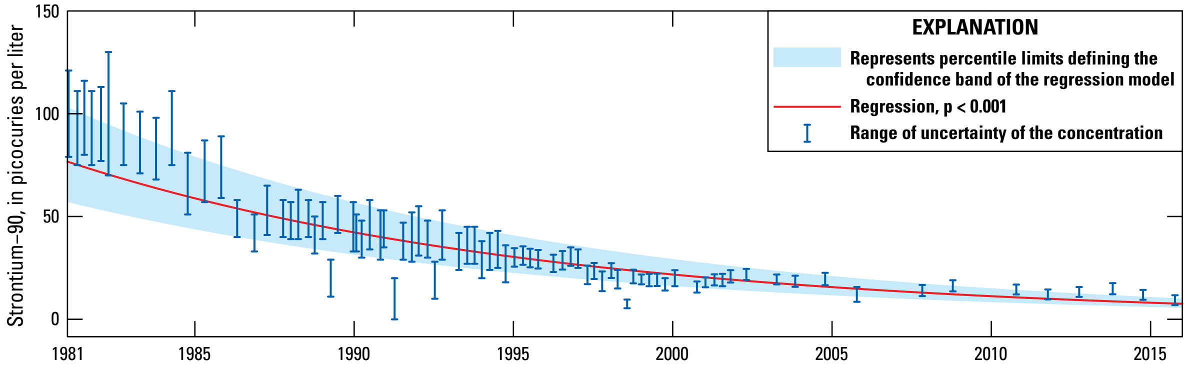
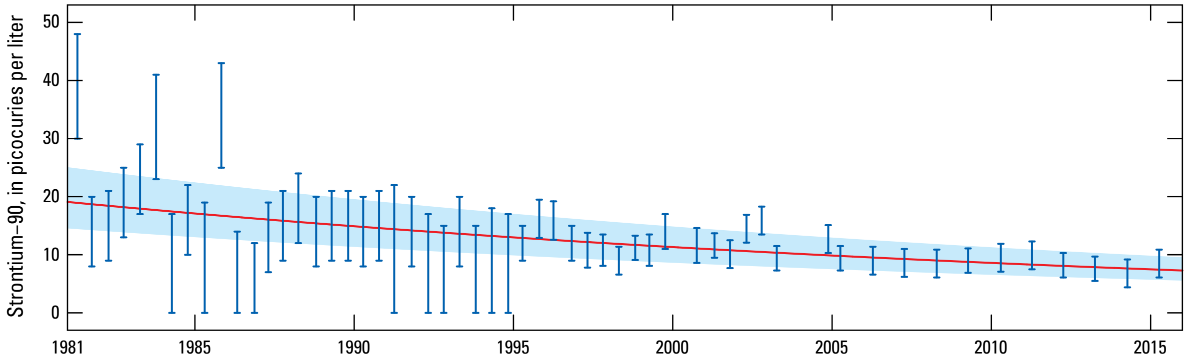


Figure 17. Strontium-90 concentrations in water from eight wells at and near the Idaho Nuclear Technology and Engineering Center, Idaho, 1981–2015. Location of wells shown in figure 6.

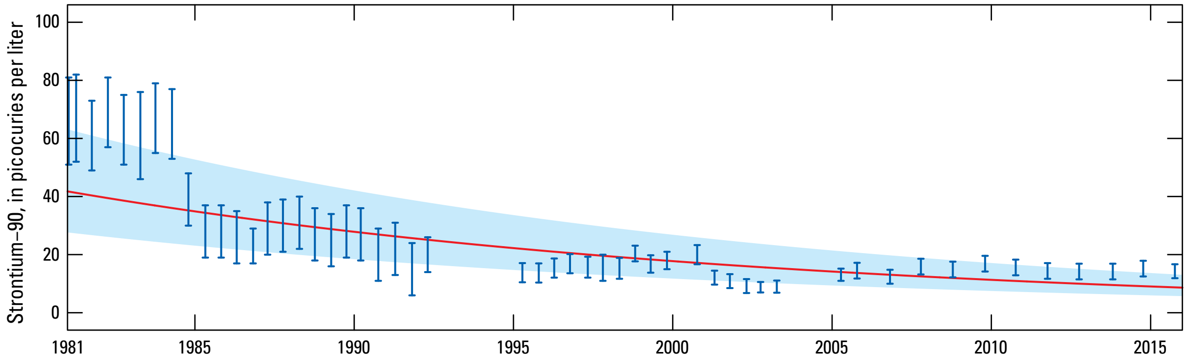
USGS 57 (433344112562601)



USGS 59 (433354112554701)



USGS 67 (433344112554101)



USGS 113 (433314112561801)

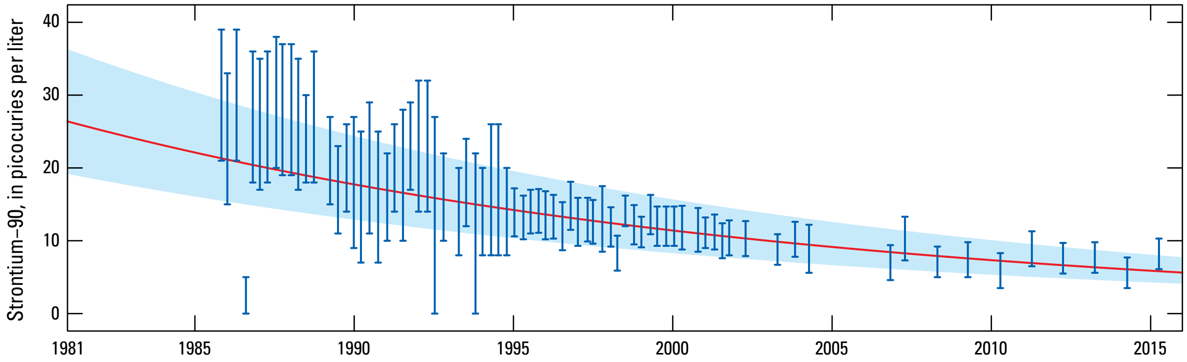


Figure 17.—Continued

Cesium-137

From 1952 to 2000, about 138 Ci of cesium-137 in wastewater was discharged to the ATR Complex radioactive-waste infiltration and lined evaporation ponds, and about 23 Ci was discharged to the INTEC disposal well and percolation ponds. In 1972, an additional 19,100 Ci of cesium-137 leaked at the INTEC tank farm (fig. 7) (Cahn and others, 2006). The half-life of cesium-137 is 30.17 years (Walker and others, 1989, p. 34).

During 2012–15, water from 69 aquifer wells was sampled and analyzed for cesium-137. Water from four of these wells (RWMC M11S, RWMC PROD, USGS 37, and USGS 136) had cesium-137 concentrations that equaled or slightly exceeded the reporting level. Concentrations of cesium-137 exceeding the reporting level ranged from 25±8 to 33±11 pCi/L. Concentrations of cesium-137 also equaled or slightly exceeded the reporting level in four wells equipped with MLMS. In June 2012, the cesium-137 concentration in water from well USGS 103 at 992.9 ft BLS was 25±8 pCi/L. In June 2015, the cesium-137 concentration in water from well USGS 108 at 1,172 ft BLS equaled the reporting level at 21±7 pCi/L. In October 2012, the cesium-137 concentration in water from well USGS 131A at 812 ft BLS exceeded the reporting level at 22±7 pCi/L. In October 2012, the cesium-137 concentration in water from well USGS 137A at 841 ft BLS was 40±12 pCi/L (Bartholomay and others, 2015, table 7). These concentrations that were slightly greater than the reporting level were not consistent with any distinct zone of water or area in the aquifer and could be attributed to false positives.

The absence of significant concentrations of cesium-137 probably resulted from discontinuation of wastewater discharge to the INTEC disposal well and ATR Complex radioactive waste infiltration ponds and to sorption processes in the unsaturated and perched groundwater zones.

Plutonium

In 1974, the USGS began monitoring plutonium-238 and plutonium-239, -240 (undivided) in wastewater discharged to the ESRP aquifer through the disposal well (fig. 6) at the INTEC. During 1974–2000, approximately 0.26 Ci of plutonium in wastewater was discharged to the disposal well and percolation ponds at the INTEC (Davis, 2008). About 17,100 Ci of plutonium-238, 64,900 Ci of plutonium-239, and 17,100 Ci of plutonium-240 were buried in the SDA during 1952–99 (Holdren and others, 2002, table 4-1).

Before 1974, alpha radioactivity from disintegration of plutonium was not separable from the monitored, undifferentiated alpha radioactivity. 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 radioactive wastewater discharged to the disposal well at INTEC, concentrations of plutonium isotopes in some water samples from wells USGS 40 and 47 near INTEC (fig. 6) through January 1987 exceeded the reporting level (Orr and Cecil, 1991, p. 37). Concentrations in water samples collected from these wells since 1987 have been less than the reporting level.

During 2012–15, concentrations of plutonium-238 and plutonium-239, -240 (undivided) in water from all 25 aquifer wells and all zones in 2 wells equipped with MLMS (USGS 131A and 137A) were less than the reporting level.

Americium-241

Americium-241 is a decay product of plutonium-241. Plutonium isotopes were in wastewater discharged to the ESRP aquifer at the INL 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 USGS 87, 88, 89, and 90 at the RWMC (fig. 6) and in water samples collected through 1988 from the TAN disposal well (fig. 5) exceeded the reporting level (Orr and Cecil, 1991, p. 38–39). During 1992–95, concentrations of americium-241 in water samples from two wells were equal to the reporting level. On October 2, 1992, the concentration in water from well USGS 37 was 0.09±0.03 pCi/L; on April 20, 1993, the concentration in water from well USGS 120 was 0.06±0.02 pCi/L (Bartholomay and others, 1997). The concentration in one water sample collected on April 12, 2001, from the RWMC PROD was 0.003±0.001 pCi/L, equal to the reporting level (Davis, 2008). During 2012–15, concentrations in water from all 25 aquifer wells and all zones of the 2 MLMS-equipped wells sampled were less than 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. The radioactivity is usually reported as if it occurred as 1 radionuclide. Gross alpha and beta measurements are used to screen for radioactivity in the aquifer as a possible indicator of groundwater contamination. Water samples collected during 2012–15 were analyzed for gross alpha- and gross beta-particle radioactivity by RESL. In 2008, RESL increased the sensitivity of the gross alpha- and gross beta- particle radioactivity and changed the radionuclide reported for gross alpha-particle radioactivity from plutonium-239 to thorium-230, and for gross beta-particle radioactivity from cesium-137 to strontium-90/yttrium-90. The minimum detectable activity decreased from about 1.6 to 1.5 pCi/L for gross alpha-particle radioactivity and from about 6.4 to 3.4 pCi/L for gross beta, allowing for increased detectable concentrations (Bartholomay and Twining, 2010).

During 2012–15, water from 48 aquifer wells was sampled and analyzed for gross alpha-particle radioactivity. Four wells had concentrations of gross alpha-particle radioactivity that equaled the reporting level, and concentrations ranged from 6±2 pCi/L in USGS 101 to 44±9 pCi/L in TAN-2271. Additionally, water from three wells equipped with MLMS had concentrations of gross alpha-particle radioactivity that equaled or exceeded the reporting level and ranged from 9±3 to 15±4 pCi/L. Water from all other samples in the wells sampled and analyzed for concentrations of gross alpha-particle radioactivity was less than the reporting level.

During 2012–15, concentrations of gross beta-particle radioactivity in water from most of the wells equaled or exceeded the reporting level in at least one of the sampling periods and ranged from 2.1±0.7 to 12.8±1.2 pCi/L. All 11 wells equipped with MLMS had gross beta-particle radioactivity concentrations greater than the reporting level in multiple zones during 2012–15. Concentrations ranged from 2.1±0.7 pCi/L in the Crossroads well to 1,010±60 pCi/L in well TAN 2271. The increase in the number of wells containing concentrations of gross beta-particle radioactivity exceeding the reporting level from previous reporting periods likely reflects the increase in sensitivity and change in the reporting radionuclide from cesium-137 to strontium-90/yttrium-90 by RESL in 2008.

Chromium

Between 1952 and 1972, an estimated 17,790 lb of chromium was discharged to the radioactive-waste infiltration ponds, and 31,131 lb of chromium was discharged to the TRA disposal well (U.S. Department of Energy, 2011a). In October 1972, chromium used as a corrosion inhibitor in cooling-tower operations was replaced by a polyphosphate. No disposal of chromium to the subsurface at the ATR Complex was reported after 1972.

During 1971–83, about 265 lb of chromium in wastewater were discharged to the disposal well at INTEC, and 720 lb of chromate were discharged at the Power Burst Facility (fig. 1) (Cassidy, 1984, p. 3). About 130 lbs of chromium were discharged to the old INTEC percolation ponds during 1992–98 (Bartholomay and others, 2000).

Background concentrations of chromium in the ESRP aquifer in the eastern regional and western tributary water were 3 and 4 µg/L (Bartholomay and Hall, 2016). In April 2009, the dissolved chromium concentration in water from one well, USGS 65, south of ATR Complex (fig. 6), equaled the MCL of 100 µg/L (U.S. Environmental Protection Agency, 2015) for total chromium in public drinking water supplies. In April 2015, the concentration of chromium in water from that well had decreased to 72.8 µg/L, much less than the MCL. Concentrations in water samples from 62 other wells sampled ranged from <0.3 to 25.4 µg/L.

Chromium concentrations with depth in the 11 MLMS equipped wells sampled during 2012–15 ranged from 1.55 µg/L in Middle 2050A at 517 ft BLS to 10.8 µg/L in well USGS 131A at 812 ft BLS (table 6). Wells USGS131A and 137A were completed in 2012, and chromium concentrations in the upper two zones in USGS 131A were larger than the two deepest zones (Bartholomay and others, 2015). Chromium concentrations in well USGS 137A were relatively consistent in all four zones. Chromium concentrations in only well USGS 135 were consistently less than the background concentrations for western tributary water of 4 µg/L.

Sodium

During 1989–98, an estimated average annual 1.3 million lb/yr of sodium in wastewater were discharged at the INL (Bartholomay and others, 1995, 1997, 2000). During 1996–98, about 708,000 lb/yr of sodium were discharged to the INTEC percolation ponds; about 58,000 lb/yr were discharged to the ATR Complex chemical-waste infiltration pond; about 524,000 lb/yr were discharged to the NRF industrial-waste ditch; and about 5,000 lb/yr were discharged at CFA (Bartholomay and others, 2000). The background concentration of sodium in water from the ESRP aquifer in the western part of the INL is about 8.3 mg/L and about 14.8 mg/L in the eastern part (Bartholomay and Hall, 2016). In 2015, concentrations in water from most wells in the southwestern part of the INL were greater than 8.3 mg/L.

Concentrations of dissolved sodium in water from wells near the INTEC generally was variable in the 1980s and 1990s because of variable discharge to the disposal well and infiltration ponds south of INTEC (figs. 6 and 18). Since 2002, when the infiltration ponds were taken out of service, sodium concentrations have decreased (Davis and others, 2015; appendix D). During 1999–2015, the high concentrations of sodium were in water from wells at or near INTEC (figs. 6 and 18). During 2015, the highest sodium concentration in water samples from aquifer wells near the INTEC was 38.8 mg/L in a water sample from well USGS 51 (fig. 6), an increase from 2011 (31.3 mg/L). This well is located right beside the old infiltration ponds and was one of the few that showed an increasing concentration trend near INTEC since the late 1980s (Davis and others, 2015, fig. 22). The increasing trend could be an indication that remnant water beneath the infiltration ponds is still infiltrating to the aquifer at this location. Concentrations of sodium in water from other wells south of the INTEC during 2012–15 generally were less than or equal to sodium concentrations detected during 2009–11 (fig. 18).

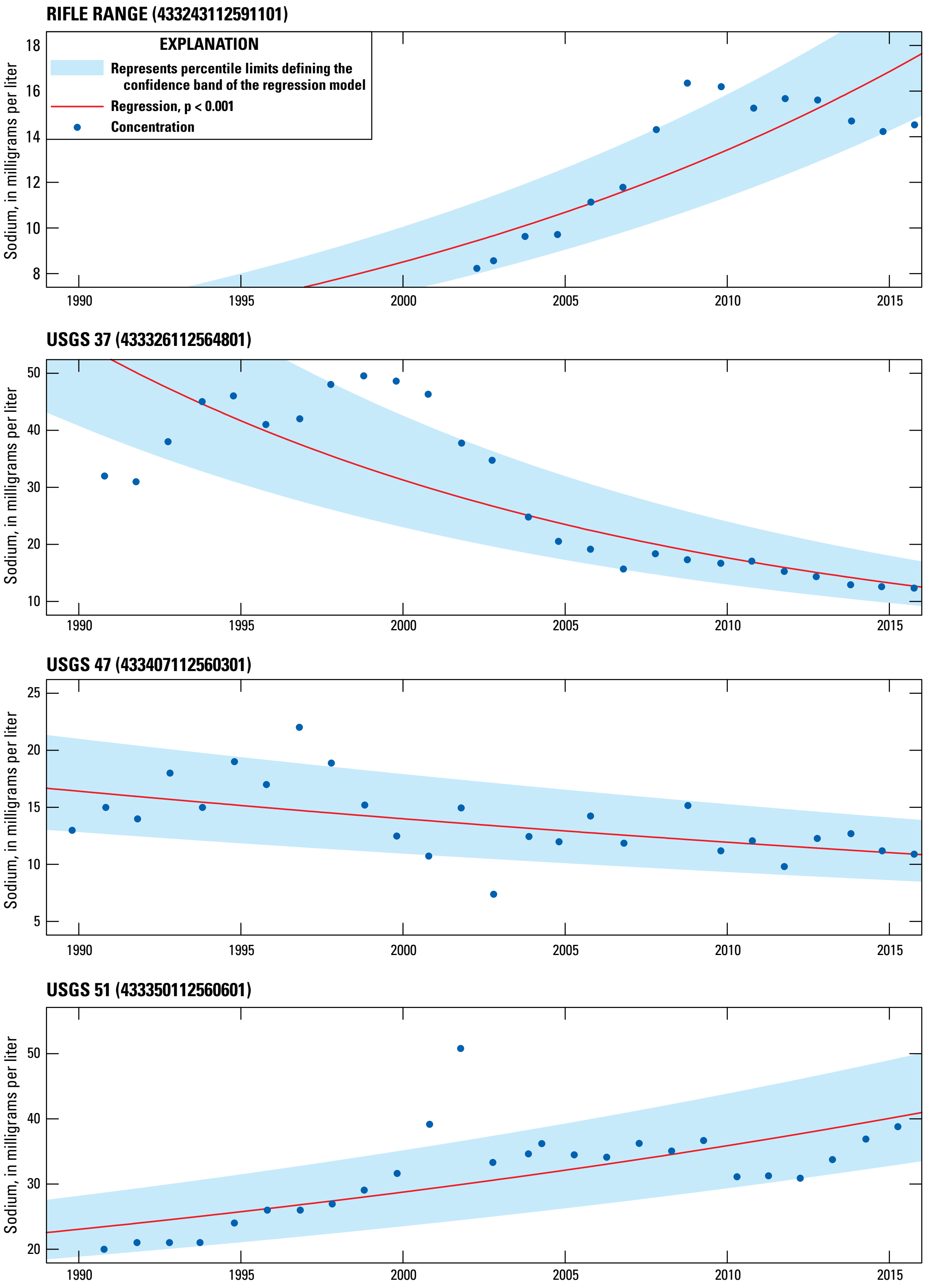
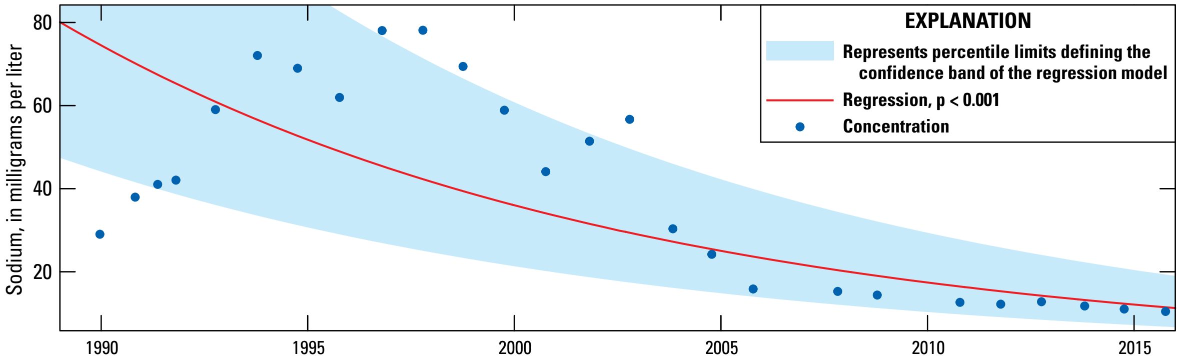
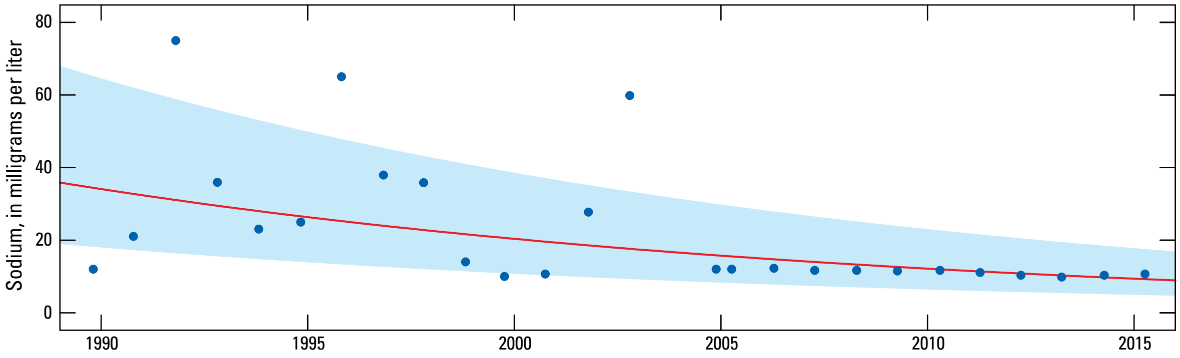


Figure 18. Dissolved sodium concentrations in water from eight wells at and near the Idaho Nuclear Technology and Engineering Center and Central Facility Area, Idaho, 1989–2015. Location of wells shown in figure 6.

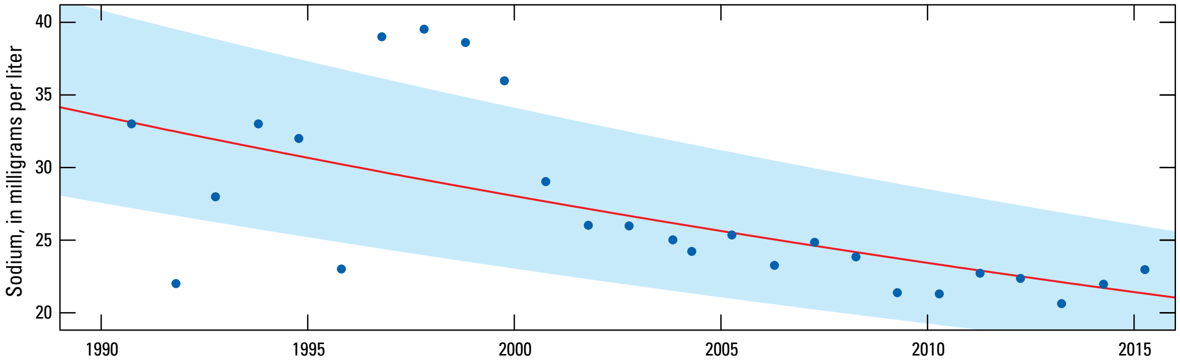
USGS 57 (433344112562601)



USGS 59 (433354112554701)



USGS 111 (433331112560501)



USGS 113 (433314112561801)

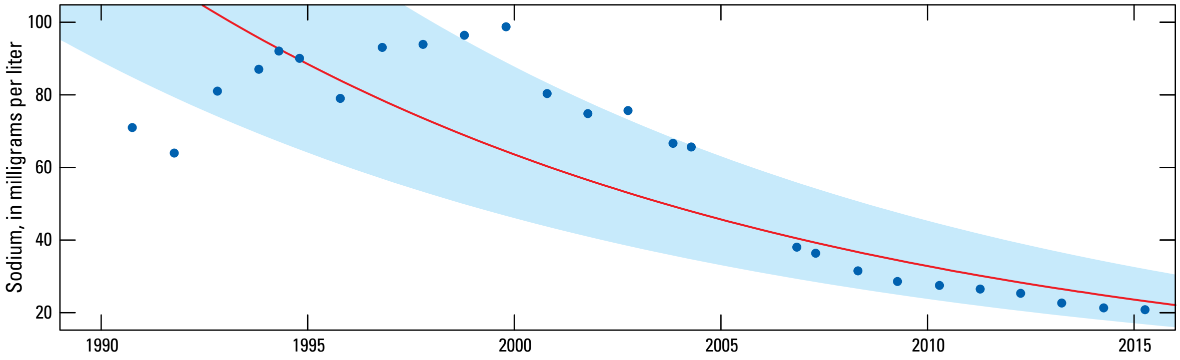


Figure 18.—Continued

Davis and others (2015, figs. 21 and 22) found increasing trends in several wells farther downgradient of INTEC near and south of CFA. The increasing trends were attributed to the movement of the high concentration water discharged in the 1970s to 1990s at INTEC, finally reaching these wells resulting in increasing concentration trends.

Installation and use of the new percolation ponds 2 mi southwest of the INTEC has contributed to increased concentrations of sodium in the Rifle Range well (fig. 18). In 1988, the concentration of sodium in this well was about at background concentrations at 9 mg/L. After the new percolation ponds were put into service in 2002, concentrations of sodium increased steadily to a concentration of 16 mg/L until 2008; since then, concentrations of sodium have remained relatively steady (fig. 18), probably due to more consistent rates of discharge of sodium to the new percolation ponds.

In October 2015, the sodium concentration in water from well USGS 88 (fig. 6), near the RWMC, was 52 mg/L, slightly larger than the 46 mg/L concentration in 2011. In April 2015, the sodium concentration in water from well MTR Test at the ATR Complex near the chemical waste pond (fig. 6) was 12.5 mg/L, significantly less than the high concentration of 42 mg/L in 1998. Concentrations of sodium in this well have remained fairly constant in the 9 to 13 mg/L range since about 2002 (Davis and others 2015, appendix D). This concentration decrease from the high in 1998 may be a result of the discontinued use of the chemical waste pond in 1999.

Sodium concentrations with depth in the 11 MLMS equipped wells sampled during 2012–15 ranged from 6.0 mg/L in USGS 135 at 837 ft BLS to 12.0 mg/L in well USGS 137A at 662 ft BLS. Most of the concentrations are less than or near background concentrations for western tributary water at the INL (Bartholomay and others, 2015; Bartholomay and Hall, 2016). Wells USGS131A and 137A were completed in 2012 and sodium concentrations in water were similar in all four zones (Bartholomay and others, 2015).

Chloride

Chloride in wastewater has been discharged to infiltration ponds at the INL. The background chloride concentration in water in the western part of the ESRP aquifer at the INL is about 12 mg/L (Bartholomay and Hall, 2016), the background chloride concentration near the INTEC is about 10 mg/L, and the ambient chloride concentration near the Central Facilities Area (CFA) is about 20 mg/L (Robertson and others, 1974, p. 150). The secondary MCL for chloride in drinking water is 250 mg/L (U.S. Environmental Protection Agency, 2015). In 2015, concentrations of chloride in most water samples from wells south of the INTEC and at the CFA (figs. 19 and 20) exceeded 20 mg/L, but were less than the secondary MCL.

Concentrations of dissolved chloride in water from wells near the INTEC generally were variable in the 1980s and 1990s because of variable discharge to the disposal well and infiltration ponds south of INTEC (figs. 6 and 20). Since 2002, when the infiltration ponds were taken out of service, chloride concentrations have mostly decreased except for wells southeast of INTEC (Davis and others, 2015; fig. 18, appendix D). During 2015, the highest chloride concentration in water samples from aquifer wells near the INTEC was 171 mg/L in a water sample from well USGS 51 (fig. 6), an increase from 2011 (131 mg/L). This well is located at the old infiltration ponds and was one of the few that showed an increasing concentration trend near INTEC since the late 1980s (fig. 20). The increasing trend in this well and several wells to the southeast of INTEC could be an indication that remnant water below the infiltration ponds is still infiltrating to this part of the ESRP aquifer at a slower rate than the rest of the INL as interpreted by Davis and others (2015). Concentrations of chloride in water from other wells south and southwest of the INTEC during 2012–15 generally were less than or equal to chloride concentrations detected during 2009–11 and generally show decreasing trends (fig. 20).

Chloride concentrations in the Rifle Range well (figs. 5 and 20) increased from 9 mg/L in October 2002 to 42 mg/L in 2008 and decreased to 25.2 mg/L in October 2015. This well is downgradient from the new INTEC percolation ponds so the changes in concentrations are probably due to variable rates of chloride discharge to the ponds.

The chloride concentration in water from well CFA 2 at the CFA decreased slightly from 140 mg/L in October 2011 to 134 mg/L in October 2015; however, the trend for concentrations from 1989 to 2015 is increasing (fig. 20). Concentrations of other wells in the CFA area ranged from 16 to 144 mg/L in 2015. The concentrations at CFA are attributed to past disposal at INTEC and the increasing trend in CFA 2 is probably representative of a period of increased wastewater disposal at INTEC during some previous timeframe.

In April 2015, the chloride concentration in water from well USGS 65 south of the ATR Complex (fig. 6) was greater than background at 19.5 mg/L. Chloride concentrations in water from all other wells completed in the ESRP aquifer at or near the ATR Complex were near background concentrations and ranged between 10.5 and 12.8 mg/L during 2015, similar to the 2009–11 reporting period (Davis and others, 2013).

During 2015, chloride concentrations in water from wells USGS 88 and 89 at the RWMC were 109 and 60.7 mg/L, respectively, slightly higher than the 2009–11 reporting period. Concentrations of chloride in all other wells near the RWMC ranged from 5.98 to 28.9 mg/L.

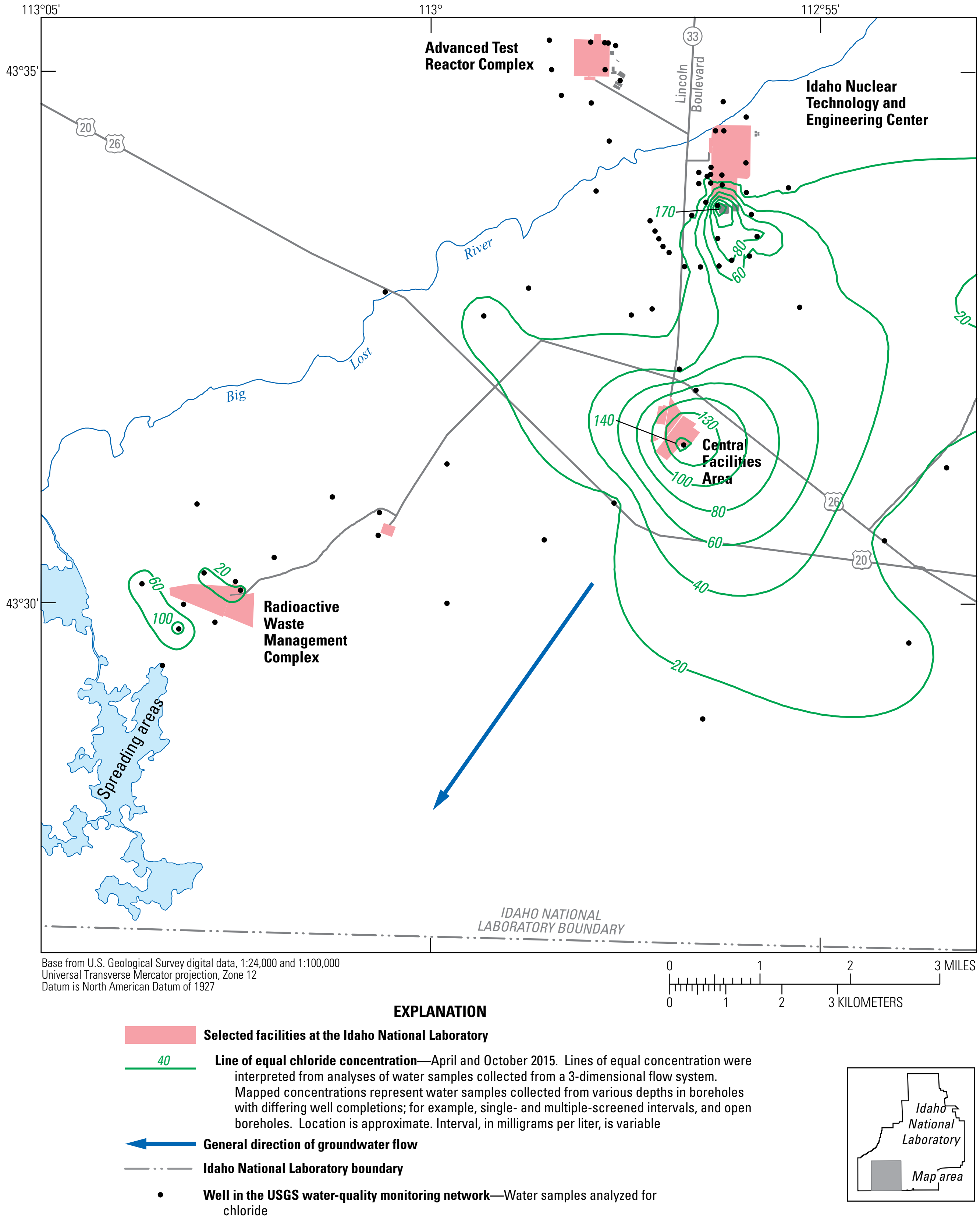
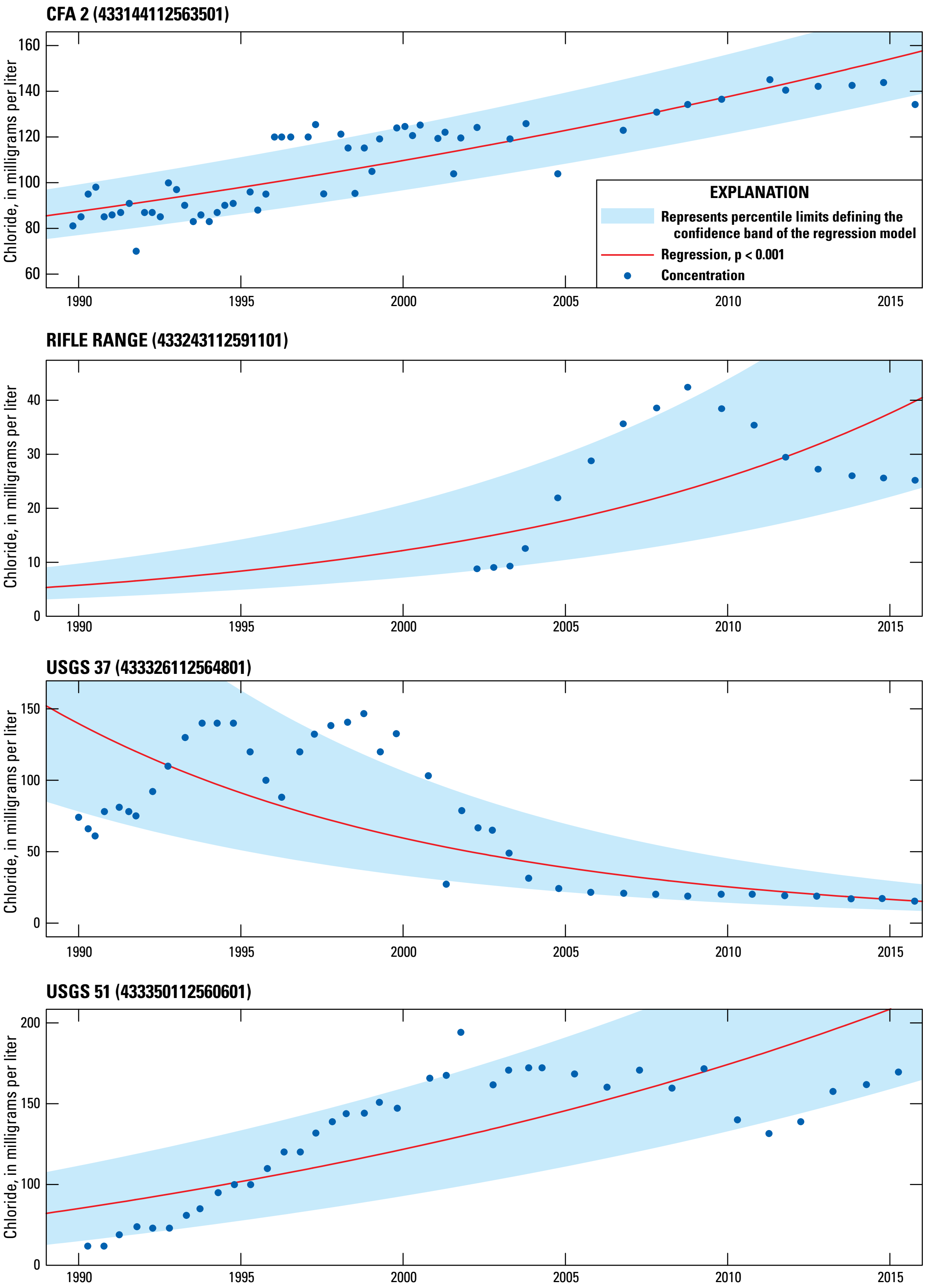


Figure 19. Distribution of chloride in water from wells at and near the Advanced Test Reactor Complex, Idaho Nuclear Technology and Engineering Center, Central Facilities Area, and Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, April or October 2015.


CFA 2 (433144112563501)

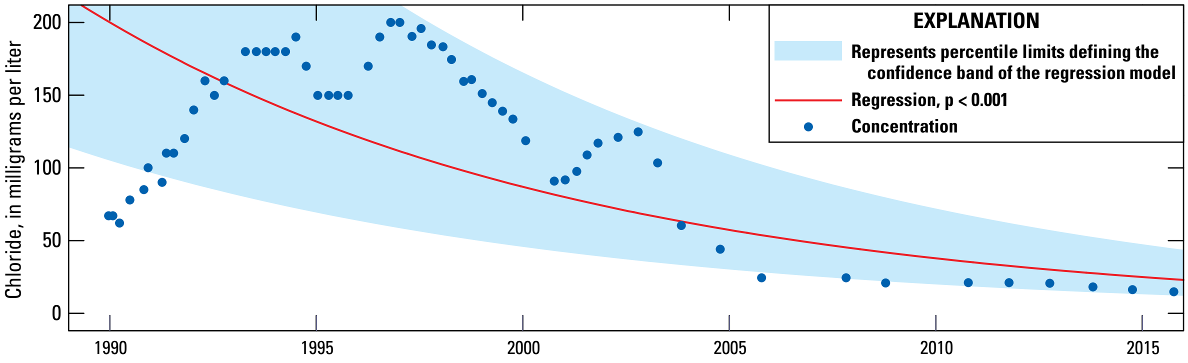
RIFLE RANGE (433243112591101)

USGS 37 (433326112564801)

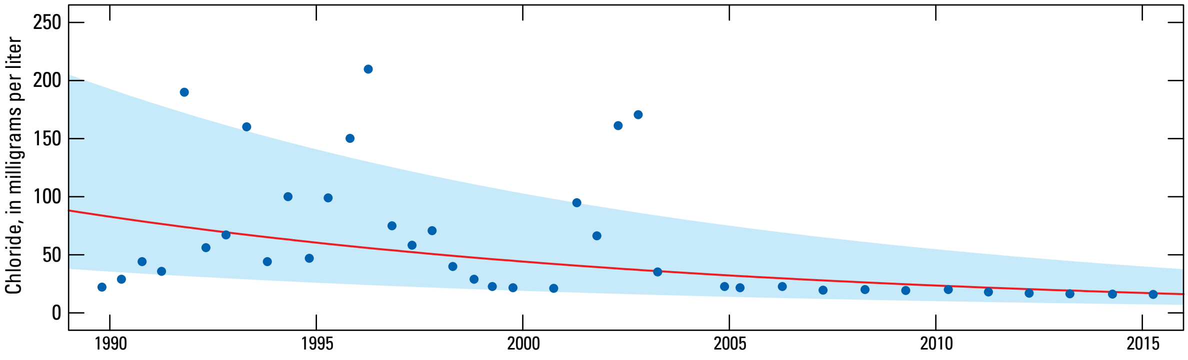
USGS 51 (433350112560601)

Figure 20. Dissolved chloride concentrations in water from eight wells at and near the Idaho Nuclear Technology and Engineering Center, Idaho National Laboratory, Idaho 1989–2015. Location of wells shown in figure 6.

USGS 57 (433344112562601)



USGS 59 (433354112554701)



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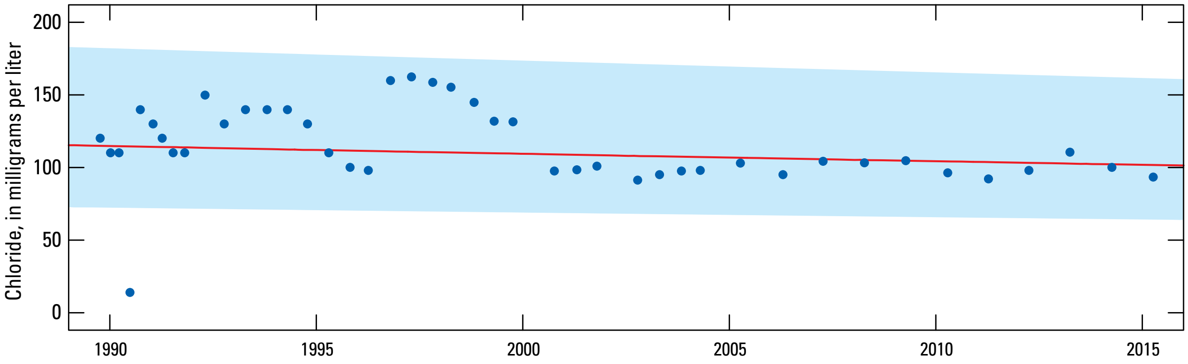


USGS 113 (433314112561801)

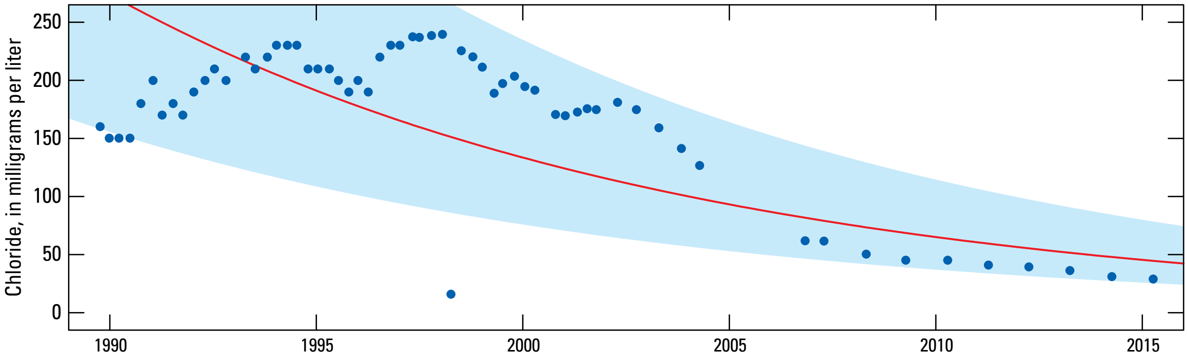


Figure 20.—Continued

Chloride concentrations with depth in the 11 MLMS equipped wells sampled during 2012–15 ranged from 6.67 mg/L in USGS 135 at 837 ft BLS to 26.4 mg/L in well USGS 131A at 812 ft BLS (table 6). Most of the concentrations are less than or near background concentrations for western tributary water at the INL (Bartholomay and others, 2015; Bartholomay and Hall, 2016). Wells USGS 131A and 137A were completed in 2012 and chloride concentrations in the upper two zones in well USGS 131A were greater than background concentrations and were larger than the two deepest zones (Bartholomay and others, 2015). Chloride concentrations in well USGS 137A were relatively consistent in all but the upper zone, which had concentrations slightly larger than background. Chloride concentrations in the three samples zones in well USGS 108 and the three deepest zones in well USGS 103 also were larger than background concentrations. These larger than background concentrations represent influence from wastewater disposal.

Sulfate

Sulfate in wastewater has been discharged to percolation (infiltration) ponds at the INTEC, ATR Complex, and to the NRF industrial-waste ditch (Bartholomay and others, 2000). Background concentrations of sulfate in the ESRP aquifer in the western part of the INL are about 21 mg/L (Bartholomay and Hall, 2016). The secondary MCL for sulfate in drinking water is 250 mg/L (U.S. Environmental Protection Agency, 2015).

Because of the sulfate disposal history at the various facilities, water-sample collection for sulfate analyses at several wells was added to the USGS water-quality monitoring network in 1995. In 2015, sulfate concentrations in water samples from several wells in the western part of the INL exceeded the 21 mg/L background concentration of sulfate and ranged from 22 mg/L in well TRA 3 to 162 mg/L in well USGS 65 (fig. 6). In October 2015, the sulfate concentration in well CFA 2, south of INTEC (fig. 5), was 48.2 mg/L and was similar to the October 2011 sulfate concentration of 50 mg/L; however, data through 2012 did indicate an increasing trend (Davis and others, 2015, appendix D). During 2015, concentrations were 47.5, 46.9, and 44.7 mg/L in water from wells USGS 34, 35, and 36, respectively, southwest of INTEC. Davis and others (2015, fig. 25) indicated increasing trends in these and several other wells southwest of INTEC from 1989 to 2012, but also indicated that sulfate concentrations fluctuated in response to water levels changes. As indicated previously water levels in this part of the aquifer have mostly declined in the past 15 years so the increasing concentrations may be due to decreasing dilution. The greater-than-background concentrations in water from these wells probably resulted from sulfate disposal at the ATR Complex infiltration ponds or the old INTEC percolation ponds.

In April or October 2015, sulfate concentrations in water samples from most wells around and near the RWMC (fig. 6), were greater than the background concentration of 21 mg/L and were highest in well USGS 88 at 54.6 mg/L, but long-term trend data indicated either decreasing or no trends in the wells. The sulfate concentrations in water from these wells that were greater than the upper background level could have resulted from the well construction techniques (Pittman and others, 1988, p. 57–61) and (or) waste disposal at the RWMC or the ATR Complex.

Sulfate concentrations with depth in the 11 MLMS equipped wells sampled during 2012–15 ranged from 17.2 mg/L in well USGS 133 at 706 ft BLS to 28.3 mg/L in well USGS 131A at 616 ft BLS. Most of the concentrations are near or greater than background concentrations for western tributary water at the INL (Bartholomay and others, 2015; Bartholomay and Hall, 2016). Wells USGS 131A and 137A were completed in 2012 and sulfate concentrations were similar in all four zones except for the 812 ft zone in USGS 131A, which was slightly larger due to more wastewater disposal influence (Bartholomay and others, 2015).

Nitrate (As Nitrogen)

Wastewater containing nitrate was injected into the ESRP aquifer through the INTEC disposal well from 1952 to February 1984 and was discharged to the INTEC percolation ponds after February 1984 (Orr and Cecil, 1991). Additionally, nitrate was present in waste leaked at the INTEC tank farm during a transfer from one tank to another (Cahn and others, 2006). Concentrations of nitrate in groundwater not affected by wastewater disposal from INL facilities are less than the background for western tributary water of about 0.655 and 1 mg/L for eastern tributary water (N) (Bartholomay and Hall, 2016).

Concentrations of dissolved nitrate in this report are reported as N. Until the 2006–08 reporting period for publications in this series, nitrate was reported as nitrate. To convert concentrations as N to concentrations as NO_3^-, the nitrate (as N) concentration should be multiplied by 4.4266 (Hem, 1989, table 8) so that concentrations reported here can be compared with those given in previous reporting-period publications. Historical nitrite analyses indicate that almost all nitrite concentrations are less than the LRL for analyses at the INL, so concentrations of nitrite plus nitrate are referred to as nitrate in this report.

All nitrate concentrations measured in 2015 were less than the MCL for drinking water of 10 mg/L (U.S. Environmental Protection Agency, 2015). Nitrate concentrations at the INL near INTEC have mostly decreased in response to reduced disposal rates and to the transition in 1984 from injection of wastewater to the INTEC disposal well to discharge to the old percolation ponds (Davis and others, 2015, fig. 28). Although concentrations have generally decreased, concentrations in several of the wells have shown variable increases and decreases. The variability could have resulted from periodic dilution by recharge from the Big Lost River and variation in discharge rates to the injection well prior to 1984 or to the percolation ponds later. The two exceptions to decreasing or no trends are wells USGS 20 and 67, which show variable decreases and increases but overall have been increasing (fig. 21).The increases could be due to mobilization of nitrate beneath the INTEC tank farm, as both wells are downgradient of the INTEC tank farm and nitrate was present in the reported 1972 leak (Cahn and others, 2006; U.S. Department of Energy, 2011a). The increases occur during and after wetter periods such as the late 1990s when more recharge to the aquifer was occurring and presumably mobilizing these constituents below the tank farm. Lower concentrations occur in the early to mid 2000s when dryer conditions occurred and presumably less opportunity for surface recharge to mobilize constituents (fig. 21). In April or October 2015, concentrations of nitrate in water from most wells at and near the INTEC exceeded the background concentration of 0.655 mg/L. Concentrations ranged from 0.496 mg/L in well USGS 82 to 5.52 mg/L in well USGS 67.

Concentrations of nitrate in wells south of INTEC and farther away from the influence of disposal areas and the Big Lost River (wells CFA 1, USGS 77, 111, 113, 114, and 116 [figs. 5 and 6]) show much less variability and a general decrease in nitrate concentration trends through time (Davis and others, 2015; figs. 27–28, appendix D). In the southern part of CFA, well CFA-2 shows an increasing trend (fig. 21). Nitrate concentration samples collected in 2015 from wells CFA-2 and USGS 130 in the southern part of CFA were 3.89 and 3.38 mg/L, respectively, and these concentrations are higher than other wells upgradient and downgradient of CFA. Nitrate contamination south of CFA has been attributed to contamination from the old CFA mercury pond south of the facility (U.S. Department of Energy, 2011b), and it is possible that the increased nitrate in these wells could be due to movement of nitrate in the unsaturated zone from the old CFA pond.

Historically, nitrate concentrations in water from wells near the RWMC have been near or slightly exceeded the western tributary background concentration of about 0.655 mg/L (Bartholomay and Hall, 2016) in most wells. In 1998, nitrate concentrations in water samples from wells USGS 88 and 89 near the RWMC (fig. 6) exceeded the background and were 1.6 and 2.0 mg/L, respectively (Bartholomay and others, 2000). Concentrations in wells USGS 88 and 89 show decreasing trends (Davis and others, 2015, fig. 28) and concentrations were 0.84 and 1.39 mg/L, respectively, in 2015.

In 2015, near the ATR Complex, the concentration of nitrate in water from several wells was equal to or greater than the background concentration of 0.655 mg/L with the largest concentration of 1.46 mg/L in well USGS 65.

Nitrate concentrations in several wells in the eastern part of the INL were greater than the background concentration of about 1 mg/L for eastern regional recharge. The trends for many of these wells were also increasing and the increasing trends were attributed to agricultural and other anthropogenic influences upgradient of the INL (Bartholomay, and others, 2012, p. 26).

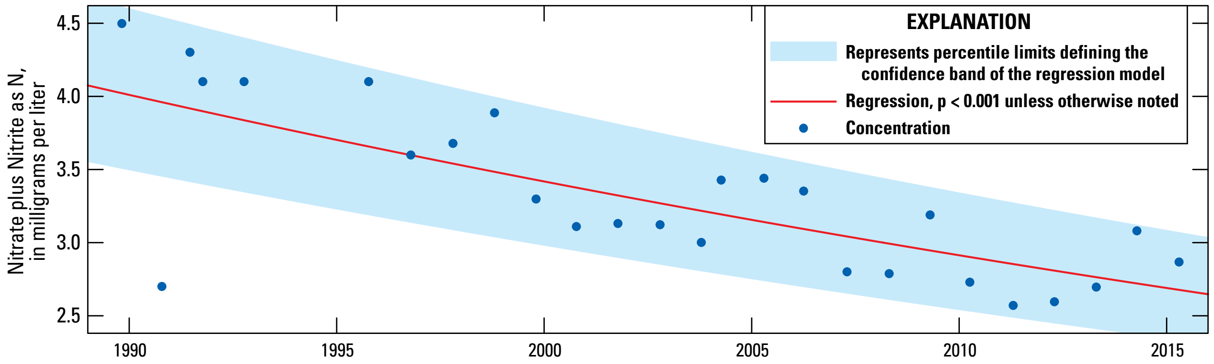
Nitrate concentrations with depth in the 11 MLMS equipped wells sampled during 2012–15 ranged from 0.468 mg/L in well USGS 134 at 706 ft BLS to 1.31 mg/L in well USGS 131A at 812 ft BLS. Most of the concentrations are near or greater than background concentrations for western tributary water at the INL (Bartholomay and others, 2015; Bartholomay and Hall, 2016). Wells USGS 131A and 137A were completed in 2012 and nitrate concentrations were similar in all four zones in each well, respectively, except for the 812 ft zone in well USGS 131A, which was slightly higher due to more wastewater disposal influence (Bartholomay and others, 2015).

Fluoride

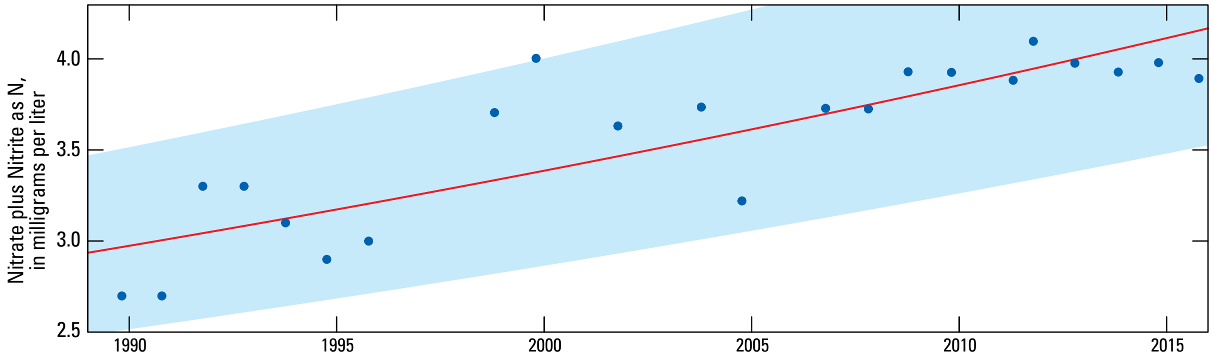
The USGS began analyzing water samples collected near the INTEC for fluoride in 1994, because fluoride in wastewater was being discharged to the old percolation ponds. During April or October 2015, water samples from four wells near INTEC (CPP 1, USGS 34, 38, and 77, fig. 6) were analyzed for fluoride; detected concentrations ranged from 0.17 to 0.22 mg/L. These concentrations were near the range of background concentrations of fluoride of the ESRP aquifer for the western part of the INL reported by Bartholomay and Hall (2016), which indicates that wastewater disposal has not had an appreciable effect on fluoride concentrations in the ESRP aquifer near the INTEC. Additionally, fluoride was collected from five new wells (ARA MON A 002, PBF-MON-A-003, Gin 2, USGS 130, and USGS 140) and concentrations ranged from 0.165 to 0.529 mg/L, which were near background concentrations relative to each well's location in the ESRP aquifer.

Fluoride concentrations in water samples collected from two wells equipped with MLMS (USGS 131A and USGS 137 A) during 2012–13 were near the range of background concentrations reported by Bartholomay and Hall (2016). Concentrations in all zones of each well ranged from 0.149 to 0.234 mg/L (Bartholomay and others, 2015, table 4).

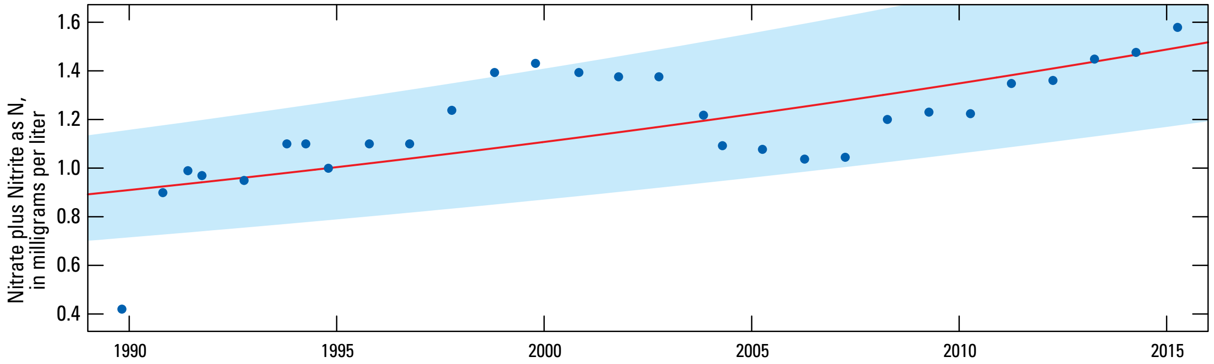
CFA 1 (433204112562001)



CFA 2 (433144112563501)



USGS 20 (433253112545901)



USGS 43 (433415112561501)

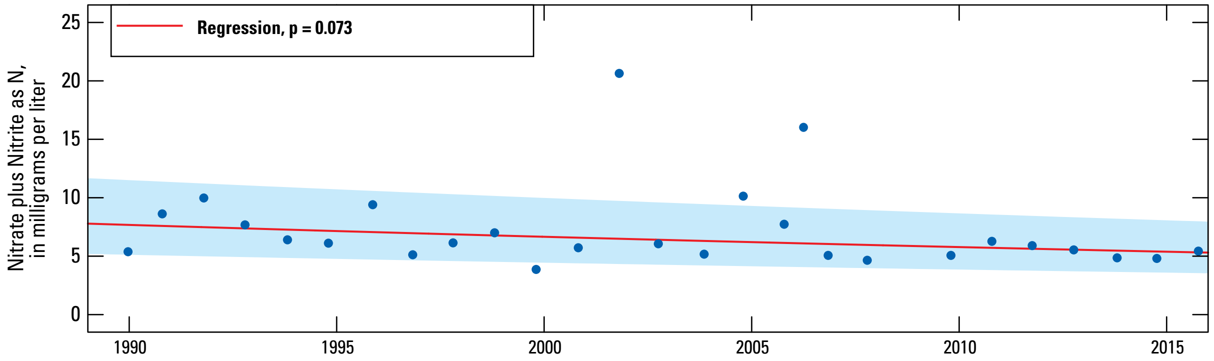
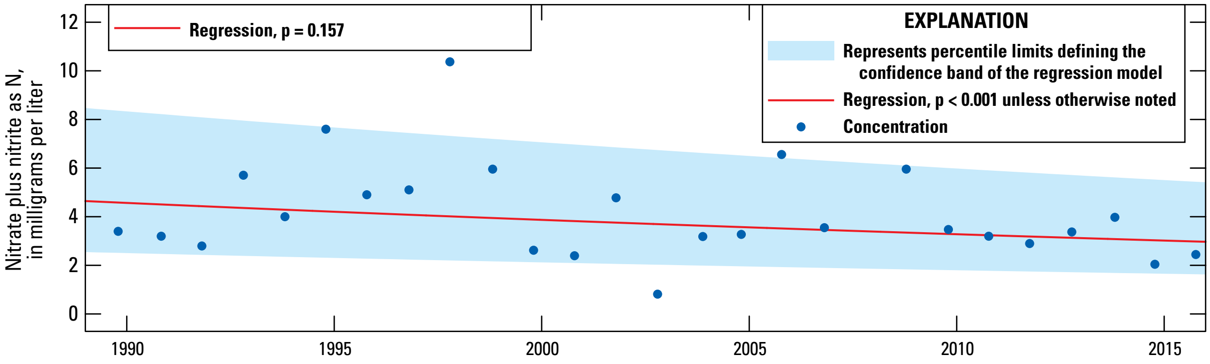
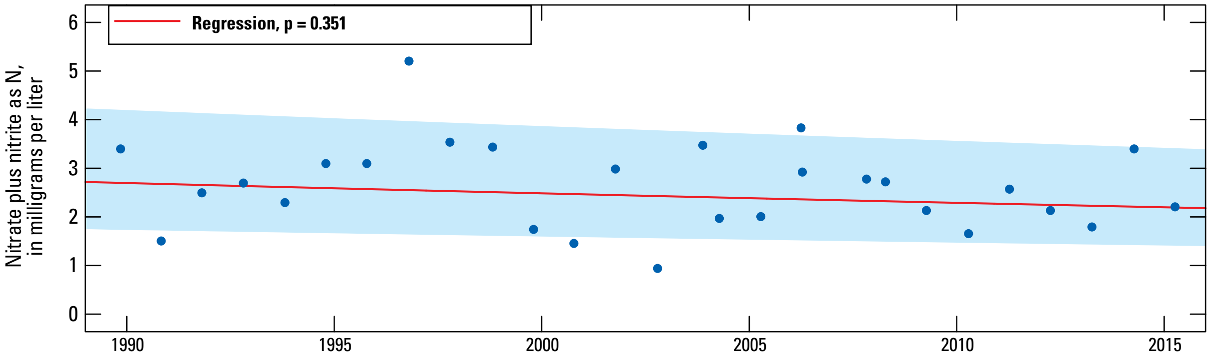


Figure 21. Concentration of nitrate (as N) in water from wells at and near the Idaho Nuclear Technology and Engineering Center and Central Facilities Area, Idaho National Laboratory, Idaho, 1989–2015.

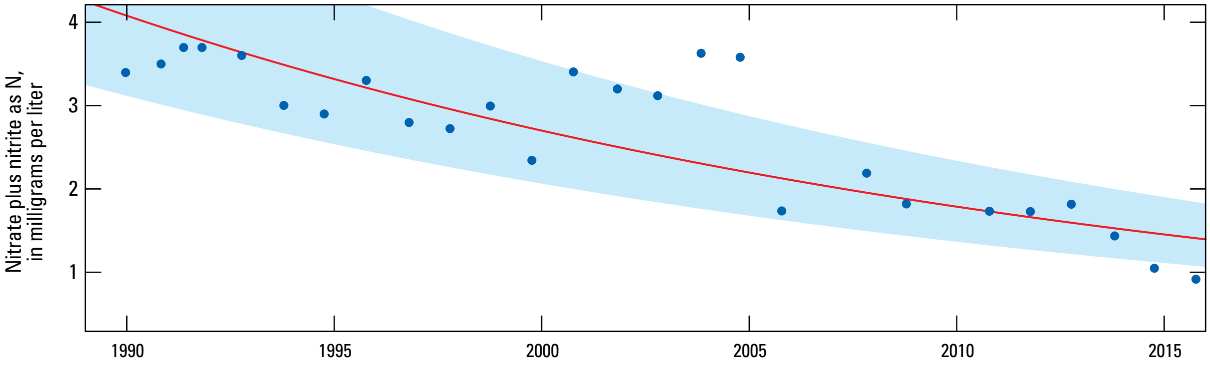
USGS 47 (433407112560301)



USGS 48 (433401112560301)



USGS 57 (433344112562601)



USGS 67 (433344112554101)

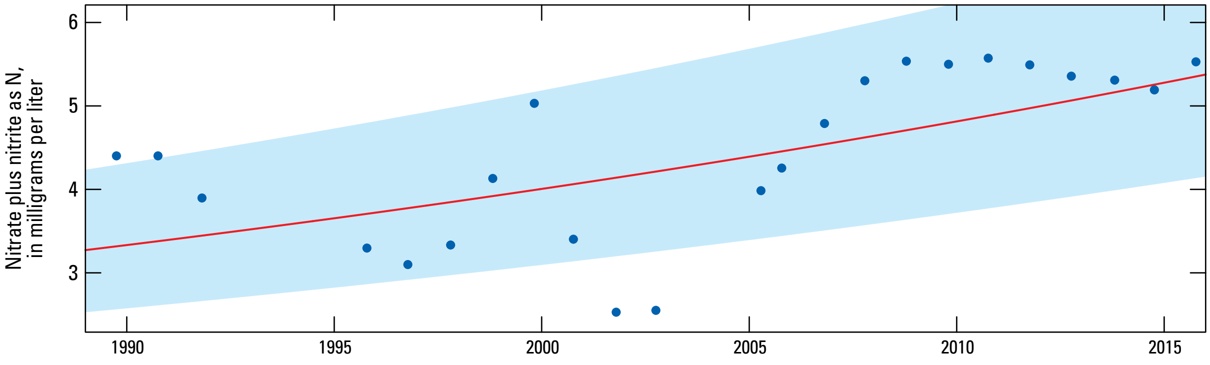


Figure 21.—Continued

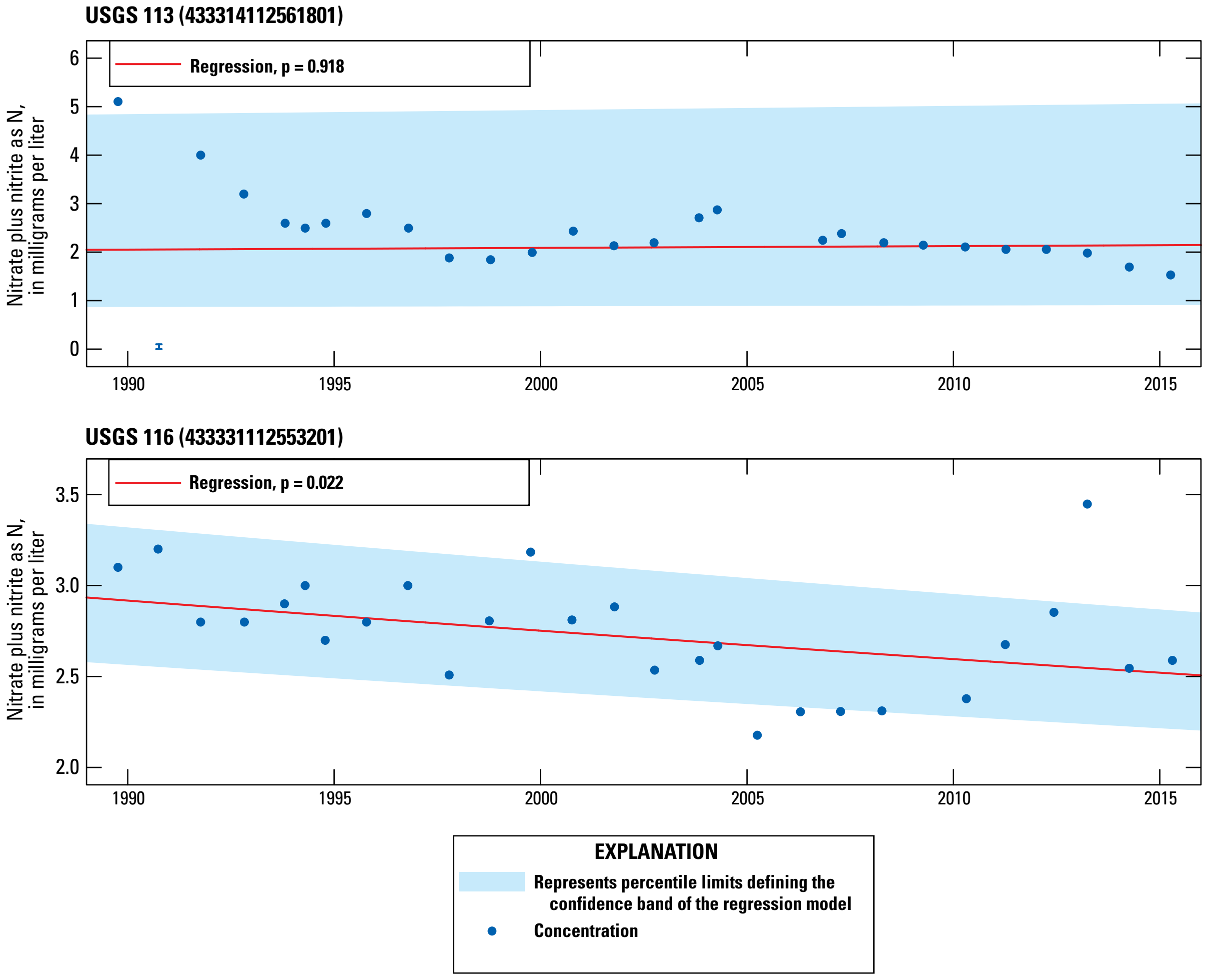


Figure 21.—Continued

Trace Elements

As part of the INL groundwater monitoring program adopted in 1994 and several special sampling programs, water samples from 14 wells were collected and analyzed for various trace elements during 2012–15. These trace elements included aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, selenium, silver, strontium (stable), thallium, vanadium, and zinc. A summary of background concentrations of selected constituents in ESRP aquifer water samples is presented in Knobel and others (1992, p. 52). Bartholomay and others (2000, p. 32–34) give estimated disposal amounts of various trace elements in wastewater through 1998. Beginning in 1998, NWQL began implementing new reporting procedures based on long-term method detection levels (LT-MDLs) for some analytical methods (Childress and others, 1999). This change in LRLs (as opposed to MRLs) for some trace elements accounts for concentrations of some elements detected during 1999–2015, although historically the concentrations were less than the MRL. A summary of past disposal data, disposal periods, and trace-element concentration ranges in water samples analyzed during 2012–15 by the USGS are shown in table 7. Data for two new MLMS wells (USGS 131A and 137A) sampled in 2012–13 are reported in Bartholomay and others (2015, table 5). Data for the other nine MLMS wells are provided in Bartholomay and Twining (2010, table 5); and Bartholomay and others (2015, table 5).

Table 7. Trace elements disposed during various periods, number of wells sampled, and range of concentrations detected in water, Idaho National Laboratory, Idaho, 2012–15.

[Because the amounts of each constituent in wastewater discharged from INL facilities have not been compiled annually from monitoring data since 1998, no amounts are available for 1999–2015. **Approximate amount disposed**, **disposal period**, and **disposal facility** from French and others (1999a) and Bartholomay and others (2000). Number of wells do not include multilevel monitoring system wells. **Abbreviations:** INL, Idaho National Laboratory; INTEC, Idaho Nuclear Technology and Engineering Center; NR, none recorded; lb, pound; µg/L, microgram per liter. **Symbol:** <, less than]

Constituent	Approximate amount disposed (lb)	Disposal period	Disposal facility	Number of wells sampled at the INL during 2012–15	Range of concentrations (µg/L)
Aluminum	117	1995–98	INTEC	15	<2.2–207
Antimony	NR	NR	INL	15	0.028–0.257
Arsenic	11	1971–98	INL	15	0.908–3.69
Barium	4,740	1971–98	INL	15	11.5–894
Beryllium	<1	1971–98	INL	15	<0.006–0.166
Boron	26,429	1971–98	INL	8	14.8–2,525
Cadmium	22	1971–98	INL	15	<0.016–0.058
Cobalt	NR	NR	INL	15	<0.023–4.65
Copper	81	1995–98	INTEC	15	<0.8–10.4
Iron	752	1995–98	INTEC	8	<4–1,610
Lead	556	1971–98	INL	15	<0.025–0.873
Lithium	NR	NR	INL	8	1.78–16.4
Manganese	44	1995–98	INTEC	15	<0.15–1,523
Mercury	141	1971–98	INL	15	<0.005
Molybdenum	NR	NR	INL	15	1.08–13.6
Nickel	NR	NR	INL	15	<0.09–43.2
Selenium	9	1971–98	INL	13	0.146–3.64
Silver	190	1971–98	INL	15	<0.005–0.093
Strontium (stable)	NR	NR	INL	8	177–1,057
Thallium	NR	NR	INL	11	<0.01–0.032
Tungsten	NR	NR	INL	8	0.073–2.57
Uranium	NR	NR	INL	15	0.019–6.34
Vanadium	NR	NR	INL	8	0.541–7.79
Zinc	5,240	1971–98	INL	15	<1.4–36.9

Volatile Organic Compounds

Volatile organic compounds (VOCs) are present in water from the ESRP aquifer because of waste-disposal practices at the INL. From 1987 to 2011, water samples from many wells completed in the ESRP aquifer at and near the INL were analyzed for VOCs for various water-quality studies (Mann and Knobel, 1987; Mann, 1990; Liszewski and Mann, 1992; Greene and Tucker, 1998; Bartholomay and others, 2000; Davis, 2006b, 2008, 2010; Davis and others, 2013). Analyses from these studies indicated that from 1 to 19 VOCs in water samples from several wells exceeded their reporting levels during these years. The primary VOCs detected included carbon tetrachloride; 1,1-dichloroethane; 1,1,1-trichloroethane; trichloroethylene; tetrachloroethylene; chloroform; and toluene.

During 2012–15, water samples from 32 wells were collected and analyzed for VOCs. Eighteen different VOCs were detected (table 8). Water samples collected from 14 wells during 2012–15 each contained at least 1 and up to 7 of the different VOCs detected. Table 8 shows the VOCs and concentrations detected in the 14 different wells. The primary VOCs detected included carbon tetrachloride, trichloromethane, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. Concentrations for all VOCs except carbon tetrachloride in three wells near RWMC (RWMC M7S, RWMC PROD, and USGS 87), trichloroethene in three wells near TAN (GIN 2, TAN 2271, and TAN 2272), and vinyl chloride in one well near TAN (TAN 2272) were less than the MCL for drinking water (U.S. Environmental Protection Agency, 2015). In addition to these wells, during 2015, 31 wells at and near INTEC were sampled for 49 VOCs as part of a special study (Maimer and Bartholomay, 2016). One to five different VOCs were measured above detection levels in 29 of the 31 wells.

Historically, concentrations of VOCs in water samples from several wells at and near the RWMC exceeded the reporting levels (Davis and others, 2013). In December 2015, five VOCs were detected in water from the RWMC Production Well. The VOCs and concentrations detected in December 2015 were 6.10 µg/L of carbon tetrachloride (tetrachloromethane), 2.00 µg/L of trichloromethane (chloroform), 0.40 µg/L of 1,1,1-trichloroethane, 0.40 µg/L of tetrachloroethene, and 3.50 µg/L of trichloroethene. The same five VOCs were also present in wells RWMC M7S and USGS 87 (table 8). A plot of carbon tetrachloride concentrations in water from the RWMC Production Well (fig. 22) indicates that concentration trends have increased with time from about 1 to 8 µg/L since 1987. The MCL for drinking water for carbon tetrachloride is 5 µg/L. Although the concentrations have been increasing since 1987 (Davis and others, 2015), more recent data since 2005 show a statistically significant decreasing trend indicating concentrations probably have reached their upper level and should decrease in the future (fig. 22).

During 2012–15, water from well USGS 87, just north of the RWMC (fig. 6), had detectable concentrations of carbon tetrachloride and exceeded the MCL of 5 µg/L for the first time in 2011 and again in 2014. Concentrations of carbon tetrachloride from this well also have increased with time from less than 1 to 5.62 µg/L in April 2014 (fig. 22). During 2012–15, carbon tetrachloride, trichloromethane, and trichloroethylene were detected in wells USGS 88 and 120 near the RWMC (fig. 6). Trend information for well USGS 88 indicated these constituents were decreasing over time, but were increasing in USGS 120 (Davis and others, 2015; appendix E). Toluene also was detected in well USGS 88 in 2013 after a new pump was installed (table 8).

With a change to the USGS sampling program in 2012, sampling began in well GIN 2 near TAN, and sampling began in well TAN 2271 in 2015 after that well was drilled. Trichloroethene is present above drinking water standards in several wells in the TAN area, and remediation by the INL cleanup project site contractor is occurring to try to reduce concentration levels (Twining and others, 2016). Trichloroethene exceeded the MCL in all five samples collected from GIN 2 during 2012–15 and exceeded the MCL for the sample collected from TAN 2271 in August 2015, but was less than the MCL in a sample collected during November 2015 (table 8). The sample collected in November was collected from a different completion depth with a smaller volume pump than the sample collected in August, which may account for the change in the concentration level given in table 8.

Table 8. Concentrations of volatile organic compounds in aquifer wells at the Idaho National Laboratory, Idaho, 2012–15.

[Analyses completed by the U.S. Geological Survey (USGS) National Water Quality Laboratory. Data are from U.S. Geological Survey (2016). **Well No. or name:** Location of wells shown in figures 5 and 6. **Abbreviations:** E, estimated. NWIS, National Water Information System. **Symbol:** <, less than respective reporting level]

Well No. or name	USGS site No.	Date	Volatile organic compounds, in micrograms per liter								
			Bromo-dichloro-methane	Carbon tetra-chloride	1,2-Di-chloro-ethane	Tribromo-methane	Dibromo-chloro-methane	Trichloro-methane	Toluene	Tetra-chloro-ethene	1,1-Di-chloro-ethane
	NWIS parameter code		**P32101**	**P32102**	**P32103**	**P32104**	**P32105**	**P32106**	**P34010**	**P34475**	**P34496**
GIN 2	434949112413401	04-24-12	<0.1	<0.2	<0.2	<0.2	<0.2	0.131	<0.1	1.94	<0.1
		10-11-12	<0.1	<0.2	<0.2	<0.2	<0.2	0.175	<0.1	1.822	<0.1
		10-29-13	<0.1	<0.2	<0.2	<0.2	<0.2	0.166	<0.1	2.55	<0.1
		10-14-14	<0.1	<0.2	<0.2	<0.2	<0.2	0.124	<0.1	2.42	<0.1
		10-20-15	<0.1	<0.2	<0.2	<0.2	<0.2	0.1	<0.1	1.9	<0.1
RWMC M1SA	432956113030901	11-05-13	<0.1	<0.2	<0.2	<0.2	<0.2	<0.1	0.173	<0.1	<0.1
RWMC M7S	433023113014801	10-04-12	<0.1	8.43	<0.2	<0.2	<0.2	1.23	<0.1	0.536	<0.1
		11-04-13	<0.1	8.53	<0.2	<0.2	<0.2	1.31	<0.1	0.526	<0.1
		10-15-14	<0.1	4.9	<0.2	<0.2	<0.2	0.999	<0.1	0.372	<0.1
		10-20-15	<0.1	5	<0.2	<0.2	<0.2	1.2	<0.1	0.4	<0.1
RWMC PROD	433002113021701	01-11-12	<0.1	7.86	<0.2	<0.2	<0.2	2.20	<0.1	0.421	<0.1
		02-09-12	<0.1	7.21	<0.2	<0.2	<0.2	2.05	<0.1	0.366	<0.1
		03-15-12	<0.1	8.63	<0.2	<0.2	<0.2	2.76	<0.1	0.433	<0.1
		04-12-12	<0.1	8.99	<0.2	<0.2	<0.2	3.09	<0.1	0.450	<0.1
		05-10-12	<0.1	7.9	<0.2	<0.2	<0.2	2.15	<0.1	0.396	<0.1
		06-14-12	<0.1	9.12	<0.2	<0.2	<0.2	2.22	<0.1	0.402	<0.1
		07-12-12	<0.1	9.26	<0.2	<0.2	<0.2	2.45	<0.1	0.412	<0.1
		08-09-12	<0.1	8.84	<0.2	<0.2	<0.2	2.26	<0.1	0.360	<0.1
		09-13-12	0.368	7.28	<0.2	1.57	0.506	2.03	<0.1	0.321	<0.1
		10-11-12	<0.1	5.31	<0.2	<0.2	<0.2	1.76	<0.1	0.293	<0.1
		11-15-12	<0.1	6.90	<0.2	<0.2	<0.2	2.15	<0.1	0.350	<0.1
		12-13-12	<0.1	7.95	<0.2	<0.2	<0.2	2.06	<0.1	0.368	<0.1
		01-17-13	<0.1	7.01	<0.2	<0.2	<0.2	1.93	<0.1	0.355	<0.1
		02-14-13	<0.1	6.02	<0.2	<0.2	<0.2	1.64	<0.1	0.333	<0.1
		03-14-13	<0.1	7.14	<0.2	<0.2	<0.2	2.09	<0.1	0.292	<0.1
		04-11-13	<0.1	5.92	<0.2	<0.2	<0.2	1.78	<0.1	0.341	<0.1
		05-09-13	<0.1	7.55	<0.2	<0.2	<0.2	1.76	<0.1	0.359	<0.1
		06-17-13	<0.1	7.09	<0.2	<0.2	<0.2	2.65	<0.1	0.432	<0.1
		07-11-13	<0.1	9.23	<0.2	<0.2	<0.2	2.22	<0.1	0.354	<0.1
		08-14-13	<0.1	7.33	<0.2	<0.2	<0.2	2.07	<0.1	0.377	<0.1
		09-12-13	<0.1	8.90	<0.2	<0.2	<0.2	2.34	<0.1	0.354	<0.1
		10-24-13	<0.1	7.49	<0.2	<0.2	<0.2	2.09	<0.1	0.364	<0.1
		11-14-13	<0.1	5.74	<0.2	<0.2	<0.2	2.85	<0.1	0.436	<0.1
		12-12-13	<0.1	6.72	<0.2	<0.2	<0.2	2.9	<0.1	0.435	<0.1
		01-16-14	<0.1	8.23	<0.2	<0.2	<0.2	2.26	<0.1	0.385	<0.1
		02-13-14	<0.1	7.96	<0.2	<0.2	<0.2	2.51	<0.1	0.328	<0.1
		03-13-14	<0.1	E6.45	<0.2	<0.2	<0.2	2.73	<0.1	0.419	<0.1

Table 8. Concentrations of volatile organic compounds in aquifer wells at the Idaho National Laboratory, Idaho, 2012–15.—Continued

Well No. or name	USGS site No.	Date	Volatile organic compounds, in micrograms per liter								
			Bromo-dichloro-methane	Carbon tetra-chloride	1,2-Di-chloro-ethane	Tribromo-methane	Dibromo-chloro-methane	Trichloro-methane	Toluene	Tetra-chloro-ethene	1,1-Di-chloro-ethane
	NWIS parameter code		P32101	P32102	P32103	P32104	P32105	P32106	P34010	P34475	P34496
RWMC PROD (Continued)	433002113021701	04-17-14	<0.1	E8.33	<0.2	<0.2	<0.2	E3.70	<0.1	0.453	<0.1
		05-22-14	<0.1	6.29	<0.2	<0.2	<0.2	2.04	<0.1	0.407	<0.1
		06-12-14	<0.1	6.09	<0.2	<0.2	<0.2	1.84	<0.1	0.398	<0.1
		08-14-14	<0.1	5.96	<0.2	<0.2	<0.2	1.61	<0.1	0.309	<0.1
		09-11-14	<0.1	5.20	<0.2	<0.2	<0.2	1.97	<0.1	0.339	<0.1
		10-16-14	<0.1	5.17	<0.2	<0.2	<0.2	1.64	<0.1	0.279	<0.1
		11-13-14	<0.1	5.51	<0.2	<0.2	<0.2	1.61	<0.1	0.325	<0.1
		12-18-14	<0.1	6.24	<0.2	<0.2	<0.2	1.96	<0.1	0.337	<0.1
		01-15-15	<0.1	6.40	<0.2	<0.2	<0.2	2.10	<0.1	0.400	<0.1
		02-12-15	<0.1	6.90	<0.2	<0.2	<0.2	2.20	<0.1	0.400	<0.1
		03-18-15	<0.1	6.00	<0.2	<0.2	<0.2	1.90	<0.1	0.300	<0.1
		04-16-15	<0.1	5.10	<0.2	<0.2	<0.2	2.70	<0.1	0.400	<0.1
		05-18-15	<0.1	6.70	<0.2	<0.2	<0.2	1.90	<0.1	0.300	<0.1
		07-15-15	<0.1	6.20	<0.2	<0.2	<0.2	1.70	<0.1	0.300	<0.1
		08-17-15	<0.1	4.10	<0.2	<0.2	<0.2	1.20	<0.1	0.200	<0.1
		09-15-15	<0.1	6.00	<0.2	<0.2	<0.2	2.10	<0.1	0.400	<0.1
		10-14-15	<0.1	5.20	<0.2	<0.2	<0.2	1.90	<0.1	0.400	<0.1
		11-16-15	<0.1	5.80	<0.2	<0.2	<0.2	1.80	<0.1	0.400	<0.1
		12-15-15	<0.1	6.10	<0.2	<0.2	<0.2	2.00	<0.1	0.400	<0.1
TAN 2271	435053112423101	08-25-15	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	0.3	0.1	0.2
		11-30-15	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.1	0.2
TAN 2272	435053112423001	08-27-15	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	2.23	<0.1	0.2
USGS 77	433315112560301	10-07-14	<0.1	<0.2	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
USGS 87	433013113024201	04-19-12	<0.1	4.65	<0.2	<0.2	<0.2	0.318	<0.1	0.172	<0.1
		04-17-13	<0.1	3.1	<0.2	<0.2	<0.2	0.271	0.334	0.138	<0.1
		04-17-14	<0.1	5.62	<0.2	<0.2	<0.2	0.363	<0.1	0.184	<0.1
		04-13-15	<0.1	4.3	<0.2	<0.2	<0.2	0.4	<0.1	0.2	<0.1
USGS 88	432940113030201	05-08-13	<0.1	1.28	<0.2	<0.2	<0.2	0.472	63.6	<0.1	<0.1
		10-31-13	<0.1	0.994	<0.2	<0.2	<0.2	0.582	0.334	<0.1	<0.1
		10-21-14	<0.1	0.598	<0.2	<0.2	<0.2	0.413	<0.1	<0.1	<0.1
		10-13-15	<0.1	0.4	<0.2	<0.2	<0.2	0.4	<0.1	<0.1	<0.1
USGS 119	432945113023401	04-17-12	<0.1	0.361	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
USGS 120	432919113031501	10-10-12	<0.1	0.909	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
		10-29-13	<0.1	1.34	<0.2	<0.2	<0.2	0.169	<0.1	<0.1	<0.1
		10-14-14	<0.1	0.433	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
		10-21-15	<0.1	0.6	<0.2	<0.2	<0.2	<0.1	<0.1	<0.1	<0.1
USGS 130	433130112562801	04-11-12	<0.1	<0.2	<0.2	<0.2	<0.2	0.227	<0.1	<0.1	<0.1
USGS 140	433441112581201	07-31-13	<0.1	<0.2	<0.2	<0.2	<0.2	<0.1	0.194	<0.1	<0.1
USGS 141	433441112581601	09-25-13	<0.1	<0.2	<0.2	<0.2	<0.2	<0.1	1.04	<0.1	<0.1

Table 8. Concentrations of volatile organic compounds in aquifer wells at the Idaho National Laboratory, Idaho, 2012–15.—Continued

Well No. or name	USGS site No.	Date	Volatile organic compounds, in micrograms per liter								
			1,1-Di-chloro-ethene	1,1,1-Tri-chloro-ethane	1,2-Di-chloro-propane	Trans-1,2-dichloro-ethene	Vinyl chloride	Trichloro-ethene	Cis-1,2-Di-chloro-ethene	Styrene	1,1,1,2-Tetrachlo-roethane
	NWIS parameter code		**P34501**	**P34506**	**P34541**	**P34546**	**P39175**	**P39180**	**P77093**	**P77128**	**P77652**
GIN 2	434949112413401	04-24-12	<0.1	<0.1	<0.1	<0.1	<0.2	6.74	<0.1	<0.1	0.1034
		10-11-12	<0.1	<0.1	<0.1	<0.1	<0.2	7.61	<0.1	<0.1	<0.1
		10-29-13	<0.1	<0.1	<0.1	<0.1	<0.2	6.52	<0.1	<0.1	<0.1
		10-14-14	<0.1	<0.1	<0.1	<0.1	<0.2	9.49	<0.1	<0.1	<0.1
		10-20-15	<0.1	<0.1	<0.1	<0.1	<0.2	7.8	0.1	<0.1	<0.1
RWMC M1SA	432956113030901	11-05-13	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
RWMC M7S	433023113014801	10-04-12	<0.1	0.591	<0.1	<0.1	<0.2	3.59	<0.1	<0.1	<0.1
		11-04-13	<0.1	0.614	<0.1	<0.1	<0.2	3.36	<0.1	<0.1	<0.1
		10-15-14	<0.1	0.413	<0.1	<0.1	<0.2	2.37	<0.1	<0.1	<0.1
		10-20-15	<0.1	0.4	<0.1	<0.1	<0.2	2.7	<0.1	<0.1	<0.1
RWMC PROD	433002113021701	01-11-12	<0.1	0.530	<0.1	<0.1	<0.2	4.13	<0.1	<0.1	<0.1
		02-09-12	<0.1	0.485	<0.1	<0.1	<0.2	3.79	<0.1	<0.1	<0.1
		03-15-12	<0.1	0.590	<0.1	<0.1	<0.2	4.67	<0.1	<0.1	<0.1
		04-12-12	<0.1	0.604	<0.1	<0.1	<0.2	4.88	<0.1	<0.1	<0.1
		05-10-12	<0.1	0.468	<0.1	<0.1	<0.2	3.89	<0.1	<0.1	<0.1
		06-14-12	<0.1	0.497	<0.1	<0.1	<0.2	3.98	<0.1	<0.1	<0.1
		07-12-12	<0.1	0.505	<0.1	<0.1	<0.2	4.00	<0.1	<0.1	<0.1
		08-09-12	<0.1	0.481	<0.1	<0.1	<0.2	4.01	<0.1	<0.1	<0.1
		09-13-12	<0.1	0.430	<0.1	<0.1	<0.2	3.07	<0.1	<0.1	<0.1
		10-11-12	<0.1	0.350	<0.1	<0.1	<0.2	3.22	<0.1	<0.1	<0.1
		11-15-12	<0.1	0.420	<0.1	<0.1	<0.2	3.40	<0.1	<0.1	<0.1
		12-13-12	<0.1	0.462	<0.1	<0.1	<0.2	3.62	<0.1	<0.1	<0.1
		01-17-13	<0.1	0.430	<0.1	<0.1	<0.2	3.58	<0.1	<0.1	<0.1
		02-14-13	<0.1	0.387	<0.1	<0.1	<0.2	2.99	<0.1	<0.1	<0.1
		03-14-13	<0.1	0.418	<0.1	<0.1	<0.2	3.83	<0.1	<0.1	<0.1
		04-11-13	<0.1	0.376	<0.1	<0.1	<0.2	3.12	<0.1	<0.1	<0.1
		05-09-13	<0.1	0.435	<0.1	<0.1	<0.2	3.23	<0.1	<0.1	<0.1
		06-17-13	<0.1	0.595	<0.1	<0.1	<0.2	4.11	<0.1	<0.1	<0.1
		07-11-13	<0.1	0.418	<0.1	<0.1	<0.2	3.90	<0.1	<0.1	<0.1
		08-14-13	<0.1	0.474	<0.1	<0.1	<0.2	3.58	<0.1	<0.1	<0.1
		09-12-13	<0.1	0.468	<0.1	<0.1	<0.2	3.83	<0.1	<0.1	<0.1
		10-24-13	<0.1	0.460	<0.1	<0.1	<0.2	3.59	<0.1	<0.1	<0.1
		11-14-13	<0.1	0.585	<0.1	<0.1	<0.2	4.37	<0.1	<0.1	<0.1
		12-12-13	<0.1	0.571	<0.1	<0.1	<0.2	4.29	<0.1	<0.1	<0.1
		01-16-14	<0.1	0.484	<0.1	<0.1	<0.2	3.77	<0.1	<0.1	<0.1
		02-13-14	<0.1	0.489	<0.1	<0.1	<0.2	3.82	<0.1	<0.1	<0.1
		03-13-14	<0.1	E0.573	<0.1	<0.1	<0.2	4.36	<0.1	<0.1	<0.1

Table 8. Concentrations of volatile organic compounds in aquifer wells at the Idaho National Laboratory, Idaho, 2012–15.—Continued

Well No. or name	USGS site No.	Date	Volatile organic compounds, in micrograms per liter								
			1,1-Di-chloro-ethene	1,1,1-Tri-chloro-ethane	1,2-Di-chloro-propane	Trans-1,2-dichloro-ethene	Vinyl chloride	Trichloro-ethene	Cis-1,2-Di-chloro-ethene	Styrene	1,1,1,2-Tetrachlo-roethane
	NWIS parameter code		P34501	P34506	P34541	P34546	P39175	P39180	P77093	P77128	P77652
RWMC PROD (Continued)	433002113021701	04-17-14	<0.1	E0.654	<0.1	<0.1	<0.2	4.85	<0.1	<0.1	<0.1
		05-22-14	<0.1	0.559	<0.1	<0.1	<0.2	2.80	<0.1	<0.1	<0.1
		06-12-14	<0.1	0.508	<0.1	<0.1	<0.2	2.47	<0.1	<0.1	<0.1
		08-14-14	<0.1	0.325	<0.1	<0.1	<0.2	2.99	<0.1	<0.1	<0.1
		09-11-14	<0.1	0.393	<0.1	<0.1	<0.2	3.31	<0.1	<0.1	<0.1
		10-16-14	<0.1	0.307	<0.1	<0.1	<0.2	2.65	<0.1	<0.1	<0.1
		11-13-14	<0.1	0.330	<0.1	<0.1	<0.2	2.89	<0.1	<0.1	<0.1
		12-18-14	<0.1	0.385	<0.1	<0.1	<0.2	3.34	<0.1	<0.1	<0.1
		01-15-15	<0.1	0.400	<0.1	<0.1	<0.2	3.50	<0.1	<0.1	<0.1
		02-12-15	<0.1	0.400	<0.1	<0.1	<0.2	3.70	<0.1	<0.1	<0.1
		03-18-15	<0.1	0.400	<0.1	<0.1	<0.2	3.20	<0.1	<0.1	<0.1
		04-16-15	<0.1	0.500	<0.1	<0.1	<0.2	4.50	<0.1	<0.1	<0.1
		05-18-15	<0.1	0.400	<0.1	<0.1	<0.2	3.40	<0.1	<0.1	<0.1
		07-15-15	<0.1	0.300	<0.1	<0.1	<0.2	3.10	<0.1	<0.1	<0.1
		08-17-15	<0.1	0.200	<0.1	<0.1	<0.2	2.00	<0.1	<0.1	<0.1
		09-15-15	<0.1	0.400	<0.1	<0.1	<0.2	3.90	<0.1	<0.1	<0.1
		10-14-15	<0.1	0.300	<0.1	<0.1	<0.2	3.50	<0.1	<0.1	<0.1
		11-16-15	<0.1	0.300	<0.1	<0.1	<0.2	3.30	<0.1	<0.1	<0.1
		12-15-15	<0.1	0.400	<0.1	<0.1	<0.2	3.50	<0.1	<0.1	<0.1
TAN 2271	435053112423101	08-25-15	<0.1	<0.1	<0.1	22.7	0.5	12.0	3.37	<0.1	<0.1
		11-30-15	<0.1	<0.1	<0.1	36.7	1.9	4.80	3.50	<0.1	<0.1
TAN 2272	435053112423001	08-27-15	<0.1	<0.1	<0.1	27.2	2.9	33.0	14.20	<0.1	<0.1
USGS 77	433315112560301	10-07-14	0.118	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
USGS 87	433013113024201	04-19-12	<0.1	0.205	<0.1	<0.1	<0.2	1.06	<0.1	<0.1	<0.1
		04-17-13	<0.1	0.147	<0.1	<0.1	<0.2	0.773	<0.1	0.507	<0.1
		04-17-14	<0.1	0.215	<0.1	<0.1	<0.2	1.1	<0.1	<0.1	<0.1
		04-13-15	<0.1	0.2	<0.1	<0.1	<0.2	1.1	<0.1	<0.1	<0.1
USGS 88	432940113030201	05-08-13	<0.1	<0.1	<0.1	<0.1	<0.2	0.576	<0.1	<0.1	<0.1
		10-31-13	<0.1	<0.1	<0.1	<0.1	<0.2	0.477	<0.1	<0.1	<0.1
		10-21-14	<0.1	<0.1	<0.1	<0.1	<0.2	0.43	<0.1	<0.1	<0.1
		10-13-15	<0.1	<0.1	<0.1	<0.1	<0.2	0.3	<0.1	<0.1	<0.1
USGS 119	432945113023401	04-17-12	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
USGS 120	432919113031501	10-10-12	<0.1	<0.1	<0.1	<0.1	<0.2	0.11	<0.1	<0.1	<0.1
		10-29-13	<0.1	<0.1	<0.1	<0.1	<0.2	0.232	<0.1	<0.1	<0.1
		10-14-14	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
		10-21-15	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
USGS 130	433130112562801	04-11-12	<0.1	0.158	<0.1	<0.1	<0.2	2.94	<0.1	<0.1	<0.1
USGS 140	433441112581201	07-31-13	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1
USGS 141	433441112581601	09-25-13	<0.1	<0.1	<0.1	<0.1	<0.2	<0.1	<0.1	<0.1	<0.1

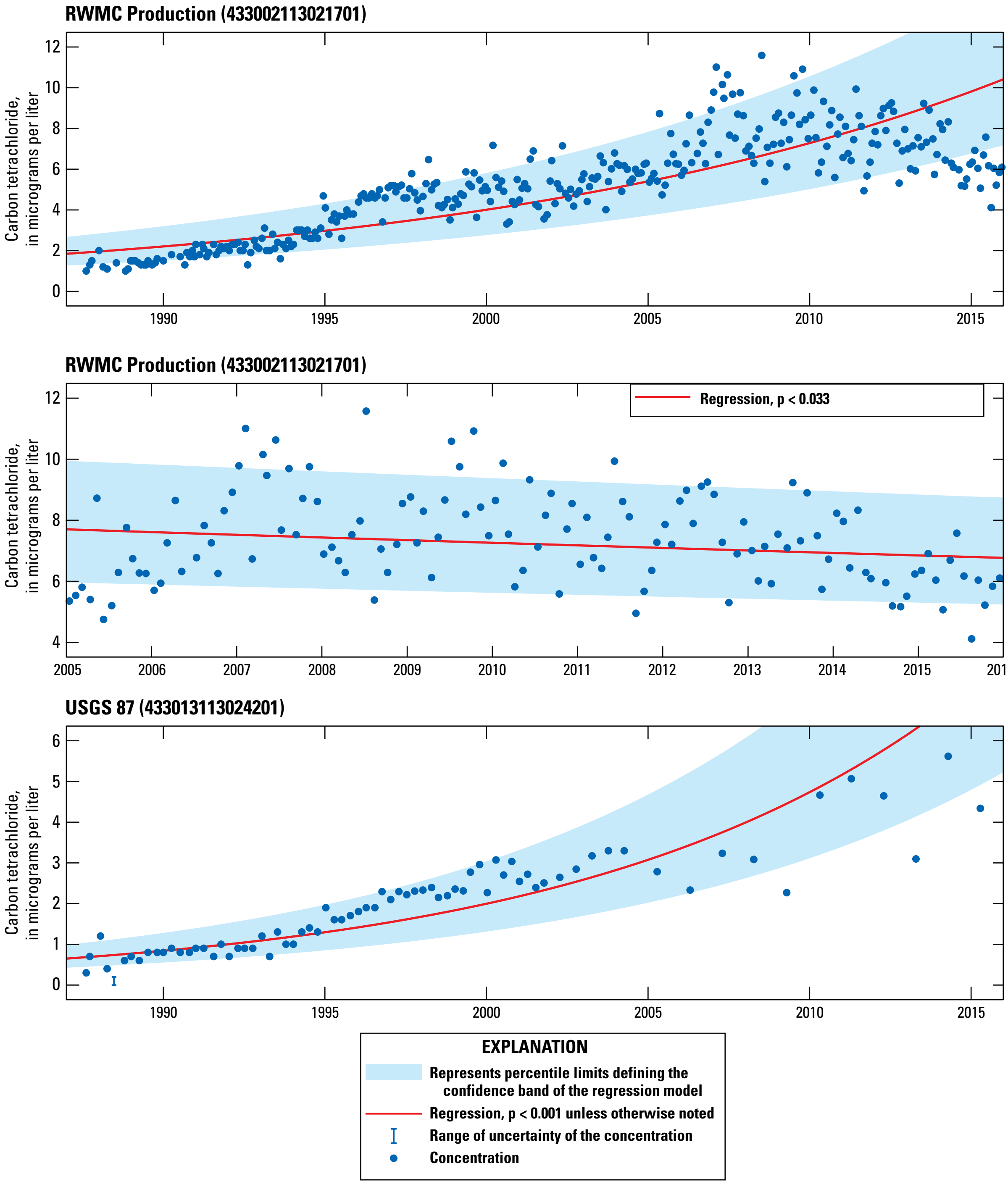


Figure 22. Carbon tetrachloride concentrations in water from the Radioactive Waste Management Complex (RWMC) Production Well and well USGS 87, Idaho National Laboratory, Idaho, 1987–2015.

Selected Radiochemical and Chemical Constituents in Perched Groundwater at the Advanced Test Reactor Complex, Idaho Nuclear Engineering and Environmental Center, and Radioactive Waste Management Complex

Disposal of wastewater to infiltration ponds and ditches, lined evaporation ponds, drain fields, and infiltration of surface water at waste-burial pits resulted in formation of perched groundwater in basalts and in sedimentary interbeds that overlie the ESRP aquifer (Cecil and others, 1991) beneath the ATR Complex, the INTEC, and the RWMC. Wastewater-disposal sites at these INL facilities are the primary sources of radiochemical and chemical constituents in perched groundwater at the INL. During 2012–15, wastewater was discharged to infiltration and lined-evaporation ponds. Bartholomay and others (2000) provides a comprehensive summary of waste disposal at the INL through 1998 and very little disposal information is available since 1998.

Advanced Test Reactor Complex

Bodies of shallow and deep perched groundwater formed at the ATR Complex in response to wastewater disposal into radioactive-, chemical-, cold-, and sanitary-waste ponds (Tucker and Orr, 1998) (fig. 6). Radiochemical and chemical constituents in wastewater migrate to the ESRP aquifer through perched groundwater beneath these wastewater infiltration ponds. The extent of perched groundwater is affected by the waste-disposal practices. Selected radiochemical and inorganic chemical constituents in wastewater have been monitored in the shallow and deep perched groundwater since the early 1960s.

Water samples from three wells (CWP 1, 3, and 8) completed in shallow perched groundwater near the ATR Complex (fig. 7) routinely were collected and analyzed for selected radiochemical and chemical constituents during 2012–15. Water samples were collected from 18 wells (PW 8, PW 9, USGS 53–56, 60–63, 66, 68–73, and 78) that were completed in deep perched groundwater beneath the ATR Complex. Sampling was discontinued at some perched groundwater wells during the 2002–05 reporting period because of lack of water in the wells (Davis, 2008, fig. 21).

Selection of radiochemical and chemical constituents for analyses was based on the waste-disposal history at the ATR Complex. Selected radiochemical constituents were tritium, strontium-90, and gamma analyses (which may yield detections of cesium-137, cobalt-60, or chromium-51); chemical constituents were dissolved chromium, sodium, chloride, and sulfate.

Tritium

Wells CWP 1, 3, and 8 (fig. 4) are used to monitor shallow perched groundwater around the cold-waste ponds at the ATR Complex. During 2012–15, tritium concentrations in water samples collected from wells CWP 1, 3, and 8 were less than the reporting level except for the 2013 sample from CWP-1 (table 9).

Concentrations of tritium in deep perched groundwater near the ATR Complex during April or October 2015 are shown in figure 23. Concentrations of tritium in wells near the ATR Complex in 2015 were lower than historical measurements. Tritium concentrations continued to decrease during the 2012–15 reporting period in all wells and show long term declining trends in most wells around ATR Complex (Davis and others, 2015, fig. 13). The decrease in tritium concentrations in water from wells near the ATR Complex likely is a result of changes in wastewater disposal practices dating back to the early 1990s when evaporation ponds began to be used in place of infiltration ponds. In some cases, the change in disposal practices also may have led to a decrease in the amount of perched groundwater available to sample.

Tritium concentrations in water from 13 wells completed in deep perched groundwater (PW 9, USGS 53, 55, 56, 60, 61, 66, 68, 69, 70, 71, 72, and 73) near the ATR Complex generally were greater than or equal to the reporting level during at least one sampling event during 2012–15 (table 9). Tritium concentrations in water from five wells (PW-8, USGS 54, 62, 63, and 78) were less than the reporting level during 2012–15 (table 9).

Tritium concentrations equal to or greater than the reporting level ranged from 210±60 pCi/L in water from well USGS 68 in 2012 to 28,100±900 pCi/L in water from well USGS 55 in 2012 (table 9). Water samples collected in October 2015 from well USGS 73 had a tritium concentration of 1,510±70 pCi/L, significantly less than the October 2011 concentration of 3,300±150 pCi/L. Well PW 9 had a concentration of 3,320±100 pCi/L, also significantly less than the October 2011 concentration of 14,500±500 pCi/L. Concentrations of tritium in these two wells have decreased significantly since October 1993 when concentrations were 296,000±10,000 pCi/L in water from well USGS 73 and 193,000±6,000 pCi/L in water from well PW 9. Historically, high tritium concentrations in water from wells USGS 73 and PW 9 indicate that the chemistry of perched groundwater west of the ATR Complex was affected by radioactive-waste infiltration pond disposal. Discontinuation of wastewater discharge to the radioactive-waste infiltration ponds and the subsequent use of lined evaporation ponds, together with the radioactive decay process, most likely is the cause for the decreased tritium concentrations in this area from 1993 to 2015.

Table 9. Concentrations of tritium, strontium-90, and cesium-137 in perched groundwater from selected wells, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, 2012–15.

[Analyses completed by the Department of Energy's Radiological and Environmental Sciences Laboratory. Analytical uncertainties are reported as 1 times the sample standard deviation. Concentrations equal to or greater than 3 times the sample standard deviation are considered to be greater than the reporting level and are **bold**. **Well No.:** Locations of wells are shown in figure 7. DP, well completed in deep perched groundwater; SP, well completed in shallow perched groundwater. **Cesium-137:** NR, analysis not requested; pCi/L, picocurie per liter. **Abbreviation:** USGS, U.S. Geological Survey. **Symbol:** ±, plus or minus]

Well No.	Date sampled	Tritium (pCi/L)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)
CWP 1 (SP)	04-11-12	-20±50	1.6±0.6	NR
	04-08-13	**300±60**	0.3±0.6	NR
	04-16-14	14.3±47.4	1.5±0.7	NR
	04-13-15	-50±50	0.5±0.6	NR
CWP 3 (SP)	04-11-12	20±50	0.7±0.6	NR
	04-08-13	-10±50	2±0.7	NR
	04-16-14	0±50	1.4±0.7	NR
	04-13-15	-140±50	1.5±0.7	NR
CWP 8 (SP)	04-11-12	80±60	1.7±0.6	NR
	04-08-13	30±60	**3.4±0.7**	NR
	04-16-14	-80±50	1.8±0.7	NR
	04-13-15	-50±50	**3.1±0.7**	NR
PW 8 (DP)	04-09-12	120±60	**5.1±0.7**	7±8
	04-08-13	30±60	**4.4±0.7**	10±10
	04-01-14	130±50	**4.3±0.7**	11±6
	03-31-15	15±55.3	**4.1±0.7**	14±6
PW 9 (DP)	10-11-12	**10,500±200**	**2.2±0.7**	11±8
	10-30-13	**9,490±170**	1.1±0.6	20±8
	10-20-14	**5,600±130**	1.9±0.7	17±7
	10-20-15	**3,320±100**	1.0±0.6	16±9
USGS 53 (DP)	11-26-12	**530±70**	**23.5±1**	26±10
	10-16-14	**1,290±80**	**22.1±1**	19±8
USGS 54 (DP)	10-11-12	50±50	**33±1.2**	6±6
	11-04-13	-30±50	**36.5±1.3**	18±9
	10-15-14	-10±50	**27.1±1.1**	5±6
	10-01-15	10±50	**21.6±1**	6±6
USGS 55 (DP)	04-09-12	**28,100±900**	**32.7±1.2**	11±6
	05-20-13	**9,700±200**	**31.8±1.2**	15±8
	04-02-14	**14,200±200**	**35.3±1.2**	20±10
	03-31-15	**14,700±200**	**28.9±1.1**	14±8
USGS 56 (DP)	10-17-12	**1,670±90**	**73.6±2**	13±8
	10-28-13	**1,180±70**	**32.8±1.2**	17±10
	10-16-14	**1,080±70**	**25.8±1.1**	5±5
	10-14-15	**930±60**	**44.9±1.4**	16±7
USGS 60 (DP)	04-17-13	**250±60**	0.5±0.6	7±6
	09-30-13	30±50	1.5±0.7	16±8
	10-20-14	-90±50	1.2±0.7	14±8
	10-13-15	30±50	0.3±0.6	12±7

Table 9. Concentrations of tritium, strontium-90, and cesium-137 in perched groundwater from selected wells, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, 2012–15.—Continued

Well No.	Date sampled	Tritium (pCi/L)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)
USGS 61 (DP)	04-09-12	**1,480±100**	0.8±0.6	6±5
	04-08-13	**1,430±90**	1.1±0.7	17±8
	03-31-14	**1,210±70**	0.8±0.7	12±9
	03-31-15	**760±70**	**1.8±0.6**	15±8
USGS 62 (DP)	10-10-12	120±60	**3.2±0.7**	13±7
	04-08-13	90±60	**2.1±0.7**	2.8±1.4
	03-31-14	50±50	**2.7±0.7**	19±10
	03-31-15	-10±54.7	2.1±0.9	15±7
USGS 63 (DP)	10-10-12	30±50	**4±0.7**	28±12
	11-04-13	90±60	**3.4±0.7**	21±9
	10-15-14	50±50	**2.4±0.7**	17±8
	10-15-15	0±50	1.5±0.7	27±10
USGS 66 (DP)	10-15-12	**270±60**	0.126±0.683	16±8
	10-28-13	120±50	0.8±0.7	16±8
	10-22-14	140±50	1.5±0.7	8±5
	10-20-15	40±50	**1.8±0.6**	6±6
USGS 68 (DP)	04-10-12	**210±60**	1.2±0.7	**27±9**
	04-16-13	-60±50	1.8±0.7	4±2
	04-03-14	12.3±47.4	1.8±0.7	37±15
	04-01-15	-100±50	1.2±0.6	13±7
USGS 69 (DP)	10-10-12	**230±60**	0.3±0.7	17±8
	09-30-13	60±50	0.6±0.6	18±10
	10-15-14	-50±50	2±0.7	18±9
	10-01-15	20±50	0.7±0.7	41±14
USGS 70 (DP)	04-16-12	**920±80**	**30.8±1.1**	**27±9**
	04-17-13	**620±70**	**25.9±1.1**	27±11
	04-01-14	**1,040±70**	**26.2±1.1**	22±12
	04-02-15	**610±70**	**22.4±1**	19±9
USGS 71 (DP)	10-17-12	**800±70**	1±0.7	11±9
	10-28-13	**600±60**	-0.6±0.6	15±7
	10-16-14	**510±60**	1.2±0.6	12±7
	10-14-15	**500±60**	0.6±0.6	15±7
USGS 72 (DP)	04-10-12	**450±70**	-0.118±0.622	13±6
	04-16-13	-20±50	0.8±0.6	30±12
	04-03-14	-40±50	1.8±0.7	9±7
	04-01-15	-70±50	0.6±0.6	7±6
USGS 73 (DP)	10-11-12	**1,930±70**	**3.8±0.7**	23±9
	11-04-13	**2,800±100**	1.8±0.7	6±5
	04-02-15	**680±70**	1.9±0.7	26±11
	10-20-15	**1,510±70**	0.7±0.6	13±7
USGS 78 (DP)	10-17-12	100±60	0.7±0.7	11±6
	10-28-13	60±50	1.3±0.7	3±5
	10-16-14	-40±50	1.3±0.7	5±5
	10-14-15	40±50	0.151±0.643	5±5

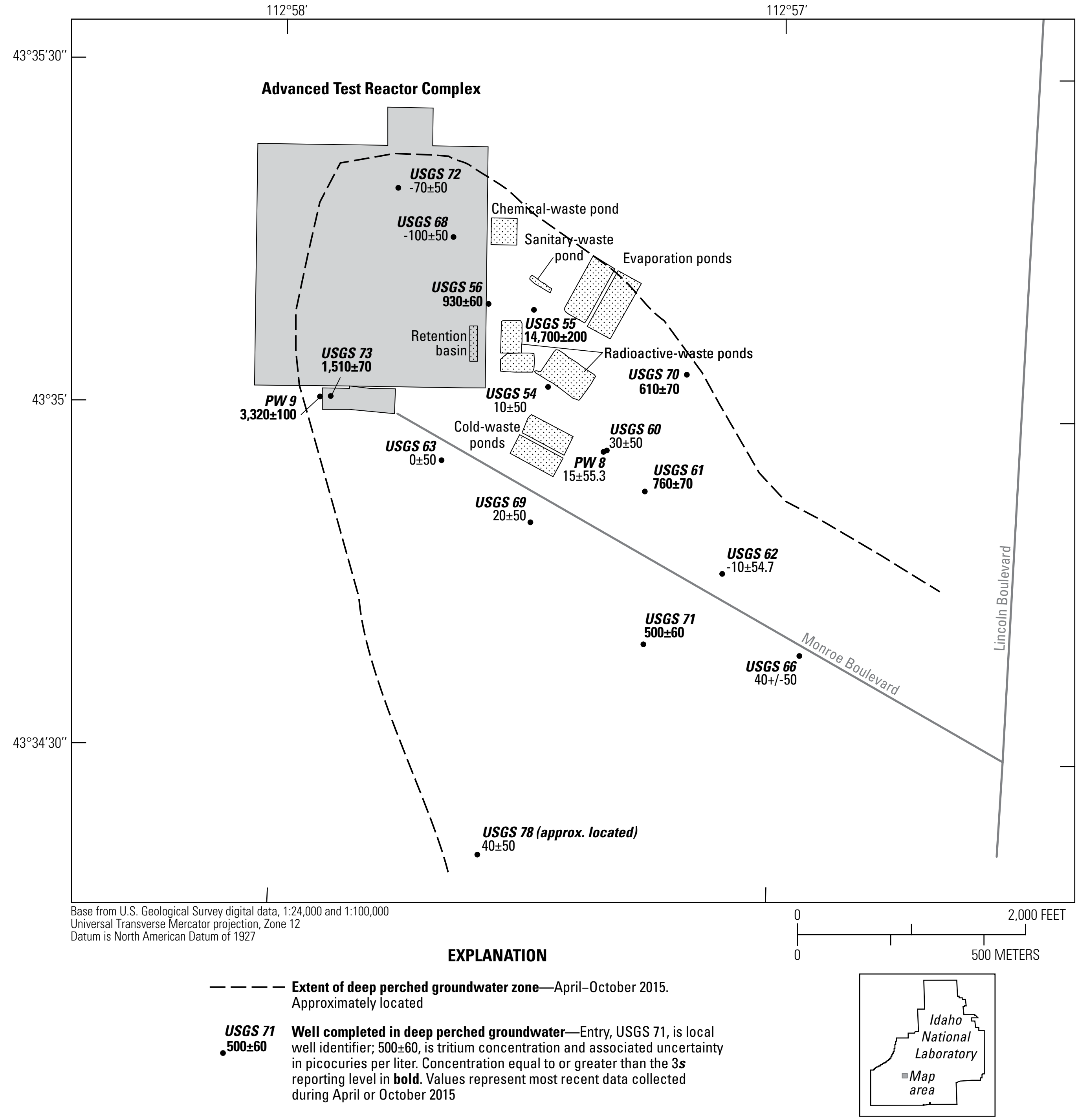


Figure 23. Concentrations of tritium in water from wells completed in deep perched groundwater, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, April or October 2015.

Tritium concentrations have fluctuated substantially in USGS 55 (located between the evaporation ponds and the radioactive-waste ponds [fig. 7]) during recent sampling periods with a large concentration of 28,100±900 pCi/L in 2012, and a small concentration of 9,700±200 pCi/L in 2013. Similar large and small values were noted in Davis (2008, table 10; 2010, table 7) and Davis and others (2013, table 9). These variable changes may indicate remnant radioactive-waste pond wastewater is still present between the land surface and the perched groundwater zone, or there is possible leakage coming from the evaporation ponds or piping to the ponds. To evaluate possible leakage, tritium concentrations were plotted with water levels in this well (fig. 24). The higher concentrations mostly occur right after a period when water levels were lower, which alleviates concern about leaky pipes as the cause. A more likely cause is that when water levels rise, tritium becomes more diluted with fresh water that reduces the concentration level.

Several factors affected the distribution of tritium in perched groundwater at the ATR Complex, including proximity of wells to the old radioactive-waste infiltration ponds, depth of water below the ponds, variations in tritium disposal rate, and radioactive decay. Since 1982, tritium concentrations also have been affected by dilution from the cold-waste ponds. Replacement of the radioactive-waste infiltration ponds with the lined evaporation ponds in 1993 contributed to decreases in tritium concentrations in perched groundwater and decreases in perched groundwater in some wells. Infiltration from the Big Lost River during 1999, early 2000, 2005, and 2006 may have contributed to diluted tritium concentrations in perched groundwater southeast of the ATR Complex although a direct connection has never been documented.

Strontium-90

Wells CWP 1, 3, and 8 (fig. 4) completed in shallow perched groundwater at the ATR Complex were sampled for strontium-90 during 2012–15 and concentrations were less than the reporting level from all samples collected from CWP 1 and CWP 3, and greater than the reporting level in two samples collected from CWP 8 (table 9).

During at least one sampling event in the period 2012–15, concentrations of strontium-90 in water from wells PW 8, PW 9, USGS 53–56, 61–63, 70, and 73, completed in deep perched groundwater at the ATR Complex, were greater than or equal to reporting levels (table 9, fig. 25). Concentrations equal to or greater than the reporting level ranged from 1.8±0.6 pCi/L in well USGS 61 to 73.6±2 pCi/L in well USGS 56. The distribution of strontium-90 concentrations in perched groundwater from these wells during 2012–15 is attributed to exchange reactions between strontium-90 in solution and to sediments beneath the radioactive-waste infiltration ponds. Well USGS 56 shows variable concentrations through time and USGS 55 showed an increasing trend until about 2006 when concentrations started to decrease (Davis and others, 2015, appendix C). Both these wells are near the chemical waste ponds that were taken out of service in 1999, and high sodium concentrations in remnant water from the old chemical waste ponds may still be periodically exchanging with sediments in the unsaturated zone and mobilizing strontium-90.

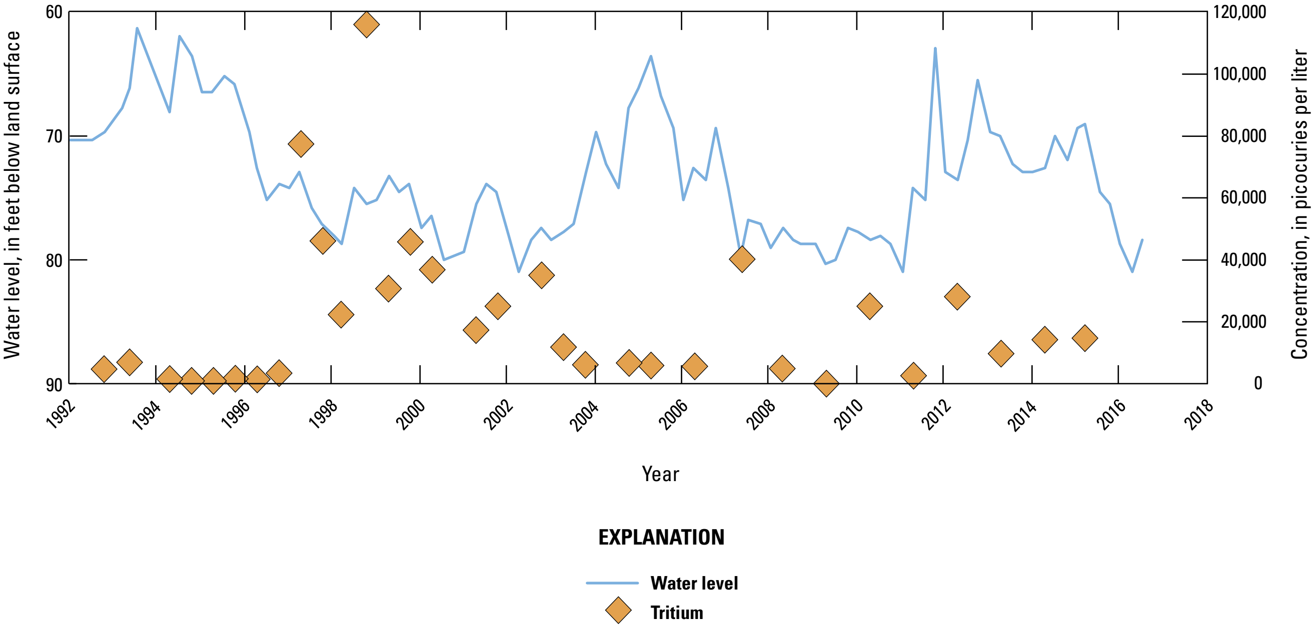


Figure 24. Concentrations of tritium plotted versus water level from well USGS 55 completed in deep perched groundwater, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho.

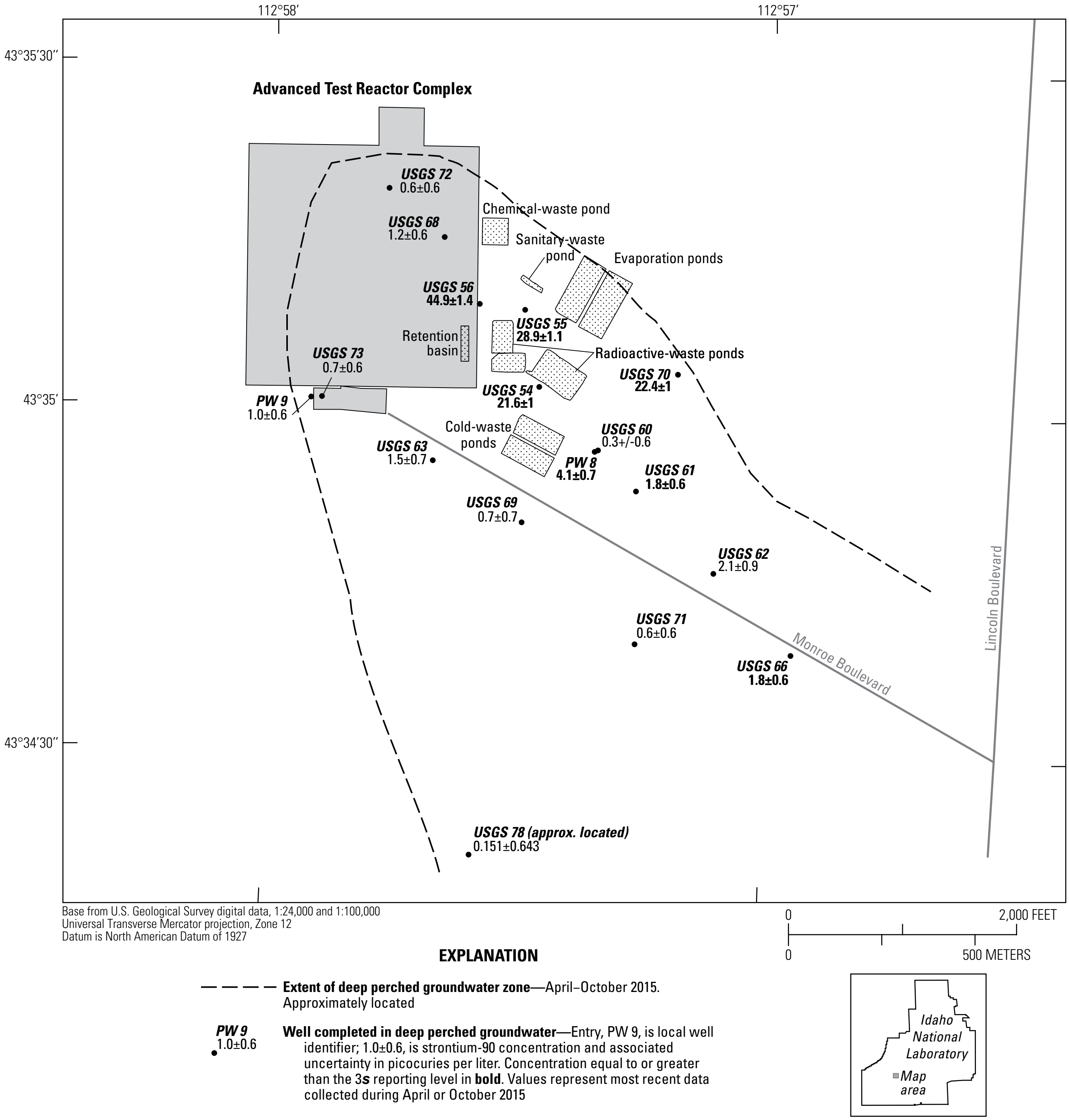


Figure 25. Concentrations of strontium-90 in water from wells completed in deep perched groundwater, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, April or October 2015.

Although strontium-90 has been detected in water from shallow and deep perched groundwater at the ATR Complex, it has not been detected in the ESRP aquifer beneath the ATR Complex. This may be because of the exclusive use of waste-disposal ponds and lined evaporation ponds rather than injection of waste directly to the aquifer (Bartholomay and others, 1997, p. 30). The absence of detectable concentrations in the aquifer indicates that strontium-90 in solution is removed possibly by sorption and (or) exchange reactions in the unsaturated zone. Studies of strontium distribution coefficients for samples of surficial sediment, sedimentary interbeds, and sediment-filled fractures in basalts at the INL (Liszewski and others, 1997, 1998; Pace and others, 1999) support this theory.

Gamma Spectrometry

Water samples collected are routinely analyzed by gamma spectrometry, and the results may yield concentrations of cesium-137, chromium-51, and cobalt-60. Water samples from wells completed in both shallow and deep perched groundwater at and near the ATR Complex have not yielded concentrations of cesium-137 greater than the reporting level between 1997 through 2011 (Davis and others, 2013). However, in April 2012, cesium-137 concentrations in wells USGS 68 and 70 were equal to the reporting level (table 9). Water from wells at and near the ATR Complex has not had concentrations greater than the reporting level of chromium-51 since 1995 or cobalt-60 since 1998 (Davis, 2010).

Chromium

In October 1972, chromium used as a corrosion inhibitor in cooling-tower operations was replaced by a polyphosphate. No disposal of chromium to the subsurface at the ATR Complex was reported after 1972 (Bartholomay and Tucker, 2000). The presence of dissolved chromium in water from wells completed in perched groundwater represents chromium in cooling-tower blowdown water that was discharged to the radioactive-waste infiltration ponds before 1965 when disposal practices changed to injection of water to the disposal well; concentrations in the perched groundwater zone are expected to continue to decrease in the future.

Historically, dissolved chromium concentrations in shallow perched groundwater at the ATR Complex have been very low (less than or slightly greater than the LRL) because of lack of disposal of chromium to the cold waste ponds. Over the past decade, several wells completed in shallow perched groundwater were not sampled because they were dry and were removed from the USGS sampling program. During 2012–15, three shallow perched groundwater wells (CWP 1, 3, and 8) were sampled for chromium. Chromium was detected in well CWP 1 in April of each year with a concentration ranging from 2.49 to 3.29 µg/L (table 10). Chromium also was detected in well CWP 3 in April 2013 with a concentration of 0.888 µg/L. All other concentrations were less than the reporting level of 0.6 µg/L during 2012–15.

Dissolved chromium was detected in water from all the wells sampled for chromium and completed in deep perched groundwater at the ATR Complex during 2012–15 (table 10). The highest concentrations during 2015 were in water from wells north and west of the radioactive-waste infiltration ponds (PW 9 and USGS 55, 56, and 73) (table 10; fig. 26). During April or October 2015, detectable concentrations of dissolved chromium in wells completed in deep perched groundwater near the ATR Complex ranged from 4.41 µg/L in well USGS 60 to 37.0 µg/L in well PW-9. The maximum concentration of chromium of 37 µg/L in well PW-9 in October 2015 increased from 11 µg/L in October 2011 (table 10; fig. 26); however, the long-term trend for this constituent has been decreasing in this well along with most other perched wells around the ATR Complex (Davis and others, 2015, appendix D).

Sodium

Dissolved sodium was not sampled for in shallow perched groundwater at the ATR Complex (table 10). During April or October 2015, dissolved sodium concentrations in water from 18 wells completed in deep perched groundwater were determined and ranged from 7.09 to 33.4 mg/L (table 10). The highest concentration was in water from well USGS 68 (table 10); the sodium concentration in well USGS 68 decreased from 146 mg/L in April 2011 (Davis and others, 2013, table 10). Sodium concentrations in this well have varied through time, but overall show a decreasing trend (Davis and others, 2015, fig. 23). The reason for the variability of the concentrations in well USGS 68 probably is a result of movement of water through the unsaturated zone from the chemical-waste pond which was closed in 1999, and the closure of the pond is why concentrations have decreased.

Chloride

Concentrations of dissolved chloride in most wells varied during 2012–15 (table 10). During April 2015, dissolved chloride concentrations in shallow perched groundwater ranged from 10.9 mg/L in well CWP 1 to 15.2 mg/L in well CWP 3 (table 10). Dissolved chloride concentrations in deep perched groundwater during April or October 2015 ranged from 4.18 mg/L in well USGS 78 to 78.1 mg/L in well USGS 73. High concentrations of chloride were in water from deeper perched groundwater wells in the western part of the perched groundwater zone at the ATR Complex and both USGS 73 and PW-9 have shown increasing trends with time (Davis and others, 2015, fig. 19). The increasing concentrations may be a result of movement of remnant water through the unsaturated zone from the chemical-waste pond, which was closed in 1999.

Table 10. Concentrations of selected dissolved ions in perched groundwater from selected wells, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, 2012–15.

[Analyses completed by the U.S. Geological Survey National Water Quality Laboratory. **Well No.:** Locations of wells are shown in figure 7. DP, well completed in deep perched water; SP, well completed in shallow perched water; NR, analysis not requested; µg/L, microgram per liter; mg/L, milligram per liter. **Symbol:** <, less than respective reporting level]

Well No.	Date sampled	Chromium, dissolved (µg/L)	Sodium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Sulfate, dissolved (mg/L)
CWP 1 (SP)	04-11-12	2.61	NR	14.1	76.0
	04-08-13	2.49	NR	15.7	84.6
	04-16-14	3.29	NR	14.2	76.7
	04-13-15	2.82	NR	10.9	27.5
CWP 3 (SP)	04-11-12	<0.6	NR	19.3	175
	04-08-13	0.888	NR	17.5	98.5
	04-16-14	<0.6	NR	19.2	162
	04-13-15	<0.6	NR	15.2	44.4
CWP 8 (SP)	04-11-12	<0.6	NR	10.5	51.8
	04-08-13	<0.6	NR	6.05	13.4
	04-16-14	<0.6	NR	13.2	89.5
	04-13-15	<0.6	NR	12.3	44.4
PW 8 (DP)	04-09-12	6.26	17.6	21.7	229
	04-08-13	4.92	12.7	15.7	106
	04-01-14	5.82	16.0	20.7	204
	03-31-15	5.40	13.6	15.3	85.6
PW 9 (DP)	10-11-12	33.9	21.7	47.3	70.9
	10-30-13	39.4	21.4	55.0	68.9
	10-20-14	21.2	20.6	52.9	66.5
	10-20-15	37.0	20.4	49.1	66.8
USGS 53 (DP)	11-26-12	9.26	12.3	13.3	41.6
	10-16-14	1.52	16.6	14.8	89.1
USGS 54 (DP)	10-11-12	4.73	12.0	13.4	49.9
	11-04-13	4.74	15.3	17.4	149
	10-15-14	3.95	14.7	13.7	66.4
	10-01-15	5.11	14.4	14.0	76.5
USGS 55 (DP)	04-09-12	27.5	18.5	18.2	151
	05-20-13	24.2	16.0	15.4	95.2
	04-02-14	24.7	16.3	17.5	140
	03-31-15	23.0	16.1	15.2	85.9
USGS 56 (DP)	10-17-12	27.9	20.5	12.2	29.1
	10-28-13	49.9	22.6	12.0	35.9
	10-16-14	37.6	20.8	13.0	30.1
	10-14-15	28.7	17.2	15.0	29.8
USGS 60 (DP)	04-17-13	4.03	12.6	14.6	79.9
	09-30-13	4.57	13.5	16.7	122
	10-20-14	4.23	13.1	15.4	99.5
	10-13-15	4.41	14.2	16.0	109
USGS 61 (DP)	04-09-12	7.03	14.0	17.8	162
	04-08-13	5.34	12.8	16.7	109
	03-31-14	10.6	12.9	16.2	133
	03-31-15	6.55	13.3	16.3	123

Table 10. Concentrations of selected dissolved ions in perched groundwater from selected wells, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, 2012–15.—Continued

Well No.	Date sampled	Chromium, dissolved (µg/L)	Sodium, dissolved (mg/L)	Chloride, dissolved (mg/L)	Sulfate, dissolved (mg/L)
USGS 62 (DP)	10-10-12	5.98	15.3	16.3	118
	04-08-13	6.78	16.0	17.8	142
	03-31-14	6.71	15.8	20.3	197
	03-31-15	8.04	15.0	15.4	88.7
USGS 63 (DP)	10-10-12	7.50	14.9	15.2	90.6
	11-04-13	12.1	16.7	23.0	234
	10-15-14	5.31	16.3	19.3	152
	10-15-15	16.1	14.2	18.1	136
USGS 66 (DP)	10-15-12	8.60	16.6	20.0	202
	10-28-13	6.19	14.8	17.0	137
	10-22-14	7.24	15.6	19.8	170
	10-20-15	6.53	14.9	15.5	118
USGS 68 (DP)	04-10-12	NR	172	30.8	638
	04-16-13	NR	80.6	20.1	297
	04-03-14	NR	58.5	15.9	191
	04-01-15	NR	33.4	16.8	89.8
USGS 69 (DP)	10-10-12	NR	9.73	15.1	46.6
	09-30-13	NR	10.7	16.9	82.5
	10-15-14	NR	11.8	17.9	89.3
	10-01-15	NR	12.0	17.0	83.4
USGS 70 (DP)	04-16-12	8.39	16.5	19.2	171
	04-17-13	7.11	13.7	15.6	94.3
	04-01-14	10.7	15.7	19.6	185
	04-02-15	7.90	13.3	15.4	81.2
USGS 71 (DP)	10-17-12	16.6	12.6	17.5	150
	10-28-13	15.5	14.1	18.8	172
	10-16-14	14.0	12.8	18.8	166
	10-14-15	16.5	15.1	17.8	155
USGS 72 (DP)	04-10-12	25.3	32.0	29.8	27.4
	04-16-13	25.4	23.9	23.7	25.6
	04-03-14	18.3	19.5	19.2	25.4
	04-01-15	18.8	18.4	18.8	24.3
USGS 73 (DP)	10-11-12	25.3	19.7	37.5	47.0
	11-04-13	25.4	20.1	64.0	49.8
	04-02-15	18.3	17.7	39.7	47.1
	10-20-15	18.8	21.2	78.1	52.5
USGS 78 (DP)	10-17-12	NR	6.42	4.59	20.0
	10-28-13	NR	6.06	4.51	19.7
	10-16-14	NR	6.58	4.16	18.8
	10-14-15	NR	7.09	4.18	19.3

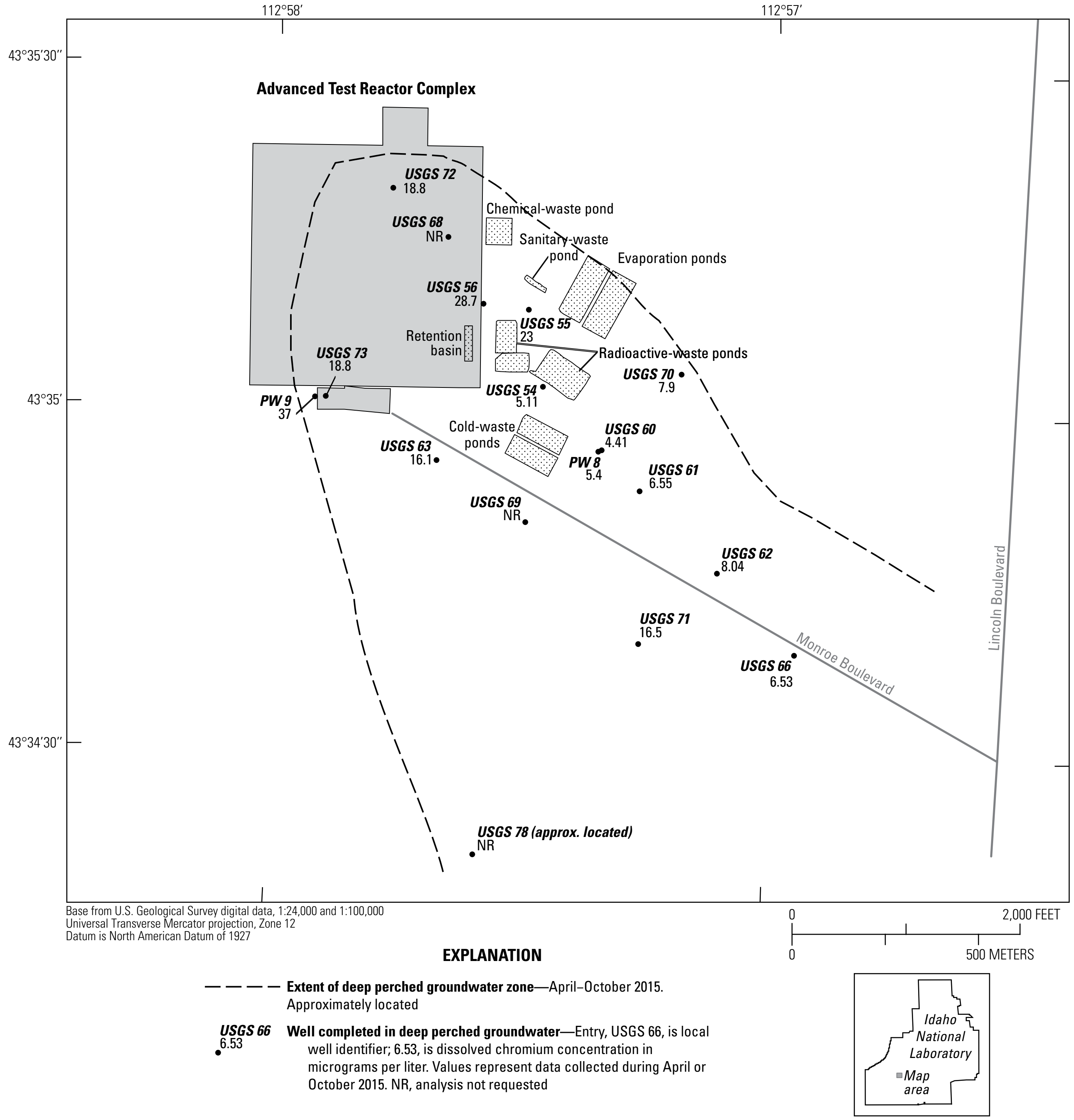


Figure 26. Concentrations of dissolved chromium in water from wells completed in deep perched groundwater, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, April or October 2015.

Sulfate

The maximum dissolved sulfate concentration in shallow perched groundwater at the ATR Complex was 175 mg/L in well CWP 3 in April 2012. Concentrations of dissolved sulfate in this well vary greatly and ranged from 44.4 to 175 mg/L during 2012 to 2015. During 2009–11, the concentrations ranged from 46 to 274 mg/L (Davis and others, 2013, table 10). The variable concentrations are probably a result of changes in the amount of sulfate disposal to the cold-waste ponds.

Concentrations of dissolved sulfate in water from wells completed in deep perched groundwater at the ATR Complex near the cold-waste ponds (USGS 54, 60, 61, 62, 63, 66, 69, 70, 71 and PW 8) ranged from 76.5 in well USGS 54 to 155 mg/L in well USGS 71 during April–October 2015 (table 10, fig. 27). These high concentrations indicate that water in these wells also were affected by discharge into the cold-waste ponds. During 2009–11, the maximum concentration of dissolved sulfate in deep perched groundwater was 1,546 mg/L in well USGS 68 (Davis and others, 2013, table 10), west of the chemical-waste pond (fig. 7). The dissolved sulfate concentration in this well had decreased to 89.8 mg/L by April 2015, and the declining trend in this well is attributed to discontinued use of the chemical-waste pond in 1999.

Idaho Nuclear Technology and Engineering Center

Two percolation ponds were constructed south of the INTEC in 1984 and 1985 to replace the INTEC disposal well (fig. 7). Wastewater infiltrating from these ponds formed perched groundwater in the basalt and sedimentary interbeds above the ESRP aquifer in the southern part of INTEC. The old percolation ponds were taken out of service when new percolation ponds, located about 2 mi southwest of INTEC (fig. 4), were put into service in August 2002 (U.S. Department of Energy, 2011a). The USGS continued to monitor water from wells in the perched groundwater zone near the old percolation ponds until the last well (PW 4) went dry in 2008. Deeper perched groundwater near the center of the INTEC was monitored from samples collected from well USGS 50 (fig. 7) until the well was abandoned in 2009. Davis (2010) gives the final analyses of data collected from the USGS perched groundwater monitoring around the INTEC. Perched groundwater has been detected in other areas at the INTEC as well and may be attributed to leaking wastewater pipelines, leach fields, damaged casing in the upper part of the disposal well, other infiltration ponds, flow from the Big Lost River, precipitation recharge, or landscape irrigation (Tucker and Orr, 1998; Mirus and others, 2011). Information on water quality monitoring of perched groundwater wells in other areas of INTEC from monitoring done by INL contractors are documented in annual groundwater monitoring reports with 2015 data presented in U.S. Department of Energy (2016).

Starting in April 2010, the USGS began to monitor perched groundwater in well ICPP-MON-V-200 (fig. 4), about 2 mi southwest of INTEC, for a general indication of water chemistry from the new percolation ponds installed in 2002 to better understand what effects the ponds may have on water quality in the ESRP aquifer. Chemical constituent results from well ICPP-MON-V-200 compared with the water chemistry from CPP-1 (a production well at INTEC used to represent water quality before wastewater constituents are added) (Knobel and others, 1999) indicated that wastewater discharged to the new percolation ponds had increased concentrations of chloride, sodium, and nitrate (Davis and others, 2013). During 2012–15, concentrations of chloride, sodium, and nitrate ranged from 19.7 to 27.5 mg/L; 16.9 to 29.3 mg/L; and 1.1 to 1.81 mg/L, respectively.

Radioactive Waste Management Complex

Perched groundwater beneath the RWMC is in sedimentary interbeds in basalts and can be attributed primarily to local snowmelt and rain infiltration, and to recharge from the Big Lost River and the INL spreading areas. This perched groundwater contains constituents leached from buried radioactive and organic-chemical wastes. Liquid and solid waste materials buried at the RWMC (fig. 1) also are sources of some constituents in perched groundwater. Perched groundwater beneath buried waste can be an integral part of the pathway for waste-constituent migration to the ESRP aquifer. The extent of this perched groundwater is affected by the waste-disposal practices.

Well USGS 92 (fig. 4) is in the SDA at the RWMC and is completed in a sedimentary interbed (Anderson and Lewis, 1989, p. 29) at 214 ft BLS. Perched groundwater in this well has moved through overlying sediments and basalt and contains waste constituents leached from radiochemical and organic-chemical wastes buried in the SDA.

During 2012–15, tritium concentrations in water samples from well USGS 92 (table 11) exceeded the reporting level in three samples and ranged from less than the reporting level at 120±60 pCi/L in April 2015 to 580±70 pCi/L in April 2012. Tritium concentrations in water from well USGS 92 have varied through time and show no trend (Davis and others, 2015, appendix C).

Historically, the concentration of americium-241 in water from well USGS 92 was greater than the reporting level in October 1992, and the concentration of plutonium-238 was greater than the reporting level in November 1994 (Bartholomay, 1998). Since the 1990s, concentrations of these constituents, as well as strontium-90, cesium-137, and plutonium-239, 240 (undivided), have been less than the reporting levels.

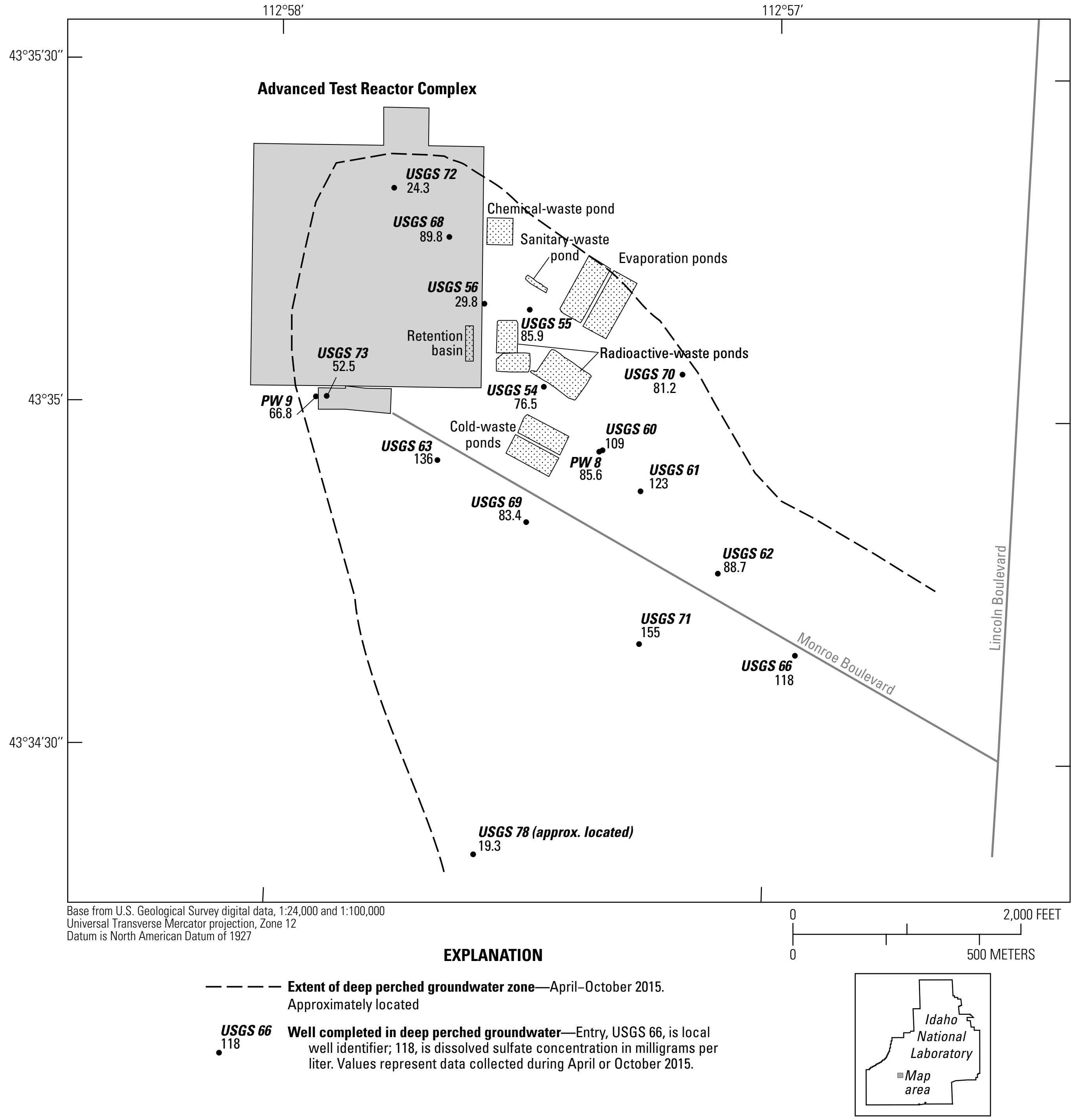


Figure 27. Concentrations of dissolved sulfate in water from wells completed in deep perched groundwater, Advanced Test Reactor Complex, Idaho National Laboratory, Idaho, April or October 2015.

Dissolved chloride concentrations in water from water samples collected from well USGS 92 during 2012–15 ranged from 104 to 106 mg/L (table 11). Dissolved chloride concentrations have increased over time, but the increase has not been statistically significant (Davis and others, 2015, appendix D).

In 1987, nine VOCs were detected in water from well USGS 92 (Mann and Knobel, 1987, p. 16–17). Since then, from 6 to 18 different VOCs have been detected during various reporting periods. Water from well USGS 92 was sampled for VOCs in April 2012–15. Table 12 lists the concentrations of nine VOCs detected. All VOCs detected in April 2012–15 had been detected previously in this well. Additionally, all VOC concentrations detected in 2012–15 were substantially lower than those detected in 2010–11 (table 11, this report; Davis and others, 2013, table 13). This decrease in VOC concentrations may be a result of removal of VOCs from the subsurface at the SDA by vapor vacuum extraction processes done by the INL contractor from 1996 to present (2016).

Table 11. Concentrations of tritium, strontium-90, cesium-137, selected transuranic elements, and dissolved chloride in perched groundwater from well USGS 92, Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, 2012–15.

[Analyses completed by the Department of Energy's Radiological and Environmental Sciences Laboratory and the U.S. Geological Survey National Water Quality Laboratory. Analyses for radionuclides, analytical uncertainties are reported as 1 times the sample standard deviation. Concentrations equal to or greater than 3 times the sample standard deviation are considered to be greater than the reporting level and are **bold**. **Well No.:** Location of well is shown in figure 7. **Abbreviations:** NR, inadequate amount of water for sample; mg/L, milligram per liter; pCi/L, picocurie per liter; USGS, U.S. Geological Survey. **Symbol:** ±, plus or minus]

Well No.	Date	Tritium (pCi/L)	Strontium-90 (pCi/L)	Cesium-137 (pCi/L)	Plutonium-238 (pCi/L)	Plutonium-239, 240 (undivided) (pCi/L)	Americium-241 (pCi/L)	Chloride (dissolved) (mg/L)
USGS 92	04-12-12	**580±70**	0.7±0.7	10±7	-0.003±0.005	0.012±0.008	0.016±0.014	104
	04-11-13	**360±60**	NR	NR	NR	NR	NR	105
	04-17-14	**230±50**	NR	NR	NR	NR	NR	106
	04-16-15	120±60	-0.10±0.6	29±12	-0.003±0.003	0.003±0.007	0.02±0.015	105

Table 12. Concentrations of selected volatile organic compounds in perched groundwater from well USGS 92, Radioactive Waste Management Complex, Idaho National Laboratory, Idaho, 2012–15.

[Location of well USGS 92 is shown in figure 7. Analyses completed by the U.S. Geological Survey's National Water Quality Laboratory using an analytical method that conforms to U.S. Environmental Protection Agency Method 524.2. **Volatile organic compound name:** Names in parentheses are alternate compound names. **Abbreviation:** NWIS, National Water Information System. **Symbol:** <, less than respective reporting level]

Volatile organic compound name	NWIS parameter code	Concentration by date, in micrograms per liter			
		04-12-12	04-11-13	04-17-14	04-16-15
1,2-Dichloroethane	P32103	0.294	<0.2	0.207	<0.2
Carbon Tetrachloride (Tetrachloromethane)	P32102	12.9	7.3	E10.7	6.97
Chloroform (Trichloromethane)	P32106	24.0	16.8	E21.9	14.4
Tetrachloroethylene (Tetrachloroethene)	P34475	3.04	4.2	2.14	1.4
1,1-dichloroethane	P34496	0.383	0.3	E0.276	0.174
1,1-dichloroethylene (1,1,-dichloroethene)	P34501	0.157	0.1	0.103	<0.1
1,1,1-trichloroethane	P34506	1.89	2.0	E1.54	0.768
1,2-dichloropropane	P34541	0.351	0.3	0.286	0.19
Trichloroethylene (Trichloroethene)	P39180	16.8	15.9	11.1	10.2

Summary

Radiochemical and chemical wastewater discharged since 1952 to infiltration ponds and disposal wells at the Idaho National Laboratory (INL) has affected water quality in the eastern Snake River Plain (ESRP) aquifer and in perched groundwater zones at the INL. The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, maintains ESRP aquifer and perched groundwater monitoring networks at the INL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the ESRP aquifer and in perched groundwater zones.

Water in the ESRP aquifer primarily moves through fractures and interflow zones in basalt, generally flows southwestward, and eventually discharges at springs along the Snake River near Twin Falls, Idaho, about 100 mi southwest of the INL. Estimated discharge from the springs was about 3.45 million acre-feet per year for water year 2015. The aquifer is recharged primarily from infiltration of irrigation water, infiltration of streamflow, groundwater inflow from adjoining mountain drainage basins, and infiltration of precipitation.

During March–May 2015, the altitude of the water table of the ESRP aquifer was about 4,560 feet (ft) in the northern part of the INL and about 4,410 ft in the southwestern part. Water flowed south and southwestward beneath the INL at an average hydraulic gradient of about 4 feet per mile.

Water levels in ESRP aquifer wells declined 3.92 to 5.03 ft in the northern part of the INL from March–May 2011 to March–May 2015. In the central and eastern part of the INL, water levels declined from about 1 to 2.5 ft during March to May 2011–15. In the southwestern part of the INL, water levels generally declined by approximately 0.5 to 2 ft during March to May 2011–15. The water-level declines near wells along the Big Lost River can be attributed to no flow in the river during the last 3 years of the study period.

Disposal of wastewater to infiltration ponds and infiltration of surface water at the Advanced Test Reactor Complex (ATR Complex) and Idaho Nuclear Technology and Engineering Center (INTEC) resulted in formation of perched groundwater in basalts and in sedimentary interbeds that overlie the ESRP aquifer. Perched groundwater beneath the Radioactive Waste Management Complex (RWMC) formed from infiltration of snowmelt and rain and recharge from the Big Lost River and INL spreading areas. This perched groundwater contains constituents leached from buried radioactive and organic-chemical wastes. Perched groundwater is an integral part of the pathway for waste-constituent migration to the ESRP aquifer.

During 2005–12, 11 ESRP aquifer wells were equipped with MLMS that enabled water samples and pressure and temperature measurements to be acquired at isolated depths in each of the wells. This multilevel monitoring helps to describe the vertical distribution of water chemistry and pressure and temperature gradients in addition to the horizontal distribution information previously gathered from open boreholes.

A tritium plume developed in the ESRP aquifer from discharge of wastewater at the INL since the 1950s. Concentrations of tritium in water samples collected in 2015 from 49 of 118 aquifer wells were greater than the reporting level and ranged from 230±50 to 5,760±120 picocuries per liter (pCi/L). The tritium plume extended south-southwestward in the general direction of groundwater flow. In 2015, concentrations of tritium in water samples generally decreased from 2009 to 2011, and all concentrations were less than the maximum contaminant level of 20,000 pCi/L.

Tritium concentrations in ESRP aquifer water from the three sampling zones from well USGS 105 (851, 952, and 1,072 ft BLS) sampled during 2012–15 exceeded the reporting level in all three zones during at least two sampling events with the largest concentration of 460 ±60 pCi/L in zone 8 (952 ft BLS) in June 2014. During 2012–15, tritium concentrations in water samples from the MLMS installed in well USGS 103 from the four deepest zones were greater than the reporting level during at least one sampling event from 2012 to 2015, with the largest concentration of 380 ±70 pCi/L in zone 6 (1,087 ft BLS) in June 2012. Tritium concentrations in water samples from the four zones in the MLMS installed in well USGS 137A completed near the southern boundary were less than the reporting level except for one sample (July 2013 sample from zone 4, 747 ft BLS; 250 ±50 pCi/L). Water from various depths in six other wells equipped with the MLMS was sampled and analyzed for tritium during 2012–15. Tritium concentrations in water from wells USGS 134 and Middle 2050A did not exceed the reporting level in any of the zones sampled during 2012–15. Other results showed that tritium concentrations in water from one or more zones in wells USGS 132, 133, Middle 2051, and USGS 131A were greater than the reporting level during 2012–15. The tritium concentrations greater than the reporting levels are attributed to wastewater disposal at the INTEC and the ATR Complex

Tritium concentrations in water from 13 wells completed in deep perched groundwater near the ATR Complex generally were greater than or equal to the reporting level during at least one sampling event during 2012–15 and concentrations ranged from 210 ±60 to 28,100 ±900 pCi/L.

During 2015, concentrations of strontium-90 in ESRP aquifer water from 18 aquifer wells exceeded the reporting level. Concentrations that exceeded the reporting level in the aquifer wells ranged from 2.2 ±0.7 pCi/L to 17.6 ±0.9 pCi/L in wells near INTEC; the largest concentration of 539 ±12 pCi/L was in a well at TAN. The area of the strontium-90 plume near the INTEC extended south-southwestward in the general direction of groundwater flow. Strontium-90 has not been detected in the ESRP aquifer beneath the ATR Complex partly because of the exclusive use of waste-disposal ponds and lined evaporation ponds rather than the disposal well for radioactive-wastewater disposal at that facility. Sorption processes in sediments in the unsaturated zone beneath the radioactive waste-disposal pond could have minimized or prevented strontium-90 migration to the aquifer at the ATR Complex. MLMS equipped wells USGS 131A and 137A were sampled for strontium-90 during 2012–13. None of the water from any zones sampled contained concentrations of strontium-90 greater than the reporting level.

During at least one sampling event during 2012–15, concentrations of strontium-90 in water from 12 wells completed in deep perched groundwater at the ATR Complex equaled or exceeded the reporting levels and concentrations ranged from 1.8 ±0.6 to 73.6 ±2 pCi/L.

During 2012–15, water from 69 ESRP aquifer wells was sampled and analyzed for cesium-137. Cesium-137 concentrations in water from four of these wells equaled or slightly exceeded the reporting level, but the wells were not located together. Concentrations of cesium-137 exceeding the reporting level ranged from 25 ±8 to 33 ±11 pCi/L. Concentrations of cesium-137 also equaled or slightly exceeded the reporting level in four wells equipped with MLMS. During 2012–15, concentrations of plutonium-238 and plutonium-239, -240 (undivided) in water from all 25 aquifer wells and all zones in 2 wells equipped with MLMS (USGS 131A and 137A) were less than the reporting level.

Gross alpha and beta measurements are used to screen for radioactivity in the ESRP aquifer as a possible indicator of groundwater contamination. During 2012–15, water from 48 ESRP aquifer wells was sampled and analyzed for gross alpha-particle radioactivity. Concentrations of gross alpha-particle radioactivity in four wells equaled the reporting level and ranged from 6 ±2 to 44 ±9 pCi/L. Additionally, concentrations of gross alpha-particle radioactivity in water from three wells equipped with MLMS equaled or exceeded the reporting level and ranged from 9±3 to 15±4 pCi/L. Concentrations of gross alpha-particle radioactivity in water from all other samples in the wells sampled and analyzed were less than the reporting level.

During 2012–15, concentrations of gross beta-particle radioactivity in water from most of the ESRP wells equaled or exceeded the reporting level in at least one of the sampling periods and ranged from 2.1 ±0.7 to 12.8 ±1.2 pCi/L. Concentrations of gross beta-particle radioactivity in all 11 wells equipped with MLMS were greater than the reporting level in multiple zones during 2012–15. The increase in the number of wells containing concentrations of gross beta-particle radioactivity exceeding the reporting level from previous reporting periods likely reflects the increase in sensitivity and change in the reporting radionuclide from cesium-137 to strontium-90/yttrium-90 by RESL in 2008.

In April 2009, the dissolved chromium concentration in water from one ESRP aquifer well, USGS 65, south of ATR Complex equaled the maximum contaminant level (MCL) of 100 µg/L. In April 2015, the concentration of chromium in water from that well had decreased to 72.8 µg/L, much less than the MCL. Concentrations in water samples from 62 other wells sampled ranged from <0.6 to 25.4 µg/L. During 2012–15, dissolved chromium was detected in water from all wells completed in deep perched groundwater at the ATR Complex and concentrations ranged from 4.41 to 37 µg/L.

In 2015, concentrations of sodium in water from most ESRP aquifer wells in the southern part of the INL were greater than the background concentration of 8.3 milligrams per liter (mg/L). During 2015, the highest sodium concentration in water samples from aquifer wells near the INTEC was 38.8 mg/L in a water sample from well USGS 51. After the new percolation ponds were put into service in 2002 southwest of the INTEC, concentrations of sodium in water samples from the Rifle Range well increased steadily until 2008, when the concentrations generally began decreasing. Sodium concentrations in most MLMS-equipped wells generally varied little with depth.

During 2015, dissolved sodium concentrations in water from 18 wells completed in deep perched groundwater ranged from 7.09 to 33.4 mg/L. The highest concentration was in water from well USGS 68 and the concentrations decreased from 146 mg/L in April 2011, and the decrease is attributed to discontinued disposal in the former chemical-waste ponds.

In 2015, concentrations of chloride in most water samples from ESRP aquifer wells closest to the INTEC and the CFA exceeded background concentrations. Trends in chloride concentrations in water from wells downgradient of the old percolation ponds at the INTEC generally decreased because of discontinued disposal. After the new percolation ponds were put into service in 2002 southwest of the INTEC, concentrations of chloride increased steadily in water samples from the Rifle Range well until 2008, when the concentrations began decreasing. Most of the concentrations in 11 MLMS wells are less than or near background concentrations for western tributary water at the INL. Wells USGS 131A and 137A were completed in 2012 and chloride concentrations in the upper two zones in well USGS 131A were greater than background and larger than the two deepest zones. Chloride concentrations in well USGS 137A were relatively consistent in all but the upper zone, which had concentrations slightly larger than background. Chloride concentrations in the three samples zones in well USGS 108 and the three deepest zones in well USGS 103 were greater than background concentrations. The greater than background concentrations represent influence from wastewater disposal.

During 2012–15, dissolved chloride concentrations in deep perched groundwater from 18 wells at the ATR Complex ranged from 4.16 to 78.1 mg/L. Higher concentrations of chloride were in water from deeper perched groundwater wells in the western part of the perched groundwater zone at the ATR Complex. The increasing concentrations may be a result of movement of remnant water through the unsaturated zone from the chemical-waste pond that was closed in 1999.

In 2015, sulfate concentrations in water samples from ESRP aquifer wells in the south-central part of the INL that exceeded the background concentration of sulfate ranged from 22 to 162 mg/L. The greater than background concentrations in water from these wells probably resulted from sulfate disposal at the ATR Complex infiltration ponds or the old INTEC percolation ponds. In 2015, sulfate concentrations in water samples from wells near the RWMC were mostly greater than background concentrations and could have resulted from well construction techniques and (or) waste disposal at the RWMC or the ATR complex. The vertical distribution of sulfate concentrations in multilevel monitoring wells near the southern boundary of the INL generally varied little with depth, and ranged between 17 and 28 mg/L.

The maximum dissolved sulfate concentration in shallow perched groundwater near the ATR Complex was 175 mg/L in well CWP 3 in April 2012. During 2012–15, dissolved sulfate concentrations in water from 18 wells completed in deep perched groundwater at the ATR Complex ranged from 18.8 to 638 mg/L.

In 2015, concentrations of nitrate in water from most ESRP aquifer wells at and near the INTEC exceeded the background concentration of 0.655 mg/L. Concentrations ranged from 0.496 to 5.52 mg/L. Nitrate concentrations at the INL near INTEC have mostly decreased in response to reduced disposal rates and to the transition in 1984 from injection of wastewater to the INTEC disposal well to discharge to the old percolation ponds. The two exceptions to decreasing or no trends are wells USGS 20 and 67 which show variable decreases and increases but overall have been increasing. The cause of the increases could be due to mobilization of nitrate beneath the INTEC tank farm, as both wells are downgradient from the INTEC tank farm.

In the southern part of CFA, nitrate concentrations in water from ESRP aquifer well CFA-2 indicate an increasing trend. Nitrate concentrations in water samples collected in 2015 from wells CFA-2 and USGS 130 in the southern part of CFA were 3.89 and 3.38 mg/L, respectively (fig. 22), and these concentrations are higher than most other wells upgradient and downgradient from CFA. Nitrate contamination south of CFA has been attributed to contamination from the old CFA mercury pond south of the facility, and it is possible that the elevated nitrate in these wells could be due to movement of nitrate in the unsaturated zone from the old CFA pond.

Nitrate concentrations in several ESRP aquifer wells in the eastern part of the INL were greater than the background concentration of about 1 mg/L for eastern regional recharge. The trends for many of these wells were also increasing and the increasing trends were attributed to agricultural and other anthropogenic influences upgradient of the INL.

Nitrate concentrations with depth in the 11 MLMS equipped ESRP aquifer wells sampled during 2012–15 ranged from 0.468 mg/L in well USGS 134 at 706 ft BLS to 1.31 mg/L in well USGS 131A at 812 ft BLS. Most of the concentrations are near or greater than background concentrations for western tributary water at the INL.

During 2015, water samples from four ESRP aquifer wells near INTEC were analyzed for fluoride and concentrations ranged from 0.17 to 0.22 mg/L. These concentrations were in the range of background concentrations of fluoride in the ESRP aquifer for the western part of the INL, which indicates that wastewater disposal has not had an appreciable effect on fluoride concentrations in the ESRP aquifer near the INTEC.

During 2012–15, water samples from 32 ESRP aquifer wells were collected and analyzed for VOCs. Eighteen different VOCs were detected. Water samples collected from 14 wells during 2012–15 each contained at least 1 and up to 7 of the different VOCs detected. The primary VOCs detected included carbon tetrachloride, trichloromethane, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. Concentrations for all VOCs except carbon tetrachloride in three wells near RWMC, trichloroethene in three wells near TAN and vinyl chloride in one well near TAN were less than the MCL for drinking water. In addition to these wells, during 2015, 31 wells at and near INTEC were sampled for 49 VOCs as part of a special study. One to 5 different VOCs were measured above detection levels in 29 of the 31 wells.

During 2012–15, nine VOCs were detected in perched aquifer water from well USGS 92 near the RWMC. All VOC concentrations detected were substantially lower than those detected in 2010–11. This decrease in VOC concentration may be a result of removal of VOCs from the subsurface at the SDA by vapor vacuum extraction processes done by the INL contractor from 1996 to the present (2016).

During 2012–15, variability and bias were evaluated from 54 replicate and 33 blank quality-assurance samples. Results from replicate analyses were investigated to evaluate sample variability. Constituents with acceptable reproducibility were major ions, nutrients, and VOCs. All radiochemical constituents and trace metals had acceptable reproducibility except for gross alpha- and beta-particle radioactivity, cesium-137, antimony, cobalt, iron, and manganese. The samples that did not meet reproducibility criteria all had very small concentrations. Bias from sample contamination was evaluated from equipment, field, container, and source-solution blanks. Concentrations of some of the constituents were small near reporting levels, but analyses indicate that no sample bias was likely for any of the sample periods.

Acknowledgments

The U.S. Department of Energy's Radiological and Environmental Sciences Laboratory (RESL) at the Idaho National Laboratory provided radiochemical analyses of water samples. Anita Bhatt, Director, supervised technical staff at the RESL during 2012–15.

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Publishing support provided by the U.S. Geological Survey
Science Publishing Network, Tacoma Publishing Service Center

For more information concerning the research in this report, contact the
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Bartholomay and others—**An Update of Hydrologic Conditions in Water, Idaho National Laboratory, Idaho, 2012–15**—Scientific Investigations Report 2017–5021

ISSN 2328-0328 (online)
https://doi.org/10.3133/sir20175021