Evaluation of Background Concentrations of Selected Chemical and Radiochemical Constituents in Water from the Eastern Snake River Plain Aquifer at and near the Idaho National Laboratory, Idaho

Scientific Investigations Report 2016–5056

U.S. Department of the Interior
U.S. Geological Survey

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By Roy C. Bartholomay and L. Flint Hall

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SALLY JEWELL, Secretary

U.S. Geological Survey
Suzette M. Kimball, Director

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
Length		
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi^2)	2.590	square kilometer (km^2)
Flow rate		
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m^3/yr)
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)
Radioactivity		
picocurie per liter (pCi/L)	0.037	becquerel per liter (Bq/L)

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.

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 Reactor Area)
CERCLA	Comprehensive Environmental Response Compensation and Liability Act
CFCs	chlorofluorocarbons
DOE	U.S. Department of Energy
ESRP	eastern Snake River Plain
INL	Idaho National Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
NRF	Naval Reactors Facility
MCL	Maximum Contaminant Level
PBF	Power Burst Facility
RWMC	Radioactive Waste Management Complex
TAN	Test Area North
USGS	U.S. Geological Survey

Evaluation of Background Concentrations of Selected Chemical and Radiochemical Constituents in Water from the Eastern Snake River Plain Aquifer at and near the Idaho National Laboratory, Idaho

By Roy C. Bartholomay[1] and L. Flint Hall[2]

Abstract

The U.S. Geological Survey and Idaho Department of Environmental Quality Idaho National Laboratory (INL) Oversight Program in cooperation with the U.S. Department of Energy determined background concentrations of selected chemical and radiochemical constituents in the eastern Snake River Plain aquifer to aid with ongoing cleanup efforts at the INL. Chemical and radiochemical constituents including calcium, magnesium, sodium, potassium, silica, chloride, sulfate, fluoride, bicarbonate, chromium, nitrate, tritium, strontium-90, chlorine-36, iodine-129, plutonium-238, plutonium-239, -240 (undivided), americium-241, technetium-99, uranium-234, uranium-235, and uranium-238 were selected for the background study because they were either not analyzed in earlier studies or new data became available to give a more recent determination of background concentrations. Samples of water collected from wells and springs at and near the INL that were not believed to be influenced by wastewater disposal were used to identify background concentrations. Groundwater in the eastern Snake River Plain aquifer at and near the INL was divided into two major water types (western tributary and eastern regional) based on concentrations of lithium less than and greater than 5 micrograms per liter (µg/L). Median concentrations for each constituent were used to define the upper limit of background.

The upper limit of background concentrations for inorganic chemicals for western tributary water was 40.7 milligrams per liter (mg/L) for calcium, 15.3 mg/L for magnesium, 8.30 mg/L for sodium, 2.32 mg/L for potassium, 23.1 mg/L for silica, 11.8 mg/L for chloride, 21.4 mg/L for sulfate, 0.20 mg/L for fluoride, 176 mg/L for bicarbonate, 4.00 µg/L for chromium, and 0.655 mg/L for nitrate.

The upper limit of background concentrations for inorganic chemicals for eastern regional water was 34.05 mg/L for calcium, 13.85 mg/L for magnesium, 14.85 mg/L for sodium, 3.22 mg/L for potassium, 31.0 mg/L for silica, 14.15 mg/L for chloride, 20.2 mg/L for sulfate, 0.4675 mg/L for fluoride, 165 mg/L for bicarbonate, 3.00 µg/L for chromium, and 0.995 mg/L for nitrate.

The upper limit of background concentrations for radiochemical constituents for western tributary water was 34.15 ±2.35 picocuries per liter (pCi/L) for tritium, 0.00098 ±0.00006 pCi/L for chlorine-36, 0.000011 ±0.000005 pCi/L for iodine-129, <0.0000054 pCi/L for technetium-99, 0 pCi/L for strontium-90, plutonium-238, plutonium-239, -240 (undivided), and americium-241, 1.36 pCi/L with undetermined uncertainty for uranium-234, 0.025 ±0.001 pCi/L for uranium-235, and 0.541 ±0.001 pCi/L for uranium-238.

The upper limit of background concentrations for radiochemical constituents for eastern regional water was 5.43 ±0.574 pCi/L for tritium, 0.0002048 ±0.0000054 pCi/L for chlorine-36, 0.000000865 ±0.000000015 pCi/L for iodine-129, <0.0000054 pCi/L for technetium-99, 0 pCi/L for strontium-90, plutonium-238, plutonium-239, -240 (undivided), and americium-241, 1.32 ±0.77 pCi/L for uranium-234, 0.016 ±0.012 pCi/L for uranium-235, and 0.477 ±0.044 pCi/L for uranium-238.

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, 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.

[1]U.S. Geological Survey.

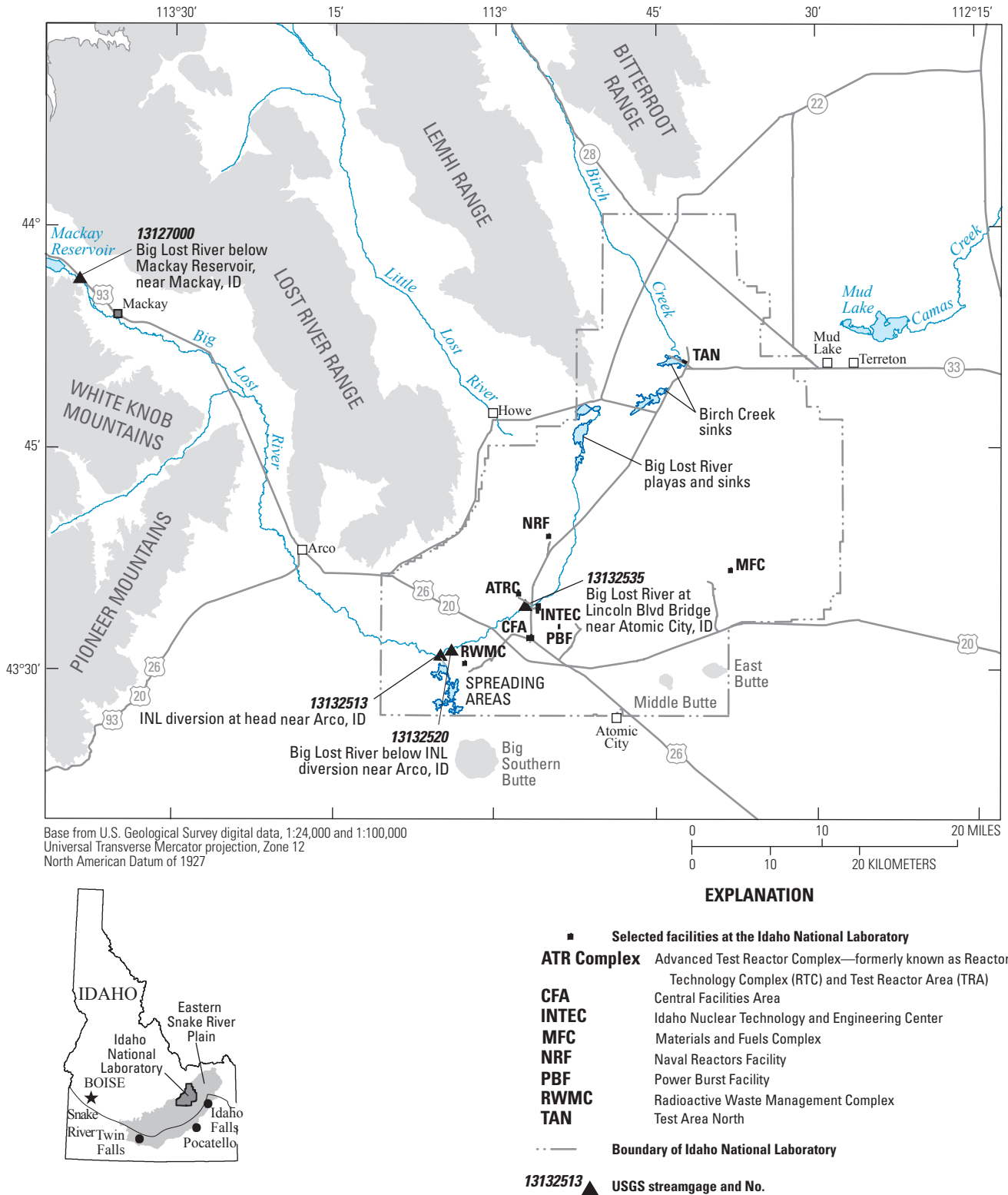[2]Idaho Department of Environmental Quality.

Figure 1.   Location of Idaho National Laboratory and selected facilities, Idaho.

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 within the Subsurface Disposal Area (SDA) at the Radioactive Waste Management Complex (RWMC) also have contributed contaminants to groundwater.

Since 1949, the U.S. Geological Survey (USGS) has worked in cooperation with the DOE at the INL to define (1) the quality and availability of water for human consumption, (2) the usability of the water for supporting construction and cooling of facilities, (3) the location and movement of contaminants in the ESRP aquifer and perched groundwater zones, (4) the sources of recharge to the aquifer, (5) an early detection network for contaminants moving past the INL boundaries, and (6) the processes controlling the origin and distribution of contaminants and naturally occurring constituents in the aquifer (Ackerman and others, 2010). Since its inception, the USGS water-quality monitoring program at the INL has included a network that once numbered as many as 200 wells. The network of wells has been sampled over the years for tritium, strontium-90, cesium-137, plutonium-238, plutonium-239, -240 (undivided), americium-241, gross alpha- and gross beta-radioactivity, sodium, bromide, chloride, fluoride, sulfate, nitrate, chromium and other trace elements, volatile organic compounds (VOCs), and total organic carbon (TOC) (Davis and others, 2013). Special studies have also analyzed chlorine-36 (Cl-36) (Beasley and others, 1993; Cecil and others, 1999), iodine-129 (I-129) (Mann and Beasley, 1994b; Cecil and others, 2003; Bartholomay, 2009, 2013), and technetium-99 (Tc-99) (Beasley and others, 1998).

The DOE, in accordance with the requirements of the Resource Conservation and Recovery Act and the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), completed background studies in the early 1990s to characterize groundwater and soils at the INL. The USGS published two reports on background concentrations in groundwater at the INL (Orr and others, 1991; Knobel and others, 1992); however, the reports did not compile background concentrations for some chemical and radiochemical constituents that may be of concern at the INL. In addition, several comprehensive sampling events took place after the background studies, so this report is being prepared to evaluate background concentrations at the INL with data collected since 1990.

Purpose and Scope

The purpose of this report is to present an analysis of water-quality data for calcium, magnesium, sodium, potassium, silica, chloride, sulfate, fluoride, bicarbonate, chromium, nitrate, tritium, strontium-90, Cl-36, I-129, plutonium-238, plutonium-239, -240 (undivided), americium-241, Tc-99, uranium-234 (U-234), -235 (U-235), and -238 (U-238) to evaluate background concentrations for CERCLA cleanup criteria. Analyses included reviewing

previous datasets from wells at and near the INL that were not believed to be influenced by INL waste and wastewater disposal activities, along with water-quality trends of the data when available, to produce a subset of wells to calculate means, medians, and ranges. Background concentrations are defined as groundwater influenced by western tributary recharge in the western INL and by eastern regional recharge in the eastern INL. Background concentrations are either naturally occurring or anthropogenic (substances present in the environment as a result of human activities), and are not influenced by waste and wastewater disposal at the INL. Recharge types are differentiated from each other using the 5-µg/L line of equal lithium concentration defined in Fisher and others (2012, fig. 13).

Geohydrologic Setting

The INL is located on the west-central part of the ESRP. The ESRP is a northeast-trending structural basin about 200 mi long and 50 to 70 mi wide (fig. 1). The basin, bounded by faults on the northwest and by downwarping and faulting on the southeast, has been filled with basaltic lava flows that are interbedded with terrestrial sediments. The basaltic rocks and sedimentary deposits combine to form the ESRP aquifer, which is the primary source of groundwater for the ESRP.

The ESRP aquifer is one of the most productive aquifers in the United States (U.S. Geological Survey, 1985, p. 193). Groundwater generally moves from northeast to southwest, and eventually discharges to springs along the Snake River downstream of Twin Falls, Idaho, about 100 mi southwest of the INL (fig. 1). Groundwater moves horizontally through basalt interflow zones and vertically through joints and interfingering edges of basalt flows. Infiltration of surface water, extensive pumping, geohydrologic conditions, and seasonal fluxes of recharge and discharge locally affect the movement of groundwater (Garabedian, 1986). The ESRP aquifer is recharged primarily from infiltration of applied irrigation water, infiltration of streamflow, groundwater inflow from adjoining mountain drainage basins, and infiltration of precipitation (Ackerman and others, 2006).

At the INL, depth to water in wells completed in the ESRP aquifer ranges from about 200 ft below land surface in the northern part of the INL to more than 900 ft below land surface in the southeastern part of the INL. A substantial proportion of the groundwater moves through the upper 200 to 800 ft of basaltic rock (Mann, 1986, p. 21). Ackerman (1991, p. 30) and Bartholomay and others (1997, table 3) reported transmissivity values for basalt in the upper part of the aquifer ranging from 1.1 to 760,000 ft^2/d. The hydraulic gradient at the INL ranges from 2 to 10 ft/mi, with an average of 4 ft/mi (Davis and others, 2013, fig. 9). Horizontal flow velocities of 2 to 26 ft/d have been calculated based on the movement of various constituents in different areas of the aquifer at and near the INL (Robertson and others, 1974; Mann and Beasley, 1994b; Cecil and others, 2000; Plummer and others, 2000; Busenberg and others, 2001). These flow

rates equate to a travel time of about 50–700 years for water beneath the INL to travel to springs that discharge at the terminus of the ESRP groundwater-flow system near Twin Falls, Idaho. Localized tracer tests at the INL have shown that vertical- and horizontal-transport rates are as high as 60–150 ft/d (Nimmo and others, 2002; Duke and others, 2007).

Olmsted (1962), Robertson and others (1974), and Busenberg and others (2001) classified groundwater at the INL based on chemical types derived from dissolution of the rocks and minerals within the recharge source areas. Olmsted's type A water consisted of calcium and magnesium concentrations that constituted at least 85 percent of the cations, and bicarbonate constituted at least 70 percent of the anions. Type A water is present in the central and western parts of the INL. Type A water is attributed to seepage loss from the Big Lost River and from groundwater underflow from the Big Lost River, Little Lost River, and Birch Creek drainage basins to the west and northwest of the INL (fig. 1) that contain alluvium derived from Paleozoic carbonate rocks from the surrounding mountains.

Olmsted's type B water, which is characterized by higher equivalent fractions of sodium, potassium, fluoride, and silica than type A water, underlies much of the eastern part of the INL and is commonly referred to as regional water. Type B groundwater originates from the area northeast of the INL that is composed of a much higher fraction of rhyolitic and andesitic volcanic rocks than mountains west and northwest of the INL that contribute to type A water. Busenberg and others (2001) used dating techniques of chlorofluorocarbons (CFCs), sulfur hexafluoride, and tritium/helium to further classify the regional water at the INL into two types based on the recharge type of the young fraction of groundwater. Water in the southeastern part of the INL represented a binary mixture of old regional groundwater underflow (water greater than 40 or 55 years old that did not contain tritium or CFCs, respectively) with young water derived from rapid, focused recharge, probably from precipitation infiltration. Water in the northeastern part of the INL is old, regional groundwater underflow that is mixed with local, rapid, focused recharge; slow, diffuse areal recharge through the unsaturated zone; and agricultural return flow from the Mud Lake and Terreton areas (fig. 1). The 5-µg/L line of equal lithium concentration (fig. 2) defined in Fisher and others (2012, fig. 13) is very similar to the boundary between type A and B water defined by Olmsted (1962).
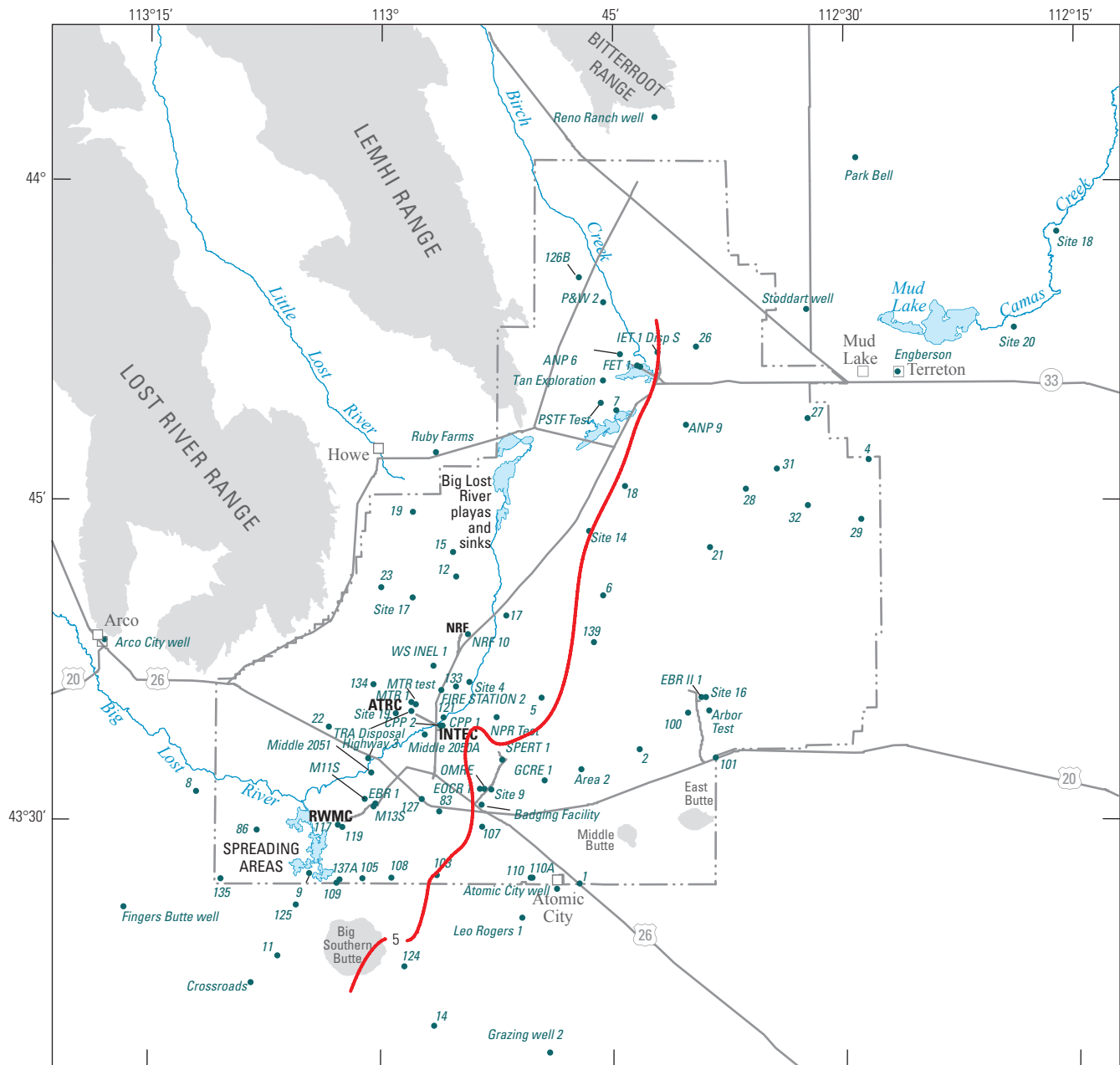
Previous Investigations

Early work defining background concentrations at the INL was accomplished by Robertson and others (1974). Natural distributions for chemical constituents including calcium, magnesium, sodium, potassium, bicarbonate, sulfate, nitrate, fluoride, and silica are presented in Robertson and others (1974, figs. 21–30). Data used to calculate concentration ranges are also presented in Robertson and others (1974, appendix B). Calcium concentrations ranged

from a high of about 50 mg/L toward the northwest decreasing southeastward to about 30 mg/L. Magnesium concentrations ranged from a high of about 20 mg/L to the northwest to a low of about 10 mg/L in the southeast. Sodium concentrations ranged from a high of about 15 mg/L to the east to 6 mg/L near the western mountains. Potassium concentrations decreased from east to west across the INL. Background concentrations of chloride ranged from 6 to 10 mg/L with localized areas with much larger concentrations to the south and southwest of Mud Lake. Bicarbonate exhibits a pattern of decreasing concentration southeastward away from the western mountains. Sulfate decreased from about 25 mg/L to the northwest to 10 mg/L to the southeast. Nitrate (as nitrate) concentrations around the entire INL ranged from about 2 to 5 mg/L. Fluoride concentrations ranged from 0.1 to 0.3 mg/L in the western INL to as high as 0.9 mg/L in the southeastern part of the INL. Silica concentrations showed a decreasing trend from about 30 mg/L in the southeast to 15 mg/L in the western part of the INL.

Orr and others (1991) did the first extensive summary of background constituents for selected radionuclides, organic compounds, and chemical constituents. Orr and others (1991) reported background tritium concentrations that ranged from 75 to 150 pCi/L. They also reported that concentrations of transuranic elements and strontium-90 should not be present in the aquifer and I-129 background concentrations should be between 0 and 0.05 pCi/L. Background concentrations of organic compounds were less than 0.2 µg/L. Orr and others (1991) also presented background concentration ranges for several trace elements including chromium, which was reported to have a range between 2 and 3 µg/L. Nitrate (as nitrogen) concentrations ranged from 0 to about 1.4 mg/L.

Knobel and others (1992) did a summary of background concentrations and compared several of the parameter constituents to the background values calculated by Orr and others (1991). Knobel and others (1992) reported background concentrations for strontium-90, plutonium-238, plutonium-239, -240 (undivided), americium-241, and I-129 as 0 pCi/L. Background concentrations for tritium were estimated to be from 0 to 40 pCi/L using data from the Magic Valley downgradient of the INL. Upper level background concentration ranges for gross alpha, beta, gamma measurements, and total uranium isotopes reported by Knobel and others (1992) were smaller than those reported by Orr and others (1991). Conversely, background concentrations of purgeable organic compounds and trace elements were calculated to be the same as Orr and others (1991). Background concentrations of nitrate as nitrogen was 1–2 mg/L.

Mann and Beasley (1994a) made the first attempt to derive background concentrations of I-129 using accelerator mass spectrometry methods, which allowed for much lower reporting levels than previous methods used at the INL. Mann and Beasley (1994a) calculated I-129 concentrations from 16 sites including groundwater and surface-water samples around the ESRP and calculated a background concentration of 0.0000082 pCi/L at the 99-percent confidence level.

Figure 2.   Line of equal lithium concentration separating water types and location of wells used for background calculations at and near the Idaho National Laboratory, Idaho.

Mann and Beasley (1994b) derived background concentrations of I-129 using accelerator mass spectrometry methods, which allowed for much lower reporting levels than previous methods used at the INL. Mann and Beasley (1994b) interpreted that I-29 concentrations in water collected from well USGS 121 (well upgradient of INTEC) at the INL were representative of the background concentration for I-129 in the aquifer and indicated that background was less than or equal to 0.0000012 pCi/L.

Cecil and others (2003) reevaluated the I-129 background concentration in the aquifer using a subset of 30 groundwater samples and estimated background for I-129 to be 0.0000054 pCi/L with a 95-percent nonparametric confidence interval of 0.0000052–0.00001 pCi/L.

Cecil and others (1999) evaluated concentrations of Cl-36 from water, snow, and mid-latitude glacial ice and determined that only concentrations greater than 1×10^9 atoms/L (or 0.002 pCi/L) measured in the environment at the INL could be attributed to wastewater disposal.

Methods of Data Analyses

Data for background concentrations of selected chemical and radiochemical constituents in water are presented as a minimum and maximum concentration with a calculated median and mean. Datasets used to calculate median and means with censored data (concentration values less than a reporting level for chemical constituents) were calculated using one-half the value of the reporting level. General information for groundwater sampling sites selected for data analyses is shown in appendix A. Data for wells used to calculate background concentrations for chemical constituents are shown in appendix B. Data for wells used to calculate background concentrations for radiochemical constituents are shown in appendix C. Location of wells and springs used for background calculations are given in figures 1–4. Caution should be used when interpreting median and mean concentrations because the data may not be normally
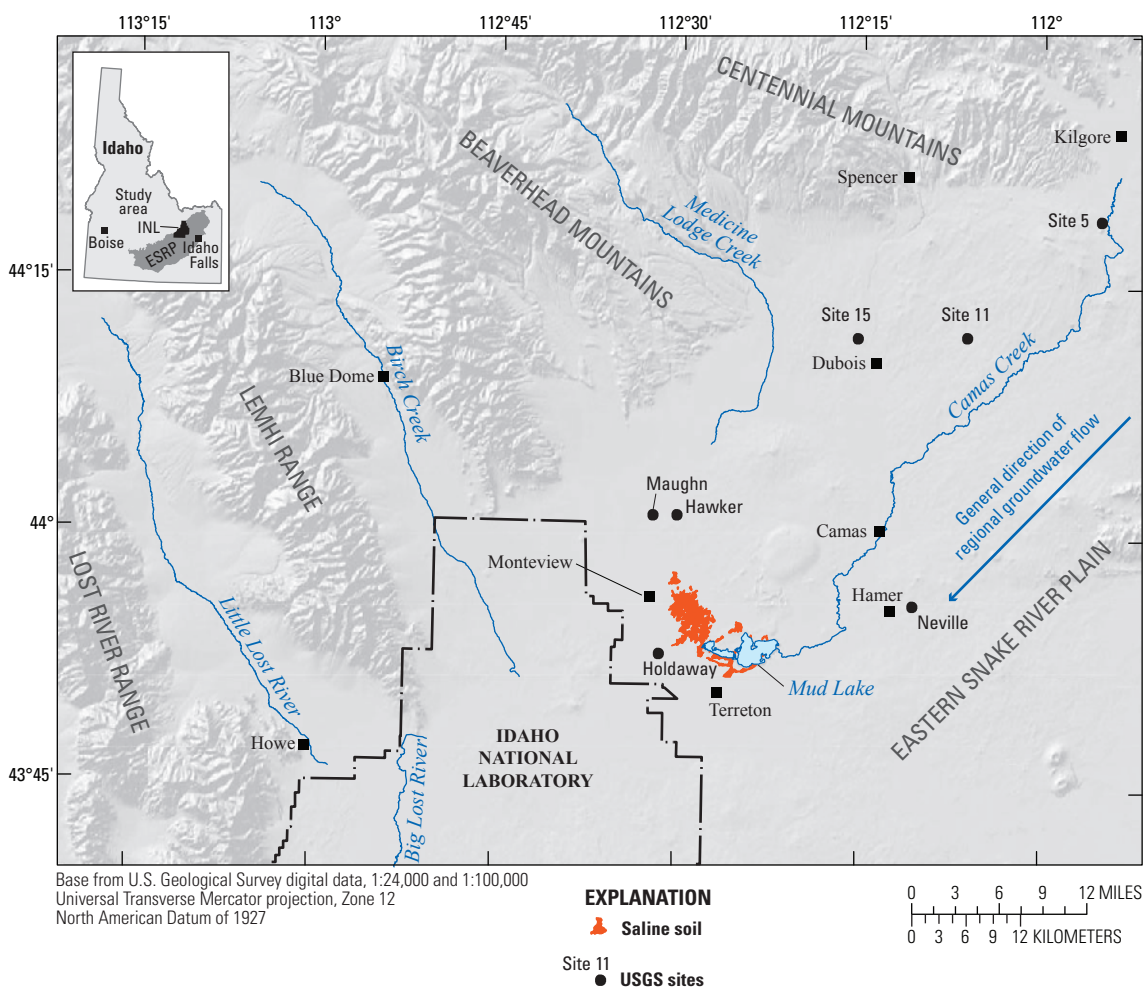
Figure 3.   Location of wells used for background calculations north and northeast of the Idaho National Laboratory, Idaho.
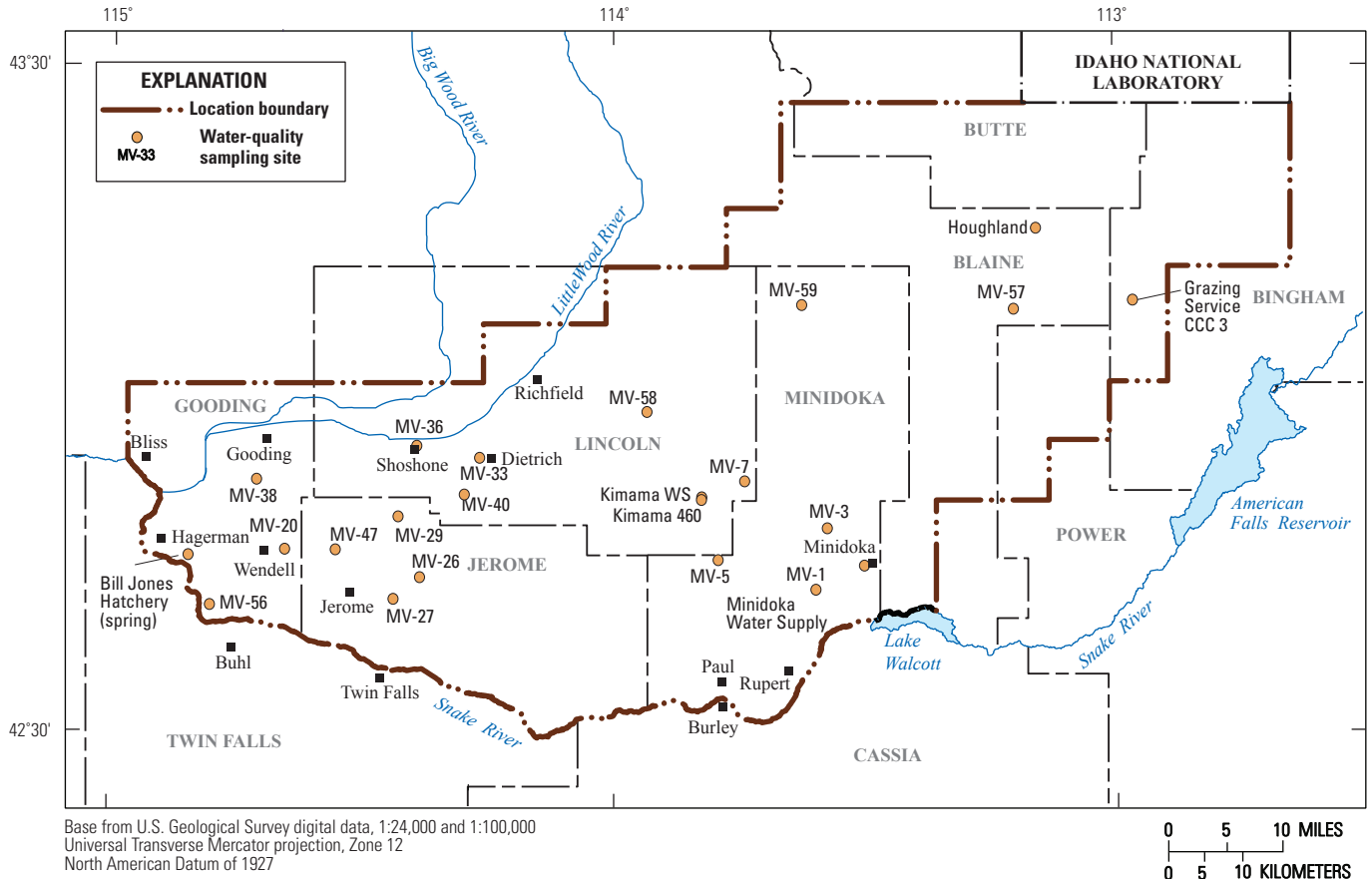
Figure 4. Location of wells and springs used for background calculations south and southwest of the Idaho National Laboratory, Idaho.

or log-normally distributed and may not represent true background concentrations for the selected constituents in the ESRP aquifer. Factors that may differ among datasets and influence the comparability of the data are water-sample collection methods and field-preservation methods (Knobel and others, 1992), along with different time periods for data collection. Also, the wells used to calculate background concentrations are a combination of several water types and sources collected at different times (Bartholomay and Twining, 2010; Rattray and Ginsbach; 2014, Rattray, 2015). Sample collection and methods for analyses for each constituent collected followed USGS or Idaho State Department of Environmental Quality methods that were described in the corresponding report for which the data were collected. Data collected by the USGS INL Project were collected in accordance with quality assurance most recently described by Bartholomay and others (2014).

Water samples from wells selected to calculate background concentrations were chosen because they generally were not believed to have been influenced by wastewater disposal. Some of the wells downgradient from

waste disposal areas at the INL may or may not have had some minor wastewater influence as noted with low level radiochemical analyses, but were used for calculating background concentrations of chemical constituents and for radiochemical analyses when appropriate. This study does not attempt to exclude wells that have had anthropogenic influences from bomb testing in the 1960s or from farming or other human practices that have occurred in the upgradient tributary areas that recharge the aquifer that moves through the INL. Because of this, median values of the datasets are used as the upper limit for background for most of the constituents as opposed to maximum concentrations or complex statistical derivations. Busenberg and others (2001); Bartholomay and Twining, (2010); Rattray and Ginsbach, (2014); and Rattray (2015) showed that most of the wells at and upgradient of the INL include a mixture of old and young water and that wells commonly contain a mixture of different types of water. The 5 μg/L line of equal lithium concentration (fig. 2) separates the western tributary and eastern regional water types as described by Fisher and others (2012, fig. 13).

The analytical results for radionuclides are presented with calculated analytical uncertainties (counting errors). There is about a 67-percent probability that the true radionuclide concentration is in a range of the reported concentrations plus or minus the uncertainty. The uncertainties are expressed as 1 sample standard deviation (Knobel and others, 1992). For single measurements on samples collected at different locations and (or) times, it is not appropriate to propagate the uncertainties for the individual measurements when calculating the mean because of the variability in sample collection. Sampling variability is usually assumed to be much larger than laboratory measurement variability. Therefore, the standard error of the mean is the best estimate of uncertainty for the mean measurement (and median measurement when the median value is collected from an even numbered dataset). It is calculated using equation 1 (McCurdy and others, 2008).

$$s\left(\overline{\mathrm{x}}\right) = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{\mathrm{x}})^2}{n(n-1)}} \qquad (1)$$

where

$s\left(\overline{\mathrm{x}}\right)$	is the standard error of the mean,
x_i	is the sample concentration,
$\overline{\mathrm{x}}$	is mean of sample concentrations,
$\sum$	is the sum, and
n	is number of samples.

Some of the radiochemical values in appendix C are presented as negative values. Negative analytical results occur if the radioactivity of the water sample is less than the background radioactivity or radioactivity of the prepared blank sample ran along with it in the laboratory (Knobel and others, 1992). A similar distribution of data about the median value should occur if the true background concentration is greater than zero, so median radionuclide concentrations are used to estimate the upper range of background.

Background Concentrations of Selected Chemical Constituents

For chemical constituents, historical data from Olmsted (1962) along with data from selected wells from a tributary geochemical study (Rattray and Ginsbach, 2014), data from an INL geochemical study (Knobel and others, 1999), data from an age dating study (Busenberg and others, 2000), some data downgradient from the INL (Bartholomay and others, 2001; Twining and Bartholomay, 2011), and some data from multiple levels in the aquifer (Bartholomay and Twining, 2010; Bartholomay and others, 2015) were used to calculate background. The minimum, maximum, median, and mean from the concentrations given in appendix B for calcium, magnesium, sodium, potassium, silica, bicarbonate, sulfate, chloride, nitrate, fluoride, and chromium are shown in table 1. A water trend study completed by Bartholomay and others (2012) showed that some wells exhibited temporal variability because of wet and dry cycles and some wells showed concentration variability because of sample collection methods used, for example, collecting samples from a well with a thief sampler and later collecting samples from the same well with a pump in it. For these reasons, median values are used to represent the upper range of background concentrations instead of the upper values of the ranges.

Calcium

Calcium is the fifth most abundant element in the Earth's crust and present in several of the mineral types in the ESRP. Groundwater at the INL primarily contains calcium ions from the hydrolysis of calcite and dolomite that make up much of the Paleozoic carbonate rocks comprising much of the mountains and alluvial sediments northwest of the INL (Robertson and others, 1974, p. 62). High concentrations in the Mud Lake area have been attributed to irrigation water infiltrating through sediments containing evaporite deposits and subsequent dissolution of the deposits (Rattray, 2015).

Calcium has been detected in water samples from various wells at and around the INL (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 22.6 to 71.1 mg/L for western tributary water with a median of 40.7 mg/L and ranged from 19.0 to 68.9 mg/L for eastern regional water with a median of 34.05 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Magnesium

Magnesium is among the most prevalent elements in the Earth's crust and present in several of the mineral types in the ESRP. Groundwater at the INL primarily contains magnesium ions from the hydrolysis of dolomite that make up much of the Paleozoic carbonate rocks comprising the mountains and alluvial sediments northwest of the INL; however, weathering of clay minerals may also contribute some magnesium. High concentrations in the Mud Lake area have been attributed to recharge from evaporatively concentrated irrigation water (Robertson and others, 1974, p. 62).

Magnesium has been detected in water samples from various wells at and around the INL (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 10.1 to 27.4 mg/L for western tributary water with a median of 15.3 mg/L and ranged from 5.0 to 28.6 mg/L for eastern regional water with a median of 13.85 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Table 1.   Statistical summary of selected chemical and radiochemical concentrations in water samples at and near the Idaho National Laboratory, Idaho.

[Statistical summaries are from data in appendixes B and C. **Abbreviations:** UND, undetermined because numerical calculation equals zero; mg/L, milligram per liter; µg/L, microgram per liter; pCi/L, picocurie per liter]

Constituent	Sample size	Minimum	Maximum	Median	Mean
			Western tributary water		
Calcium, mg/L	75	22.6	71.1	40.7	41.2
Magnesium, mg/L	75	10.1	27.4	15.3	15.5
Sodium, mg/L	75	2.6	27.0	8.30	9.29
Potassium, mg/L	75	1.2	5.8	2.32	2.41
Silica, mg/L	75	14.4	41.0	23.1	23.3
Bicarbonate, mg/L	74	91	261	176	176
Sulfate, mg/L	75	9.57	40.4	21.4	22.7
Chloride, mg/L	75	4.90	66.6	11.8	14.6
Nitrate as nitrogen, mg/L	75	<0.04	3.59	0.655	[1]0.760
Fluoride, mg/L	75	0.10	1.50	0.20	0.222
Chromium, µg/L	64	<0.012	45	[2]4.00	[1]5.53
Tritium, pCi/L	54	-0.64±0.96	149±4.86	34.15±2.35	47.7±5.36
Strontium-90, pCi/L	46	-4±2	2.6±1.6	-0.1125±0.0125	-0.339±0.182
Chlorine-36, pCi/L	8	0.0002±0.00002	0.01±0.004	0.00098±0.00006	0.0024±0.00115
Iodine-129, pCi/L	11	0.0000055±0.0000002	0.00005±0.0000025	0.000011±0.000005	0.0000164±0.0000039
Plutonium-238, pCi/L	45	-0.04±0.02	0.02±0.02	-0.003±0.003	-0.003±0.001
Plutonium-239-240 (undivided), pCi/L	45	-0.01±0.01	0.03±0.02	0.003±0.006	0.0008±0.001
Americium-241, pCi/L	45	-0.06±0.03	0.04±0.03	-0.003±0.012	-0.005±0.003
Technetium-99, pCi/L	9	<0.0000027	0.081±0.003	[2]<0.0000054	[1]0.018±0.01
Uranium-234, pCi/L	24	0.043±0.018	1.9±0.11	1.36±UND	1.21±0.104
Uranium-235, pCi/L	24	0±0.0008	0.048±0.016	0.025±0.001	0.019±0.003
Uranium-238, pCi/L	24	0.021±0.011	0.719±0.048	0.541±0.001	0.447±0.04
			Eastern regional water		
Calcium, mg/L	46	19.0	68.9	34.05	35.8
Magnesium, mg/L	46	5.0	28.6	13.85	13.9
Sodium, mg/L	46	9.0	38.2	14.85	16.0
Potassium, mg/L	46	2.30	6.80	3.22	3.49
Silica, mg/L	46	6.89	47.1	31.0	30.4
Bicarbonate, mg/L	45	122	340	165	168
Sulfate, mg/L	46	9.0	42.1	20.2	20.7
Chloride, mg/L	46	5.6	61.9	14.15	17.5
Nitrate as nitrogen, mg/L	46	<0.05	6.50	0.995	[1]1.33
Fluoride, mg/L	46	0.190	1.30	0.4675	0.486
Chromium, µg/L	40	<1	28.0	3.00	[1]4.07
Tritium, pCi/L	42	-4±2.3	72.4±2.9	5.43±0.574	10.3±2.47
Strontium-90, pCi/L	23	-3.5±1.5	3.3±1.6	0.3±0.6	-0.135±0.40
Chlorine-36, pCi/L	23	0.000066±0.000006	0.00178±0.0001	0.0002048±0.0000054	0.000378±0.00009
Iodine-129, pCi/L	26	0.00000007±0.000000008	0.0000177±0.000001	0.000000865±0.000000015	0.0000025±0.00000079
Plutonium-238, pCi/L	23	-0.6±0.02	0.3±0.3	-0.003±0.005	-0.029±0.026
Plutonium-239-240 (undivided), pCi/L	23	-0.02±0.01	0.013±0.016	0.003±0.007	0.001±0.002
Americium-241, pCi/L	23	-0.7±0.05	-0.01±0.02	0.02±0.03	-0.042±0.030
Technetium-99, pCi/L	1	<0.0000027	NA	NA	NA
Uranium-234, pCi/L	3	0.327±0.032	1.52±0.084	1.32±0.77	1.06±0.368
Uranium-235, pCi/L	3	0±0.006	0.034±0.013	0.016±0.012	0.017±0.01
Uranium-238, pCi/L	3	0.157±0.021	0.594±0.046	0.477±0.044	0.409±0.131

[1]One-half of reporting level used for calculation of mean.

[2]One-half of reporting level used for calculation of median.

Sodium

Sodium is an abundant element in the Earth's crust and present in several of the mineral types in the ESRP. High concentrations in the Mud Lake area have been attributed to irrigation water infiltrating through sediments containing evaporite deposits and subsequent dissolution of the deposits (Rattray, 2015). Dissolution from sodium chloride in soil and contributions from thermal water also have been suggested as possibilities for high sodium concentrations in the Mud Lake area (Robertson and others, 1974, p. 62).

Sodium has been detected in water samples from various wells at and around the INL (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 2.6 to 27.0 mg/L for western tributary water with a median of 8.30 mg/L and ranged from 9.0 to 38.2 mg/L for eastern regional water with a median of 14.85 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Potassium

Potassium is a mineral-forming element in a large variety of crustal rocks and is present in several of the mineral types in the ESRP. High concentrations in the Mud Lake area have been attributed to irrigation (Robertson and others, 1974, p. 68).

Potassium has been detected in water samples from various wells at and around the INL (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 1.2 to 5.8 mg/L for western tributary water with a median of 2.32 mg/L and ranged from 2.3 to 6.8 mg/L for eastern regional water with a median of 3.22 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Silica

Silicon is the second most abundant element in the Earth's crust and is present in silicate minerals that make up a large amount of the rock types of the ESRP. Higher concentrations in the eastern regional water than in the western tributary water are attributed to mineralogical differences between rhyolitic source rocks present in the eastern tributaries versus carbonate rocks present in the western tributaries (Knobel and others, 1997).

Silica (SiO_2 or $Si(OH)_4$) has been detected in water samples from various wells at and around the INL (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 14.4 to 41.0 mg/L for western tributary water with a median of 23.1 mg/L and ranged from 6.89 to 47.1 mg/L for eastern regional water with a median of 31.0 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Bicarbonate

Bicarbonate is an anion with the empirical formula of HCO_3^- and is present in the ESRP aquifer from the dissolution of carbonate minerals and rocks that are predominant in mountain ranges surrounding the ESRP. Bicarbonate is calculated from alkalinity measurements performed in the field and has been reported in several studies (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 91 to 261 mg/L for western tributary water with a median of 176 mg/L and ranged from 122 to 340 mg/L for eastern regional water with a median of 165 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Sulfate

Sulfate is predominantly present in evaporite deposits of gypsum and anhydrite in the ESRP. High concentrations in the Mud Lake area have been attributed to irrigation water infiltrating through sediments containing evaporite deposits and subsequent dissolution of the deposits (Rattray, 2015).

Sulfate has been detected in water samples from various wells at and around the INL (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 9.57 to 40.4 mg/L for western tributary water with a median of 21.4 mg/L and ranged from 9.0 to 42.1 mg/L for eastern regional water with a median of 20.2 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Chloride

Chloride predominantly forms halite with sodium and may be present in evaporite deposits in the ESRP or in salt deposits in soils. High concentrations in the Mud Lake area have been attributed to irrigation water infiltrating through sediments containing evaporite deposits and subsequent dissolution of the deposits (Rattray, 2015). Dissolution from sodium chloride in soil and contributions from thermal water also have been suggested as possibilities for high chloride concentrations in the Mud Lake area (Robertson and others, 1974).

Chloride has been detected in water samples from various wells at and around the INL (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 4.9 to 66.6 mg/L for western tributary water with a median of 11.8 mg/L and ranged from 5.6 to 61.9 mg/L for eastern regional water with a median of 14.15 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Nitrate

Nitrate is an anion that is naturally present owing to atmospheric and soil organic sources. Additionally, nitrate is present in the ESRP aquifer at the INL from anthropogenic sources including chemical and organic fertilizers and sewage disposal from practices taking place in source waters to the INL; it is also present from wastewater disposal practices and disposal of nitrate salts at the INL. Nitrate is normally analyzed as nitrite plus nitrate, but nitrate is the predominant form. The MCL for nitrate as nitrogen is 10 mg/L (40 CFR §141.62).

Nitrate has been reported in several studies (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from <0.04 to 3.59 mg/L for western tributary water with a median of 0.655 mg/L and ranged from <0.05 to 6.50 mg/L for eastern regional water with a median of 0.995 mg/L (as N) (table 1); median concentrations are considered the upper limit of background for each water type.

Fluoride

Fluoride is present in nearly all igneous and metamorphic rocks where it substitutes for the hydroxyl in mineral structures. Fluoride has been used as a flux in industrial processes and is commonly added to drinking water supplies as a means of reducing dental caries (Simpson, 1972). Fluoride has been discharged in wastewater at INTEC (Davis and others, 2013) and has a maximum contaminant level (MCL) of 4.0 mg/L (40 CFR §141.62).

Fluoride has been detected in water samples from various wells at and around the INL (Olmsted, 1962; Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from 0.1 to 1.5 mg/L for western tributary water with a median of 0.2 mg/L and ranged from 0.190 to 1.30 mg/L for eastern regional water with a median of 0.4675 mg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Chromium

Chromium is introduced into the Earth's crust as a component of basaltic magmas from deeper levels in the mantle, and it typically is precipitated from magmas at an early stage, either in chromium spinel or in silicate minerals especially clinopyroxene (Smith, 1972). Little chromium goes into solution and thus natural water has a low concentration. Chromium has been discharged in wastewater at the ATR Complex and INTEC (Davis and others, 2013), and has a MCL in drinking water of 100 µg/L (40 CFR §141.62).

Chromium has been detected in water samples from various wells at and around the INL (Knobel and others, 1999; Busenberg and others, 2000; Bartholomay and others, 2001; Swanson and others, 2003; Bartholomay and Twining, 2010; Rattray and Ginsbach, 2014; Bartholomay and others, 2015). The minimum, maximum, median, and mean concentrations are shown in table 1. Concentrations ranged from <0.012 to 45 µg/L for western tributary water with a median of 4.00 µg/L and ranged from <1 to 28.0 µg/L for eastern regional water with a median of 3.00 µg/L (table 1); median concentrations are considered the upper limit of background for each water type.

Background Concentrations of Selected Radiochemical Constituents

The upper level background concentration of tritium, 150 pCi/L, defined by Orr and others (1991) was used to determine which wells or zones from wells (in the case of the multilevel monitoring systems) would be used to calculate background for radiochemical constituents. Data for the other radiochemical constituents considered for this study were included if the well met the tritium criteria of having concentrations less than 150 pCi/L. Some wells were included if no tritium data were available, and in the case of I-129, some wells were excluded if past report information indicated contamination from wastewater disposal at the INL.

Tritium

Tritium, the radioactive isotope of hydrogen, is formed in nature by the interactions of cosmic rays with gases in the upper atmosphere. Tritium also is produced in thermonuclear detonations and is a waste product of the nuclear power industry (Orr and others, 1991). Tritium has a half-life of 12.43 years (Walker and others, 1989). The natural concentration of tritium in surface water ranged from 5 to 20 pCi/L prior to atmospheric weapons testing (Eisenbud, 1973, p. 188). Concentrations of tritium in precipitation near the INL reached a maximum of about 4,300 pCi/L in the early 1960s as a result of nuclear weapons testing (Michel, 1989, table 12). Background concentrations for groundwater at the INL in the early 1990s were reported to be between 0 and 150 pCi/L (Orr and others, 1991; Knobel and others, 1992).

Background tritium concentrations were calculated for datasets from Busenberg and others (2000), Bartholomay and others (2001), Bartholomay and Twining (2010), Twining and others (2010), Ginsbach (2013), Rattray and Ginsbach (2014), and Bartholomay and others (2015) (appendix C). In order to reduce variability in laboratories and detection levels, samples used for background concentrations were only analyzed at two different laboratories as described by Busenberg and others (2000) to determine tritium concentrations. Laboratory method detection levels were generally about 1 pCi/L. Samples were collected during different time periods ranging from 1993 to 2012 and were not corrected for radioactive decay, which is part of the reason for using median concentrations for background instead of maximum concentrations. Analytical methods used for the analyses are described in Busenberg and others (2000). Concentrations of tritium in western tributary water ranged from -0.64 ±0.96 to 149 ±4.86 pCi/L with a median concentration of 34.15 ±2.35 pCi/L, which is considered the upper limit of background (table 1). Concentrations of tritium in eastern regional water ranged from -4 ±2.3 to 72.4 ±2.9 pCi/L with a median concentration of 5.43 ±0.574 pCi/L, which is considered the upper limit of background (table 1).

Strontium-90

Strontium-90 does not occur naturally with the exception of natural reactors such as Oklo, where nuclear fission reactions have occurred in an uranium-enriched deposit (Durrance, 1986, p. 90). Strontium-90 has been discharged in wastewater and detected in several wells at the INL (Davis and others, 2013). It 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 (40 CFR §141.66).

Strontium-90 was analyzed in water samples from 46 wells and zones from wells that sample western tributary water and 23 wells and zones from wells that sample eastern regional water. All concentrations were less than the reporting level of 3 times the sample standard deviation (see Davis and others, 2013, for more information on reporting levels for radiochemical constituents) using a 2 pCi/L detection level. The median concentration for strontium-90 in western tributary water was -0.1125 ±0.0125 pCi/L; the median concentration in eastern regional water was 0.3 ±0.6 pCi/L (table 1). Given that wastewater disposal practices are the only source of strontium-90 in the ESRP aquifer at the INL, background concentrations of strontium-90 in western tributary water and eastern regional water are essentially zero.

Chlorine-36

The possible sources of Cl-36 in groundwater in the ESRP aquifer are meteoric input from wet and dry precipitation of cosmogenically produced Cl-36 in the Earth's atmosphere, Cl-36 produced during nuclear-weapons tests in the 1950–60s and transported globally in the upper atmosphere, in situ production in rocks and soils by natural interactions of nuclear particles with stable elements, and wastewater disposal at the INL (Beasley and others, 1993; Cecil and others, 1999). The background concentration derived for this report incorporates Cl-36 from the first three sources. Cl-36 has a half-life of 301,000 years (Cecil and others, 1999). The MCL for Cl-36 in drinking water is about 700 pCi/L (U.S. Environmental Protection Agency, 2002).

Cl-36 was detected in water samples from eight wells that sample western tributary water. Concentrations ranged from 0.0002 ±0.00002 to 0.01 ±0.004 pCi/L with a median of 0.00098 ±0.00006 pCi/L (table 1), which is considered the upper limit of background for this report. Cl-36 was detected in water samples from 23 sites that sample eastern regional water. Concentrations ranged from 0.000066 ±0.000006 to 0.00178 ±0.0001 pCi/L with a median concentration of 0.0002048 ±0.0000054 pCi/L (table 1), which is considered the upper limit of background.

Iodine-129

The principal natural sources of I-129 in groundwater in the ESRP aquifer are (1) production in the atmosphere by cosmic-ray spallation of xenon isotopes, and (2) spontaneous fission of U-238 in the lithosphere (Fabryka-Martin and others, 1985; Cecil and others, 2003). Additionally, Cecil and others (2003) indicated I-129 was introduced into the atmosphere from above ground nuclear testing, and was also discharged into the aquifer at the INL from wastewater disposal. Background concentrations calculated in previous studies by Mann and Beasley (1994a, 1994b) and Cecil and others (2003) take into account concentrations derived naturally and from fallout from nuclear testing. The half-life is 15.7 million years (Mann and Beasley, 1994b). The MCL for I-129 in drinking water is 1 pCi/L (Forbes and others, 2007).

I-129 concentrations analyzed in 11 water samples from wells that sample western tributary water ranged from 0.0000055 ±0.0000002 to 0.00005 ±0.0000025 pCi/L with a median of 0.000011 ±0.000005 pCi/L (table 1), which is considered the upper limit of background. I-129 concentrations detected in water samples from 26 sites that sample eastern regional water ranged from 0.00000007 ±0.000000008 to 0.0000177 ±0.000001 pCi/L with a median concentration of 0.000000865 ±0.000000015 pCi/L, which is considered the upper limit of background.

Plutonium-238, Plutonium-239, -240 (undivided), and Americium-241

Some transuranic elements such as plutonium and americium may be produced in nature because of the availability of neutrons that can be captured by uranium isotopes (Orr and others, 1991). The half-lives of plutonium-238, plutonium-239, plutonium-240, and americium-241 are 87.7 years, 24,100 years, 6,560 years, and 432.7 years, respectively (Walker and others, 1989). Schonfeld (1972) reported that plutonium-239 is naturally present as a secondary product in various uranium and thorium ores in concentrations approximating 10^{-12} to 10^{-14} per weight of material. Given that uranium isotope concentrations in the ESRP aquifer are relatively small (appendix C) and the ratio to plutonium is very small, natural concentrations should essentially be zero.

Plutonium and americium isotopes were analyzed in water samples from 45 wells and zones from wells that sample western tributary water and 23 wells and zones from wells that sample eastern regional water. All concentrations were less than the reporting level of 3 times the sample standard deviation (see Davis and others, 2013, for more information on reporting levels for radiochemical constituents) using a 0.02- and 0.03-pCi/L detection level for plutonium and americium isotopes, respectively. Given that wastewater disposal practices are the only source of detectable

concentrations of plutonium and americium isotopes in the ESRP aquifer at the INL, background concentrations of western tributary water and eastern regional water for plutonium and americium isotopes are essentially zero.

Technetium-99

Minute quantities of Tc-99 are found in uranium ores where it is produced by spontaneous fission. Traces of Tc-99 may also be formed by interaction of cosmic rays with ores such as molybdenite (Boyd, 1972). Tc-99 has been discharged in wastewater and detected in several wells at the INL (Beasley and others, 1998). The MCL for Tc-99 in drinking water is 900 pCi/L (Forbes and others, 2007).

Tc-99 concentrations analyzed in water samples from nine wells that sample western tributary water ranged from <0.0000027 to 0.081 ±0.003 pCi/L with a median value of <0.0000054 pCi/L (table 1). One well that sampled eastern regional water had a concentration of <0.0000027. Given that wastewater disposal practices are the only feasible source of Tc-99 for wells that had detectable concentrations in the ESRP aquifer at the INL, as reported by Beasley and others (1998), background concentrations of Tc-99 are <0.0000054 pCi/L for both western tributary water and eastern regional water at the INL.

Uranium-234, -235, -238

Elemental uranium consists of three naturally occurring isotopes in the proportion of 99.27 percent U-238 to 0.72 percent U-235 and 0.0056 percent U-234 (Haglund, 1972). U-234 typically occurs as a daughter product of U-238. The MCL for uranium in drinking water is 30 μg/L (U.S. EPA 2014). Assuming natural isotopic abundances, this equates to activities of 10 pCi/L U-238, 0.47 pCi/L U-235, and 10.7 pCi/L U-234.

Samples for uranium isotopes were collected from several zones from seven wells that sample western tributary water and three zones from one well that sampled eastern regional water. Concentrations for western tributary water ranged from 0.043 ±0.018 to 1.9 ±0.11 pCi/L with a median of 1.36 pCi/L with an undetermined uncertainty for U-234, from 0 ±0.0008 to 0.048 ±0.016 pCi/L with a median of 0.025 ±0.001 pCi/L for U-235, and from 0.021 ±0.011 to 0.719 ±0.048 pCi/L with a median of 0.541 ±0.001 pCi/L for U-238 (table 1, appendix C). Concentrations for eastern regional water ranged from 0.327 ±0.032 to 1.52 ±0.084 pCi/L with a median of 1.32 ±0.77 pCi/L for U-234, from 0 ±0.006 to 0.034 ±0.013 pCi/L with a median of 0.016 ±0.012 pCi/L for U-235, and from 0.157 ±0.021 to 0.594 ±0.046 pCi/L with a median of 0.477 ±0.044 pCi/L for U-238 (table 1, appendix C). The median concentrations are considered the upper limit of background in the western and eastern parts of the aquifer at the INL.

Summary

In order to calculate background concentrations at and near the Idaho National Laboratory (INL), sample concentrations were examined to determine the source of concentration input and the naturally occurring and anthropogenic background. Samples collected from wells and springs upgradient, downgradient, and at the INL that were believed to be uninfluenced by wastewater disposal were used to establish background concentrations. The eastern Snake River Plain aquifer at and near the INL was divided into two major water types (western tributary and eastern regional) based on concentrations of lithium less than and greater than 5 µg/L. Median concentrations for most of the chemical and radiochemical constituents were used to define background concentrations. Background concentrations are needed to establish a baseline concentration for ongoing cleanup efforts at the INL.

The range, median, and mean concentrations for respective constituents provided an indication of the distribution of these constituents in the eastern Snake River Plain aquifer. Chemical and radiochemical constituents including calcium, magnesium, sodium, potassium, silica, chloride, sulfate, fluoride, bicarbonate, chromium, nitrate, tritium, strontium-90, Cl-36, iodine-129, plutonium-238, plutonium-239, -240 (undivided), americium-241, technetium-99, and uranium-234, -235, and -238 were selected for the background study because they were either not analyzed in earlier studies or new data became available to give a more recent interpretation of background concentrations.

The upper limit of background concentrations for inorganic chemicals for western tributary water are 40.7 mg/L for calcium, 15.3 mg/L for magnesium, 8.30 mg/L for sodium, 2.32 mg/L for potassium, 23.1 mg/L for silica, 11.8 mg/L for chloride, 21.4 mg/L for sulfate, 0.2 mg/L for fluoride, 176 mg/L for bicarbonate, 4.00 µg/L for chromium, and 0.655 mg/L for nitrate.

The upper limit of background concentrations for inorganic chemicals for eastern regional water are 34.05 mg/L for calcium, 13.85 mg/L for magnesium, 14.85 mg/L for sodium, 3.22 mg/L for potassium, 31.0 mg/L for silica, 14.15 mg/L for chloride, 20.2 mg/L for sulfate, 0.4675 mg/L for fluoride, 165 mg/L for bicarbonate, 3.00 µg/L for chromium, and 0.995 mg/L for nitrate.

The upper limit of background concentrations for radiochemical constituents for western tributary water are 34.15 ±2.35 pCi/L for tritium, 0.00098 ±0.00006 pCi/L for chlorine-36, 0.000011 ±0.000005 pCi/L for iodine-129, <0.0000054 pCi/L for technetium-99, zero for strontium-90, plutonium-238, plutonium-239, -240 (undivided), and americium-241, 1.36 pCi/L with undetermined uncertainty for uranium-234, 0.025 ±0.001 pCi/L for uranium-235, and 0.541 ±0.001 pCi/L for uranium-238.

The upper limit of background concentrations for radiochemical constituents for eastern regional water are 5.43 ±0.574 pCi/L for tritium, 0.0002048 ±0.0000054 pCi/L for chlorine-36, 0.000000865 ±0.000000015 pCi/L for iodine-129, <0.0000054 pCi/L for technetium-99, zero for strontium-90, plutonium-238, plutonium-239, -240 (undivided), and americium-241, 1.32 ±0.77 pCi/L for uranium-234, 0.016 ±0.012 pCi/L for uranium-235, and 0.477 ±0.044 pCi/L for uranium-238.

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Appendixes

Appendixes A–C are Microsoft® Excel files and are available for download at http://dx.doi.org/10.3133/sir20165056.

Appendix A. General Information for Groundwater Sampling Sites Used in Data Analyses at and near the Idaho National Laboratory, Idaho

Appendix B. Chemical Concentrations in Water Samples Used to Calculate Background Concentrations for Selected Wells at and near the Idaho National Laboratory, Idaho

Appendix C. Radiochemical Concentrations in Water Samples Used to Calculate Background Concentrations for Selected Wells and Springs at and near the Idaho National Laboratory, Idaho