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RADIOCHEMICAL AND CHEMICAL CONSTITUENTS IN WATER FROM SELECTED WELLS SOUTH OF THE IDAHO NATIONAL ENGINEERING AND ENVIRONMENTAL LABORATORY, IDAHO

U.S. GEOLOGICAL SURVEY
OPEN-FILE REPORT 01-138

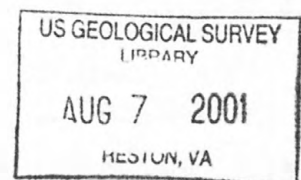
Prepared in cooperation with the
U.S. DEPARTMENT OF ENERGY

Radiochemical and Chemical Constituents in Water from Selected Wells South of the Idaho National Engineering and Environmental Laboratory, Idaho

*By Roy C. Bartholomay, Betty J. Tucker, LeRoy L. Knobel,
and Larry J. Mann*

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U.S. DEPARTMENT OF ENERGY**

Idaho Falls, Idaho

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CONVERSION FACTORS AND ABBREVIATED UNITS

	Multiply	By	To Obtain
	foot (ft)	0.3048	meter
	gallon (gal)	3.785	liter
	mile (mi)	1.609	kilometer
	picocurie per liter (pCi/L)	.037	becquerel per liter
	square mile (mi ²)	2.590	square kilometer

Temperature can be converted from degrees Celsius (°C) to degrees Fahrenheit (°F) by the equation: °F = (°C × 1.8) + 32.

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

Radiochemical and Chemical Constituents in Water from Selected Wells South of the Idaho National Engineering and Environmental Laboratory, Idaho

By Roy C. Bartholomay, Betty J. Tucker, LeRoy L. Knobel, and Larry J. Mann

Abstract

The U.S. Geological Survey and the Bureau of Land Management, in cooperation with the U.S. Department of Energy, sampled water from five stock wells to monitor water quality of the Snake River Plain aquifer south of the Idaho National Engineering and Environmental Laboratory. The samples were analyzed for selected radiochemical and chemical constituents.

The concentrations of strontium-90, transuranic elements, and cesium-137 in all samples were less than the reporting level. Concentrations of tritium in four samples and concentrations of gross alpha- and beta-particle radioactivity in all samples were greater than the reporting level. Most of the inorganic-constituent concentrations were greater than the minimum reporting levels. Concentrations of all 63 purgeable organic compounds analyzed for were less than the respective minimum reporting levels.

INTRODUCTION

For several years, the public has expressed concern about waste-disposal practices at the Idaho National Engineering and Environmental Laboratory (INEEL) and the effect these practices could have on the water quality of the Snake River Plain aquifer. In 1993, the U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM), in cooperation with the U.S. Department of Energy (DOE) conducted a study to respond to the public's concern and to gain a greater understanding of the radiochemical and chemical quality of water in the aquifer south of the INEEL in an area locally referred to as "no-man's land".

This report summarizes the results of analyses of water samples collected in 1993 from five BLM stock wells in no-man's land.

The INEEL includes about 890 mi² of the northeastern part of the eastern Snake River Plain (fig. 1). In the past, wastewater containing radiochemical and chemical wastes generated at the INEEL was discharged mostly to ponds and wells. Since 1983, most wastewater has been discharged to infiltration ponds. Many of the constituents in the wastewater enter the aquifer indirectly by percolation through the unsaturated zone (Pittman and others, 1988).

Chemical and radioactive wastes have migrated as much as 13 mi southwest of the disposal areas at the INEEL (Bartholomay and others, 2000). Tritium was detected intermittently at concentrations of $3,400 \pm 200$ pCi/L or less in water from three wells along the southern boundary of the INEEL between 1983 and 1985 (Pittman and others, 1988). From April 1985 to October 1995, tritium concentrations in water from wells near the southern boundary of the INEEL were less than the reporting level (Bartholomay and others, 1997, p. 27), but in 1998, because lower laboratory detection limits were used, tritium was detected at concentrations greater than the reporting level in one well at the boundary and one well south of the boundary (Bartholomay and others, 2000).

Water samples collected from the five wells (fig. 2) were analyzed for selected radionuclides, stable isotopes, common ions, trace elements, nutrients, and purgeable organic compounds by the USGS National Water Quality Laboratory (NWQL) at Arvada, Colo. Samples also were col-

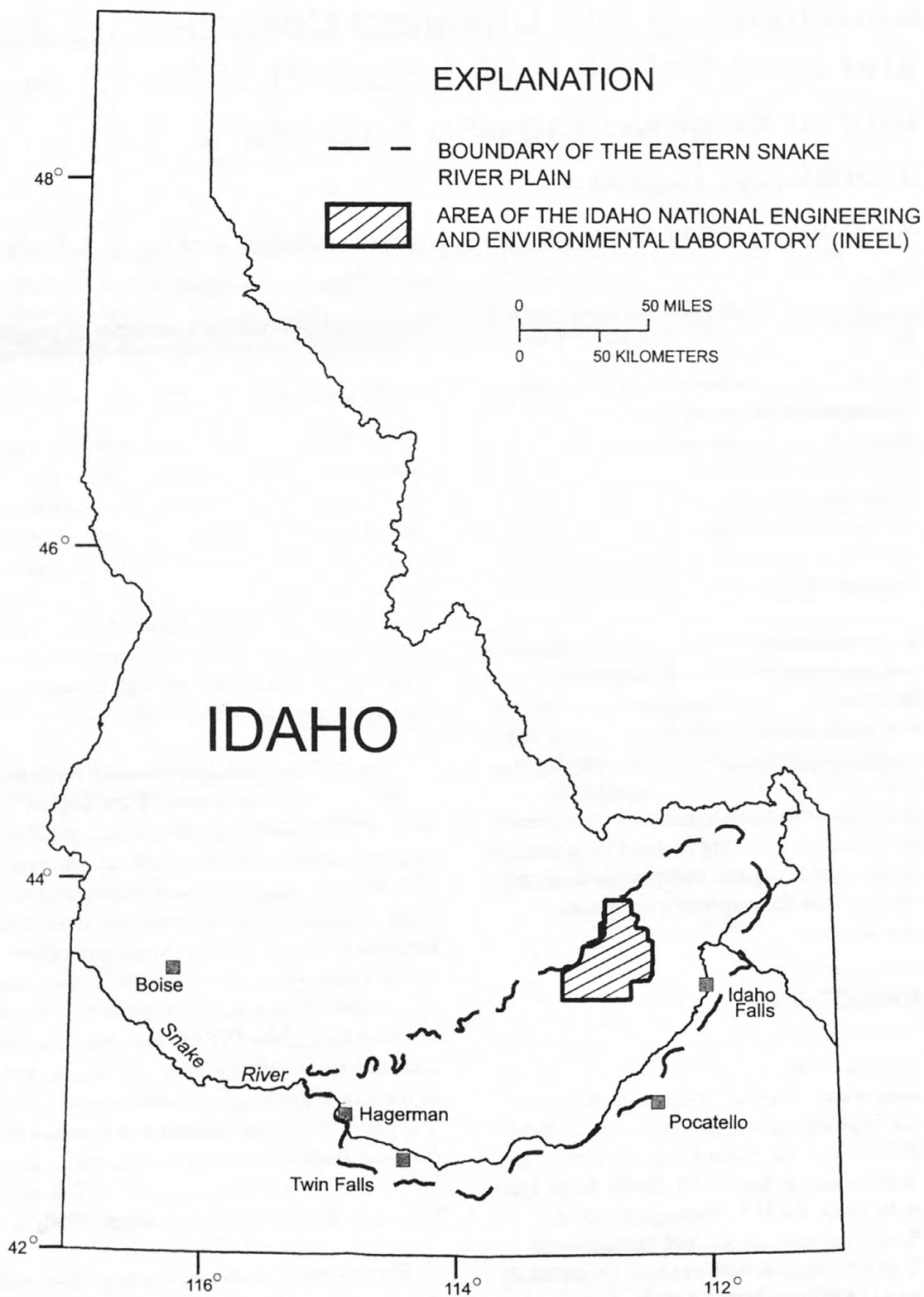


Figure 1. Location of the eastern Snake River Plain and the Idaho National Engineering and Environmental Laboratory, Idaho

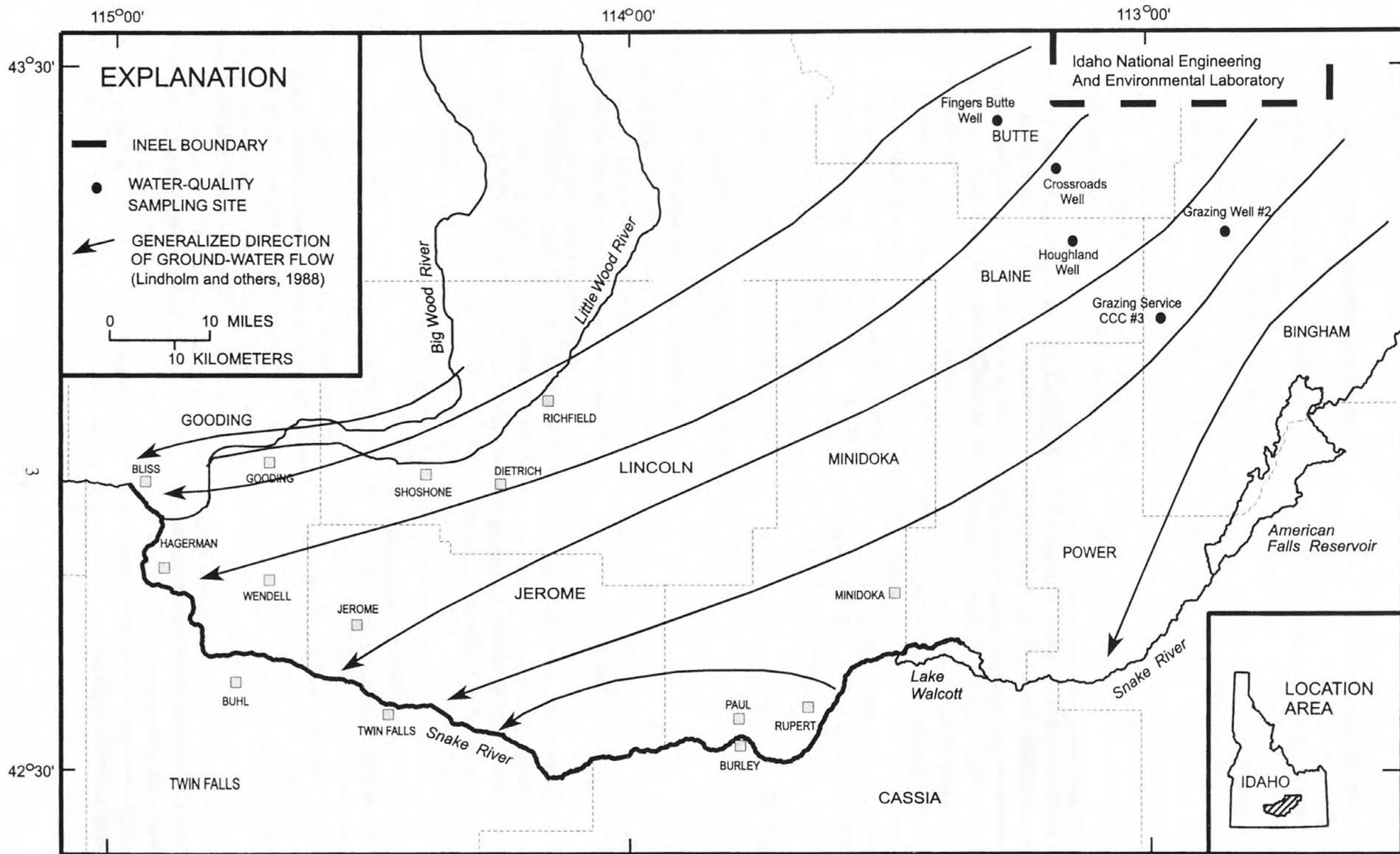


Figure 2. Location of selected wells

lected at the same sites for selected radionuclide analyses by the Radiological and Environmental Sciences Laboratory (RESL) at the INEEL.

Geohydrologic Setting

The eastern Snake River Plain is a northeast-trending structural basin about 200 mi long and 50 to 70 mi wide. The basin, bounded by faults on the northwest and downwarping and faulting on the southeast, has been filled with basaltic lava flows interbedded with terrestrial sediments (Whitehead, 1986). Individual basalt flows average 20 to 25 ft in thickness with an aggregate thickness of several thousand feet in places. Alluvial fan deposits are composed primarily of sand and gravel, whereas in areas where streams were dammed by basalt flows, the sediments are predominantly silt and clay (Garabedian, 1986). Rhyolitic lava rocks and tuffs are exposed locally at the surface and may exist at depth under most of the eastern plain. A 10,365-ft-deep test hole at the INEEL penetrated about 2,160 ft of basalt and sediment and 8,205 ft of rhyolitic and tuffaceous volcanic rocks (Mann, 1986).

Movement of water in the aquifer generally is from the northeast to the southwest (fig. 2). Water moves horizontally through basalt interflow zones and vertically through joints and interfingering edges of the interflow zones. Infiltration of surface water, heavy pumpage, geologic conditions, and seasonal fluxes of recharge and discharge locally affect the movement of ground water (Garabedian, 1986).

The Snake River Plain aquifer is recharged by seepage from the upper reaches of the Snake River, tributaries and canals, infiltration from irrigation and precipitation, and underflow from tributary valleys on the perimeter of the plain. Discharge from the aquifer primarily is by pumpage for irrigation and spring flow to the Snake River (Mann and Knobel, 1990). Discharge from all of the springs in the eastern Snake River Plain has fluctuated over the years as a result of changes in water use, irrigation practices, and precipitation (Kjelstrom, 1992, p. 2).

Acknowledgments

The authors gratefully acknowledge the BLM for granting permission to collect the water samples and extend special thanks to Mark Storzer, formerly of the Idaho Falls BLM, for his help in locating and pumping wells for sample collection. The authors are grateful for technical review of the manuscript by Daniel J. Kotansky, hydrologist, BLM and Amy J. Wehnke, hydrologic technician, USGS.

METHODS AND QUALITY ASSURANCE

The methods used in sampling and analyzing for selected chemicals generally followed the guidelines established by the USGS (Goerlitz and Brown, 1972; Stevens and others, 1975; Wood, 1981; Claassen, 1982; W.L. Bradford, USGS, written commun., 1985; Wershaw and others, 1987; Fishman and Friedman, 1989; Faires, 1992; Fishman, 1993; and Wilde and others, 1998). The methods used in the field and quality-assurance practices are described in the following sections.

Sample Containers and Preservatives

Sample containers and preservatives differ depending on the constituent(s) for which analyses are requested. Samples analyzed by the NWQL were collected and preserved in accordance with laboratory requirements specified by Timme (1995). Water samples analyzed by the RESL were collected in accordance with laboratory requirements specified by the Chief and research chemists of the Analytical Chemistry Branch of the RESL. Containers and preservatives used for this study are listed on table 1.

Sample Collection

Water samples were collected from five stock wells (fig. 2). One of the wells (Fingers Butte) was not pumping at arrival, but water had recently been pumped into a large storage tank and was sampled from the tank. There was no sample spigot near the Grazing Service CCC #3 well so samples were collected from a hose off a storage tank. Water from the other three wells (Grazing Well #2, Houghland, and Crossroads) was sampled from spigots near the wells. The pumps were started on

arrival and pumped long enough to ensure chemical stability of the water, as indicated by stable pH, specific conductance, and water-temperature measurements. These characteristics were monitored during pumping using methods described by Wood (1981) and Hardy and others (1989). After collection, sample containers were sealed with laboratory film, labeled, and packed into ice chests for shipment to the NWQL. The samples collected for RESL were stored under secure conditions until they were hand-delivered to the laboratory.

Field measurements of pH, specific conductance, water temperature, alkalinity, and dissolved oxygen are shown on table 2. Ranges for these measurements were from 8.1 to 8.3 for pH, from 290 to 337 $\mu\text{S}/\text{cm}$ for specific conductance, from 11.0 to 16.0 $^{\circ}\text{C}$ for water temperature; from 122 to 142 mg/L for alkalinity as calcium carbonate; and from 8.0 to 8.4 mg/L for dissolved oxygen.

Conditions at the sampling site during sample collection were recorded in a field logbook; a chain-of-custody record was used to track the samples from the time of collection until delivery to the analyzing laboratory. These records are available for inspection at the USGS INEEL Project Office.

Quality Assurance

Detailed descriptions of internal quality control and overall quality-assurance practices used by the NWQL are provided in reports by Friedman and Erdmann (1982), Jones (1987), and Pritt and Raese (1995). Water samples were collected in accordance with a quality-assurance plan for quality-of-water activities conducted by personnel at the INEEL Project Office. The plan was finalized in June 1989, revised in March 1992 and in 1996 (Mann, 1996), and is available for inspection at the USGS INEEL Project Office. No quality assurance samples were collected for this study.

RADIOCHEMICAL CONSTITUENTS

Water samples were analyzed for strontium-90, plutonium-238, plutonium-239, -240 (undivided), americium-241, and gamma-emitting radionuclides by RESL. Water samples were ana-

lyzed for tritium, gross alpha- and gross beta-particle radioactivity by the NWQL. The samples analyzed by the RESL followed procedures described in reports by Bodnar and Percival (1982) and the U.S. Department of Energy (1995). The NWQL samples were analyzed by using methods described by Thatcher and others (1977).

An analytical uncertainty, s , is calculated for each radionuclide concentration or radioactivity measurement. This report presents the analytical uncertainty as $1s$. Guidelines for interpreting analytical results are based on an extension of the method described by Currie (1984). In radiochemical analyses, laboratory measurements are made on a target sample and a prepared blank. Instrument signals for the sample and 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 for the blank to make the decision that there was detection; and (2) an estimation must be made of the minimum concentration that will yield a sufficiently large signal to make the correct decision for detection or nondetection most of the time. The first aspect of the problem is a qualitative decision based on signals and a definite criterion for detection. The second aspect of the problem is an estimation of the detection capabilities of a complete measurement process that includes hypothesis testing.

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

Once the critical level of $1.6s$ has been defined, the minimum detectable concentration can be established. Concentrations that equal $3s$ represent a measurement at the minimum detectable concentration. For true concentrations of $3s$ or greater,

there is a 95-percent-or-more probability of correctly concluding that the radioactive constituent was detected in a sample. Given a large number of samples, as many as 5 percent of the samples with true concentrations greater than or equal to 3s, which were concluded as being not detected, could contain the radioactive constituent at the minimum detectable concentration. These measurements are referred to as false negatives and are errors of the second kind in hypothesis testing.

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

These guidelines are based on counting statistics alone and do not include systematic or random errors inherent in laboratory procedures. The values 1.6s and 3s vary slightly with background or blank counts and with the number of gross counts for individual analyses. The use of the critical level and minimum detectable concentration aids the reader in the interpretation of analytical results and does not represent absolute concentrations of radioactivity that may or may not have been detected. In this report, if the concentration of a selected radionuclide was equal to or greater than 3s, the concentration is considered to be above a reporting level. The reporting level should not be confused with the analytical method detection limit, which is based on laboratory procedures. At small concentrations, the reporting level approaches the analytical method detection limit; however, at larger concentrations, they may be significantly different.

Many analytical results of environmental radioactivity measurements are at or near zero. If the true concentration for a given radionuclide is zero, a given set of analytical results for that radionuclide should be distributed about zero, with an equal number of negative and positive measurements. Negative analytical results occur if the radioactivity of a water sample is less than the background radioactivity or the radioactivity of the

prepared blank sample in the laboratory (American Society for Testing and Materials, 1992, p. 126; Knobel and others, 1992, p. 51).

Strontium-90

Strontium-90 is a fission product that was widely distributed in the environment during atmospheric weapons tests. Strontium-90 generally is present in ground water as a result of these tests and from nuclear industry waste-disposal practices. Because strontium-90 tends to sorb onto sedimentary material in the aquifer, it is not expected to move past its current location at the INEEL (Bartholomay, 1998). Samples were submitted to the RESL for analysis. Concentrations of dissolved strontium-90 in all samples were less than the reporting level (table 3).

Tritium

Tritium, a radioactive isotope of hydrogen, is formed in nature by 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. Samples were analyzed by the NWQL using an enrichment and gas-counting technique. Concentrations of tritium in four of the five water samples were greater than the reporting level and ranged from 1.6 ± 0.29 to 16.7 ± 0.54 pCi/L (table 3). For comparison, the maximum contaminant level for tritium in public drinking water is 20,000 pCi/L (U.S. Environmental Protection Agency, 1999), and background concentrations of tritium in ground water in Idaho generally range from 0 to 40 pCi/L (Knobel and others, 1992).

Gross Alpha-Particle Radioactivity

Gross alpha-particle radioactivity is a measure of the total radioactivity given off as alpha particles during the radioactive decay process; however, laboratories normally report the radioactivity as if it were all given off by one radionuclide. For this report, concentrations were reported by the NWQL both as natural uranium in micrograms per liter and as dissolved thorium-230 in picocuries per liter.

Concentrations of dissolved gross alpha-particle radioactivity reported as uranium and thorium-230 in all of the water samples were greater than the reporting level (table 4) and ranged from 2.50 ± 0.80 to 5.80 ± 1.21 $\mu\text{g/L}$ and 1.77 ± 0.57 to 3.71 ± 0.78 pCi/L , respectively.

Gross Beta-Particle Radioactivity

Gross beta-particle radioactivity is a measure of the total radioactivity given off as beta particles during the radioactive decay process. The laboratory instruments used for these measurements are calibrated to either a single radionuclide, cesium-137, or a pair of radionuclides, strontium-90 in equilibrium with yttrium-90. For this report, concentrations were reported by the NWQL as cesium-137 in picocuries per liter and as strontium-90 in equilibrium with yttrium-90 in picocuries per liter. Reporting of the concentrations of gross beta-particle radioactivity in these ways is for reference purposes only and does not imply that the radioactivity is attributed to these specific isotopes.

Concentrations of dissolved gross beta-particle radioactivity reported as strontium-90 in equilibrium with yttrium-90 and as cesium-137 in all of the water samples were greater than the reporting levels (table 4) and ranged from 2.46 ± 0.366 to 3.13 ± 0.59 pCi/L and 3.34 ± 0.56 to 4.24 ± 0.63 pCi/L , respectively.

Transuranic Elements and Cesium-137

Transuranic elements.—Some transuranic elements may be produced in nature because of the availability of neutrons that can be captured by uranium isotopes (Orr and others, 1991, p. 16), and some are produced as by-products of the nuclear industry (Wampler, 1972, p. 6–7). Concentrations of plutonium-238, plutonium-239, -240 (undivided), and americium-241 in five samples were determined by the RESL (table 5). All concentrations were less than the reporting level (table 5).

Cesium-137.—Cesium-137 is not naturally occurring; however, it can be present in ground water as a fission product from nuclear facilities and weapons tests (Orr and others, 1991, p. 28).

The concentrations of cesium-137 in all five samples were less than the reporting level (table 5).

Stable Isotopes

Water samples were analyzed for relative concentrations of stable isotopes of hydrogen (H), oxygen (O), and carbon (C). Because the absolute measurement of isotopic ratios is analytically difficult, relative isotopic ratios are measured instead (Toran, 1982). For example, $^{18}\text{O}/^{16}\text{O}$ of a sample is compared with $^{18}\text{O}/^{16}\text{O}$ of a standard:

$$\delta^{18}\text{O} = (R_{\text{sample}}/R_{\text{standard}} - 1) \times 1,000, (1)$$

where

$$R_{\text{sample}} = ^{18}\text{O}/^{16}\text{O} \text{ in the sample,}$$

$$R_{\text{standard}} = ^{18}\text{O}/^{16}\text{O} \text{ in the standard, and}$$

$$\delta^{18}\text{O} = \text{relative concentration, in parts per thousand (permil).}$$

Delta ^{18}O ($\delta^{18}\text{O}$) is referred to as delta notation and is the value reported by isotopic laboratories for stable isotope analysis. $^2\text{H}/^1\text{H}$ and $^{13}\text{C}/^{12}\text{C}$ are defined in a similar manner with the respective ratios replacing $^{18}\text{O}/^{16}\text{O}$ in R_{sample} and R_{standard} . The standard used for determining $\delta^2\text{H}$ and $\delta^{18}\text{O}$ in water is standard mean ocean water as defined by Craig (1961). The standard used for determining $\delta^{13}\text{C}$ in water is the Pee Dee Belemnite reference standard (Timme, 1995, p. 71).

The respective precisions of measurement at the NWQL for $\delta^2\text{H}$, $\delta^{18}\text{O}$, and $\delta^{13}\text{C}$ are 1.5 permil, 0.15 permil, and 0.3 permil at the 95-percent confidence level (C.A. Watterson and A.T. Kashuba, USGS, written commun., 1993).

Relative concentrations of stable isotopes are shown in table 6. Relative isotopic ratios reported as $\delta^2\text{H}$ for water from five samples ranged from -139 to -135 permil. Relative isotopic ratios reported as $\delta^{18}\text{O}$ for water from five samples ranged from -18.41 to -17.96 permil. Relative isotopic ratios reported as $\delta^{13}\text{C}$ for water from three samples ranged from -11.2 to -9.9 permil.

CHEMICAL CONSTITUENTS

Water samples were analyzed for selected chemical constituents. These constituents included common ions, trace elements, nutrients, and purgeable organic compounds. In this report, minimum reporting levels and method detection limits established for these constituents are not to be confused with reporting levels and analytical method detection limits for selected radionuclides. The minimum reporting level for inorganic and organic constituents is the smallest measured concentration of a constituent that can be reliably reported by using a given analytical method (Timme, 1995, p. 92). The method detection limit is the minimum concentration of a substance that can be identified, measured, and reported with 99-percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte (Timme, 1995, p. 92).

Common Ions

Water samples were analyzed for dissolved common ions including bromide, calcium, chloride, fluoride, magnesium, potassium, sodium, sulfate, and dissolved silica. The concentrations of dissolved common ions are shown on table 7.

Bromide.—Concentrations of bromide in all samples were greater than the minimum reporting level and ranged from 0.03 to 0.04 mg/L.

Calcium.—Concentrations of calcium in all samples were greater than the minimum reporting level and ranged from 29 to 41 mg/L.

Chloride.—Concentrations of chloride in all samples were greater than the minimum reporting level and ranged from 9.0 to 14 mg/L.

Fluoride.—Concentrations of fluoride in all samples were greater than the minimum reporting level and ranged from 0.2 to 0.6 mg/L.

Magnesium.—Concentrations of magnesium in all samples were greater than the minimum reporting level and ranged from 12 to 15 mg/L.

Potassium.—Concentrations of potassium in all samples were greater than the minimum reporting level and ranged from 2.1 to 3.3 mg/L.

Sodium.—Concentrations of sodium in all samples were greater than the minimum reporting level and ranged from 7.3 to 15 mg/L.

Sulfate.—Concentrations of sulfate in all samples were greater than the minimum reporting level and ranged from 14 to 21 mg/L.

Silica.—Concentrations of silica in all samples were greater than the minimum reporting level and ranged from 23 to 33 mg/L.

Trace Elements

Water samples were analyzed for selected dissolved trace elements including aluminum, barium, beryllium, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, mercury, molybdenum, nickel, silver, strontium, vanadium, and zinc. Water samples also were analyzed for hexavalent and total chromium. The concentrations of dissolved trace elements and hexavalent and total chromium are shown on table 8.

Aluminum.—Concentrations of aluminum in all samples were less than the minimum reporting level of 10 µg/L.

Barium.—Concentrations of barium in all samples were greater than the minimum reporting level and ranged from 14 to 36 µg/L.

Beryllium.—Concentrations of beryllium in all samples were less than the minimum reporting level of 0.5 µg/L.

Cadmium.—Concentrations of cadmium in all samples were less than the minimum reporting level of 1 µg/L.

Chromium.—Concentrations of dissolved chromium in all samples were less than the reporting level of 5 µg/L. The concentration of hexavalent chromium in one sample was 2 µg/L, which exceeded the reporting level of 1 µg/L. Concentrations of total chromium in all samples exceeded the reporting level and ranged from 2 to 4 µg/L.

Cobalt.—Concentrations of cobalt in all samples were less than the minimum reporting level of 3 µg/L.

Copper.—Concentrations of copper in all samples were less than the minimum reporting level of 10 µg/L.

Iron.—Concentrations of iron in three samples were greater than the minimum reporting level and ranged from 5 to 51 µg/L.

Lead.—Concentrations of lead in two samples were equal to the minimum reporting level of 1 µg/L.

Lithium.—Concentrations of lithium in three samples were greater than the minimum reporting level and ranged from 12 to 18 µg/L.

Manganese.—Concentrations of manganese in three samples were equal to or larger than the minimum reporting level and ranged from 1 to 7 µg/L.

Mercury.—Concentrations of mercury in all samples were less than the minimum reporting level of 0.1 µg/L.

Molybdenum.—Concentrations of molybdenum in all samples were less than the minimum reporting level of 10 µg/L.

Nickel.—Concentrations of nickel in all samples were less than the minimum reporting level of 10 µg/L.

Silver.—Concentrations of silver in all samples were less than the minimum reporting level of 1 µg/L.

Strontium.—Concentrations of strontium in all samples were greater than the minimum reporting level and ranged from 130 to 210 µg/L.

Vanadium.—Concentrations of vanadium in three samples were 7 µg/L. Concentrations in the other two samples were less than 6 µg/L.

Zinc.—Concentrations of zinc in all samples were greater than the minimum reporting level and ranged from 27 to 320 µg/L.

Nutrients

Water samples were analyzed for dissolved ammonia (as nitrogen), nitrite (as nitrogen), nitrite plus nitrate (as nitrogen), and orthophosphate (as phosphorus). Concentrations of nutrients are shown on table 9.

Ammonia (as nitrogen).—Concentrations of ammonia (as nitrogen) in all samples were at the minimum reporting level of 0.01 mg/L.

Nitrite (as nitrogen).—Concentrations of nitrite (as nitrogen) in all samples were less than the minimum reporting level of 0.01 mg/L.

Nitrite plus nitrate (as nitrogen).—Concentrations of nitrite plus nitrate (as nitrogen) in all samples were greater than the minimum reporting level and ranged from 0.6 to 0.86 mg/L.

Orthophosphate (as phosphorus).—Concentrations of orthophosphate (as phosphorus) in one sample was equal to the minimum reporting level of 0.01 mg/L; concentrations in the other four samples were less than the minimum reporting level.

Purgeable Organic Compounds

Three water samples were analyzed for 63 purgeable organic compounds. The minimum reporting levels of these compounds are shown on table 10. Concentrations of purgeable organic compounds in all three samples were less than the respective minimum reporting levels.

SUMMARY

The USGS and the BLM, in cooperation with the DOE, sampled water from five wells to monitor water quality of the Snake River Plain aquifer south of the Idaho National Engineering and Environmental Laboratory. Water samples were collected and analyzed for selected radiochemical and chemical constituents.

The concentrations of strontium-90, transuranic elements, and cesium-137 were less than the reporting level in all samples. Concentrations of tritium in four of the samples were greater than the reporting level and ranged from 1.6 ± 0.29 to 16.7 ± 0.54 pCi/L (table 3). Concentrations of

dissolved gross alpha-particle radioactivity reported both as natural uranium and dissolved thorium-230 in all of the water samples were greater than the reporting level and ranged from 2.50 ± 0.80 to 5.80 ± 1.21 $\mu\text{g/L}$, and 1.77 ± 0.57 to 3.71 ± 0.78 pCi/L , respectively. Concentrations of dissolved gross-beta-particle radioactivity reported as strontium-90 in equilibrium with yttrium-90 and cesium-137 in all of the water samples were greater than the reporting levels and ranged from 2.46 ± 0.366 to 3.13 ± 0.59 pCi/L , and 3.34 ± 0.56 to 4.24 ± 0.63 pCi/L , respectively.

The relative concentration ranges of stable isotopes of hydrogen, oxygen, and carbon were -139 to -135 permil, -18.41 to -17.96 permil, and -11.2 to -9.9 permil, respectively.

The ranges of concentrations of dissolved common ions and silica were: bromide, 0.03 to 0.04 mg/L ; calcium, 29 to 41 mg/L ; chloride, 9.0 to 14 mg/L ; fluoride, 0.2 to 0.6 mg/L ; magnesium, 12 to 15 mg/L ; potassium, 2.1 to 3.3 mg/L ; sodium, 7.3 to 15 mg/L ; sulfate, 14 to 21 mg/L , and silica, 23 to 33 mg/L . Samples were analyzed for 18 trace elements. Concentrations of aluminum, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, molybdenum, nickel, silver, and vanadium, were either less than or near laboratory reporting levels. The respective ranges of concentrations for barium, iron, lithium, manganese, strontium, and zinc were 14 to 36 $\mu\text{g/L}$, less than the reporting level to 51 $\mu\text{g/L}$, less than the reporting level to 18 $\mu\text{g/L}$, less than the reporting level to 7 $\mu\text{g/L}$, 130 to 210 $\mu\text{g/L}$, and 27 to 320 $\mu\text{g/L}$. The predominant nitrogen-bearing compound in the five samples was nitrite plus nitrate, which ranged in concentration from 0.6 to 0.86 mg/L .

Concentrations of all 63 purgeable organic compounds, which were analyzed for in three samples, were less than the respective minimum reporting levels.

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Table 1. Containers and preservatives used for water-sample collection

[Abbreviations: L, liter; mL, milliliter; μm , micrometer; $^{\circ}\text{C}$, degrees Celsius. Chemical formulas: HgCl_2 , mercuric chloride; NaCl , sodium chloride; HNO_3 , nitric acid; $\text{K}_2\text{Cr}_2\text{O}_7$, potassium dichromate; SrCl_2 , strontium chloride. Chilled samples were shipped by overnight-delivery mail. Analyzing laboratory: NWQL, U.S. Geological Survey National Water Quality Laboratory; RESL, Radiological and Environmental Sciences Laboratory]

Constituent or type of constituent	Container		Preservative		Other treatment	Analyzing laboratory
	Type	Size	Type	Amount		
Tritium	Polyethylene	1 L	None	None	None	NWQL
Strontium-90	Polyethylene, acid rinsed	500 mL	HNO_3	2 mL	None	RESL
Gross alpha, gross beta	Polyethylene, acid rinsed	1 L	HNO_3	4 mL	.45- μm filter	NWQL
Transuranics and gross-gamma	Polyethylene, acid rinsed	1 L	HNO_3	4 mL	None	RESL
Stable isotopes	Glass, baked	1 L	Ammoniacal SrCl_2	50 mL	None	NWQL
	Glass, baked	125 mL	None	None	Chill 4°C	NWQL
Trace elements	Polyethylene, acid rinsed	250 mL	HNO_3	1 mL	.45- μm filter	NWQL
	Polyethylene	125 mL	None	None	None	NWQL
Mercury	Glass, acid rinsed	250 mL	$\text{K}_2\text{Cr}_2\text{O}_7/\text{HNO}_3$	10 mL	.45- μm filter	NWQL
Common ions and silica	Polyethylene, acid rinsed	500 mL	HNO_3	2 mL	.45- μm filter	NWQL
	Polyethylene, acid rinsed	500 mL	HNO_3	2 mL	None	NWQL
	Polyethylene	250 mL	None	None	.45- μm filter	NWQL
	Polyethylene	250 mL	None	None	None	NWQL
Nutrients	Polyethylene, brown	125 mL	$\text{HgCl}_2/\text{NaCl}$	None	.45- μm filter, chill 4°C	NWQL
Purgeable organic compounds	Glass, baked	40 mL	None	None	Chill 4°C	NWQL

Table 2. Results of field measurements of water for pH, specific conductance, temperature, alkalinity, and dissolved oxygen, and laboratory calculations of total hardness and dissolved solids in water from selected wells south of the Idaho National Engineering and Environmental Laboratory, Idaho
[See figure 2 for location of wells. Units: pH, negative base-10 logarithm of hydrogen-ion activity in moles per liter; specific conductance, microsiemens per centimeter at 25°C (degrees Celsius); temperature, °C; all others in milligrams per liter. Symbols: CaCO₃, calcium carbonate; m/d/y, month/day/year; NA, not analyzed; DO, dissolved oxygen]

Well	Date sampled (m/d/y)	Time	pH	Specific conductance	Temperature (°C)	Alkalinity (as CaCO ₃)	DO	Total hardness	Dissolved solids, sum (as CaCO ₃)
Grazing Well #2	6/21/93	1150	8.1	290	15.0	122	8.2	120	195
Grazing Service CCC #3	6/21/93	1450	8.1	310	15.0	NA	NA	120	197
Houghland Well	6/22/93	1030	8.1	327	16.0	131	8.0	140	208
Crossroads Well	6/22/93	1325	8.2	337	11.0	142	8.4	160	205
Fingers Butte Well	6/22/93	1615	8.3	306	15.0	NA	NA	130	183

Table 3. Concentrations of strontium-90 and tritium in water from selected wells south of the Idaho National Engineering and Environmental Laboratory

[See figure 2 for location of wells. RESL, the U.S. Department of Energy Radiological and Environmental Sciences Laboratory; NWQL, the U.S. Geological Survey National Water Quality Laboratory. Analytical results and uncertainties—for example -3 ± 2 —in picocuries per liter. Analytical uncertainties are reported as **1s**. Concentrations that exceed the reporting level of 3 times the **1s** value are shown in boldface type]

Well	Strontium-90 (RESL)	Tritium (NWQL)
Grazing Well #2	-3 ± 2	2.4 ± 0.29
Grazing Service CCC #3	1 ± 2	2.3 ± 0.32
Houghland Well	-1.3 ± 1.9	1.6 ± 0.29
Crossroads Well	-1 ± 2	16.7 ± 0.54
Fingers Butte Well	-3 ± 2	$.61\pm0.29$

Table 4. Concentrations of gross alpha- and gross beta-particle radioactivity in water from selected wells south of the Idaho National Engineering and Environmental Laboratory

[See figure 2 for location of wells. Analyses were performed by the U.S. Geological Survey National Water Quality Laboratory using a residue procedure. Analytical results and uncertainties—for example, 3.33 ± 0.89 —in indicated units. Analytical uncertainties are reported as **1s**. Abbreviations: $\mu\text{g/L}$, micrograms per liter; pCi/L , picocuries per liter. Concentrations that exceed the reporting level of 3 times the **1s** value are shown in bold-face type]

Well	Gross alpha		Gross beta	
	as uranium ($\mu\text{g/L}$)	as thorium-230 (pCi/L)	as strontium-90 in equilibrium with yttrium-90 (pCi/L)	as cesium-137 (pCi/L)
Grazing Well #2	3.33 ± 0.89	2.39 ± 0.64	2.83 ± 0.382	3.60 ± 0.486
Grazing Service CCC #3	5.80 ± 1.21	3.71 ± 0.78	2.46 ± 0.366	3.34 ± 0.56
Houghland Well	3.65 ± 0.91	2.80 ± 0.70	3.13 ± 0.59	4.24 ± 0.63
Crossroads Well	2.50 ± 0.80	1.77 ± 0.57	2.57 ± 0.370	3.35 ± 0.483
Fingers Butte Well	3.32 ± 0.80	2.45 ± 0.59	2.60 ± 0.373	3.50 ± 0.58

Table 5. Concentrations of selected transuranic elements and cesium-137 in water from selected wells south of the Idaho National Engineering and Environmental Laboratory

[See figure 2 for location of wells. Analyses were performed by the U.S. Department of Energy Radiological and Environmental Sciences Laboratory. Analytical results and uncertainties—for example, 0.01 ± 0.02 —in picocuries per liter. Analytical uncertainties are reported as 1s]

Well	Plutonium-238	Plutonium-239, 240 (undivided)	Americium-241	Cesium-137
Grazing Well #2	0.01 ± 0.02	0.004 ± 0.014	-0.04 ± 0.02	20 ± 30
Grazing Service CCC #3	$.01 \pm 0.02$	$.013 \pm 0.016$	0 ± 0.02	0 ± 20
Houghland Well	$-.007 \pm 0.015$	$.009 \pm 0.013$	$-.06 \pm 0.02$	-15 ± 27
Crossroads Well	$-.005 \pm 0.014$	$.004 \pm 0.016$	$.04 \pm 0.03$	-10 ± 20
Fingers Butte Well	$-.016 \pm 0.017$	$-.003 \pm 0.012$	$-.02 \pm 0.03$	10 ± 20

Table 6. Relative concentrations of stable isotopes in water from selected wells south of the Idaho National Engineering and Environmental Laboratory

[See figure 2 for location of wells. Analyses were performed by the U.S. Geological Survey National Water Quality Laboratory. Symbols: $\delta^2\text{H}$, delta notation for stable hydrogen isotope ratios; $\delta^{18}\text{O}$, delta notation for stable oxygen isotope ratios; $\delta^{13}\text{C}$, delta notation for stable carbon isotope ratios; \pm , plus or minus; permil, parts per thousand relative to a standard; NA, not analyzed]

Well	$\delta^2\text{H}$ (± 1.5 permil)	$\delta^{18}\text{O}$ (± 0.15 permil)	$\delta^{13}\text{C}$ (± 0.3 permil)
Grazing Well #2	-135	-17.96	-11.2
Grazing Service CCC #3	-136	-18.11	NA
Houghland Well	-136	-18.0	-10.3
Crossroads Well	-138	-18.23	-9.9
Fingers Butte Well	-139	-18.41	NA

Table 7. Concentrations of dissolved common ions and silica in water from selected wells south of the Idaho National Engineering and Environmental Laboratory

[See figure 2 for location of wells. Analyses were performed by the U.S. Geological Survey National Water Quality Laboratory. Analytical results in milligrams per liter]

Well	Bromide	Calcium	Chloride	Fluoride	Magnesium	Potassium	Sodium	Sulfate	Silica
Grazing Well #2	0.04	29	12	0.6	12	3.1	15	14	33
Grazing Service CCC #3	.04	29	13	.6	12	3.1	14	16	31
Houghland Well	.04	30	14	.5	15	3.3	14	19	32
Crossroads Well	.03	41	9.0	.2	14	2.2	7.3	21	23
Fingers Butte Well	.03	33	9.8	.3	12	2.1	8.6	19	23

Table 8. Concentrations of dissolved trace elements and hexavalent and total chromium in water from selected wells south of the Idaho National Engineering and Environmental Laboratory

[See figure 2 for location of wells. Analyses were performed by the U.S. Geological Survey National Water Quality Laboratory. Analytical results in micrograms per liter. Symbol: <, concentration is less than the indicated minimum reporting level]

Well	Aluminum	Barium	Beryllium	Cadmium	Chromium			Cobalt	Copper	Iron
					Dissolved	Hexavalent	Total			
Grazing Well #2	<10	20	<0.5	<1	<5	<1	2	<3	<10	51
Grazing Service CCC #3	<10	17	<.5	<1	<5	<1	2	<3	<10	5
Houghland Well	<10	14	<.5	<1	<5	2	4	<3	<10	<3
Crossroads Well	<10	36	<.5	<1	<5	<1	3	<3	<10	12
Fingers Butte Well	<10	23	<.5	<1	<5	<1	2	<3	<10	<3

Well	Lead	Lithium	Manganese	Mercury	Molybdenum	Nickel	Silver	Strontium	Vanadium	Zinc
Grazing Well #2	<1	18	1	<0.1	<10	<10	<1	130	7	39
Grazing Service CCC #3	<1	17	2	<.1	<10	<10	<1	130	7	320
Houghland Well	1	12	<1	<.1	<10	<10	<1	160	7	46
Crossroads Well	1	<4	<1	<.1	<10	<10	<1	210	<6	27
Fingers Butte Well	<1	<4	7	<.1	<10	<10	<1	200	<6	32

Table 9. Concentrations of dissolved nutrients in water from selected wells south of the Idaho National Engineering and Environmental Laboratory

[See figure 2 for location of wells. Analyses were performed by the U.S. Geological Survey National Water Quality Laboratory. Analytical results in milligrams per liter. Symbol: <, concentration is less than the indicated reporting level]

Well	Ammonia (as nitrogen)	Nitrite (as nitrogen)	Nitrite plus nitrate (as nitrogen)	Orthophosphate (as phosphorus)
Grazing Well #2	0.01	<0.01	0.86	<0.01
Grazing Service CCC #3	.01	<.01	.84	<.01
Houghland Well	.01	<.01	.71	<.01
Crossroads Well	.01	<.01	.72	.01
Fingers Butte Well	.01	<.01	.6	<.01

Table 10. Purgeable organic compounds analyzed for in water from selected wells south of the Idaho National Engineering and Environmental Laboratory

[Analyses were performed by the U.S. Geological Survey National Water Quality Laboratory using an analytical method equivalent to U.S. Environmental Protection Agency method 524.2. Minimum reporting levels are from C.A. Waterson and A.T. Kashuba (USGS, written commun., 1993). Units are in micrograms per liter]

Compound	Minimum reporting level	Compound	Minimum reporting level
Acrolein	20	2,2-Dichloropropane	0.2
Acrylonitrile	20	cis-1,3-Dichloropropene	.2
Benzene	.2	trans-1,3-Dichloropropene	.2
Bromobenzene	.2	1,1-Dichloropropene	.2
Bromochloromethane	.2	Ethylbenzene	.2
Bromoform	.2	Hexachlorobutadiene	.2
n-Butylbenzene	.2	Isopropylbenzene	.2
sec-Butylbenzene	.2	P-Isopropyltoluene	.2
tert-Butylbenzene	.2	Methylbromide	.2
Carbon tetrachloride	.2	Methylene chloride	.2
Chlorobenzene	.2	Methylchloride	.2
Chlorodibromomethane	.2	Methyl tert-butylether	1.0
Chloroethane	.2	Naphthalene	.2
2-Chloroethylvinylether	1.0	n-Propylbenzene	.2
Chloroform	.2	Styrene	.2
1,2-Chlorotoluene	.2	1,1,1,2-Tetrachloroethane	.2
1,4-Chlorotoluene	.2	1,1,2,2-Tetrachloroethane	.2
Dibromochloropropane	1.0	Tetrachloroethylene	.2
1,2-Dibromoethane	.2	Toluene	.2
Dibromomethane	.2	1,2,3-Trichlorobenzene	.2
1,2-Dichlorobenzene	.2	1,2,4-Trichlorobenzene	.2
1,3-Dichlorobenzene	.2	1,1,1-Trichloroethane	.2
1,4-Dichlorobenzene	.2	1,1,2-Trichloroethane	.2
Dichlorobromomethane	.2	Trichloroethene	.2
Dichlorodifluoromethane	.2	Trichlorofluoromethane	.5
1,1-Dichloroethane	.2	1,2,3-Trichloropropane	.2
1,2-Dichloroethane	.2	Trichlorotrifluoroethane	.2
cis-1,2-Dichloroethene	.2	1,2,4-Trimethylbenzene	.2
1,1-Dichloroethene	.2	1,3,5-Trimethylbenzene	.2
1,2-Transdichloroethene	.2	Vinyl chloride	.2
1,2-Dichloropropane	.2	Xylenes, total ortho, meta, and para	.2
1,3-Dichloropropane	.2		

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