

FORMATION OF PERCHED GROUND-WATER ZONES AND CONCENTRATIONS OF  
SELECTED CHEMICAL CONSTITUENTS IN WATER, IDAHO NATIONAL  
ENGINEERING LABORATORY, IDAHO, 1986-88

By

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CONVERSION FACTORS, VERTICAL DATUM, AND ABBREVIATIONS FOR UNITS

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<u>Multiply</u>	<u>By</u>	<u>To obtain</u>
inch (in.)	25.40	millimeter
foot (ft)	0.3048	meter
foot per day (ft/day)	0.3048	meter per day
mile (mi)	1.609	kilometer
acre	0.4047	hectare
square mile (mi <sup>2</sup> )	2.590	square kilometer
gallon (gal)	3.785	liter
gallon per year (gal/year)	3.785	liter per year
pound (lb)	0.4536	kilogram
curie (Ci)	3.7x10 <sup>10</sup>	becquerel
curie per year (Ci/year)	3.7x10 <sup>10</sup>	becquerel per year
picocurie per milliliter (pCi/mL)	0.03700	becquerel per milliliter
picocurie per liter (pCi/L)	0.03700	becquerel per liter

For temperature, degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) by using the formula °F = (1.8)(°C)+32.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviations for units: µg/L (microgram per liter), mg/L (milligram per liter), and µS/cm (microsiemens per centimeter at 25°C).

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ABSTRACT

Wastewater containing radiochemical and chemical constituents has been discharged since 1952 to infiltration ponds and wells at the Idaho National Engineering Laboratory. Perched ground-water zones have formed from wastewater discharged to infiltration ponds. Lithologic features controlling formation of these zones include contrasts in vertical hydraulic conductivity, baked-zone alterations, unfractured basalt, and fracture filling. Waste-disposal practices, waste volumes discharged, sorption, and radioactive decay have affected concentrations of selected constituents in perched ground water.

From October 1985 to November 1988, maximum tritium concentrations in water from deep perched zones at the Test Reactors Area decreased from  $1,770 \pm 30$  to  $948 \pm 14$  picocuries per milliliter; total dissolved chromium concentrations were  $190 \pm 10$  and  $170 \pm 20$  micrograms per liter, respectively. Maximum sodium and chloride concentrations were  $840 \pm 84$  and  $64 \pm 6$  milligrams per liter in October 1985, respectively; maximum concentrations in November 1988 were  $1,000 \pm 100$  and  $66 \pm 7$  milligrams per liter, respectively. Chromium-51, cobalt-60, and cesium-137 were not detected.

Maximum tritium concentrations in water from shallow perched zones at the Test Reactors Area decreased from  $5,630 \pm 20$  picocuries per milliliter during 1982-85 to  $3,430 \pm 50$  picocuries per milliliter during 1986-88; maximum chromium-51 concentrations increased from  $28 \pm 3$  to  $90 \pm 3$  picocuries per milliliter; maximum cobalt-60 concentrations were  $11.9 \pm 0.5$  and  $12.5 \pm 0.4$  picocuries per milliliter; and maximum cesium-137 concentrations were  $2.9 \pm 0.2$  and  $2.48 \pm 0.16$  picocuries per milliliter. Maximum total dissolved

chromium concentrations were  $90\pm 10$  micrograms per liter during 1982-85 and  $80\pm 10$  micrograms per liter during 1986-88; maximum sodium concentrations decreased from  $42\pm 4$  to  $19\pm 2$  milligrams per liter.

In 1988, maximum tritium and strontium-90 concentrations in water from perched zones beneath infiltration ponds at the Idaho Chemical Processing Plant were  $36.7\pm 0.8$  picocuries per milliliter and  $18\pm 2$  picocuries per liter, respectively. The maximum sodium and chloride concentrations were  $120\pm 12$  and  $220\pm 20$  milligrams per liter, respectively.

## INTRODUCTION

The Idaho National Engineering Laboratory (INEL) comprises  $890 \text{ mi}^2$  of the eastern Snake River Plain in southeastern Idaho (fig. 1). The INEL was established in 1949 and is used by the Department of Energy to test nuclear reactors. The INEL is one of the main centers in the United States for developing the peacetime use of atomic energy and nuclear-safety research.

Radiochemical and chemical wastes generated at the INEL were in wastewater discharged to wells and infiltration ponds from 1952 to 1983. Since 1983, most of the wastewater has been discharged to infiltration ponds. This wastewater moves downward through unsaturated rock and sediment. Saturated bodies of water (perched ground water) can form in zones of contrasting vertical hydraulic conductivities. Many of the waste constituents enter the Snake River Plain aquifer below the perched ground-water zones following percolation through the unsaturated zone.

Since 1949, the U.S. Geological Survey has conducted hydrologic studies through an interagency agreement with the U.S. Department of Energy to describe the water resources of the INEL and vicinity, to determine hydrologic trends, and to characterize movement of liquid wastes discharged from facilities. As part of this agreement, the U.S. Geological Survey routinely samples water from 38 wells completed in discontinuous perched ground-water zones at the INEL. These samples are analyzed for selected radiochemical and chemical constituents, and physical and chemical characteristics.

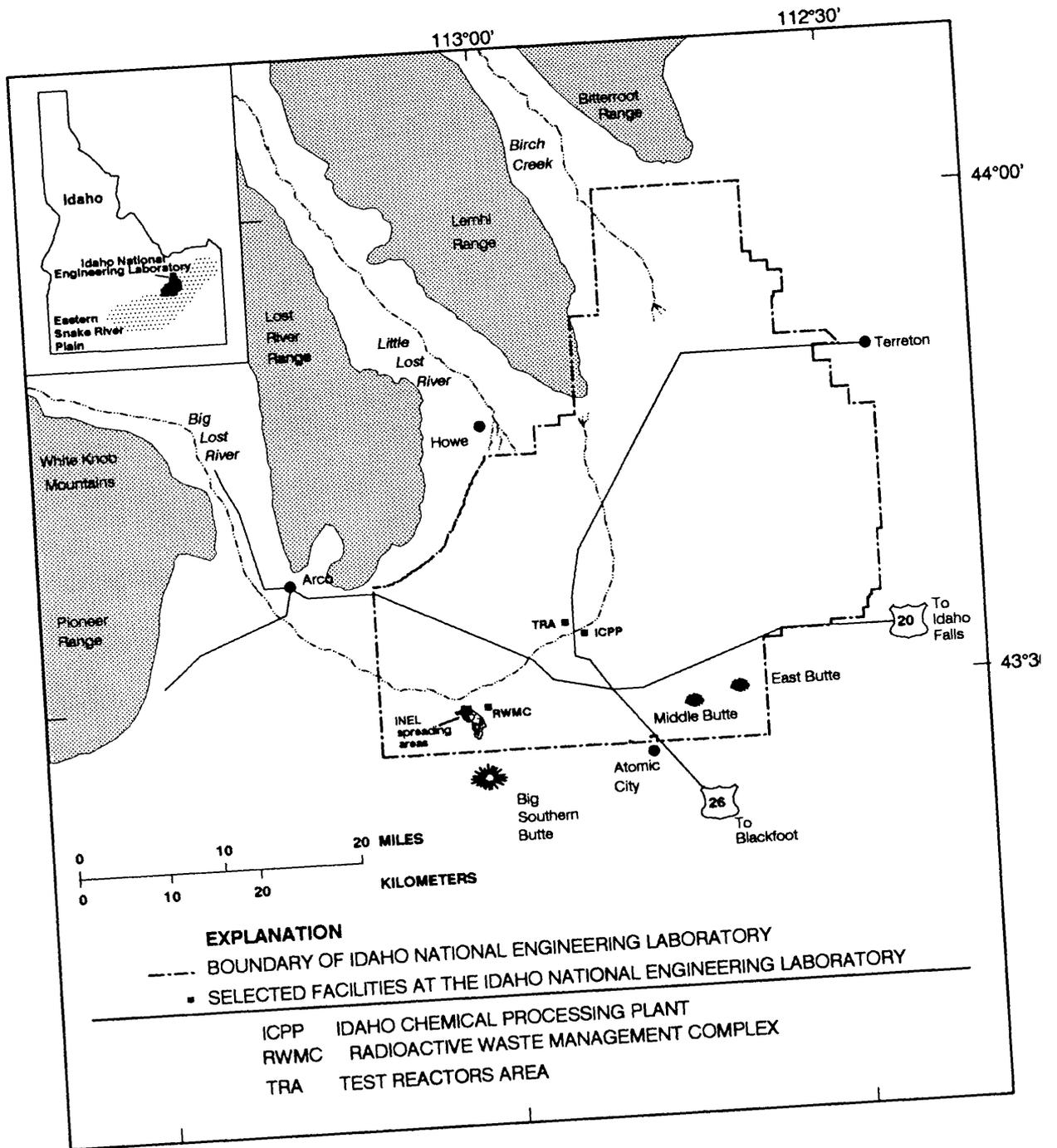


Figure 1.--Location of the Idaho National Engineering Laboratory and selected facilities.

Water-level data also are collected routinely from 30 wells and numerous shallow auger holes. Water-quality and water-level data are used to determine the effects of wastewater disposal on the formation of the discontinuous perched ground-water zones and to characterize the geochemical and hydrologic processes in these zones.

### Purpose and Scope

This report presents an analysis of water-level and water-quality data collected from discontinuous perched ground-water zones during 1986-88 as part of the ongoing geohydrologic investigation at the INEL. The formation of these zones is discussed and the distribution and concentration of selected radiochemical and chemical constituents is described. An analysis of water-level and water-quality data for the Snake River Plain aquifer during 1986-88 is presented in a report by Orr and Cecil (1991).

### Acknowledgments

The U.S. Department of Energy's Radiological and Environmental Sciences Laboratory (RESL) provided radiochemical and chemical analyses of water samples. Technical staff at the RESL are under the supervision of T.F. Gesell, Director, D.B. Martin, Chief, Analytical Chemistry Branch, and E.W. Chew, Chief, Environmental Sciences Branch. Messrs. R.G. Jensen, R.L. Whitehead, and J.R. Kolva, U.S. Geological Survey, and W.A. Owca, Westinghouse Idaho Nuclear Company, Inc., provided technical reviews of the report.

### Previous Investigations

Since 1949, numerous geologic and hydrologic studies have been conducted at the INEL. These studies focused on the Snake River Plain aquifer and the perched ground-water zones associated with the disposal of radiochemical and chemical wastes to wells and infiltration ponds.

Concentrations of selected radiochemical and chemical constituents in water from the perched zones at the Test Reactors Area (TRA) previously have been described in reports on regional hydrology.

Jones (1961) acknowledged distinct upper and lower perched ground-water zones associated with the infiltration ponds constructed in 1952 and 1954 at the TRA. The lower perched ground-water zone was linked to a sedimentary interbed approximately 150 ft below land surface. The areal extent of the lower zone and the concentrations of several constituents were described. Results of a 1962 drilling operation clarified the position of the upper perched ground-water zone at the TRA--approximately 50 ft below land surface--above the contact between the alluvium and basalt (Morris and others, 1963). Barraclough, Teasdale, and Jensen (1967) reported perched ground-water data from wells in the vicinity of an infiltration pond constructed in 1964 at the TRA.

Barraclough, Teasdale, Robertson, and Jensen (1967) reported on the development of the perched ground-water zones at the TRA and the effect of the 1964 infiltration pond with respect to selected constituent concentrations. Robertson, Schoen, and Barraclough (1974) consolidated the information concerning the regional aquifer and the perched ground-water zones during 1952-70. Barraclough and Jensen (1976), Barraclough and others (1981), Lewis and Jensen (1984), and Pittman and others (1988) reported the effects on water from perched zones at the TRA with respect to concentrations of selected radiochemical and chemical constituents.

Schmalz (1972) analyzed the distribution of radionuclides in the alluvium at the TRA. Laboratory column experiments with strontium-85-enhanced wastewater and representative sediment samples were used to derive distribution coefficients for strontium-90 and cobalt-60. These coefficients were used in mathematical models to calculate the sorption capacity of the representative sediments. Robertson (1977) constructed a numerical model incorporating convection, hydrodynamic dispersion, adsorption, and radioactive decay to simulate the movement of radionuclides from the TRA infiltration pond to associated perched ground-water zones.

## Ground-Water Monitoring Networks

Ground-water monitoring networks are maintained at the INEL to characterize the occurrence, movement, and quality of water and to delineate waste-constituent plumes in perched ground-water zones overlying the Snake River Plain aquifer. These networks consist of wells from which water-level and water-quality data periodically are obtained. Hydrologic data are on file at the Geological Survey's INEL project office.

### Water-Level Monitoring Network

The INEL water-level network for perched ground-water zones was designed to determine hydraulic-gradient changes that influence the rate and direction of ground-water movement and transport of radiochemical and chemical constituents, and to measure the areal extent of the effects of recharge. Water levels were monitored during 1986-88 in approximately 30 observation wells. Continuous recorders also monitored water-level fluctuations in three of these wells. The location of the 30 observation wells and the frequency of water-level measurements as of the date of this report are shown on figure 2. Additionally, water levels are monitored annually in numerous, shallow auger holes.

### Water-Quality Monitoring Network

The radiochemical and chemical character of water in perched zones is determined from analyses of water samples collected as part of a comprehensive sampling program to identify contaminant concentrations and to define the pattern of waste migration in the Snake River Plain aquifer. Nearby surface-water sites are sampled to document the chemical quality of water that recharges the ground-water system. Numerous samples are collected near areas of detailed study, such as the TRA, Idaho Chemical Processing Plant (ICPP), and Radioactive Waste Management Complex (RWMC).

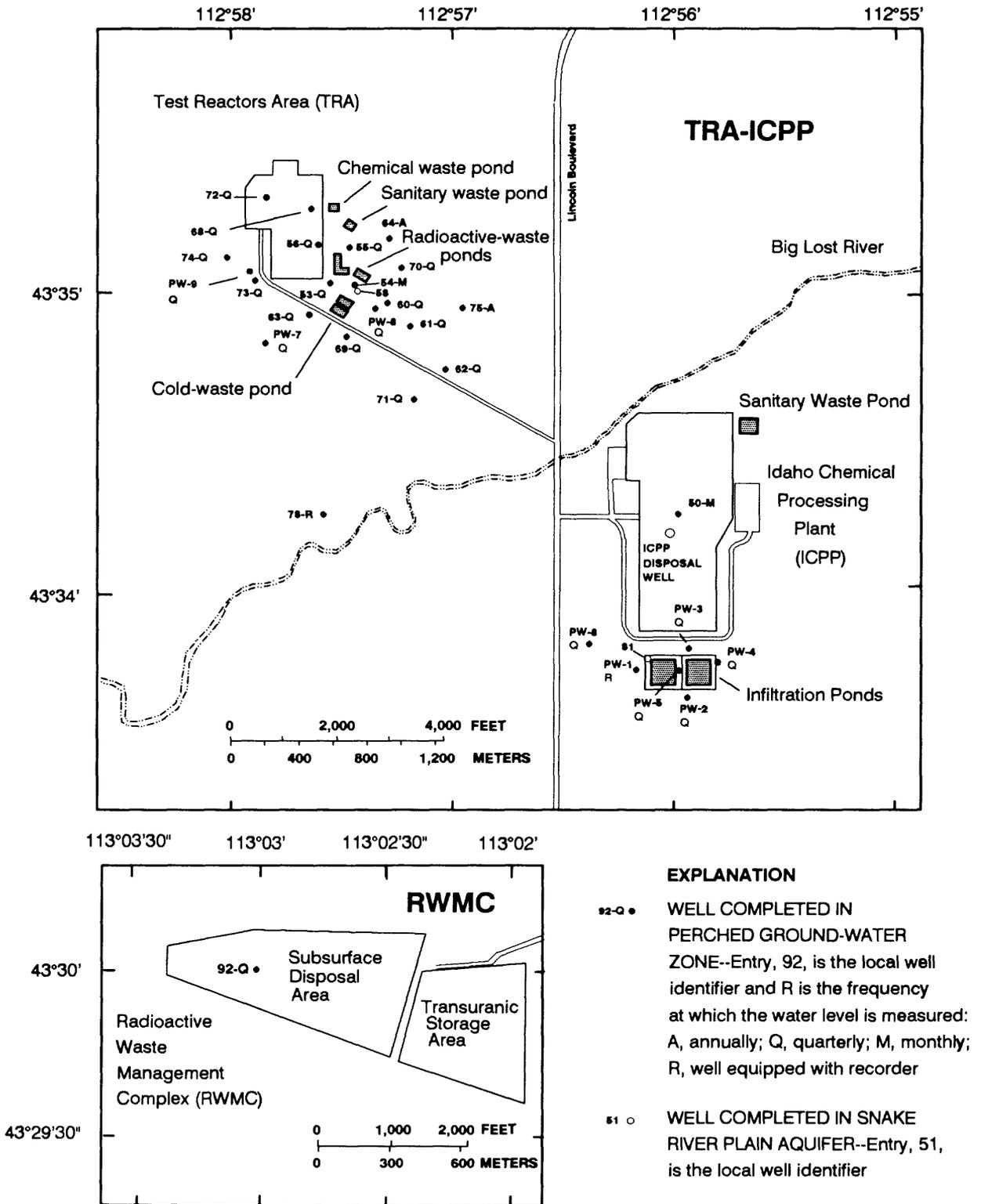


Figure 2.--Location of wells and frequency of water-level measurements in perched ground-water zones at the Test Reactors Area, Idaho Chemical Processing Plant, and Radioactive Waste Management Complex.

The type, frequency, and depth of sampling generally depend on the information needed in a specific area. Water samples are collected and analyzed for tritium, strontium-90, chromium-51, cobalt-60, cesium-137, total dissolved chromium, sodium, chloride, and selected other chemical constituents or physical properties. During 1986-88, more than 430 water samples were collected from wells completed in perched zones. The location of these wells is shown on figure 3. Frequency of sample collection during 1986-88 is given on table 1.

### Geohydrologic Setting

The eastern Snake River Plain is a northeast-southwest oriented structural basin about 200 mi long and 50 to 70 mi wide. The plain consists of surficial alluvium and basalt outcrops underlain by a layered sequence of basalt flows and sedimentary interbeds. Individual basalt flows range from 10 to 50 ft thick, although the average thickness can be from 20 to 25 ft (Mundorff and others, 1964, p. 143). The surficial alluvium and sedimentary interbeds consist mainly of sand, silt, and clay, and lesser amounts of gravel. Locally, rhyolitic lava flows and tuffs are exposed at the land surface or exist at depth. The horizontal hydraulic conductivity for basalt at the INEL ranges from 1 to 7,000 ft/day (Robertson, 1977, p. 25). The vertical hydraulic conductivity of sedimentary interbeds ranges from 0.00001 to 7 ft/day (Robertson, 1977, p. 26).

The unsaturated-zone sequence of alluvium, basalt flows and sedimentary interbeds is typical of the stratigraphy at the INEL. This sequence was formed by extrusion and cooling of basalt followed by periods of quiescence and sedimentary deposition (Nace and others, 1975, p. 16). Vertical and horizontal fractures developed as basalt flows cooled. These fractures and interflow rubble zones serve as the primary conduits by which ground water is transmitted through the basalt flows. Locally, perched ground-water zones have formed within the unsaturated zone in response to recharge from infiltration ponds at the TRA and ICPP and from localized flooding at the RWMC. Perched ground-water zones may form in response to large flows in the

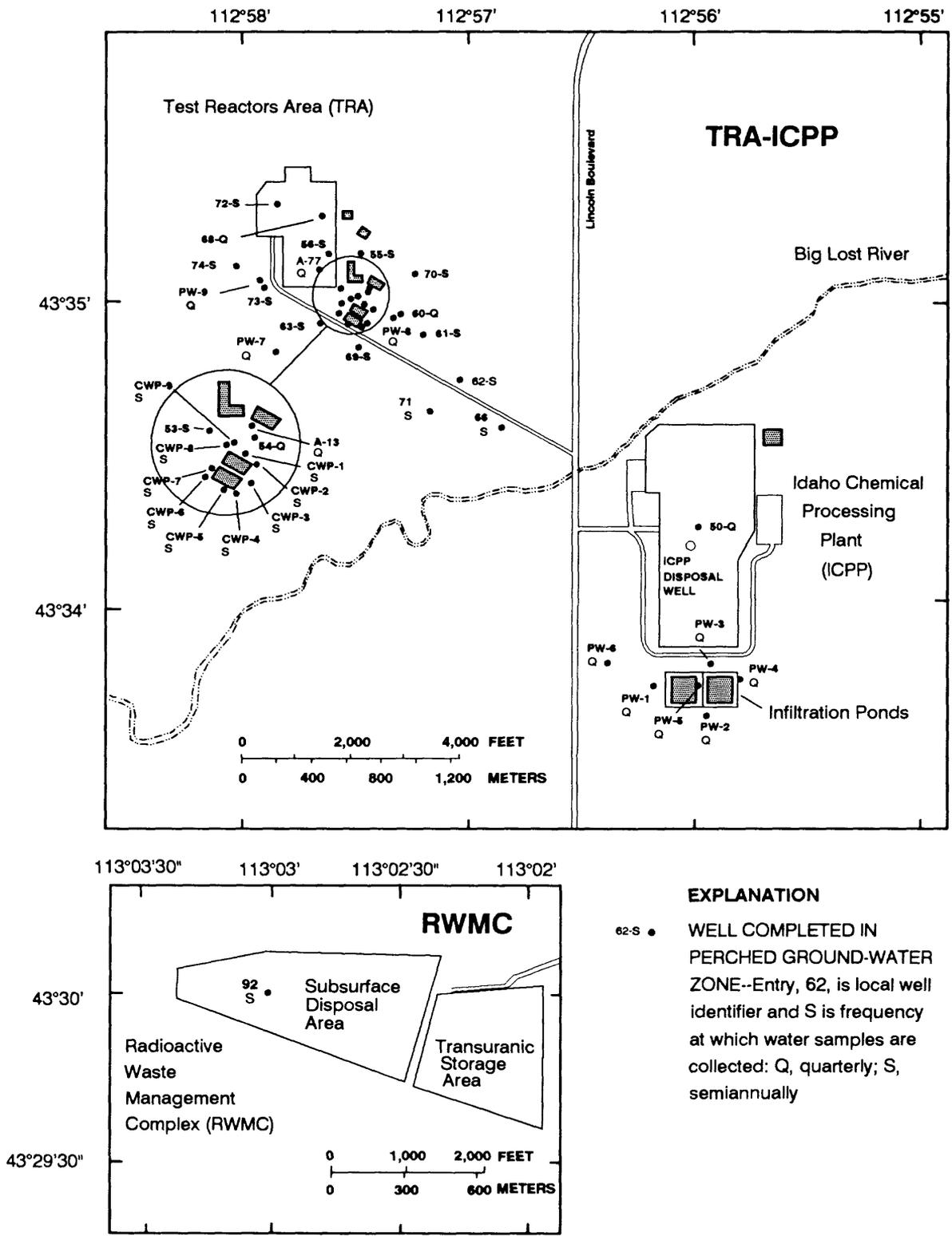


Figure 3.--Location of wells and frequency of water-sample collections in perched ground-water zones at the Test Reactors Area, Idaho Chemical Processing Plant, and Radioactive Waste Management Complex.

Table 1.--Sampling frequency of monitoring wells completed in the perched ground-water zones at the Idaho National Engineering Laboratory

[Well identifier: see figure 3 for location of wells. Sampling method: Pump - sample collected with a portable pump; Bailer - sample collected with a bail sampler; Thief - sample collected with a thief sampler; sampling depth indicated. Sampling frequency: S - semiannual; Q - quarterly.]

Well identifier	Latitude	Longitude	Sampling method	Well diameter inches	Well depth feet	Sampling frequency
CWP 1	43°34'59"	112°57'26"	Pump 65 ft	10	66.0	S
CWP 2	43°34'58"	112°57'24"	Pump 52 ft	10	52.5	S
CWP 3	43°34'55"	112°57'25"	Pump 60 ft	10	60.5	S
CWP 4	43°34'54"	112°57'26"	Pump 60 ft	10	61.0	S
CWP 5	43°34'55"	112°57'29"	Pump 53 ft	10	53.5	S
CWP 6	43°34'56"	112°57'33"	Pump 52 ft	10	52.5	S
CWP 7	43°34'58"	112°57'32"	Pump 53 ft	10	53.5	S
CWP 8	43°35'00"	112°57'30"	Pump 65 ft	10	66.0	S
CWP 9	43°35'00"	112°57'29"	Pump 64 ft	6	65.6	S
PW-1	43°33'49"	112°56'08"	Pump 105 ft	10	120	Q
PW-2	43°33'45"	112°55'57"	Pump 115 ft	10	131	Q
PW-3	43°33'51"	112°55'58"	Pump 121 ft	10	125	Q
PW-4	43°33'49"	112°55'49"	Pump 115 ft	10	123	Q
PW-5	43°33'49"	112°55'57"	Pump 115 ft	10	131	Q
PW-6	43°35'53"	112°56'22"	Pump 130 ft	10	135	Q
PW-7	43°34'47"	112°57'47"	Pump 220 ft	10	237	Q
PW-8	43°34'57"	112°57'21"	Pump 145 ft	10	178	Q
PW-9	43°35'01"	112°57'55"	Pump 195 ft	10	201	Q
TRA A-13	43°35'02"	112°57'28"	Bailer	1.5	58.8	Q
TRA A-77	43°35'07"	112°57'38"	Bailer	2	34	Q
USGS 50	43°34'19"	112°56'02"	Thief 390 ft	6	40.5	Q
USGS 53	43°35'02"	112°57'34"	Pump 80 ft	6	90	S
USGS 54	43°35'02"	112°57'28"	Pump 80 ft	6	91	Q
USGS 55	43°35'08"	112°57'29"	Pump 75 ft	6	79	S
USGS 56	43°35'09"	112°57'35"	Pump 75 ft	6	80	S
USGS 60	43°34'56"	112°57'19"	Pump 90 ft	6	117	Q
USGS 61	43°34'53"	112°57'15"	Pump 105 ft	10	123	S
USGS 62	43°34'46"	112°57'05"	Pump 150 ft	8	165	S
USGS 63	43°34'55"	112°57'40"	Pump 95 ft	10	97	S
USGS 66	43°34'39"	112°56'57"	Pump <185 ft Thief >185 ft	6	475	S
USGS 68	43°35'15"	112°57'39"	Pump 85 ft	10	128	Q
USGS 69	43°34'50"	112°57'29"	Pump 100 ft	10	115	S
USGS 70	43°35'04"	112°57'10"	Pump 85 ft	8	100	S
USGS 71	43°34'40"	112°57'15"	Pump 170 ft	8	184	S
USGS 72	43°35'19"	112°57'46"	Pump <150 ft Thief >150 ft	6	177	S
USGS 73	43°35'01"	112°57'54"	Pump 100 ft	6	127	S
USGS 74	43°35'05"	112°58'05"	Thief 190 ft	6	192	S
USGS 92	43°30'00"	113°02'53"	Bailer 213 ft	3.5	215	S

Big Lost River. The depth to the Snake River Plain aquifer is about 450 ft below land surface at the TRA and ICPP and about 600 ft below land surface at the RWMC.

### Waste-Disposal Sites

Wastewater disposal sites at the various INEL facilities have been the principal sources of radiochemical and chemical constituents in water from the perched zones. In the past, wastewater disposal sites at the INEL have included infiltration ponds, drain fields, and disposal wells. During 1986-88, wastewater disposal was accomplished using infiltration ponds and drain fields. Waste materials buried at the RWMC also are a constituent source. Radiochemical waste-disposal data presented in this report were obtained from a series of radioactive waste management information reports (Litteer, 1987b and 1988b; Litteer and Reagan, 1989b). Chemical waste-disposal data were obtained from a series of industrial waste management information reports (Litteer, 1987a and 1988a; Litteer and Reagan, 1989a). These radiochemical and chemical waste-disposal data were collected by contractors at each facility.

### Test Reactors Area

During 1986-88, approximately 259 million gal/year of wastewater were discharged to ponds at the TRA. During 1982-85, 276 million gal/year of wastewater were discharged to ponds (Pittman and others, 1988, p. 20). Low-level radiochemical, chemical, and sanitary wastes were disposed in wastewater to these ponds. Cooling-tower wastewater was discharged to a pond during 1952-64 and to the Snake River Plain aquifer through a 1,275-ft deep disposal well from 1965 to March 1982. Since 1982, this wastewater has been discharged to the cold-waste pond.

The average annual discharge to the radioactive-waste ponds during 1960-88 was 151 million gal (fig. 4). The average annual discharge for 1986-88 was 20.7 million gal.

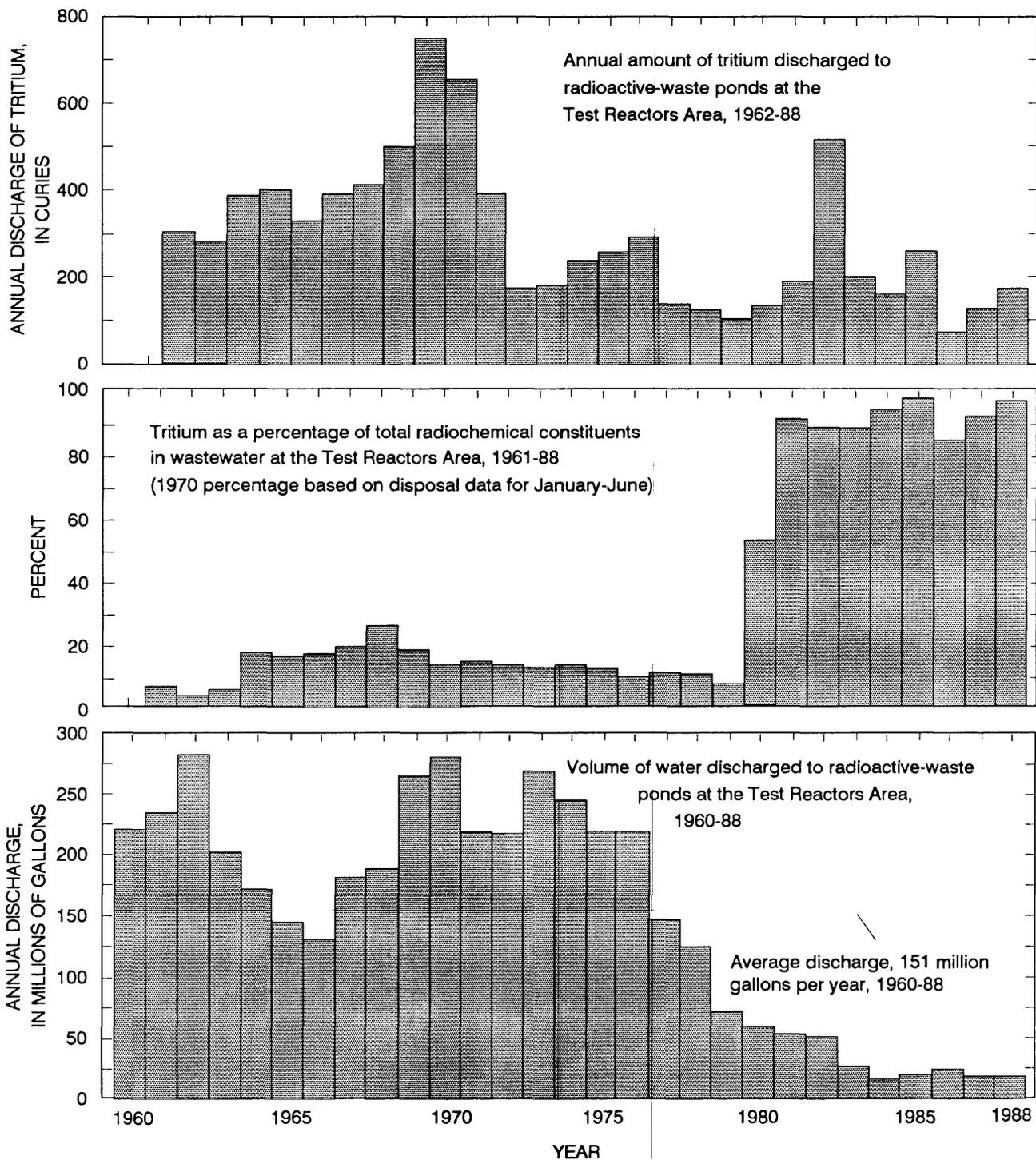


Figure 4.--Amount of tritium discharged, tritium as a percentage of total radiochemical constituents in wastewater, and volume of water discharged to the radioactive-waste ponds at the Test Reactors Area, 1960-88.

Since 1980, most of the radioactivity in wastewater discharged at the TRA was from tritium. From 1974 to 1979, tritium composed about 10 percent of the radioactivity in wastewater (Pittman and others, 1988, p. 22). In 1980, tritium composed about 50 percent of the total radioactivity and, during 1981-85, composed about 90 percent. During 1986-88, tritium accounted for about 97 percent of the total radioactivity in wastewater discharged at the TRA.

In 1976, the Department of Energy contractor at the TRA began a three-phase program to reduce the number of curies of radioactivity in wastewater. The first phase ran from 1976 to 1980 and the second phase ran during 1981-87. At the end of 1988, the contractor was in the first year of the final phase of this reduction program (R.N. Beatty, EG&G Idaho, Inc., oral commun., 1990).

An infiltration pond has been used for chemical-waste disposal from an ion-exchange system at the TRA since 1962. The average annual discharge to the chemical-waste pond was about 21 million gal for the period 1962-88. Discharge to the pond decreased from about 6 million gal in 1985 to 4.2 million gal in 1988. The mean annual discharge for 1986-88 was 5.4 million gal. Sulfate and sodium were the predominant constituents in chemical wastewater. During 1986-88, annual averages of about 507,000 lb of sulfate and 183,000 lb of sodium were discharged to the pond. The average annual concentrations of sulfate and sodium in wastewater during 1986-88 were about 11,000 and 4,100 mg/L, respectively.

A deep disposal well was used from 1964 to March 1982 for disposal of nonradioactive wastewater to the Snake River Plain aquifer. Since March 1982, infiltration ponds have been used to dispose of wastewater. The average discharge to the well and the ponds was about 230 million gal/year during 1964-88 and about 225 million gal/year during 1986-88. Most of this wastewater was from cooling-tower operations at the TRA and contained annual averages of about 469,000 lb of sulfate and 32,000 lb of other chemicals during 1986-88.

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

#### Idaho Chemical Processing Plant

From 1953 to February 1984, low-level radiochemical, chemical, and sanitary wastewater was discharged to the Snake River Plain aquifer at the ICPP through a 600-ft deep disposal well. The average wastewater volume was about 363 million gal/year (Pittman and others, 1988, p. 24). Two infiltration ponds presently are being used for wastewater disposal. The first pond was completed in February 1984 and the second pond was put into service in October 1985.

The volume of wastewater discharged to the well and infiltration ponds during 1962-88 is shown on figure 5. Wastewater discharge to the first pond totaled 474 million gal in 1984. About 390 million gal were discharged to the first pond from January to October 1985 and 143 million gal were discharged to the second pond from October to December 1985. Discharge to the second pond ranged from about 577 million to 600 million gal/year during 1986-88. The total annual discharge to the well and ponds ranged from 260 million gal in 1963 to 600 million gal in 1987 and averaged about 400 million gal/year. The average discharge during 1986-88 was about 580 million gal/year.

Tritium accounted for more than 90 percent of the radioactivity in wastewater discharged at the ICPP since 1975 (fig. 5). During 1986-88, tritium accounted for about 99.8 percent of the total radioactivity. During 1982-85, 1,088 Ci of tritium were contained in wastewater at the ICPP for an annual average of 272 Ci (Pittman and others, 1988, p. 25). During 1986-88, 556 Ci of tritium were discharged for an annual average of 185 Ci.

Chloride, sulfate, nitrate, and fluoride are the predominant constituents in chemical wastewater discharged to the ICPP infiltration ponds. Annual averages of about 1,178,000 lb of chloride, 227,000 lb of

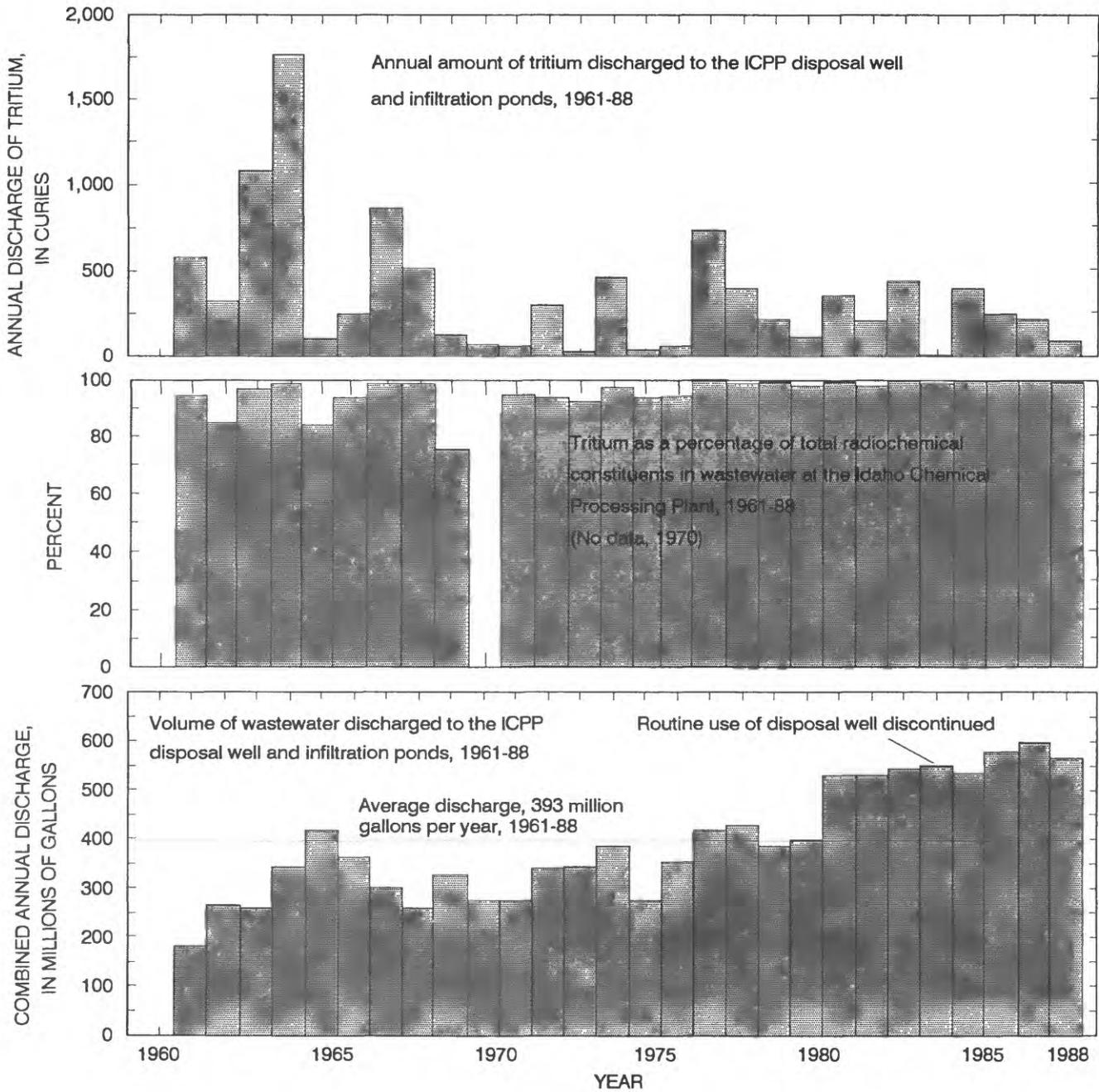


Figure 5.--Amount of tritium discharged, tritium as a percentage of total radiochemical constituents in wastewater, and volume of water discharged to the disposal well and infiltration ponds at the Idaho Chemical Processing Plant, 1961-88.

sulfate, 160,400 lb of nitrate, and 2,255 lb of fluoride were contained in ICPP wastewater during 1986-88. An annual average of 8.5 million gal of sewage effluent was discharged to a sanitary-waste infiltration pond (fig. 2) at the ICPP during 1986-88.

#### Radioactive Waste Management Complex

Radiochemical and chemical wastes have been buried in trenches and pits at the Subsurface Disposal Area (SDA) at the RWMC since 1952. Prior to 1970, little or no sediment was retained between the excavation bottoms and underlying basalt. Since 1970, a layer of sediment was retained to inhibit downward migration of waste constituents. These constituents include transuranic wastes disposed to trenches until 1970, other radiochemical and chemical constituents, and organic compounds.

Transuranic wastes buried in the SDA during 1954-70 included approximately 165,000 Ci of plutonium-241, 21,000 Ci of plutonium-239, 4,900 Ci of plutonium-240, and 550 Ci of plutonium-238. An estimated 88,400 gal of organic waste were discharged prior to 1970 (Mann and Knobel, 1987, p. 1). These buried wastes included 39,000 gal of lubricating oil, 24,400 gal of carbon tetrachloride, and 25,000 gal of other organic compounds, including trichloroethane, trichloroethylene, perchloroethylene, toluene, and benzene.

#### FORMATION OF PERCHED GROUND-WATER ZONES

The geohydrologic characteristics of the unsaturated zone underlying the TRA, ICPP, and RWMC differ with respect to basalt and sediment lithology, unit thickness, and physical orientation. The volumes of effluent discharged to infiltration ponds and the sizes of the area over which recharge occurs differ between facilities. Additionally, the degree of saturation varies both horizontally and vertically. Although these differences exist, the features that control the formation of perched ground-water zones are common to the TRA, ICPP, and RWMC.

## Lithologic Features Controlling Formation of Perched Ground-Water Zones

Lithologic features contributing to contrasts in the vertical hydraulic conductivity of basalt layers and sedimentary interbeds in the unsaturated zone provide mechanisms for the development of perched ground-water zones. Perched ground-water zones at the TRA, ICPP, and RWMC can be attributed to at least four lithologic features. First, the vertical hydraulic conductivity of a sedimentary interbed might be smaller than that of an overlying basalt flow. Second, alterations in the baked zone between two flows can contribute to reduced vertical hydraulic conductivity. Third, dense, unfractured basalt may inhibit unsaturated ground-water movement, contributing to the formation of perched ground-water zones. Fourth, sedimentary and chemical filling of fractures near the upper contact of a basalt flow reduces the vertical hydraulic conductivity.

### Contrasts in Vertical Hydraulic Conductivity Between Basalt Flows and Sedimentary Interbeds

The horizontal hydraulic conductivity of basalts in the unsaturated zone at the INEL may range from 1 to 7,000 ft/day (Robertson, 1977, p. 25). Robertson reported that the horizontal hydraulic conductivity of basalts generally is larger than the vertical hydraulic conductivity. Robertson also reported that the saturated vertical hydraulic conductivity of sedimentary interbeds may range from 0.00001 ft/day near the RWMC to 7 ft/day in playa sediments in the northern part of the INEL (Robertson, 1977, p. 26). The smaller vertical hydraulic conductivity of a sedimentary interbed underlying a more-permeable basalt will impede the movement of water and contribute to the formation of a perched ground-water zone.

### Reduced Vertical Hydraulic Conductivity in Interflow Baked Zones

The intense heating of the upper surface of an existing flow from the emplacement of an overlying flow causes oxidation of glassy matrix and olivine crystals and coats scoria fragments, vesicles, and fracture surfaces

with iron oxides and iron hydroxides (Kuntz and others, 1980, p. 11). These baked-zone alterations can modify the orientation and dimensions of fractures in the underlying flow, changing the vertical hydraulic conductivity. The extent of alteration and its effect on vertical flow can be influenced by the presence of sediment and water at the time of emplacement, the temperature of the overlying magma, and other factors (D.E. Champion, U.S. Geological Survey, oral commun., 1989).

#### Reduced Vertical Hydraulic Conductivity in Dense, Unfractured Basalt

Lithologic, geophysical, and borehole television logs from wells at the INEL indicate that some basalt flows are dense and unfractured. The absence of fractures decreases the vertical hydraulic conductivity of the basalts contributing to the formation of perched ground-water zones.

#### Reduced Vertical Hydraulic Conductivity from Sedimentary and Chemical Filling of Fractures in Basalt

The efficiency by which water is transmitted through fractures is dependent on aperture width, wall irregularity, attitude, and interconnection of the fractures. Sedimentary materials accumulate in fractures during sediment aggradation onto a basalt surface (Rightmire and Lewis, 1987, p. 22) reducing the water-transmitting efficiency of a fractured matrix. Post-depositional fracture filling continues as infiltrating water transports sediment. During periods of major recharge, sediment transported by infiltrating water may include coarse silt and fine sand, but fine clay fractions are preferentially deposited (Rightmire, 1984, p. 20). Most fracture filling generally occurs in the upper 3 ft of a basalt flow (Rightmire and Lewis, 1987, p. 23). Calcium carbonate also precipitates on fracture walls, reducing the fracture size and decreasing the capability of the fractured matrix to transmit water. Rightmire and Lewis (1987, p. 27) observed that carbonate was concentrated in fractures in the uppermost 16 feet of a basalt flow at the RWMC.

## Formation of Perched Ground-Water Zones at the Test Reactors Area, 1952-88

A vertical sequence of discontinuous perched ground-water zones has formed at the TRA in unsaturated basalt-flow groups and sedimentary interbeds. These basalt-flow groups and interbeds were identified by Anderson (1991) as flow groups BC through FG (fig. 6). In places, the sequence of perched ground-water zones is characterized by vertically continuous saturation; in other places, the sequence is characterized by vertically discontinuous zones.

Wells 53 and 54 (fig. 6) are completed in the unit identified by Anderson (1991) as basalt-flow group BC. This flow group contains the uppermost perched ground-water zones that have formed in basalt and sedimentary interbeds at the TRA. Wells 60, 61, 62, 73, 74, PW-8, and PW-9 are completed in underlying basalt flows.

Thick sections of basalt and sedimentary interbeds are saturated near the TRA ponds. Well 58, located between the TRA radioactive- and cold-waste ponds (fig. 2), was completed as a monitoring well in the Snake River Plain aquifer. The 1969 neutron-log trace for well 58 (fig. 7) indicates that surficial deposits, basalt flows corresponding to Anderson's flow groups BC, DE1, and DE2, and sedimentary interbeds were saturated or partially saturated from the land surface to a depth of at least 170 ft (fig. 7). Based on the neutron log, basalt and sedimentary interbeds below a depth of 170 ft largely were unsaturated near well 58 in 1969.

Well 60, located southeast of well 58 and the TRA (fig. 2), was completed in basalt to a depth of 105 ft. Well PW-8 was completed near well 60 to a depth of 170 ft. In November 1988, the water level in well PW-8 was 71.81 ft below land surface, 4.5 ft lower than the water level in well 60. The relatively small difference in water levels may indicate that the interval from about 72 to 170 ft below land surface is fully saturated in the vicinity of well 60. This interval contains basalt flows BC, DE1, and DE2 and a thin sedimentary interbed (fig. 6).

EXPLANATION

**B** BASALT — Basalt-flow group composed of one or more related flows. Letter, B, indicates sequence of group from top to bottom of section. Locally includes cinders and thin layers of sediment

**CLAY, SILT, SAND, AND GRAVEL** — Major sedimentary interbed between basalt-flow groups. Locally includes cinders and basalt rubble

**GEOLOGIC CONTACT** — Queried where uncertain

**WELL** — Entry, 46, is local well identifier. Dashed line indicates measured or estimated water level in aquifer in 1988. Arrow indicates measured water level in aquifer in 1988. Number, 651, at bottom of section is total depth of well in feet below land surface.

**WELL** — Entry, 53, is local well identifier. Arrow indicates measured water level of perched ground water in 1988.

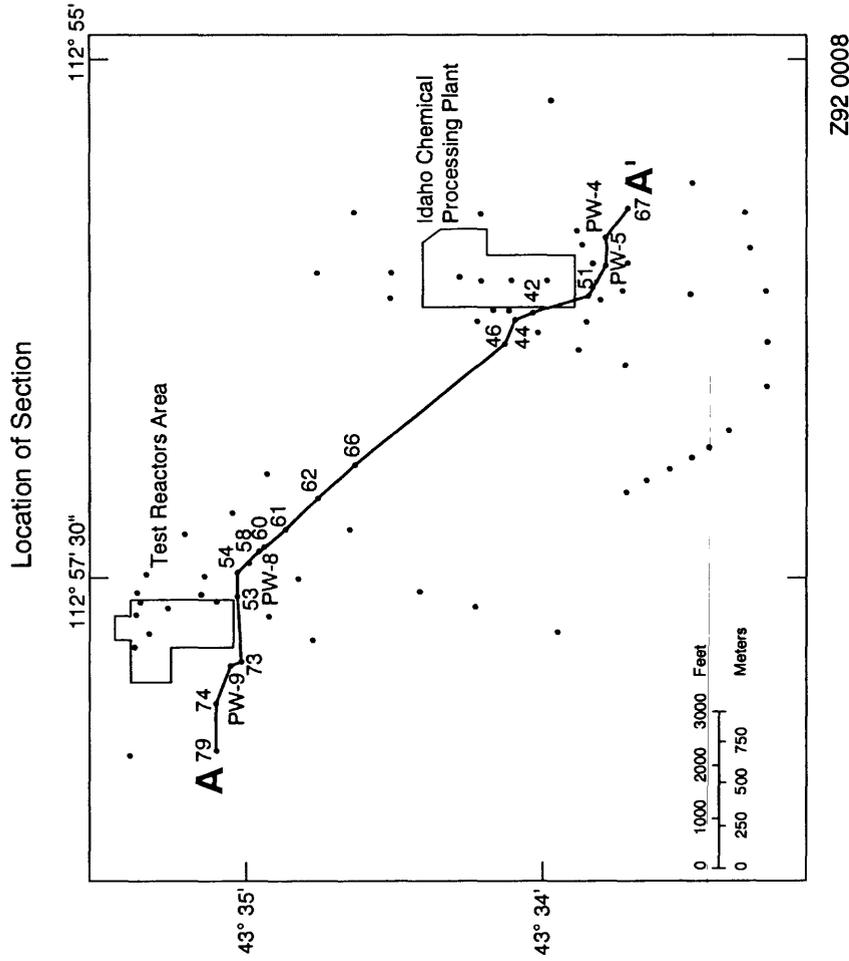


Figure 6.--Geologic section A-A' through the Test Reactors Area and the Idaho Chemical Processing Plant.



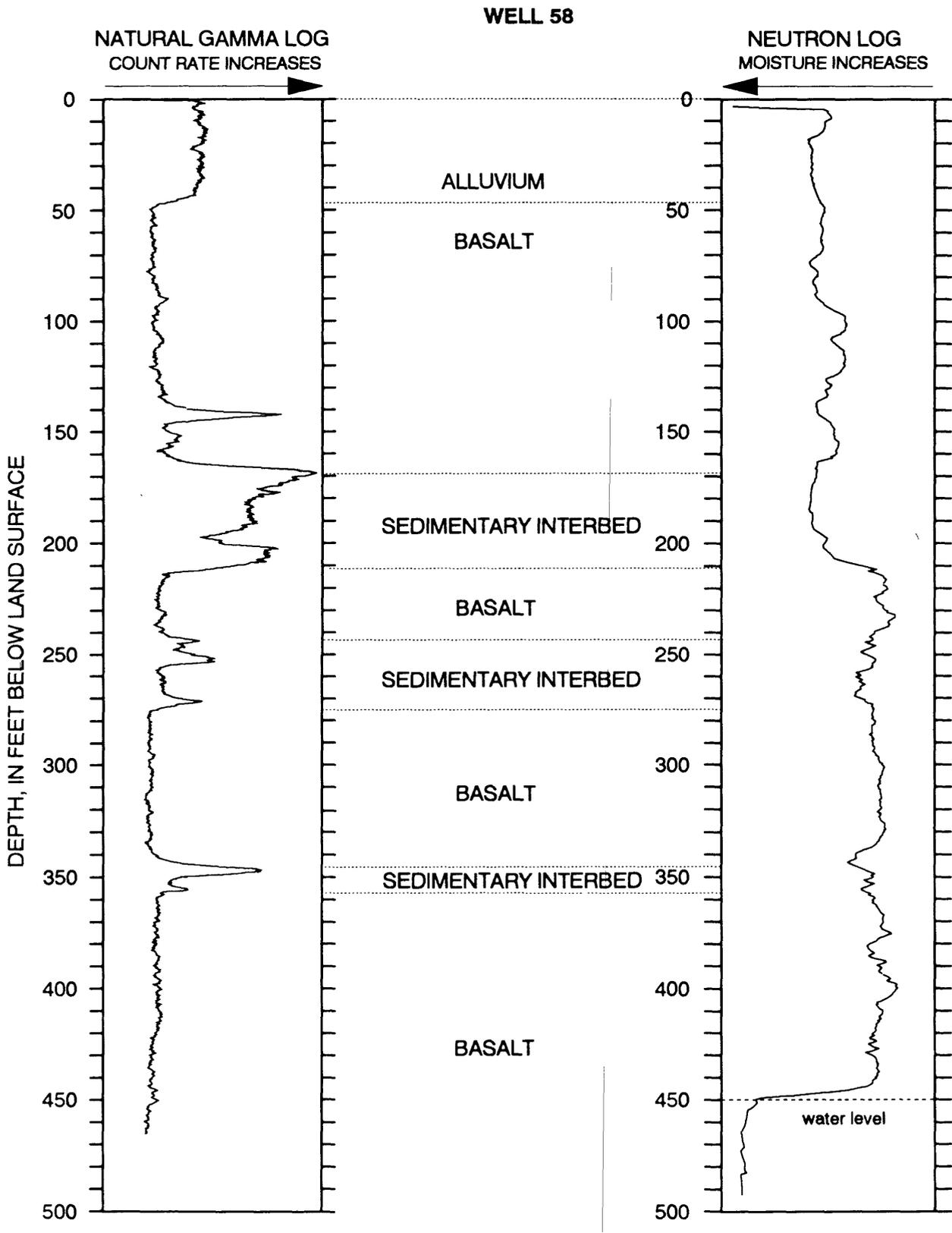


Figure 7.--Stratigraphy of the unsaturated zone and increases in moisture content of perched ground-water zones in well 58, 1969, and well 51, 1984-86.

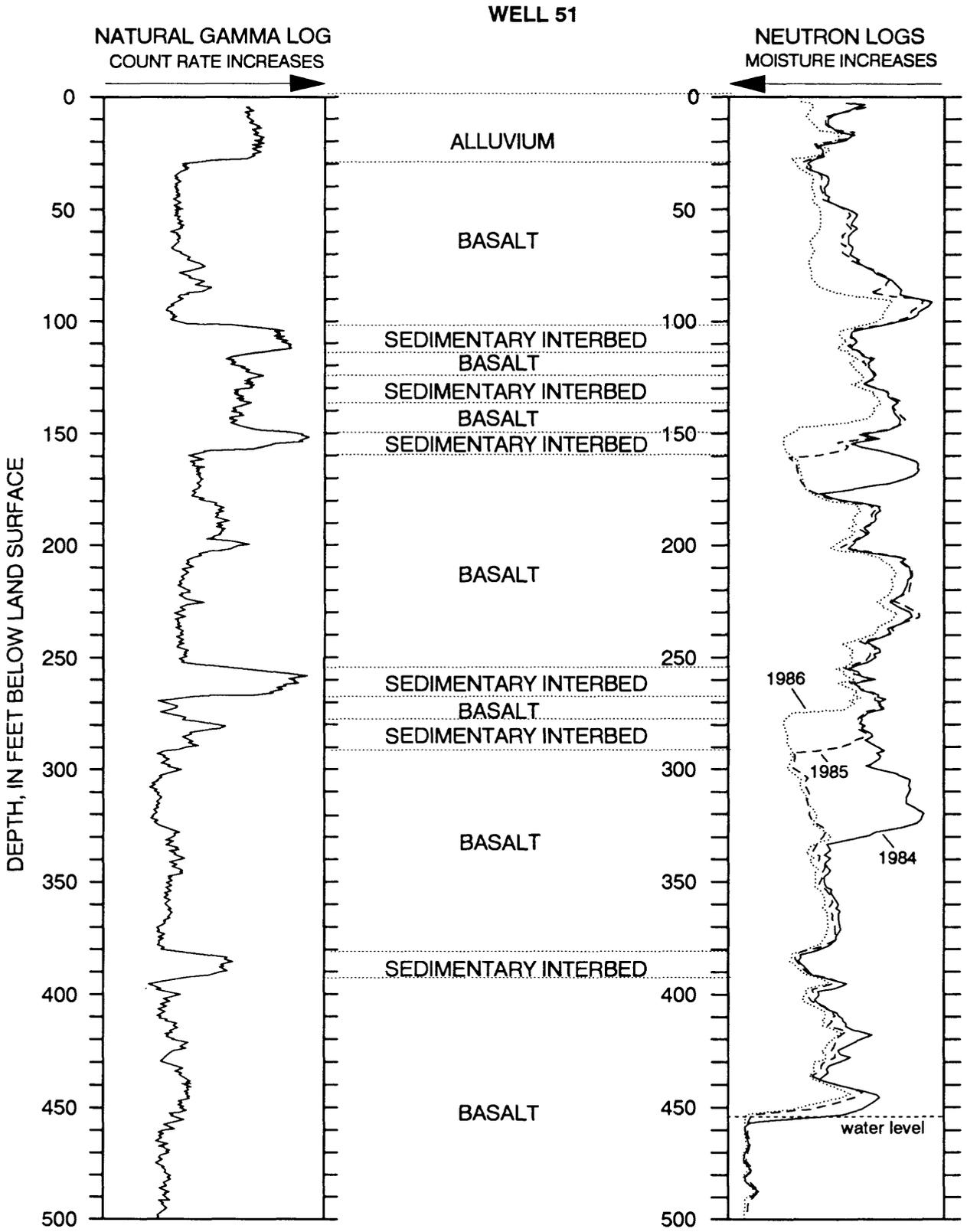


Figure 7.--Stratigraphy of the unsaturated zone and increases in moisture content of perched ground-water zones in well 58, 1969, and well 51, 1984-86--Continued.

Well 66, located southeast of well 60 (fig. 2), originally was drilled to a depth of 475 ft as an observation well in the Snake River Plain aquifer in 1961. The well was constructed with 4-in. steel casing to a depth of 378 ft. In 1986, the 4-in. casing was removed from the land surface to a depth of 220 ft and the well was cemented up to 218 ft. A new 6-in. casing was installed and perforated from a depth of 160 to 200 ft. The 1986 neutron log for well 66 (Bartholomay, 1990, p. 89) indicates that basalt flows were nearly saturated in the interval from 145 to 194 ft. At present (1991), television logs show that water is cascading from this interval to the top of the cement plug at a depth of about 220 ft.

Well 73, located near the southwest corner of the TRA, was completed in basalt to a depth of 127 ft. Well PW-9 was completed near well 73 in a sedimentary interbed to a depth of 200 ft. In November 1988, the water level in well PW-9 was 172.7 ft below land surface, about 85 ft lower than the water level in well 73. This large difference in water levels indicates that perched zones penetrated by these wells may be separated by unsaturated basalt and sediment.

Geologic structures may influence the extent of these perched ground-water zones and the vertical flow of water between zones. Anderson (1991, p. 30) described a subsurface structural dome northeast of the TRA. Domal deformation of basalts and sedimentary interbeds may limit the formation of perched ground-water zones to the northeast of the TRA ponds.

Water-table contours for 1988 (fig. 8) were constructed from water-level data obtained from only those wells completed in the uppermost deep perched ground-water zone (fig. 6) because perched ground-water zones are vertically discontinuous in places. The map showing water-level contours in perched ground water near the TRA was constructed from point data by simple linear interpolation (Davis, 1986, p. 146). However, the map as constructed should not be interpreted as providing additional information on the vertical or horizontal extent of perched ground-water zones at the TRA. A network of piezometers designed to monitor vertical hydraulic gradients is needed to better characterize the complete vertical and horizontal extent of perched ground-water zones at the TRA.

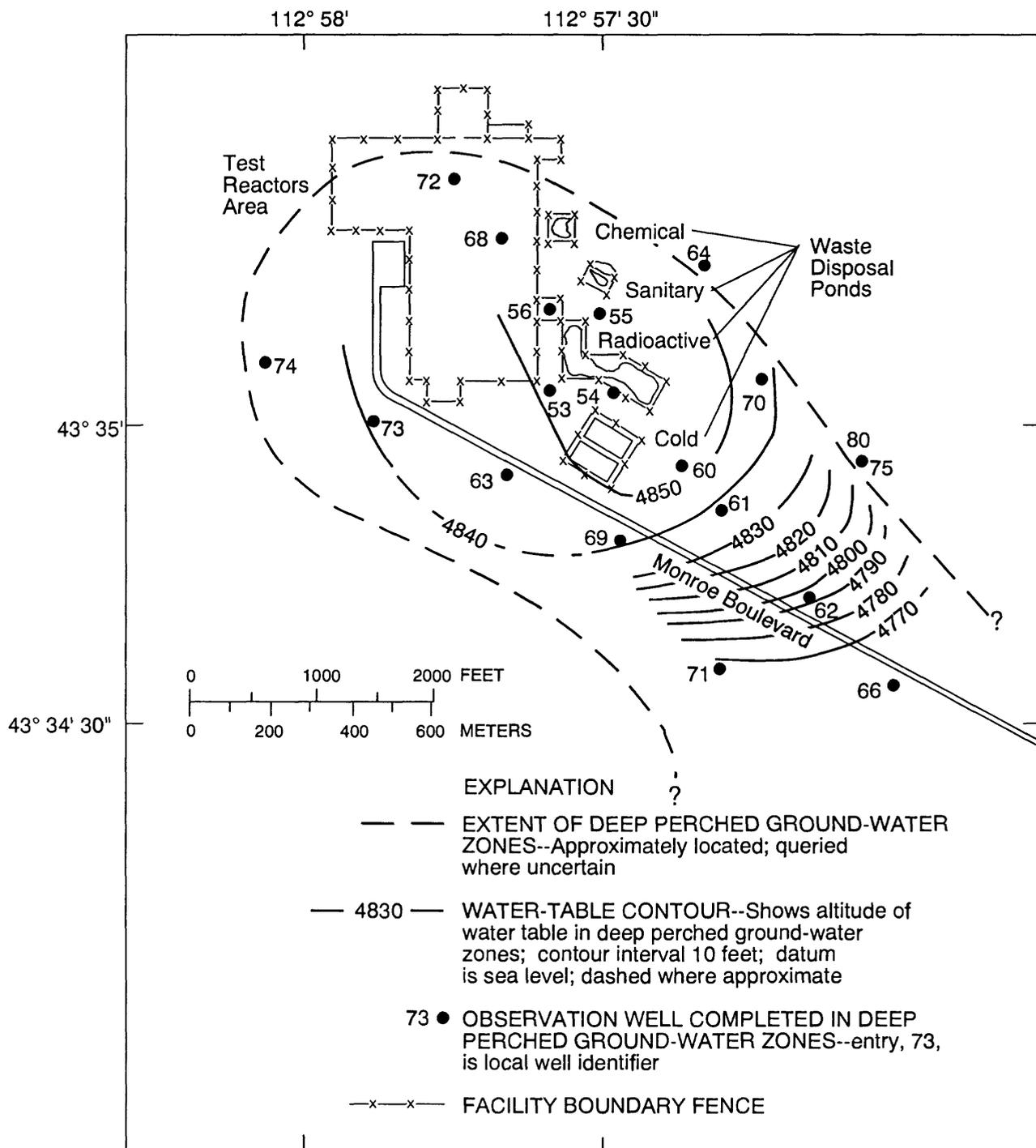


Figure 8.--The approximate extent of perched ground water and water-level contours in deep perched ground-water zones near the Test Reactors Area, November 1988.

Hydrographs for selected wells during 1986-88 indicate that water-level fluctuations were attenuated with distance from the TRA ponds (fig. 9). The water level in well 53, located at the southwest corner of the radioactive-waste pond, fluctuated about 20 ft during 1986-88. The water level in well 61, located about 800 ft southeast of the cold-waste pond, fluctuated about 13 ft. The water level in well 62, located about 2,000 ft southeast of the pond, remained essentially the same. Water-level fluctuations are attributed to short-term changes in discharge to the ponds.

#### Formation of Perched Ground-Water Zones at the Idaho Chemical Processing Plant, 1984-88

Routine use of the ICPP disposal well to discharge radiochemical and chemical wastes was discontinued in February 1984 when wastewater was diverted to an infiltration pond south of the ICPP. A second infiltration pond was constructed west of the first pond and used for disposal in October 1985 after plugging of the first pond's bottom decreased infiltration rates. Perched ground-water zones formed in the vicinity of the two ponds in response to discharge of wastewater.

The stratigraphy of the unsaturated zone beneath the ICPP infiltration ponds is shown on figure 6 and the lithology is reconstructed from geophysical logs for well 51 (fig. 7). Well 51 is completed in the Snake River Plain aquifer and is near the infiltration ponds (fig. 2). The surficial sediment penetrated by well 51 is 30 ft thick. The unsaturated zone underlying the surficial sediment at well 51 consists of as many as thirteen basalt-flow groups and six sedimentary interbeds (fig. 6). At well 51, flow groups range in thickness from 8 to 96 ft; sedimentary interbeds range in thickness from 4 to 15 ft (Anderson, 1991, Table 1).

Superimposed neutron logs from well 51 show the formation of several discontinuous perched ground-water zones during 1984-86 (fig. 7). Correlation of these logs to the gamma log from well 51 shows lithologic features that may have contributed to the formation of perched ground-water zones at the ICPP. At least four perched ground-water zones have been

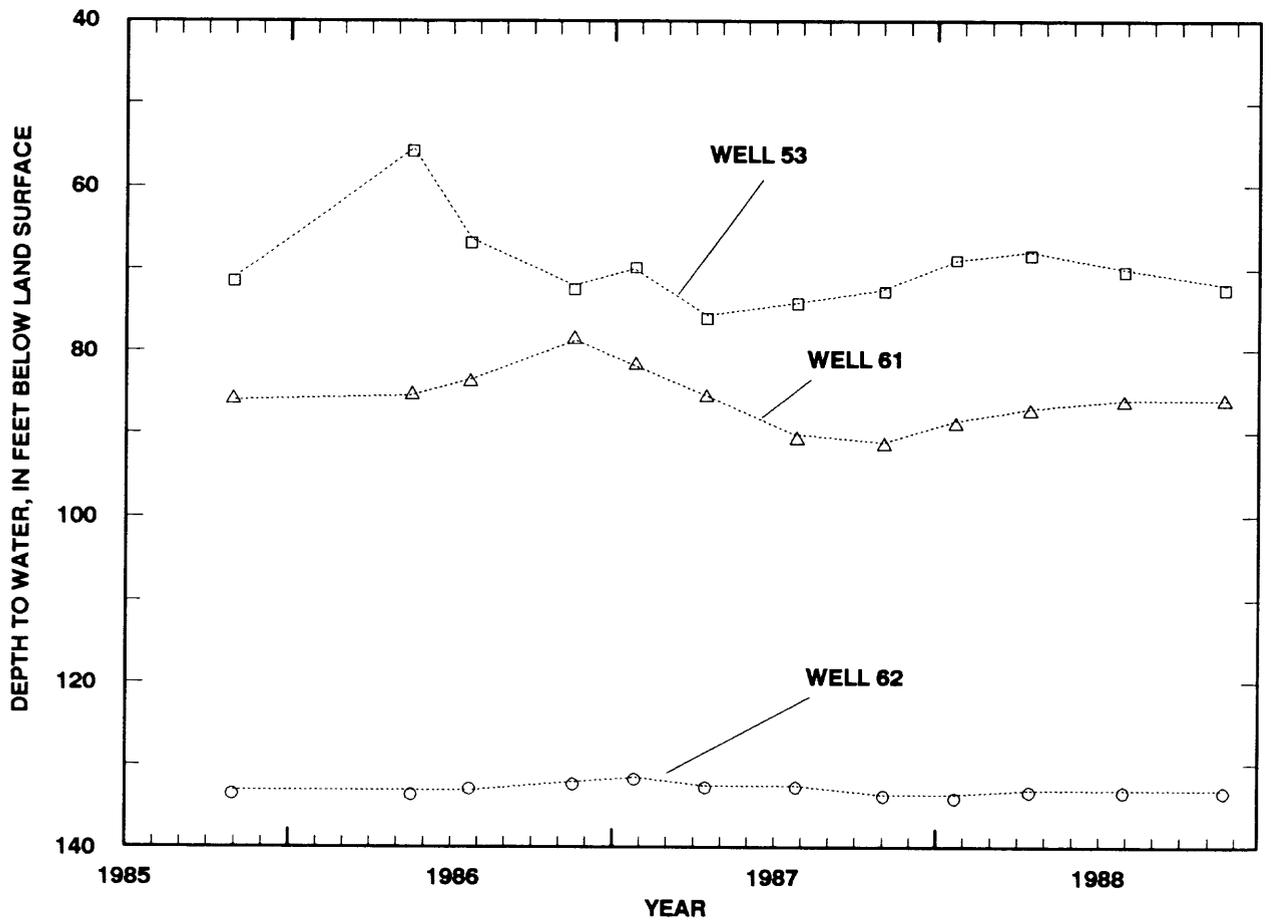


Figure 9.--Water-level changes in wells completed in deep perched ground-water zones near the Test Reactors Area, 1986-88.

identified beneath the infiltration ponds. These include a zone of saturation in the surficial alluvium and three separate zones in the underlying basalt and sedimentary interbeds. By 1986, perched ground-water zones had formed at well 51 in the depth intervals from 30 to 104 ft, 134 to 178 ft, and 266 to 332 ft. The moisture content in the intervening unsaturated zones also increased during 1984-86.

In 1986, six observation wells were constructed to monitor water levels and water quality in the perched ground-water zones that had formed near the ponds. These wells were completed to depths ranging from 120 to 150 ft. Each well was completed with approximately 20 ft of perforated casing, gravel pack, bentonite seal, and cement grout. Wells were located between the ponds, and on each side of the pond area (fig. 10).

During 1986-88, the second pond was used for wastewater disposal. Water levels in wells PW-1, PW-4, and PW-5, all close to the infiltration ponds, fluctuated as much as 5 ft in response to wastewater-disposal rates (fig. 11). Water levels in these wells ranged from about 69 to 88 ft below land surface. Water levels in wells PW-2, PW-3, and PW-6 were approximately 120 ft below land surface; water-level fluctuations in these wells were affected less by changes in pond discharge rates. Greater depths to water, smaller saturated thicknesses, and smaller water-level fluctuations in wells PW-2 and PW-3 indicate structural and stratigraphic controls on the lateral extent of perched ground-water zones to the north and south of the infiltration ponds. In well PW-6, greater distance from the infiltration ponds is a factor. Water-level fluctuations in the perched ground-water zones near the ICPP infiltration ponds are typical of transient conditions that resulted from switching disposal from one pond to another and from changing rates of wastewater disposal to the ponds.

Wastewater discharged to the infiltration ponds saturated the alluvium for a short distance directly under the ponds. Beneath this thin zone of saturation, the wastewater continued to move downward via unsaturated flow until it reached an underlying perching layer. In the vicinity of well 51, the wastewater saturated about 16 ft of alluvium by 1986; the perching layer

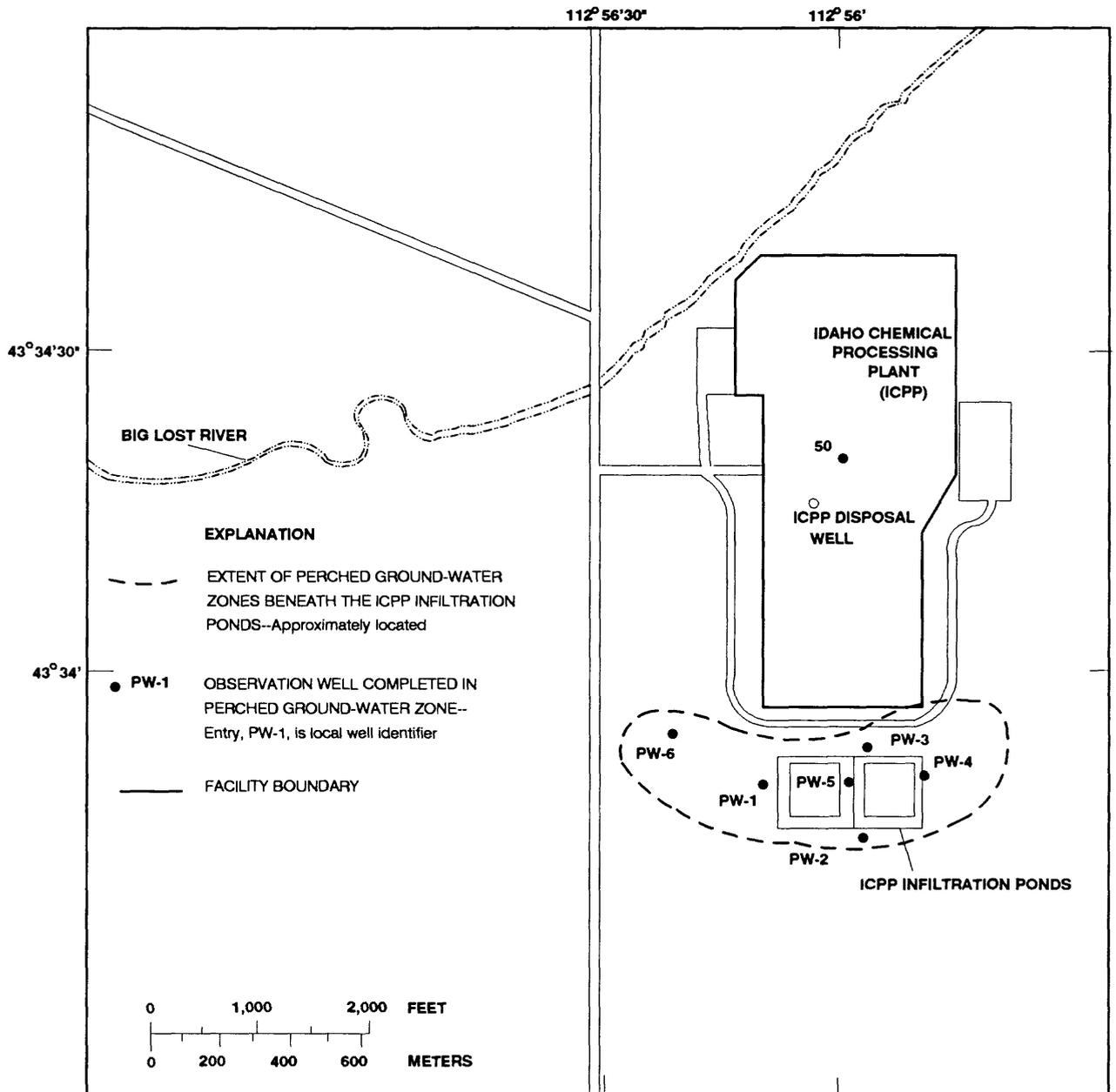


Figure 10.--Location of wells and approximate extent of perched ground-water zones near the Idaho Chemical Processing Plant infiltration ponds, October 1988.

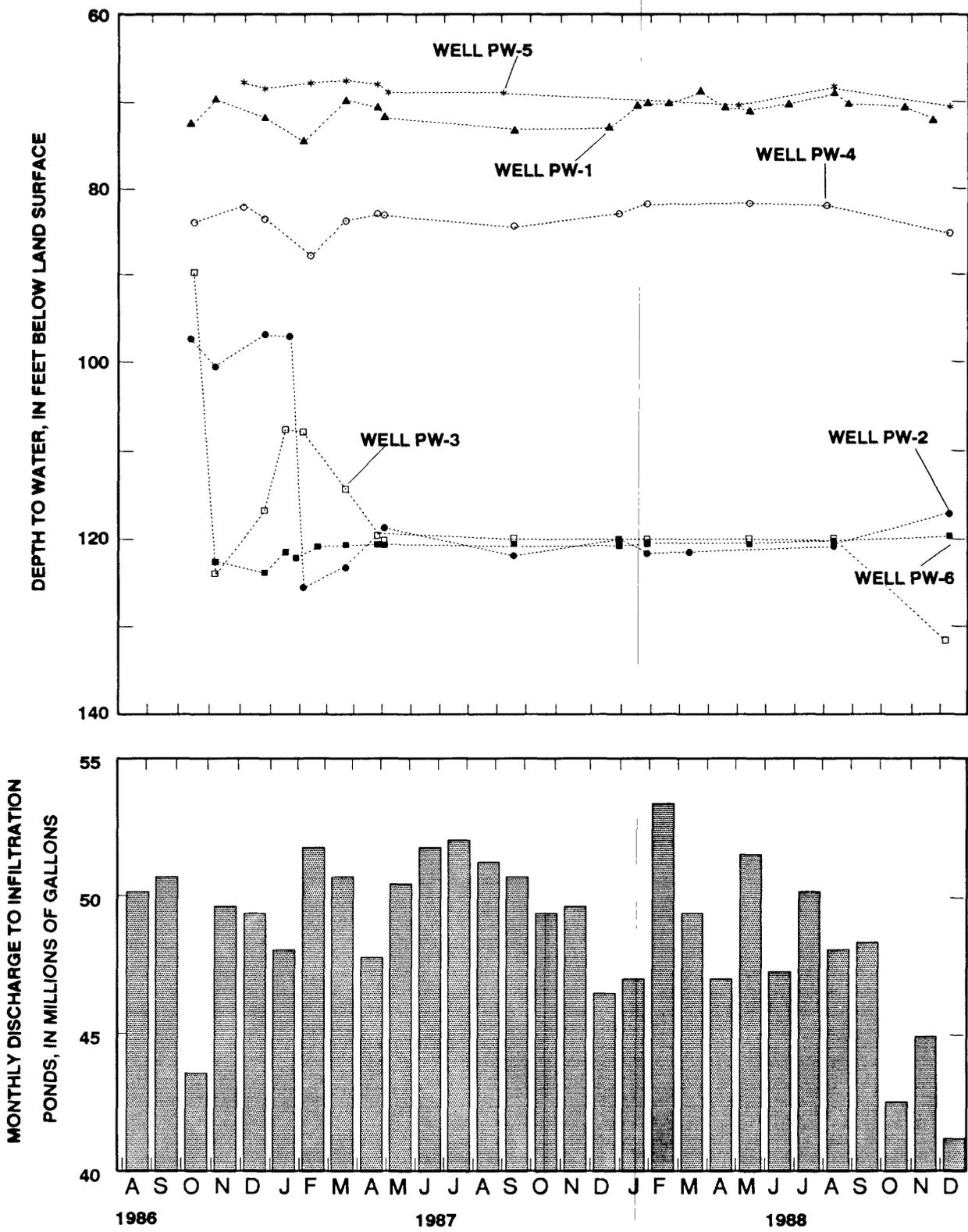


Figure 11.--Water-level changes in wells completed in perched ground-water zones and monthly discharge to infiltration ponds at the Idaho Chemical Processing Plant, 1986-88.

was at the alluvium-basalt interface (fig. 7). This thin, perched ground-water zone formed because the alluvium is more permeable than the underlying basalt.

In 1985, unsaturated conditions prevailed in the uppermost basalt at well 51. A thin perched ground-water zone had formed in the depth interval from 82 to 92 ft, probably at the contact between two flows (fig. 7). By 1986, this zone had increased to a thickness of about 74 ft and the perching layer was at the contact between the basalt-flow group and the top of an underlying sedimentary interbed at a depth of 104 ft.

Superimposed neutron logs from well 51 show that a perched ground-water zone formed at a depth of about 178 ft (fig. 7). The gamma log indicates that the perching layer for this zone was at the contact between two flow units, probably from baked-zone alterations or from sedimentary fracture filling of the lower flow. This zone was 22 ft thick in 1985; by 1986, the thickness had doubled.

A lower perched ground-water zone formed at a depth of about 332 ft at well 51 (fig. 7). Again, reduced hydraulic conductivity at the contact between flows may have provided a perching mechanism. By 1985, this zone was 44 ft thick; by 1986, the thickness had increased to 66 ft. Unsaturated flow prevailed throughout much of the interval from the lower zone to the water table in the Snake River Plain aquifer at a depth of about 456 ft.

A perched ground-water zone not associated with the infiltration ponds has been identified at well 50 (fig. 10). Well 50 was drilled near the ICPP disposal well in 1962 to a depth of 405 ft below land surface and about 50 ft above the regional water table. Perched ground water in well 50 may be attributed in part to wastewater injection from the disposal well until February 1984. The water level in well 50 declined from 374 ft below land surface in 1986 to 379 ft below land surface in 1988.

Formation of Perched Ground-Water Zones at the  
Radioactive Waste Management Complex, 1976-88

During 1976-77, wet zones were identified in five wells at the RWMC (EG&G Idaho, 1988, p. 2-86). The unsaturated zone is approximately 580 to 600 ft thick at the RWMC. Perched ground water has been identified in well 92 (fig. 2). This zone is associated with an underlying sedimentary interbed from 222 to 246 ft below land surface (Anderson and Lewis, 1989, p. 52). This well was completed at a depth of 215 ft. During 1986-88, the water level fluctuated from 208 to 210 ft below land surface.

SELECTED CHEMICAL CONSTITUENTS IN  
WATER FROM PERCHED GROUND-WATER ZONES

Perched ground-water zones containing measurable concentrations of radiochemical and chemical constituents have formed between the land surface and the Snake River Plain aquifer beneath the TRA, ICPP, and RWMC as a result of waste-disposal practices. The variability of saturation in the subsurface at the TRA, ICPP, and RWMC affects the movement, distribution, and concentration of radiochemical and chemical constituents in ground water from the perched zones. Maps showing concentrations of selected constituents in ground water from the perched zones near these facilities were constructed from point data. Concentrations are expressed with an associated analytical uncertainty and are presented in this report as detected if the concentration is equal to or greater than three times the analytical uncertainty (Mann and Cecil, 1990, p. 10). Negative concentrations indicate that the gross count for the target analyte is less than the gross count for the reagent/background blank. Constituents identified in perched ground water at the TRA, ICPP, and RWMC include tritium, strontium-90, cobalt-60, cesium-137, chromium-51, total dissolved chromium, sodium, and chloride; sulfate analyses were not performed. Other constituents may be sorbed onto geologic materials beneath ponds or discharged at concentrations insufficient for analytical detection.

## Test Reactors Area

Water from wells completed in the deep perched zones is routinely sampled and analyzed for selected radiochemical and chemical constituents. Additionally, water is routinely sampled from wells A-13, A-77, and CWP-1 through CWP-9 (fig. 3), completed in the shallow perched zone in the alluvium near the TRA. Strontium-90 analyses were not performed in water from the deep or the shallow perched zones during 1986-88. Concentrations of selected constituents in ground water from the deep (1986-88) and shallow (1982-88) zones are summarized in the following sections.

### Tritium

Approximately 9,700 Ci of tritium were discharged to the low-level radioactive-waste ponds at the TRA during 1952-88 for an average of 263 Ci/year. The average disposal rate of tritium from 1986 through 1988 was 126 Ci/year. This was about 97 percent of the total radioactivity contained in wastewater discharged at the TRA. The annual discharge of tritium to the radioactive-waste ponds from 1960 through 1988 is shown in figure 4. Tritium concentrations in the deep perched ground-water zone for November 1988 are shown in figure 12. The maximum concentrations of tritium for this period are near the radioactive-waste ponds.

Tritium concentrations from October 1985 to November 1988 in water from deep perched zones decreased because of a decrease in the amount of tritium discharged at the TRA. The maximum tritium concentration in October 1985 was  $1,770 \pm 30$  pCi/mL at well 53. The maximum tritium concentration in November 1988 was  $948 \pm 14$  pCi/mL at well 56.

During 1986-88, tritium concentrations in the shallow perched ground-water zone were less than concentrations in 1982-85, with the exception of well CWP-8. The maximum tritium concentration in water from well A-77 decreased from  $5,630 \pm 20$  pCi/mL during 1982-85 to  $3,430 \pm 50$  pCi/mL during 1986-88. The maximum tritium concentration in water from well A-13 decreased from  $158 \pm 2$  pCi/mL during 1982-85 to  $1.1 \pm 0.3$  pCi/mL during 1986-88.

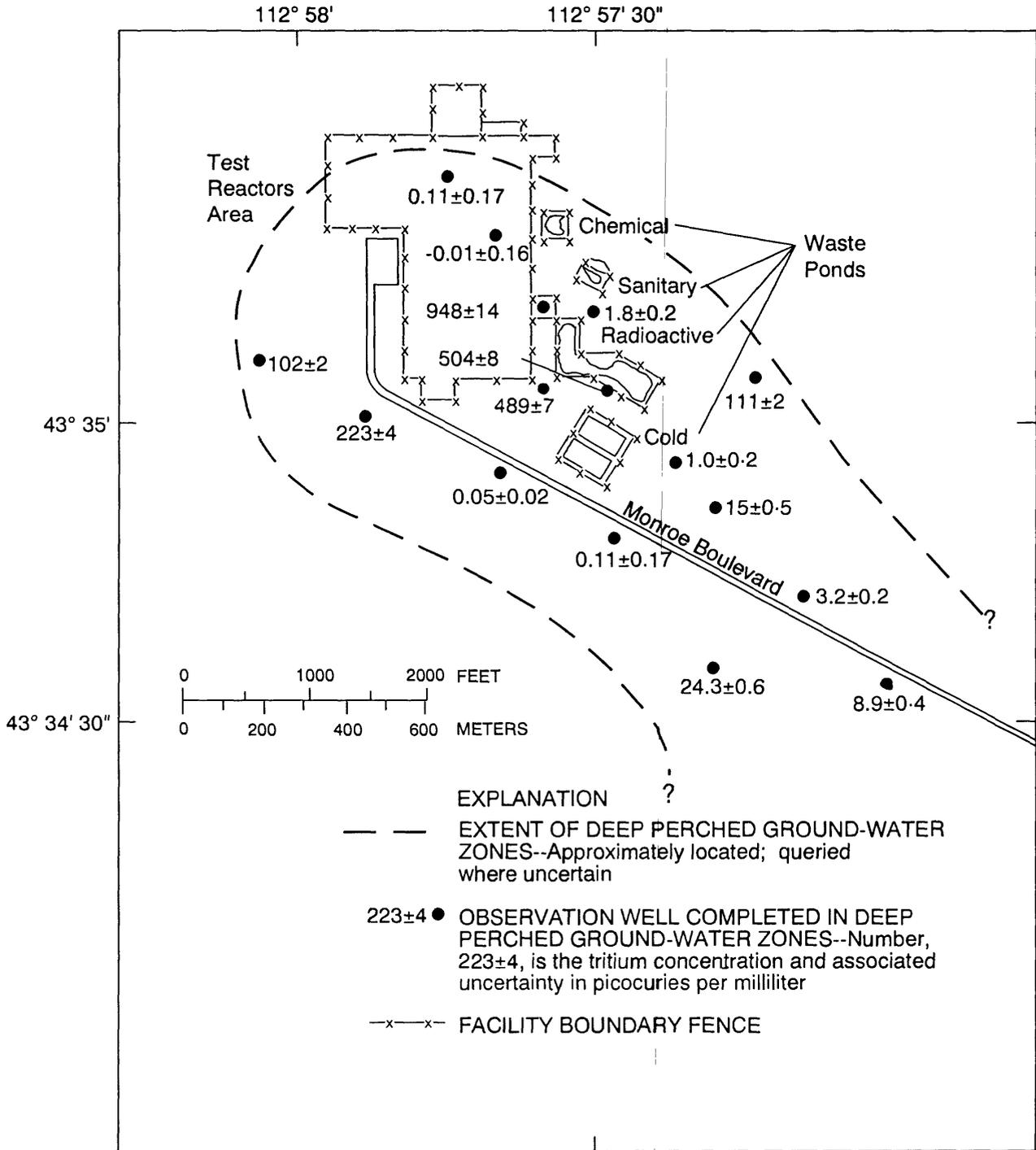


Figure 12.--Concentrations of tritium in water from deep perched ground-water zones near the Test Reactors Area, November 1988.

The maximum tritium concentration in water from well CWP-9 decreased from  $6.3 \pm 0.2$  pCi/mL during 1982-85 to  $1.1 \pm 0.2$  pCi/mL during 1986-88. Water from well CWP-8 contained no detectable tritium concentration during 1982-85. The maximum tritium concentration during 1986-88 was  $0.8 \pm 0.2$  pCi/mL. No detectable concentration of tritium was measured in water from wells CWP-1 through CWP-7 during 1982-88.

#### Chromium-51

A total of 2,381 Ci of chromium-51 was discharged to the radioactive-waste ponds during 1979-85. The average disposal rate of chromium-51 from 1979 through 1981 was 766 Ci/year (Pittman and others, 1988). A total of 25.7 Ci of chromium-51 was discharged during 1986-88 for an average of 8.6 Ci/year.

Because of the reduction in the amount of chromium-51 discharged and the relatively short half-life of 27.8 days, this radionuclide was not detected in water from wells in deep perched zones during 1986-88. The maximum chromium-51 concentration in water from well A-77 increased from  $28 \pm 3$  pCi/mL during 1982-85 to  $90 \pm 3$  pCi/mL during 1986-88. No detectable concentration of chromium-51 was measured in water from wells A-13 and CWP-1 through CWP-9 during 1982-88.

#### Cobalt-60

Approximately 435 Ci of cobalt-60 were in wastewater discharged to the ponds at the TRA from 1952 through 1988. The average disposal rate for cobalt-60 decreased from 2.3 Ci/year during 1979-81 to 1 Ci/year during 1982-85 (Pittman and others, 1988). The average disposal rate of cobalt-60 during 1986-88 was 2.2 Ci/year.

No detectable concentrations of cobalt-60 were measured in water from wells completed in deep perched zones during 1986-88. The maximum cobalt-60 concentration in water from well A-77 was  $11.9 \pm 0.5$  pCi/mL during 1982-85 and

12.5±0.4 pCi/mL during 1986-88. No detectable concentration of cobalt-60 was measured in water from well A-13 during 1986-88; the maximum concentration of cobalt-60 detected in water from well A-13 during 1982-85 was 0.75±0.1 pCi/mL. No detectable concentration of cobalt-60 was measured in water from wells CWP-1 through CWP-9 during 1982-88.

#### Cesium-137

About 139 Ci of cesium-137 were in wastewater discharged to the ponds at the TRA from 1952 through 1988. The average disposal rate for cesium-137 decreased from 2.6 Ci/year during 1979-81, to 0.65 Ci/year during 1982-85 (Pittman and others, 1988). The average disposal rate of cesium-137 during 1986-88 was 0.23 Ci/year.

Because of a reduction in disposal rates and because cesium-137 may be strongly sorbed to minerals in the surficial alluvium and sedimentary interbeds, no detectable concentrations of cesium-137 were measured during 1986-88 in water from wells completed in deep perched zones. The maximum cesium-137 concentration in water from well A-77 was 2.9±0.2 pCi/mL during 1982-85 and 2.48±0.16 pCi/mL during 1986-88. No detectable concentration of cesium-137 was measured in water from wells A-13 and CWP-1 through CWP-9 during 1982-88.

#### Total Dissolved Chromium

Wastewater from TRA cooling-tower operations containing an estimated 24,000 lb of chromium was discharged to a pond during 1952-64 (Mann and Knobel, 1988, p. 7-10). During 1965-72, an injection well at the TRA was used to dispose chromium directly to the aquifer. In October 1972, chromium was replaced by a polyphosphate as a corrosion inhibitor in cooling-tower operations.

Total dissolved chromium concentrations in deep perched zones in November 1988 are shown on figure 13. The maximum concentration of total

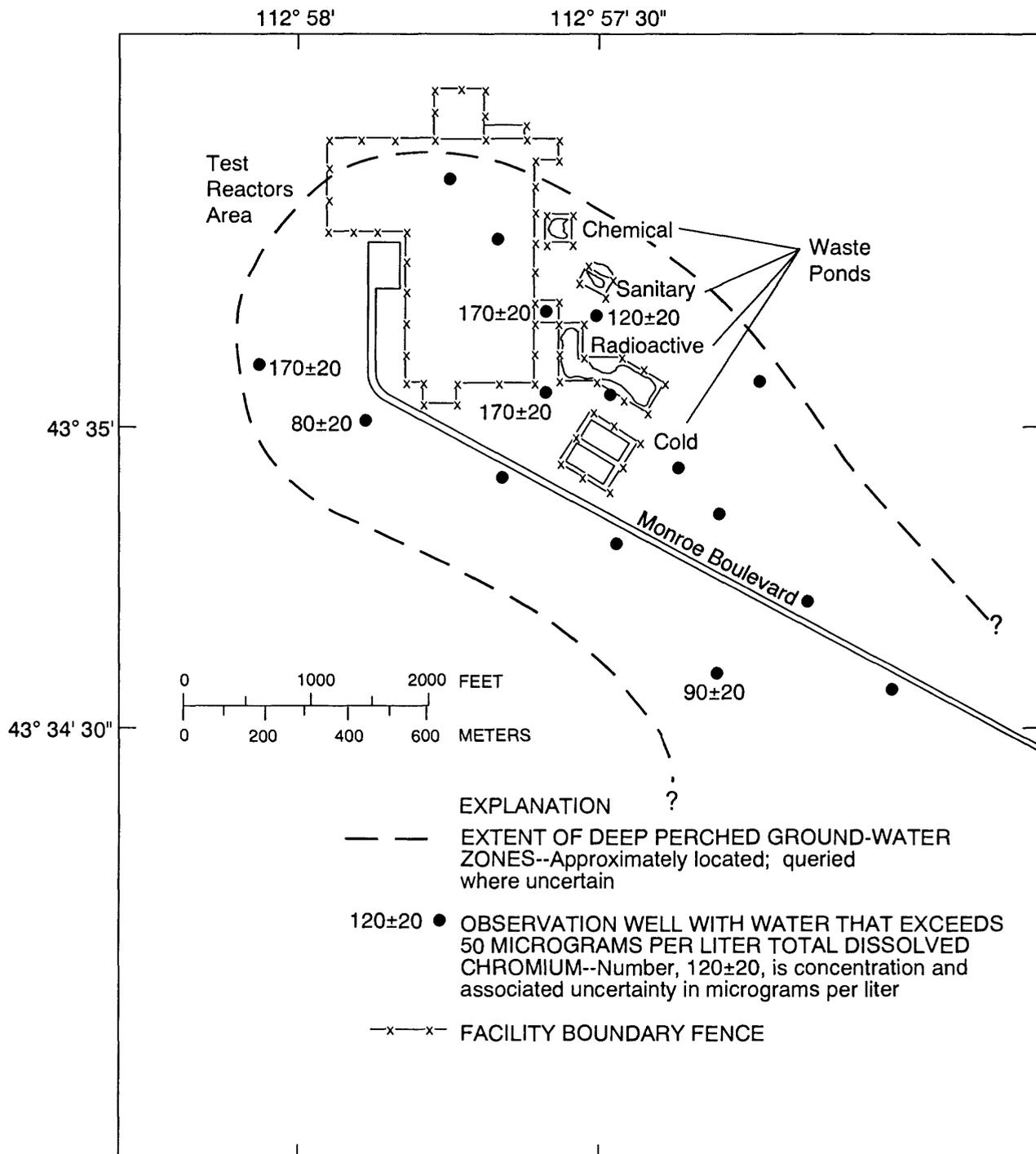


Figure 13.--Concentrations of total dissolved chromium in water from deep perched ground-water zones near the Test Reactors Area, November 1988.

dissolved chromium in water was  $190\pm 10$   $\mu\text{g/L}$  in October 1985 and  $170\pm 20$   $\mu\text{g/L}$  in November 1988. The concentrations of total dissolved chromium in water from wells completed in the deep perched zones ranged from  $80\pm 20$  to  $170\pm 20$   $\mu\text{g/L}$  in November 1988.

The maximum total dissolved chromium concentration in water from well A-77 was  $90\pm 10$   $\mu\text{g/L}$  during 1982-85 and  $80\pm 10$   $\mu\text{g/L}$  during 1986-88. Total dissolved chromium was not detected in water from wells A-13 and CWP-1 through CWP-9 during 1982-88.

### Sodium

Approximately 550,000 lb of sodium were discharged to the TRA chemical-waste pond during 1986-88. The average rate of sodium disposal and the sodium concentration in wastewater increased from approximately 85,000 lb/year and 1,500 mg/L, respectively (Pittman and others, 1988, p. 57) during 1982-85 to 183,000 lb/year and 4,100 mg/L, respectively, during 1986-88.

The largest sodium concentrations in water from deep perched zones were near the chemical-waste pond (fig. 14). The maximum sodium concentration was  $840\pm 84$  mg/L in October 1985 and  $1,000\pm 100$  mg/L in November 1988.

The maximum sodium concentration in water from well A-77 was  $42\pm 4$  mg/L during 1982-85; sodium was not detected during 1986-88. The maximum sodium concentration in water from well A-13 was  $18\pm 2$  mg/L during 1982-85 and  $19\pm 2$  mg/L during 1986-88. Changes in sodium concentrations in these wells probably can be attributed to changes in the source of process water disposed to the radioactive-waste pond and to fluctuations in disposal rates to the radioactive- and cold-waste ponds.

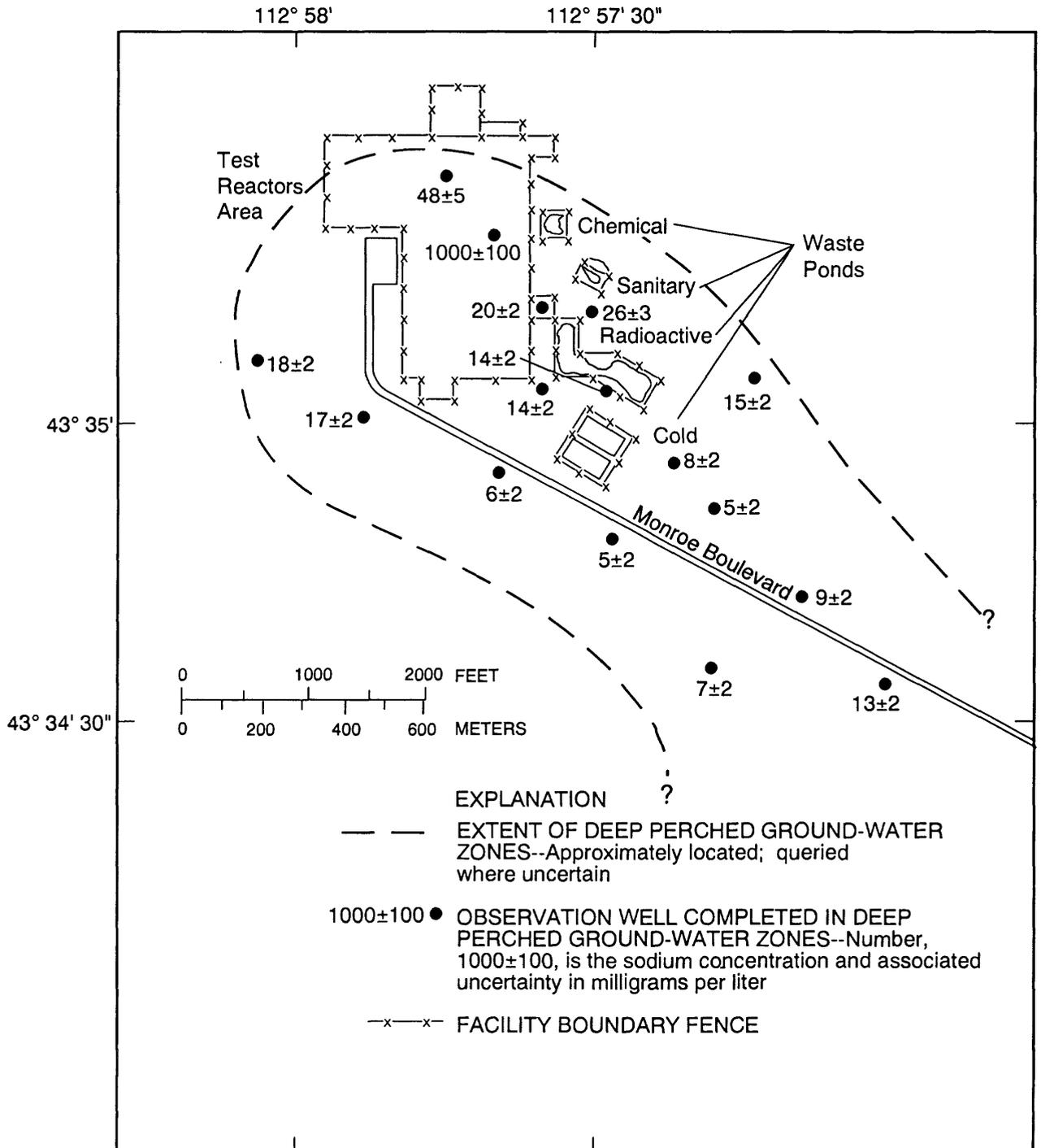


Figure 14.--Concentrations of sodium in water from deep perched ground-water zones near the Test Reactors Area, November 1988.

## Chloride

Approximately 5,900 lb of chloride were discharged in wastewater to the TRA chemical-waste and sanitary-waste ponds during 1986-88. The average disposal rate increased slightly from 1,875 lb/year during 1982-85 to 1,975 lb/year during 1986-88.

Chloride concentrations during October and November 1988 in water from wells completed in deep perched zones are shown on figure 15. In October 1985, chloride concentrations in water ranged from not detected to  $64 \pm 6$  mg/L. Chloride concentrations in October and November 1988 ranged from  $15 \pm 2$  to  $66 \pm 7$  mg/L. Slight fluctuations in chloride concentrations from 1985 to 1988 are due to changes in the amount of chloride in wastewater discharged to the ponds. Chloride concentrations in water from the shallow perched zone ranged from not detected to  $45 \pm 4$  mg/L during 1982-88.

### Idaho Chemical Processing Plant

Six wells were constructed in 1986 to monitor water-level and water-quality changes in perched ground-water zones underlying the ICPP infiltration ponds (fig. 3). Monitoring began in 1987. During 1987-88, water samples from these wells and from a separate deep perched ground-water zone in well 50 contained detectable concentrations of several radiochemical and chemical constituents. Constituents in water from well 50 probably were derived in part from wastewater injected to the ICPP disposal well prior to February 1984. Concentrations of selected constituents are summarized in the following sections.

## Tritium

Approximately 960 Ci of tritium were discharged to the infiltration ponds at the ICPP during 1984-88. The average disposal rate of tritium during 1986-88 was 185 Ci/year. This was about 99.8 percent of the total radioactivity contained in wastewater.

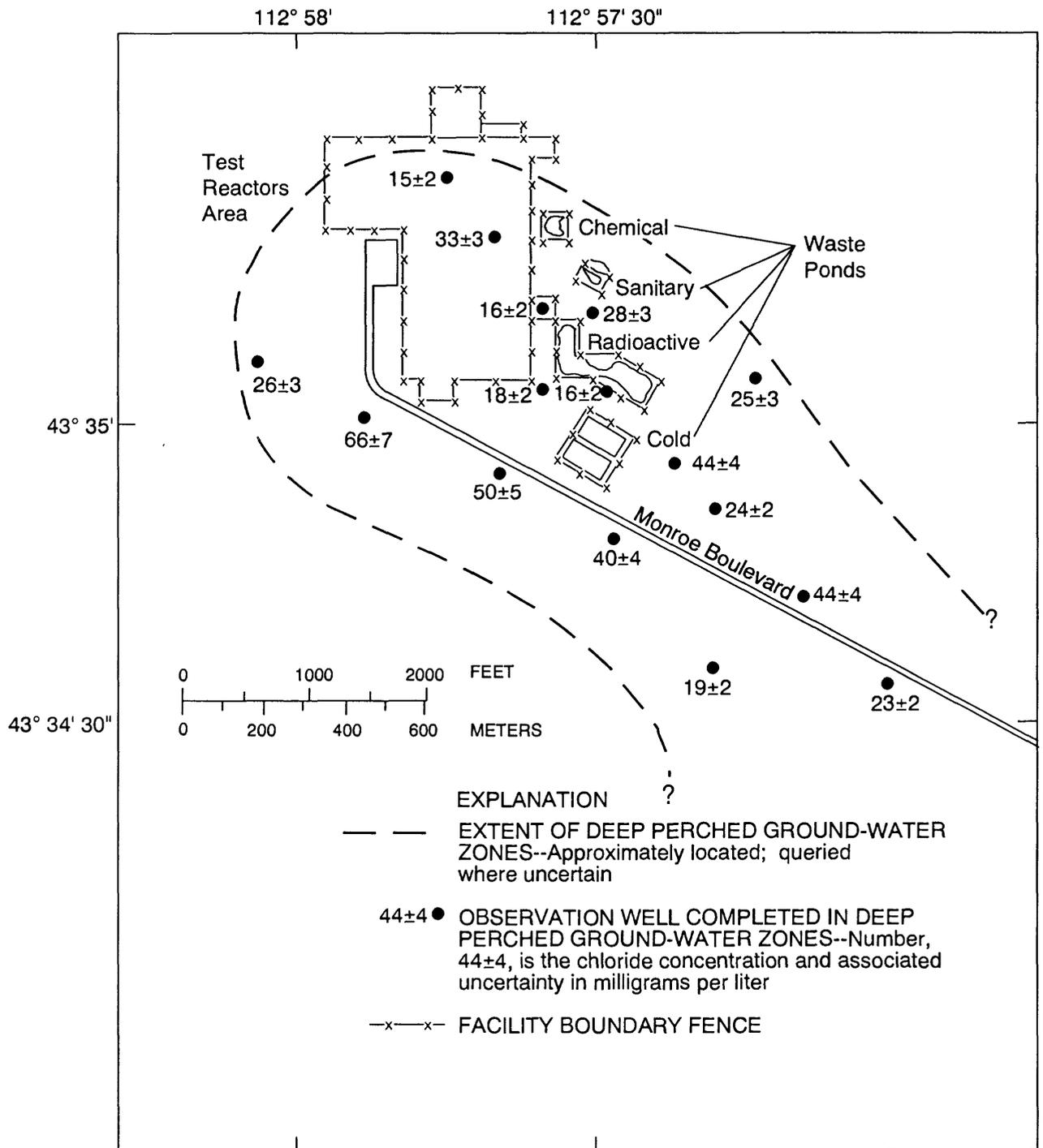


Figure 15.--Concentrations of chloride in water from deep perched ground-water zones near the Test Reactors Area, November 1988.

In November 1988, tritium concentrations in water from wells completed in the perched zones underlying the infiltration ponds ranged from  $5.5 \pm 0.3$  pCi/mL to  $36.7 \pm 0.8$  pCi/mL (fig. 16). The tritium concentration in water from well 50 decreased from  $144 \pm 2$  pCi/mL in October 1985 to  $114 \pm 2$  pCi/mL in November 1988.

#### Strontium-90

Approximately 0.13 Ci of strontium-90 was discharged to the ICPP infiltration ponds during 1986-88 for an average of about 0.04 Ci/year. This rate of disposal represents a slight decrease from the 1984-85 rate of disposal of 0.06 Ci/year.

In November 1988, strontium-90 concentrations in water from wells completed in the perched zones beneath the ICPP infiltration ponds ranged from  $12 \pm 2$  pCi/L to  $18 \pm 2$  pCi/L (fig. 17). Concentrations of strontium-90 were not detected in water from wells PW-2 and PW-6. The concentration of strontium-90 in water from well 50 was  $347 \pm 16$  pCi/L in October 1985 and  $314 \pm 11$  pCi/L in November 1988.

#### Cesium-137

Wastewater discharged to the ICPP disposal well during 1952-84 contained about 21 Ci of cesium-137. During 1984-85, about 0.06 Ci of cesium-137 was discharged to the ICPP infiltration ponds. During 1986-88, about 0.3 Ci of cesium-137 was discharged to the ponds.

No detectable concentrations of cesium-137 were measured during 1986-88 in water from wells completed in the perched zones underlying the ICPP infiltration ponds because of a reduction in disposal rates and because cesium-137 may be strongly sorbed to minerals in the surficial alluvium and sedimentary interbeds. Concentrations of cesium-137 were not detected in water from well 50.

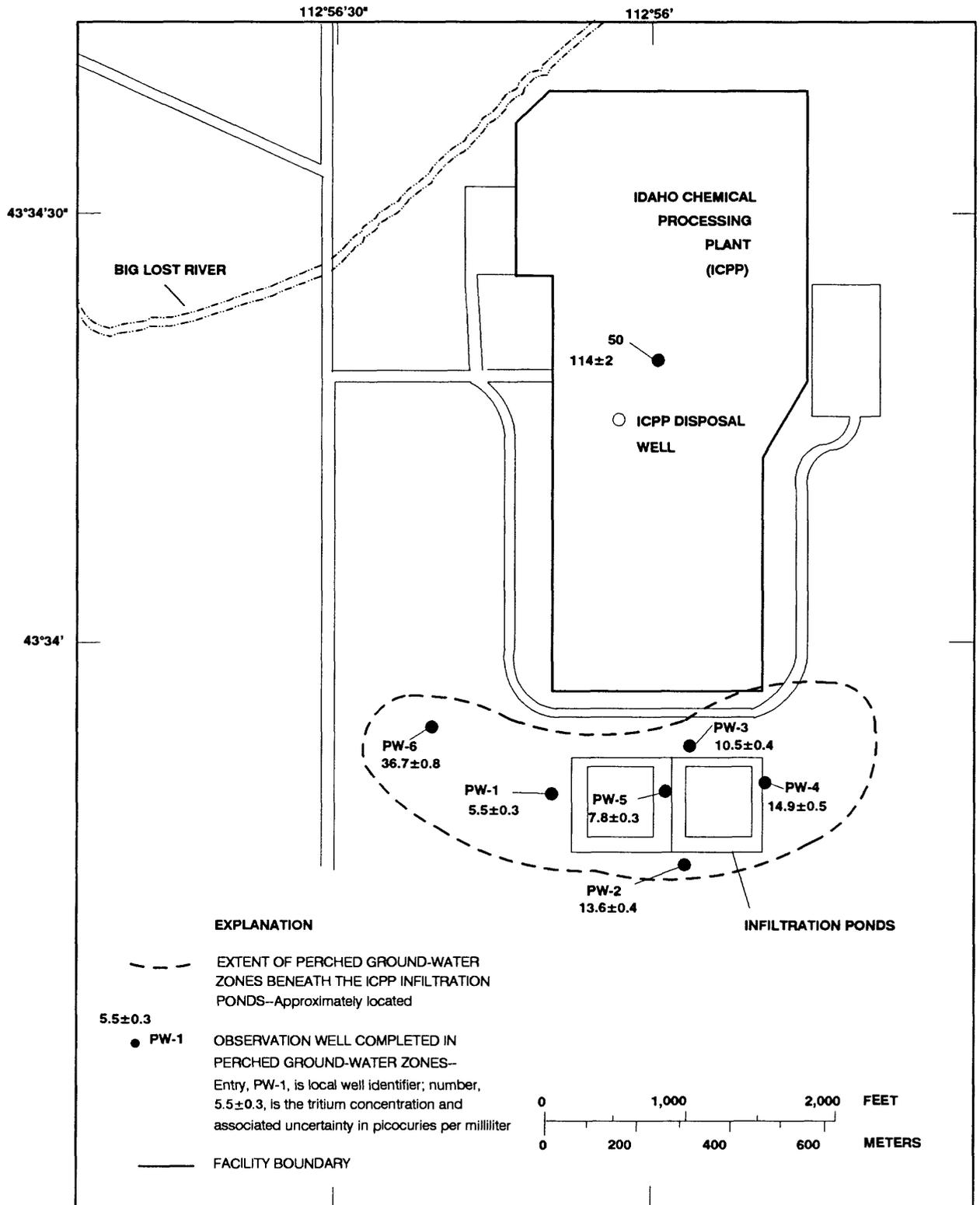


Figure 16.--Concentrations of tritium in water from perched ground-water zones near the Idaho Chemical Processing Plant, November 1988.

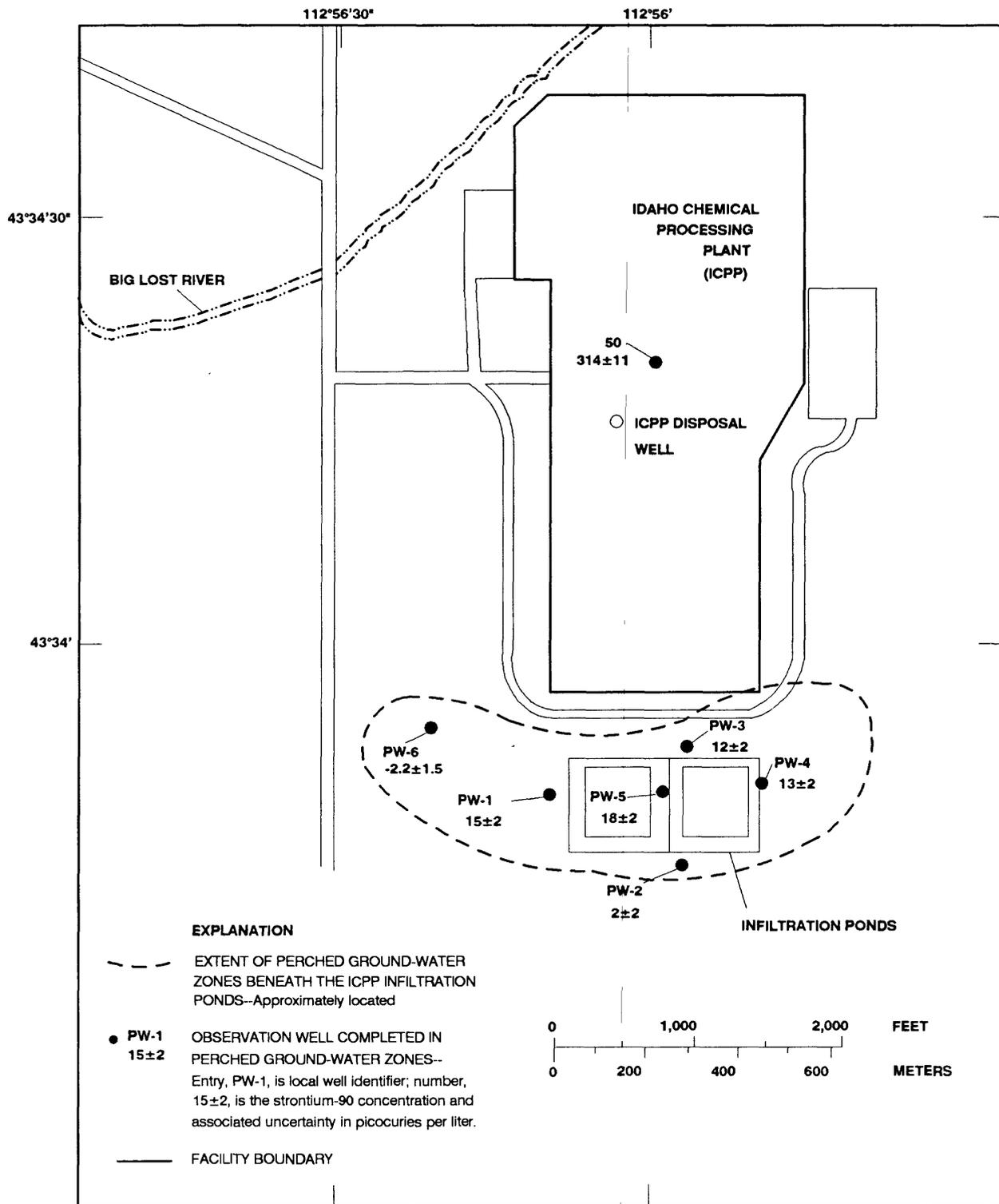


Figure 17.--Concentrations of strontium-90 in water from perched ground-water zones near the Idaho Chemical Processing Plant, November 1988.

## Sodium

About 2.2 million lb of sodium were discharged to the ICPP infiltration ponds during 1986-88. This volume of sodium is estimated from correlation to chloride disposal at that facility because no records of sodium disposal were kept at the ICPP during 1986-88.

In October 1988, the sodium concentration in water from wells completed in perched zones beneath the ICPP infiltration ponds ranged from  $28\pm 3$  mg/L to  $120\pm 12$  mg/L (fig. 18). The sodium concentration in water from well 50 was  $72\pm 7$  mg/L in October 1985 and  $73\pm 7$  mg/L in September 1987; no sodium concentrations were available for 1988.

## Chloride

Approximately 3.5 million lb of chloride were discharged to the ICPP infiltration ponds during 1986-88. Chloride concentrations in water from wells completed in the perched zones ranged from  $99\pm 10$  mg/L to  $220\pm 20$  mg/L during October and November 1988 (fig. 19). Chloride concentrations in well PW-6 increased from  $45\pm 5$  mg/L in January 1987 to  $99\pm 10$  mg/L in November 1988. Chloride concentrations in the other wells remained at approximately 200 mg/L during 1987-88, except for January 1988 when they decreased to about 125 mg/L. The chloride concentration in water from well 50 was  $80\pm 8$  mg/L in October 1985 and  $82\pm 8$  mg/L in November 1988.

## Radioactive Waste Management Complex

Perched ground-water zones and wet zones have been identified in several wells at the RWMC. Standing water has been identified at a depth of 212 ft below land surface in well 92 (fig. 2). These zones may be derived from direct infiltration from flooding events at the RWMC, or from lateral movement of water within the unsaturated zone from the INEL spreading areas and the channel of the Big Lost River. Direct infiltration of flood water

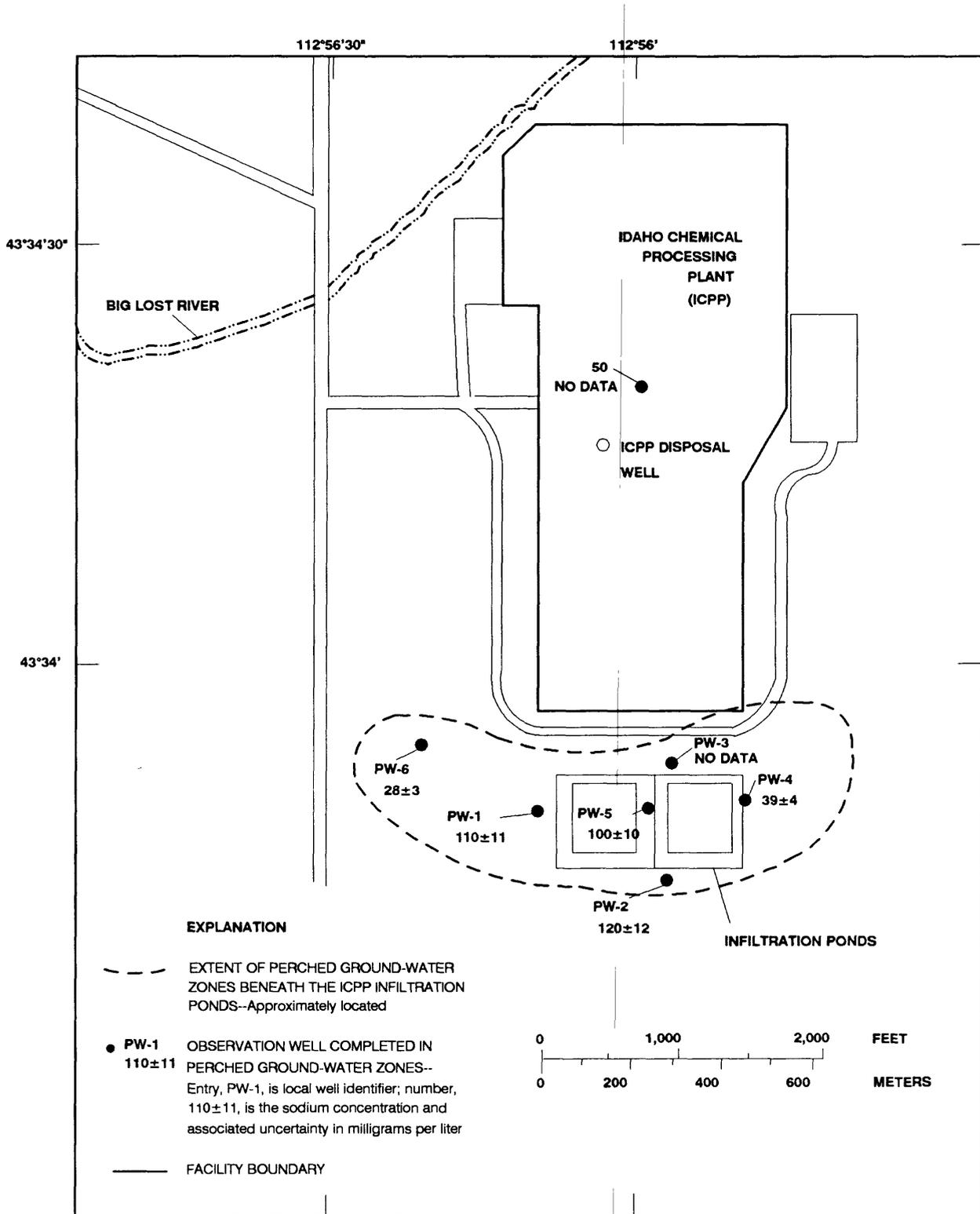


Figure 18.--Concentrations of sodium in water from perched ground-water zones near the Idaho Chemical Processing Plant, November 1988.

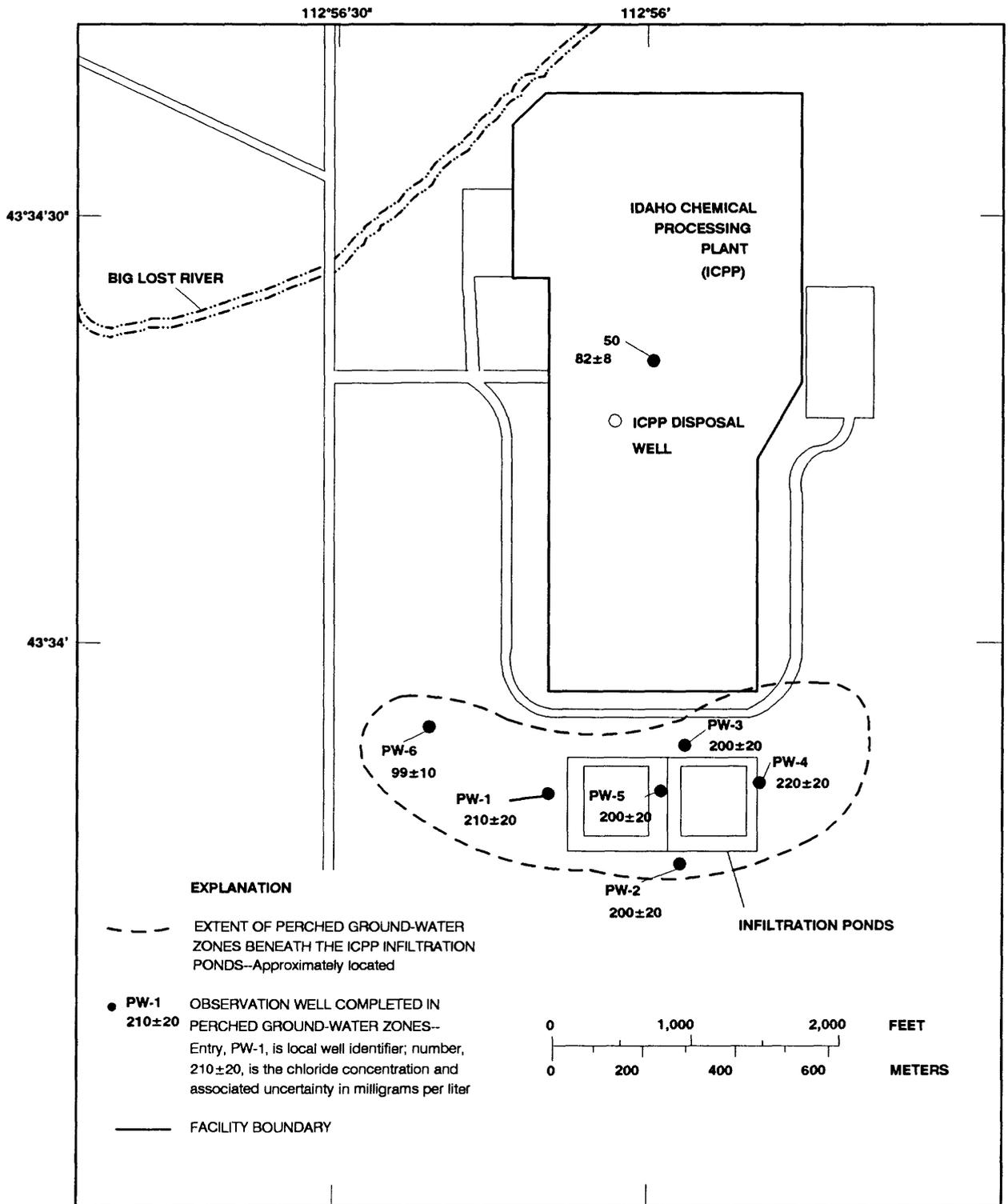


Figure 19.--Concentrations of chloride in water from perched ground-water zones near the Idaho Chemical Processing Plant, November 1988.

at the RWMC could leach soluble radiochemical and chemical constituents from buried wastes.

During 1986-88, no detectable concentrations of trace metals or radio-nuclides were measured in water from well 92. In 1987, nine purgeable organic compounds were detected in water from well 92 (Mann and Knobel, 1987, p. 16, 17).

#### SUMMARY

Several discontinuous perched ground-water zones have formed beneath the Test Reactors Area (TRA) at the Idaho National Engineering Laboratory as a result of wastewater disposal to ponds. About 259 million gal/year of wastewater were discharged during 1986-88. Deeper zones of perched ground water have formed beneath the alluvium in an interbedded sediment-basalt sequence. The areal extent of these perched ground-water zones has changed little since 1985.

Radiochemical concentrations in water from wells completed in the perched zones near the TRA generally decreased during 1986-88. The maximum tritium concentration in water from deep perched zones in October 1985 was  $1,770 \pm 30$  pCi/mL; the maximum tritium concentration in November 1988 was  $948 \pm 14$  pCi/mL. The maximum tritium concentration in water from the shallow perched zone in the alluvium decreased from  $5,630 \pm 20$  pCi/mL during 1982-85 to  $3,430 \pm 50$  pCi/mL during 1986-88. No detectable concentrations of chromium-51, cobalt-60, or cesium-137 were measured during 1986-88 in water from wells completed in deep perched zones. The maximum chromium-51 concentration in water from the shallow perched zone increased from  $28 \pm 3$  pCi/mL during 1982-85 to  $90 \pm 3$  pCi/mL during 1986-88. Cobalt-60 and cesium-137 concentrations in water from the shallow perched zone did not change.

Other chemical constituents in water from the perched zones near the TRA included total dissolved chromium, sodium, and chloride. The maximum total dissolved chromium concentration in water from deep perched zones in October 1985 was  $190 \pm 10$   $\mu$ g/L; the maximum total dissolved chromium

concentration in November 1988 was  $170\pm 20$   $\mu\text{g/L}$ . The maximum total dissolved chromium concentration in water from the shallow perched zone in the alluvium was  $90\pm 10$   $\mu\text{g/L}$  during 1982-85 and  $80\pm 10$   $\mu\text{g/L}$  during 1986-88. The maximum sodium concentration in water from wells completed in deep perched zones was  $840\pm 84$   $\text{mg/L}$  in October 1985 and  $1,000\pm 100$   $\text{mg/L}$  in November 1988. The maximum sodium concentration measured in water from the shallow perched zone decreased from  $42\pm 4$   $\text{mg/L}$  during 1982-85 to  $19\pm 2$   $\text{mg/L}$  during 1986-88. Chloride concentrations in water from wells completed in deep perched zones ranged from  $45\pm 2$  to  $66\pm 7$   $\text{mg/L}$  during 1986-88. Chloride concentrations in water from the shallow perched zone ranged from not detected to  $45\pm 4$   $\text{mg/L}$  during 1982-88.

Six wells were drilled in 1986 to monitor water-level and water-quality changes in perched ground-water zones that have formed in an interbedded sediment-basalt sequence underlying the infiltration ponds at the Idaho Chemical Processing Plant (ICPP). An additional well, well 50, completed in a deep perched ground-water zone beneath the plant inside the ICPP complex, also was monitored during 1986-88. This zone may have originated in part from wastewater injection to the ICPP disposal well prior to February 1984. From 1986 to 1988, about 580 million gal/year of wastewater were discharged at the ICPP.

About 99.8 percent of the total radioactivity in wastewater discharged at the ICPP during 1986-88 was attributed to tritium. The average disposal rate of tritium from 1986 to 1988 was 185 Ci/year. The maximum tritium concentration in water from the perched zones beneath the infiltration ponds in November 1988 was  $36.7\pm 0.8$  pCi/mL. The tritium concentration in water from well 50 decreased from  $144\pm 2$  pCi/mL in October 1985 to  $114\pm 2$  pCi/mL in November 1988. The maximum strontium-90 concentration in water from the perched zones beneath the infiltration ponds was  $18\pm 2$  pCi/L in November 1988. The strontium-90 concentration in water from well 50 was  $347\pm 16$  pCi/L in October 1985 and  $314\pm 11$  pCi/L in November 1988. No detectable concentrations of cesium-137 were measured in water from the perched zones at the ICPP during 1986-88.

Chemical constituents analyzed in water from the perched zones near the ICPP included sodium and chloride. The maximum sodium concentration in water from the perched zones beneath the infiltration ponds was  $120\pm 12$  mg/L in October 1988. The sodium concentration in water from well 50 was  $72\pm 7$  mg/L in October 1985 and  $73\pm 7$  mg/L in September 1987. The maximum chloride concentration in water from the perched zones beneath the infiltration ponds was  $220\pm 20$  mg/L in November 1988. The chloride concentration in water from well 50 was  $80\pm 8$  mg/L in October 1985 and  $82\pm 8$  mg/L in November 1988.

A perched ground-water zone has been identified at a depth of 212 ft below land surface in well 92 at the Radioactive Waste Management Complex (RWMC). This zone may be derived from infiltration of surface flooding events or from lateral movement of water in the subsurface from the INEL spreading areas and the channel of the Big Lost River. During 1986-88, no detectable concentrations of trace metals or radionuclides were measured in water from well 92; however, purgeable organic compounds were detected.

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