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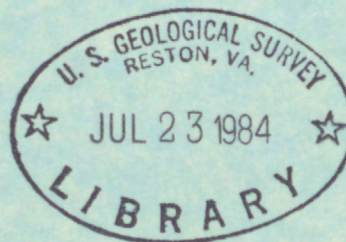
IDO-22066



HYDROLOGIC CONDITIONS AT THE IDAHO NATIONAL ENGINEERING LABORATORY, IDAHO: 1979-1981 UPDATE

U.S. GEOLOGICAL SURVEY
Open-File Report
84-230

June 1984



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PREPARED FOR THE U.S.
DEPARTMENT
OF ENERGY

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HYDROLOGIC CONDITIONS AT THE IDAHO

NATIONAL ENGINEERING LABORATORY,

IDAHO: 1979-1981 UPDATE

by Barney D. Lewis and Rodger G. Jensen

Open-File Report 84-230

Open-File Report
Geological Survey
(U.S.)

Prepared in cooperation with the

U.S. DEPARTMENT OF ENERGY



Idaho Falls, Idaho

June 1984

354437

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FACTORS FOR CONVERTING INCH-POUND UNITS TO METRIC (SI) UNITS

The following factors can be used to convert inch-pound units published herein to the International System of units (SI).

<u>Multiply inch-pound units</u>	<u>By</u>	<u>To obtain SI units</u>
inches (in)	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
square feet (ft ²)	0.0929	square meters (m ²)
acres	0.4047	hectares (ha)
square miles (mi ²)	2.590	square kilometers (km ²)
gallons (gal)	3.785	liters (L)
gallons (gal)	3.785x10 ⁻³	cubic meters (m ³)
million gallons (10 ⁶ gal or Mgal)	3,785	cubic meters (m ³)
acre-feet (acre-ft)	1,233	cubic meters (m ³)
pounds (lb)	0.4536	kilograms (kg)
feet per mile (ft/mi)	0.1894	meters per kilometer (m/km)
curies (Ci)	3.70 x 10 ¹⁰	becquerel (Bq)
micromhos (μmho)	1.00	microsiemens (μS)
temperature, degrees Celsius (°C) = 0.556 (°F-32)		

HYDROLOGIC CONDITIONS AT THE
IDAHO NATIONAL ENGINEERING LABORATORY,
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By Barney D. Lewis and Rodger G. Jensen

ABSTRACT

Aqueous chemical and radioactive wastes have been discharged shallow ponds and to shallow or deep wells on the Idaho National Engineering Laboratory (INEL) since 1952 and have affected the quality of the ground water in the underlying Snake River Plain aquifer. Ongoing studies from 1979 through 1981 have shown the perpetuation of a perched ground-water zone in the basalt underlying the waste disposal ponds at the INEL's Test Reactor Area and of several waste plumes in the regional aquifer created by deep well disposal at the Idaho Chemical Processing Plant (ICPP). The perched zone contains tritium, chromium-51, cobalt-60, strontium-90, and several nonradioactive chemicals. Tritiated waste water has formed the largest plume south of the ICPP, and accounts for 99 percent of the total radioactivity disposed of through the ICPP disposal well. Waste plumes with similar configurations and flow-paths contain sodium, chloride, nitrate and iodine-129. Strontium-90 and cesium-137 are also discharged through the well but they are sorbed from solution as they move through the aquifer. Waste water containing strontium-90 has formed a small plume and cesium-137 is detectable in only a few ground-water samples collected very near the ICPP disposal well. Radionuclide plume size and concentrations therein are controlled by aquifer flow conditions, the quantity discharged, radioactive decay, sorption, dilution by dispersion, and perhaps other chemical reactions. Chemical wastes are subject to the same processes except for radioactive decay.

INTRODUCTION

The Idaho National Engineering Laboratory (INEL), formerly the National Reactor Testing Station (NRTS), was established in 1949 by the Atomic Energy Commission (AEC) and is now operated by the U.S. Department of Energy (DOE) to build, operate, and test various types of nuclear reactors. Fifty-two reactors have been constructed to date, of which 17 are still operable.

The INEL site covers about 890 square miles on the eastern Snake River Plain (fig. 1) in southeastern Idaho. The plain is a structural and topographic basin about 200 miles long and 50 to 70 miles wide. Thin basaltic lava flows, rhyolite deposits, and interbedded sediments fill the basin from its present level (land surface) to depths of approximately 2,000 to 10,000 feet. A more detailed description of the geology is found in Robertson, Schoen, and Barraclough (1974). Underlying the plain, and contained in the upper part of this stratigraphic sequence, is a vast body of ground water contained in the Snake River Plain aquifer--the major aquifer in Idaho. The INEL obtains its entire water supply from this aquifer. Aqueous chemical and radioactive wastes are discharged to shallow ponds and to shallow or deep wells on the INEL site. Many of these waste constituents enter the aquifer either directly or indirectly following percolation through the unsaturated zone.

The study of the effects of subsurface waste disposal on the regional hydrology requires a knowledge of the hydrogeology of the Snake River Plain aquifer, the locations and quantities of aqueous-waste disposal, the methods of disposal, and the geochemistry of the waste solutions and of the ground water in the aquifer. During recent years, the prime concern has been to trace the movement of dilute chemical and low-level radioactive wastes in the subsurface and to explain the chemical and radiochemical changes that accompany such movement in terms of the geologic, hydrologic, and geochemical properties.

PURPOSE AND SCOPE

In 1949, the AEC requested the U.S. Geological Survey to investigate and describe the water resources of the INEL and adjacent areas. Information was collected which depicted hydrogeologic conditions prior to any reactor operations at the Laboratory. Current investigations serve to determine natural changes in the hydrology and also to determine changes resulting from activities at the Laboratory.

This report presents an analysis of the water-level and water-quality data collected by the U.S. Geological Survey during the calendar years 1979 through 1981. The report, therefore, covers a period following that covered by a previous report by Barraclough, Lewis and Jensen (1981), which summarized the influences of waste disposal from 1974 to 1978. Reports on previous Geological Survey investigations describing geologic and hydrologic studies of the area and related reports by the DOE staff are listed in the references and may be obtained from the INEL library or from the office of the Geological Survey at Central Facilities Area (CFA) (fig. 2).

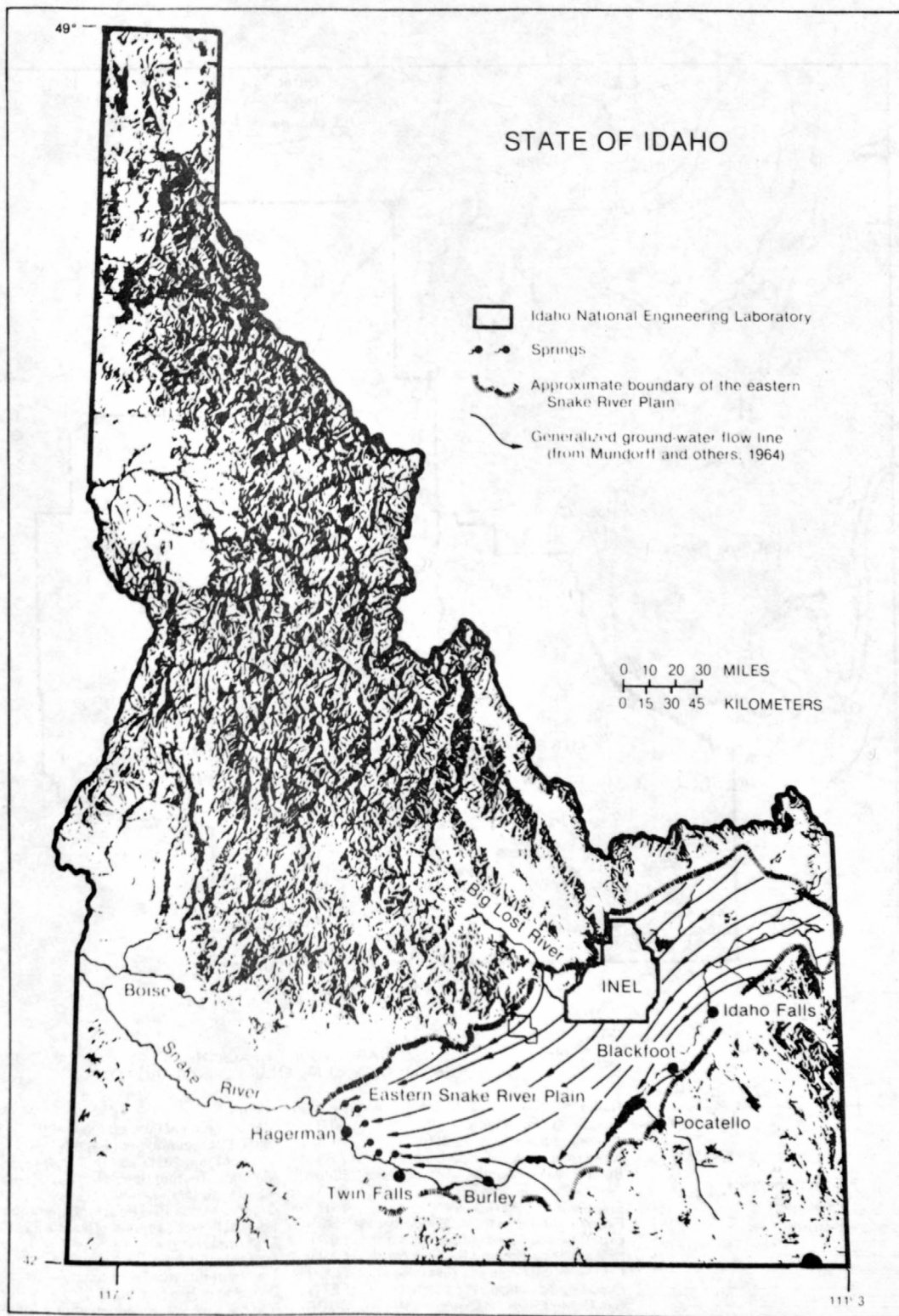


Figure 1.--Relief map of Idaho showing the location of the INEL, Snake River Plain, and generalized ground-water flow lines of the Snake River Plain aquifer (from Barraclough, Lewis, and Jensen, 1981).

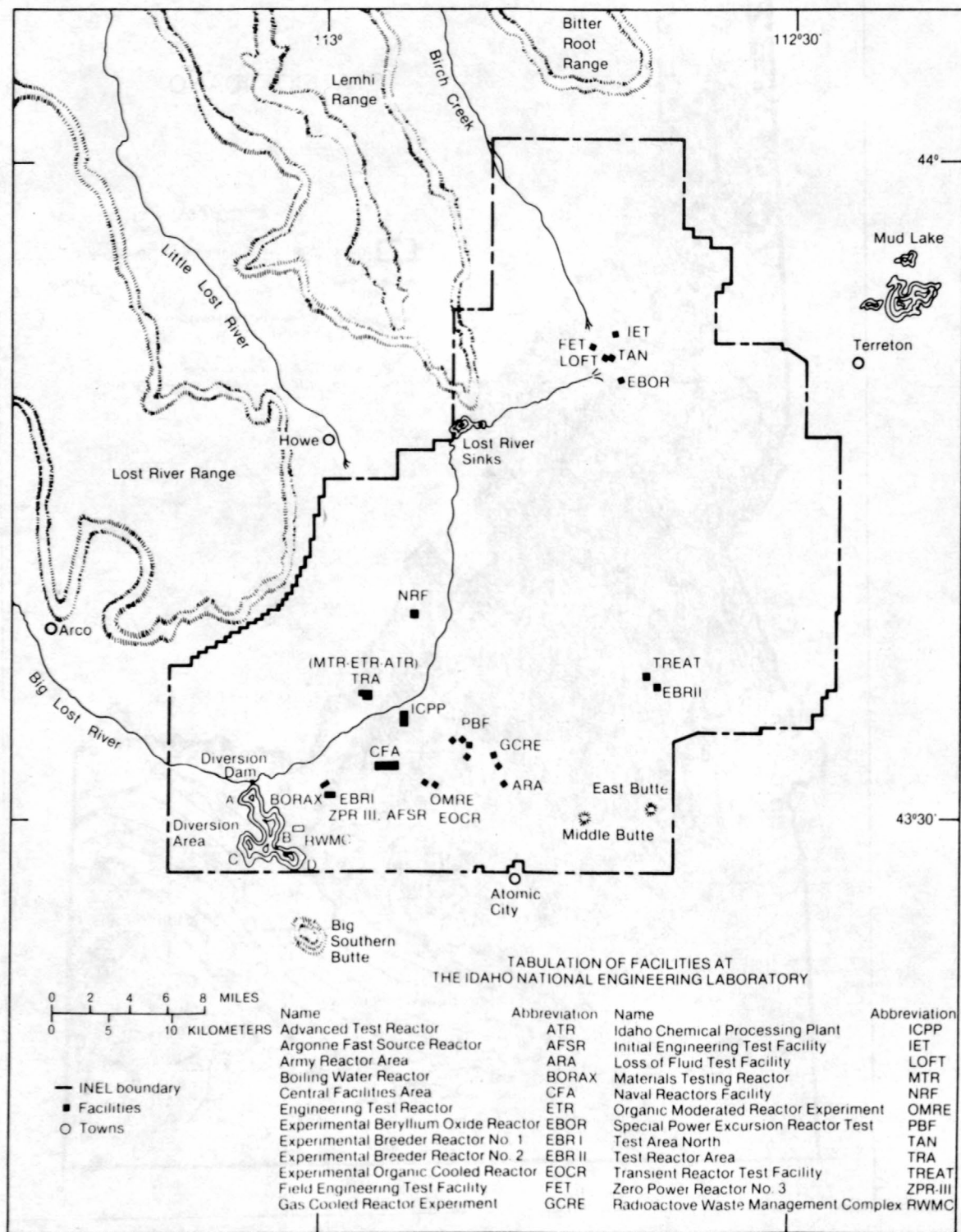


Figure 2.--Location of the INEL facilities (from Barraclough, Lewis, and Jensen, 1981).

ACKNOWLEDGMENTS

These studies have been sponsored and funded by the U.S. Department of Energy. The U.S. Geological Survey project at the INEL is coordinated through the following personnel of the DOE-Idaho Operations Office (IDO): J. P. Hamric, Director, Nuclear Fuel Cycle and Waste Management Division; J. B. Whitsett, Chief, Radioactive Waste Programs Branch; and M. M. Williamson, Director, Radiological and Environmental Sciences Laboratory. Considerable assistance has also been obtained from the following DOE-IDO personnel: the staff of the Analytical Chemistry Branch, L. Z. Bodnar, Chief, who provided most of the chemical and radiometric analyses of ground-water samples; and E. W. Chew, Chief, Environmental Sciences Branch.

REGIONAL HYDROLOGY

The eastern Snake River Plain is underlain by a vast ground-water reservoir known as the Snake River Plain aquifer, which may contain more than 1 billion acre-feet of water (Barracough, Lewis, and Jensen, 1981). The flow of ground water in the aquifer is principally to the south-southwest (fig. 1) at relatively high velocities of 5-20 feet per day. The transmissivity of the aquifer generally ranges from 1 million to 100 million gallons per day per foot or 134,000 to 13,400,000 feet squared per day (Robertson, Schoen, and Barracough, 1974).

The basaltic volcanic rocks and interbedded sediments composing the aquifer are all included in the Snake River Group of Quaternary age. The basement rocks are probably composed of older volcanic and sedimentary rocks in addition to any underlying crystalline rocks. The basalt is the principal aquifer. Water-bearing openings in the basalt are distributed throughout the rock system in the form of intercrystalline and intergranular porespace, fractures, cavities, interstitial voids, interflow zones, and lava tubes. The variety and degree of interconnection of these openings complicate the direction of ground-water movement locally throughout the aquifer.

Ground-water recharge to the aquifer is primarily by underflow from the northeastern part of the plain and also from adjacent drainages on the west and north. Most of the ground water underlying the INEL enters the ground in the uplands to the north, northeast, and northwest of the site, moves southward or southwestward through the aquifer, and discharges at springs along the valley of the Snake River near Hagerman (fig. 1). Lesser amounts of the water are derived from local precipitation on the plain. Part of the precipitation evaporates, but part infiltrates the ground surface and percolates through the subsurface to the regional water table. Significant recharge is also derived from occasional flow in the Big Lost River.

WATER-TABLE DATA

The water-table observation well program was designed to determine the changes in gradient that influence the rate and direction of ground water and radionuclide movement, to identify sources of recharge to the aquifer, and to measure the areal extent of the effects of recharge. Water levels were measured in both the regional aquifer and perched aquifers. Eleven continuous water-level recorders were operated from 1979 to 1981; water levels were measured monthly in 56 wells, and annually in 53, in order to study the regional water table. To study perched water bodies, two wells were equipped with continuous water-level recorders; and water levels in 24 wells were measured monthly, 60 were measured quarterly, and 97 were measured annually. A total of 3,400 water-level measurements were made from 1979 to 1981, for an average of 1,133 measurements per year.

Figures 3 and 4 show the locations of water-level observation wells and the frequency of water-level measurements. Data are on file in the office of the U.S. Geological Survey at the INEL.

WATER-QUALITY DATA

The study of the chemical and radiometric character of ground water in the INEL area was based on analysis of water samples collected in a comprehensive sampling program. The type, frequency, and depth of sampling generally depended upon the information needed in a specific area. The program included analyses for tritium, strontium-90, cobalt-60, chromium-51, iodine-129, cesium-137, plutonium-238, plutonium 239-240, americium-241, total chromium, specific conductance, sulfate, chloride, nitrate, and chemical analysis of 28 of the more common chemical constituents or properties.

Water samples have been collected throughout the Laboratory site and in adjacent areas to define the chemical character of the ground water entering and leaving the INEL. Near areas of detailed study, such as the Test Reactor Area (TRA) and the Idaho Chemical Processing Plant (ICPP), numerous samples were taken in order to establish the contamination levels and to define the pattern of waste migration in both the perched and the regional ground-water bodies.

The locations of wells and the frequency of sampling on or near the INEL are shown in figures 5 and 6. Water samples for tritium analyses were collected from wells near ICPP and TRA on a quarterly and semi-annual basis. Water samples for the determination of tritium concentrations and specific conductances were obtained from three wells which intercept ground-water underflow near areas of recharge at the north end of the INEL. Nearby surface-water samples were also collected at about the same time. An average of 1,249 chemical and radiometric analyses were made on 310 water samples collected yearly from 1979 through 1981. A total of 145 samples were collected from production wells, 741 from observation wells, and 38 from streams on or near the INEL. From these 924 samples, 3,746 analyses were made for chemical or radiometric determinations. Surface-water samples were collected from the following stations: Big Lost River near Moore, Idaho; Birch Creek near Blue Dome, Idaho; Little Lost River near Howe, Idaho; and Mud Lake near Terreton, Idaho.

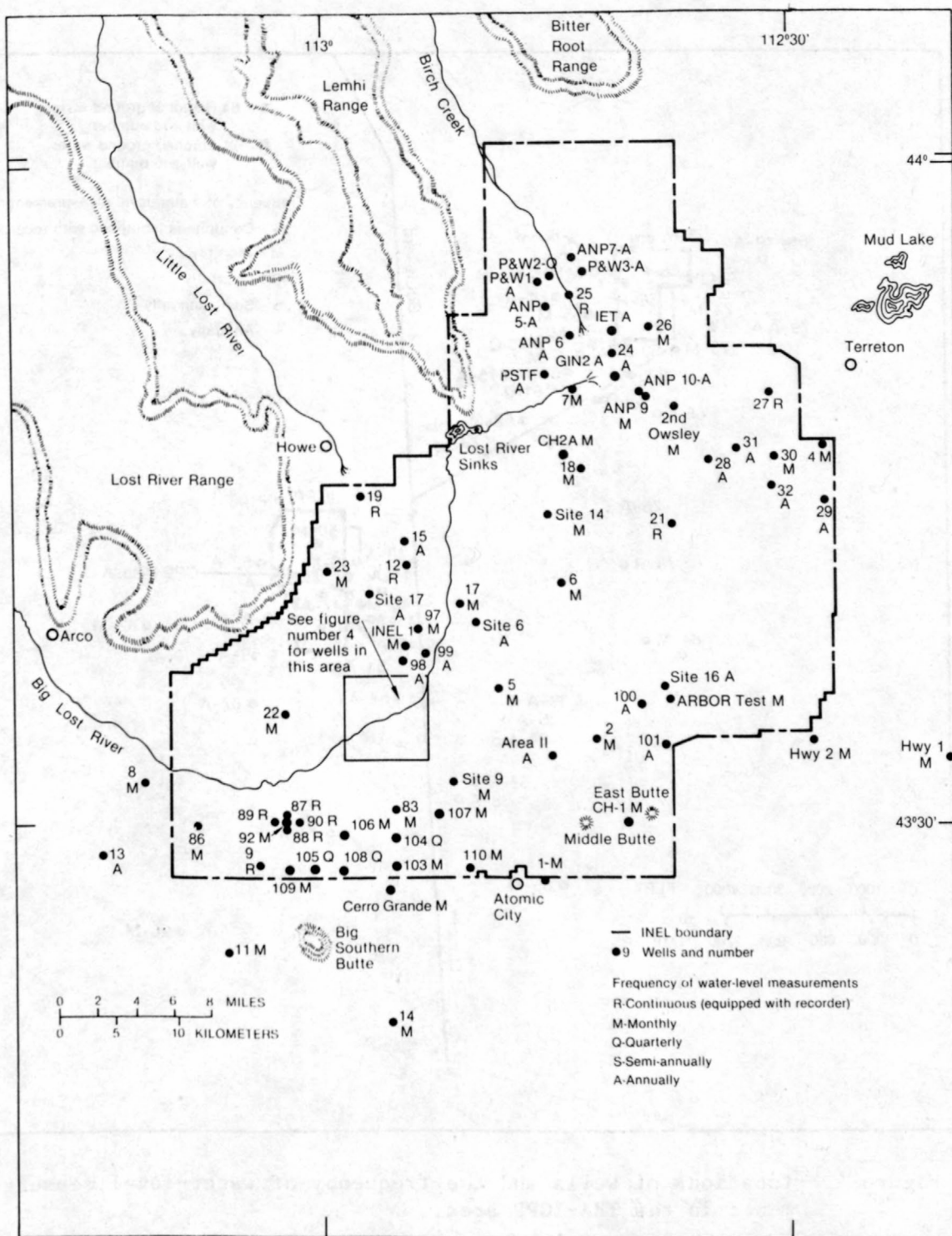


Figure 3.--Locations of wells and the frequency of water-level measurements at the INEL and vicinity.

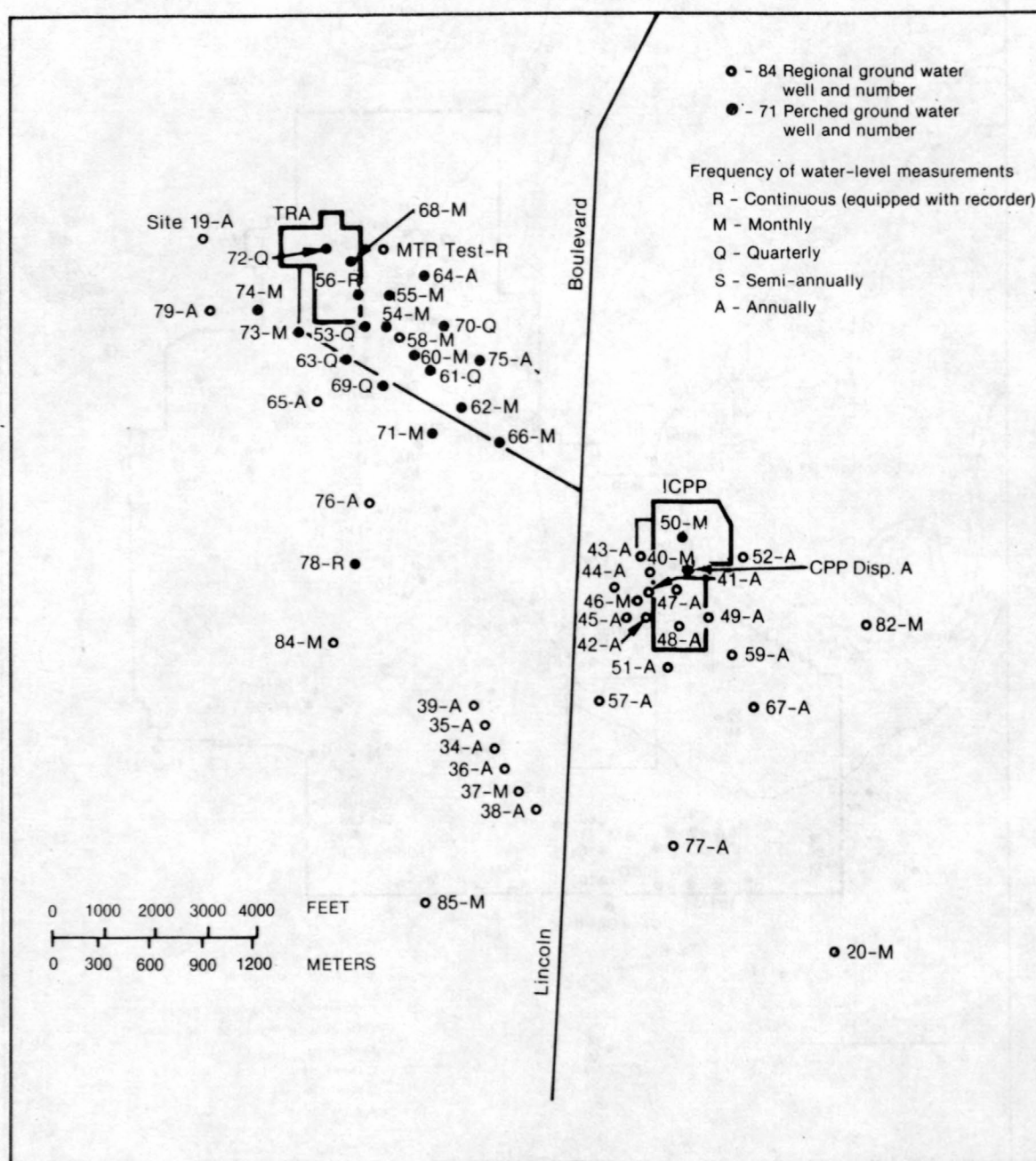


Figure 4.--Locations of wells and the frequency of water-level measurements in the TRA-ICPP area.

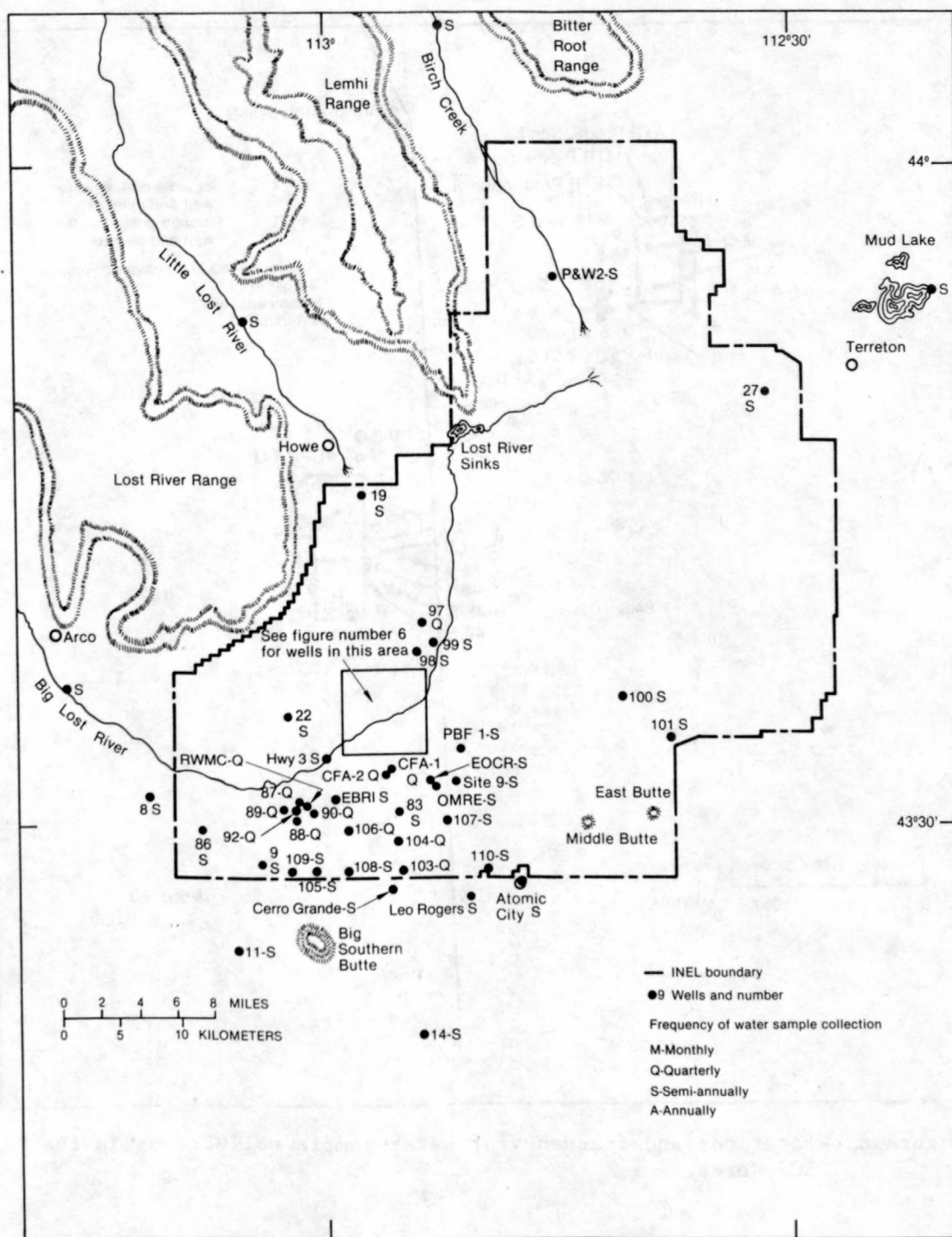


Figure 5.--Locations and frequency of water-sample collections at the INEL and vicinity.

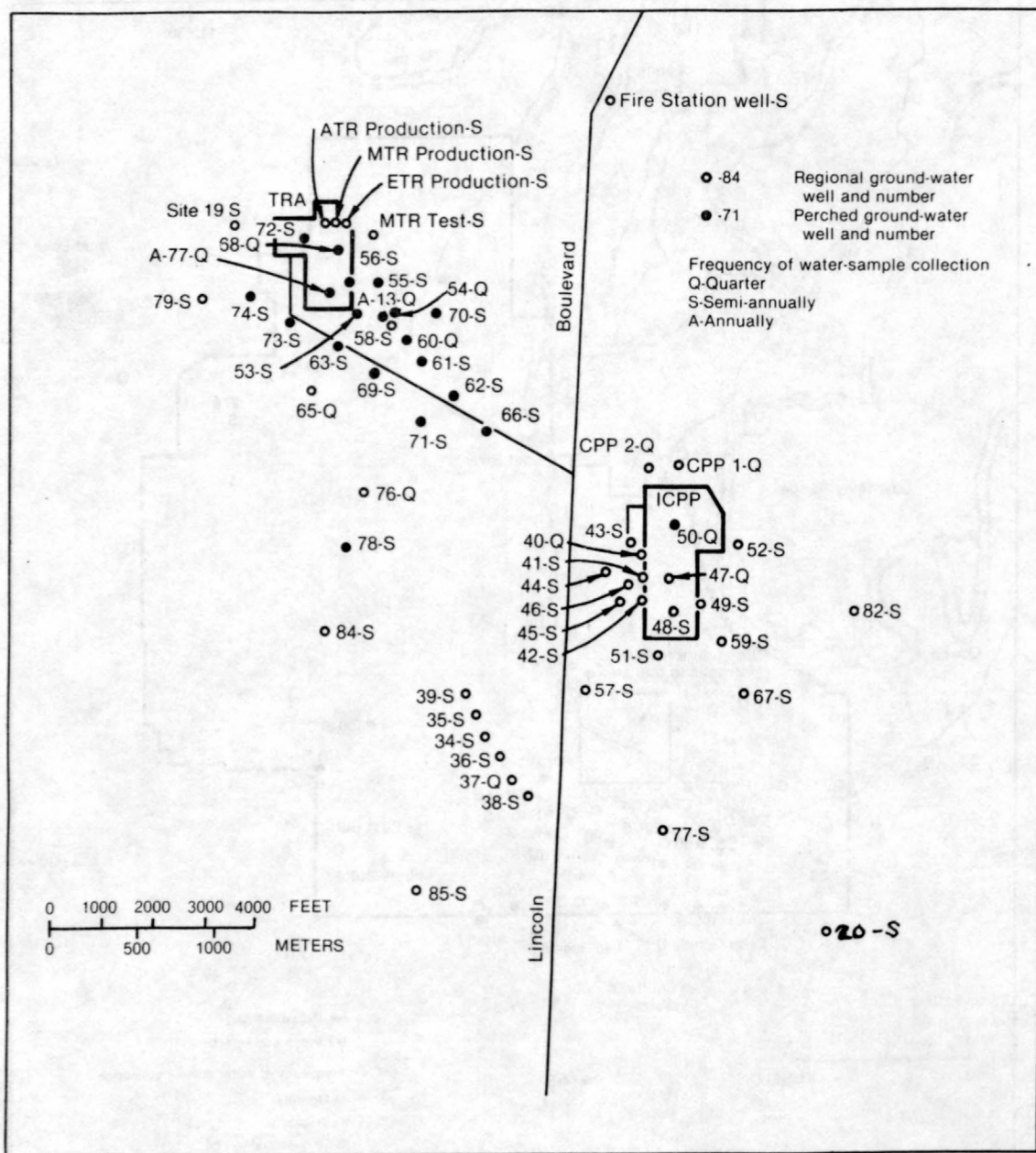


Figure 6.--Locations and frequency of water-sample collections in the TRA-ICPP area.

CONFIGURATION OF THE REGIONAL WATER TABLE

Figure 7 is a map of the INEL site and adjacent areas showing altitude contours on the water table of the Snake River Plain aquifer for July 1981 and the inferred directions of ground-water movement. The altitude of the water table ranges from 4,582 feet above the National Geodetic Vertical Datum of 1929 (NGVD of 1929) in the northern part of the site to 4,423 feet near the southwestern boundary of the site. The general direction of regional ground-water movement underlying the INEL is to the south and southwest. The average slope of the water table is about 4 feet per mile. In the northern part of the INEL, near the Birch Creek valley, the water-table gradient is relatively flat, sloping southward about 1 foot per mile (fig. 7).

The configuration of the regional water table varies with the recharge received by the system over some period prior to the measurement of water levels. From 1979 through 1981, recharge was considerably less than discharge, as was the case in the prior four-year period (Barracough, Lewis, and Jensen, 1981), and collected data show that the relative vertical position of the water table has fallen. Figure 8 shows this decline from July 1972 to July 1981. Near the northern boundary of the INEL, where recharge from the Birch Creek and Mud Lake area has been characterized by long-term consistency, the decline has been as little as 2 feet. In many parts of the INEL declines have been greater than 10 feet in observation wells that are sensitive to changes in recharge from the Big Lost River as it traverses the site. Big Lost River flow on the INEL has been abnormally low for the past five years (1977-1981). In addition, pumping from production wells at a few facilities has increased over the same period and may have contributed slightly to the declines.

SURFACE WATER

Surface water is found mainly in streams draining the mountains and valleys to the west and north of the INEL (see fig. 1). Locally, snowmelt and rain also contribute to surface water, especially in the spring. The Big Lost River is the INEL's most important source of surface-water recharge. Recharge to the Snake River Plain aquifer from streamflow during wet years is significant. All streamflow that enters the INEL is recharged to the aquifer, except for evaporation and transpiration losses. During dry periods, streamflow does not reach the INEL.

The Big Lost River flows southeastward in its valley past Arco, onto the Snake River Plain, and then turns northeastward through the INEL to its termination in playas, called the Lost River Sinks (fig. 2). The river loses water by infiltration through the channel bottom as it flows on the plain. As flow approaches the terminal playas, the channel branches into many distributaries, and the flow spreads over several flooding and ponding areas (Barracough and others, 1967).

In addition to irrigation diversions, two major artificial controls affect flow in the river. These are the Mackay Dam, 30 miles upstream from Arco, and the INEL flood-control diversion system in the southwestern part of the site (fig. 2). The INEL flood-control diversion system was

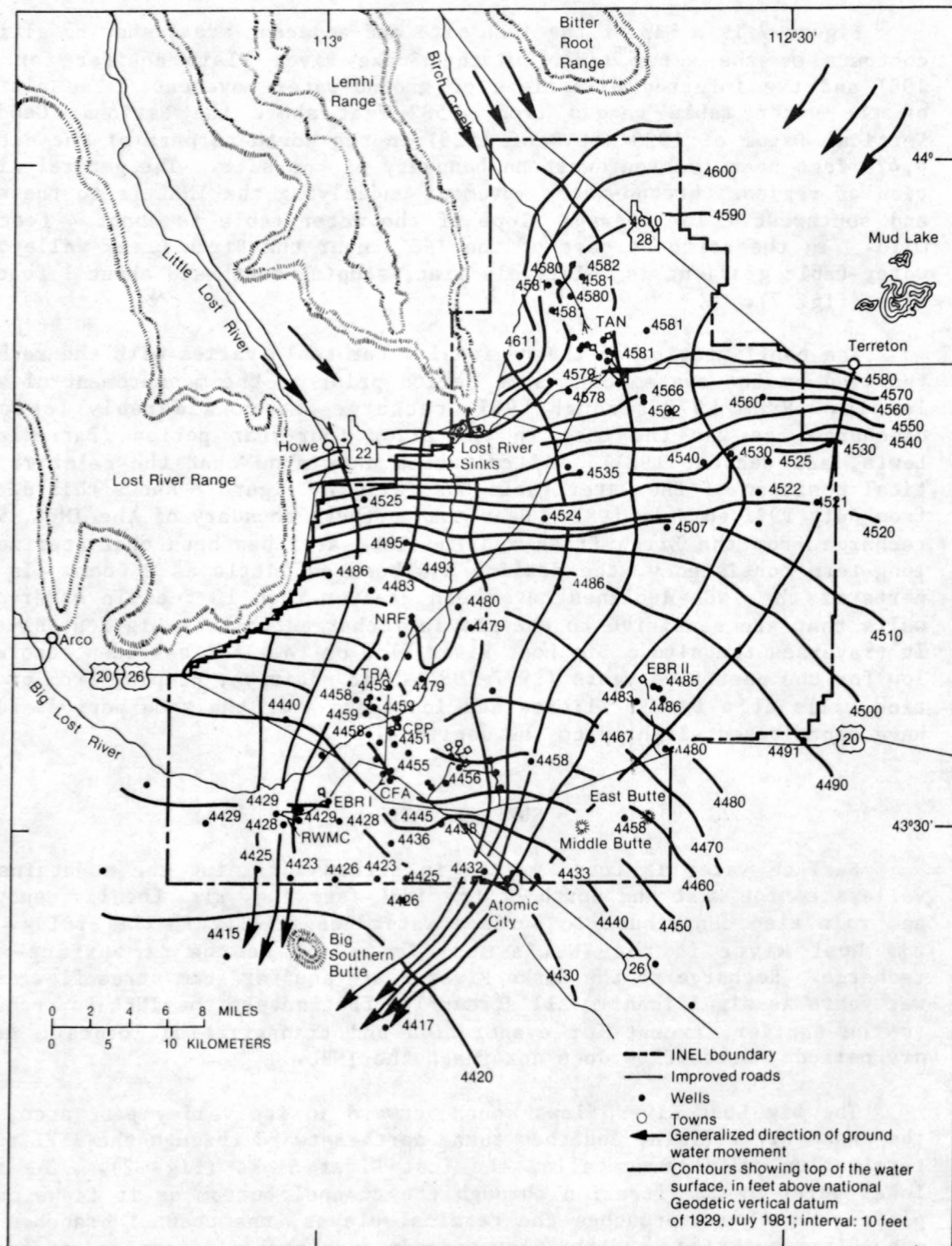


Figure 7.—Generalized altitude contours on the water table, Snake River Plain aquifer, and inferred directions of ground-water flow, INEL and vicinity, July 1981.

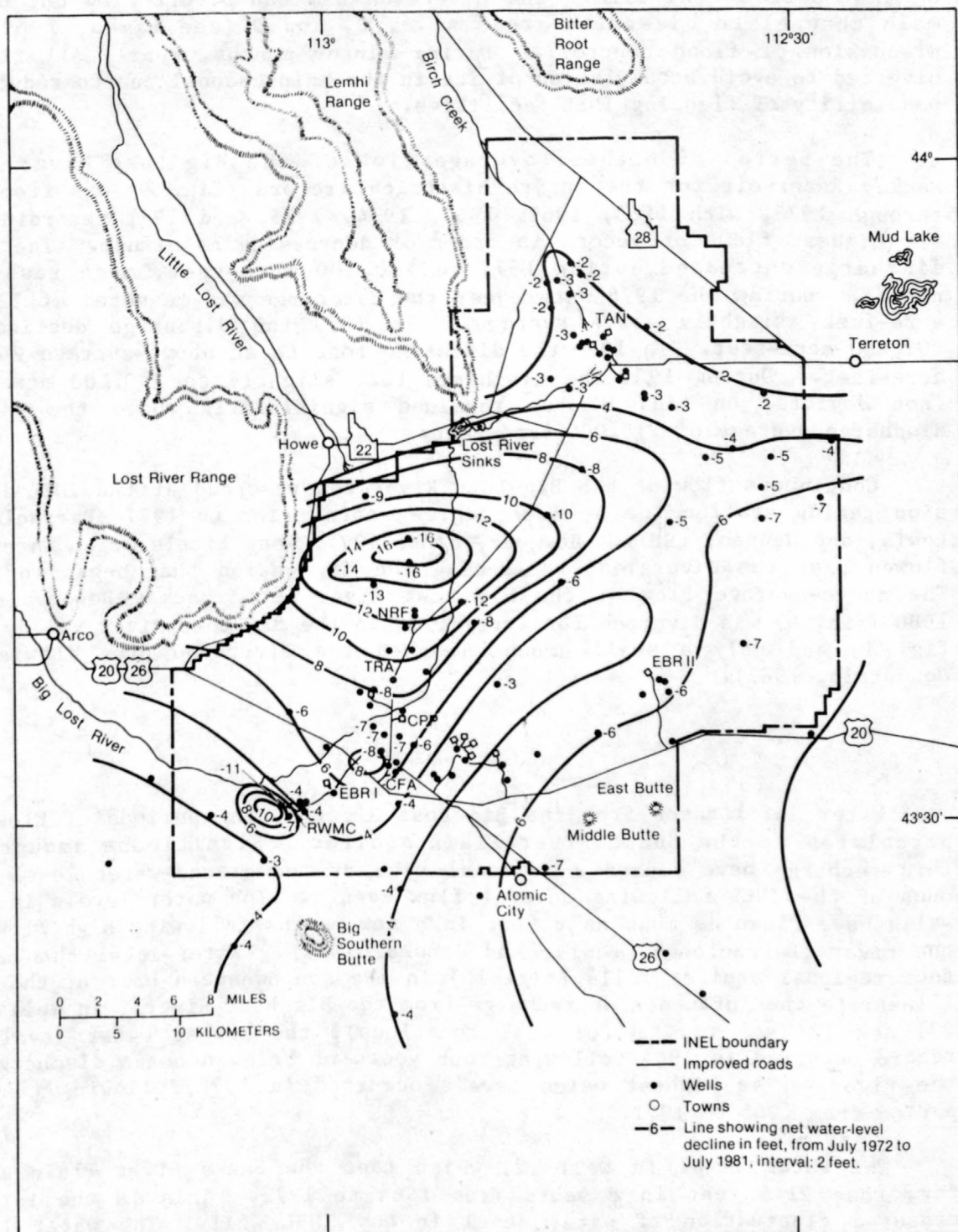


Figure 8.—Generalized net decline of the water table, Snake River Plain aquifer, INEL and vicinity, from July 1972 to July 1981.

constructed in 1958 to reduce the threat of floods from the Big Lost River on that part of the site. The diversion dam can divert flow out of the main channel to diversion areas A, B, C, and D (see Lamke, 1969, for discussion of flood control). During winter months, nearly all flow is diverted to avoid accumulation of ice in the main channel and to reduce the possibility of flooding INEL facilities.

The period of highest average flow of the Big Lost River below Mackay Reservoir for the entire historical record (fig. 9) was from 1965 through 1976, with 1965, 1969, 1967, 1974, 1975, and 1971 recording the six highest flows of record in order of decreasing magnitude. The total discharge decreased during 1977 to 160,300 acre-feet, much less than normal. During the 1978 water year the discharge was measured at 225,900 acre-feet, slightly above average. In 1979 the discharge declined to 202,400 acre-feet. In 1980 the discharge rose to an above-average 249,500 acre-feet. During 1981 the discharge fell slightly to 240,100 acre-feet (not depicted on fig. 9) but remained significantly above the 64-year discharge average of 215,000 acre-feet.

Continuous flow of the Big Lost River was recorded at the INEL diversion gaging station for at least three years prior to 1977 (Barraclough, Lewis, and Jensen, 1981). However, since 1977, very little or no water has flowed past the diversion, reflecting the dry period that began in 1977. The above-average flow of the Big Lost River below Mackay Reservoir for 1980 (fig. 9) was diverted for irrigation in the Big Lost River valley (see fig. 1) and only a small amount reached the diversion area (Lewis and Goldstein, 1982).

GROUND WATER

Water infiltrates from the Big Lost River during periods of flow and percolates to the Snake River Plain aquifer. Significant amounts of this recharge have caused a regional rise of the ground-water level over much of the INEL following several flow events. The water levels in some wells have risen as much as 6 feet in a few months following high flows in the river (Barraclough, Lewis, and Jensen, 1981). Water-level changes in four regional aquifer wells (fig. 10) in the southwestern part of the INEL illustrate the influence of recharge from the Big Lost River. In wells 17, 23, and 12 (see fig. 3 for well locations), the lowest water levels on record occurred in 1964 following four years of below average discharge in the river. The highest water levels occurred in 1972 following the wet period from 1965 to 1971.

The water level in well 12, which taps the Snake River Plain aquifer, rose 21.5 feet in 8 years from 1964 to 1972. This is the largest measured fluctuation of water level in any INEL well. The water level in well 23 rose about 18 feet during this same period, which is the second largest water-level rise that has been measured.

The water level in well 20 (see fig. 4 for well location) rose only about 6 feet from 1964 to 1972 and had declined by nearly 8 feet to a record low by the end of 1980 (fig. 10). The more stable position of

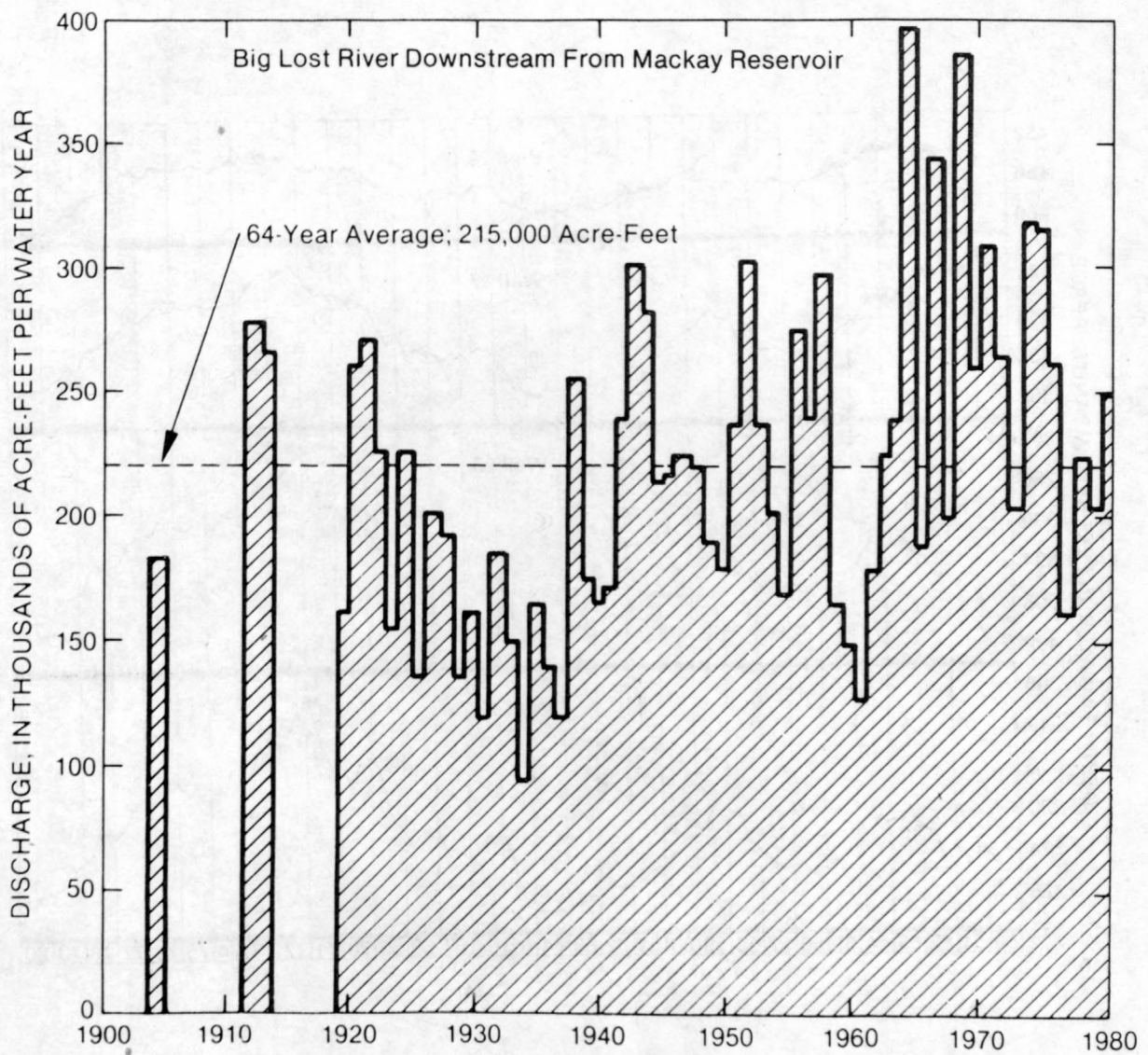


Figure 9.—Discharge of the Big Lost River below the Mackay Reservoir (from Lewis and Goldstein, 1982).

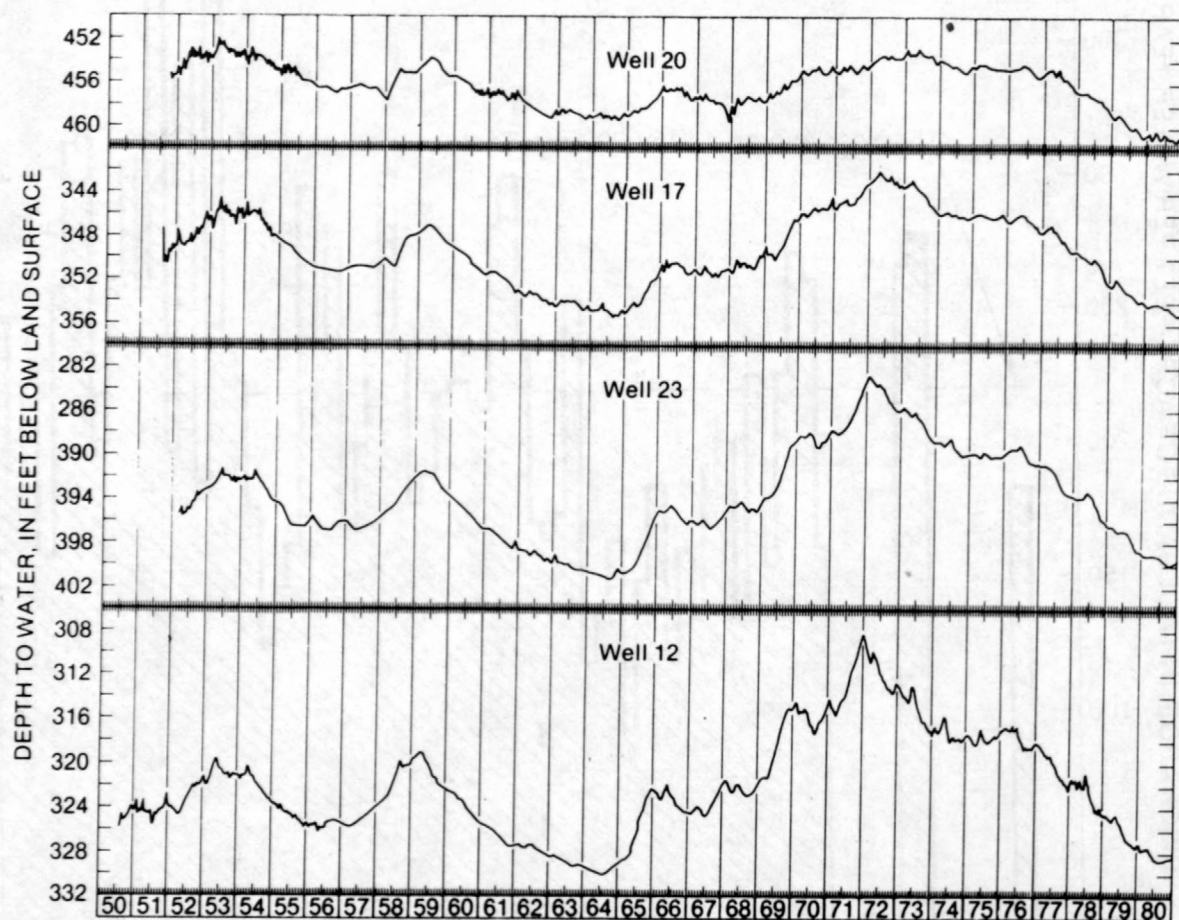


Figure 10.--Hydrographs of four wells in the southwestern part of the INEL (from Lewis and Goldstein, 1982).

this water level may indicate that well 20 is not as greatly influenced by recharge from the Big Lost River and represents the changes in water level for the Snake River Plain aquifer on a more regional basis (Lewis and Goldstein, 1982). The water level remained nearly constant at this record low level during the 1981 water year and may indicate that the aquifer has reached a discharge-recharge balance on a regional basis.

The Snake River Plain aquifer is the only source of water utilized at the INEL. Twenty-five of the 28 production wells are generally in use. The combined pumpage of these wells has been about 2.4 billion gallons of water per year for the past three years. This averages about 6.6 million gallons per day or 7,370 acre-feet per year. These volumetric rates are slightly lower than those reported by Barraclough, Lewis, and Jensen (1981) for the previous four-year period.

Not all the water pumped out of the aquifer is actually consumed. Some of the waste water is discharged directly back into the Snake River Plain aquifer through deep disposal wells. Other aqueous wastes (radioactive, chemical, and sewage) are discharged into ponds. Both methods of waste disposal contribute recharge to the aquifer. Nearly 60 percent of the water pumped is disposed to the surface or subsurface (Barraclough, Lewis, and Jensen, 1981). Pumping has little or no effect on annual water-level changes in the aquifer in the vicinity of the INEL because the amount pumped is a very small part of the total ground-water storage and recharge.

WASTE DISPOSAL SITES

Liquid low-level radioactive and dilute chemical wastes have been discharged to the subsurface at the Test Reactor Area (TRA) since 1952 through a deep disposal well and through ponds; at the Idaho Chemical Processing Plant (ICPP) since 1953 through a deep disposal well; and at the Naval Reactors Facility (NRF) since 1953 through seepage ponds and a waste ditch (Robertson, Schoen, and Barraclough, 1974).

TEST REACTOR AREA

The TRA utilized four disposal systems (fig. 11) to dispose of nearly 354 million gallons of waste water annually for the period 1979 through 1981. This is a much reduced disposal rate from the nearly 470 million gallons annually recorded in previous years (Barraclough, Lewis, and Jensen, 1981). Low-level radioactive wastes are discharged to three seepage ponds. A part of the waste percolates to the Snake River Plain aquifer, 450 feet below the land surface. Chemical wastes are discharged to another seepage pond. Two seepage ponds are used to dispose of sanitary wastes. Cooling-tower blowdown wastes are discharged to the aquifer through a deep disposal well.

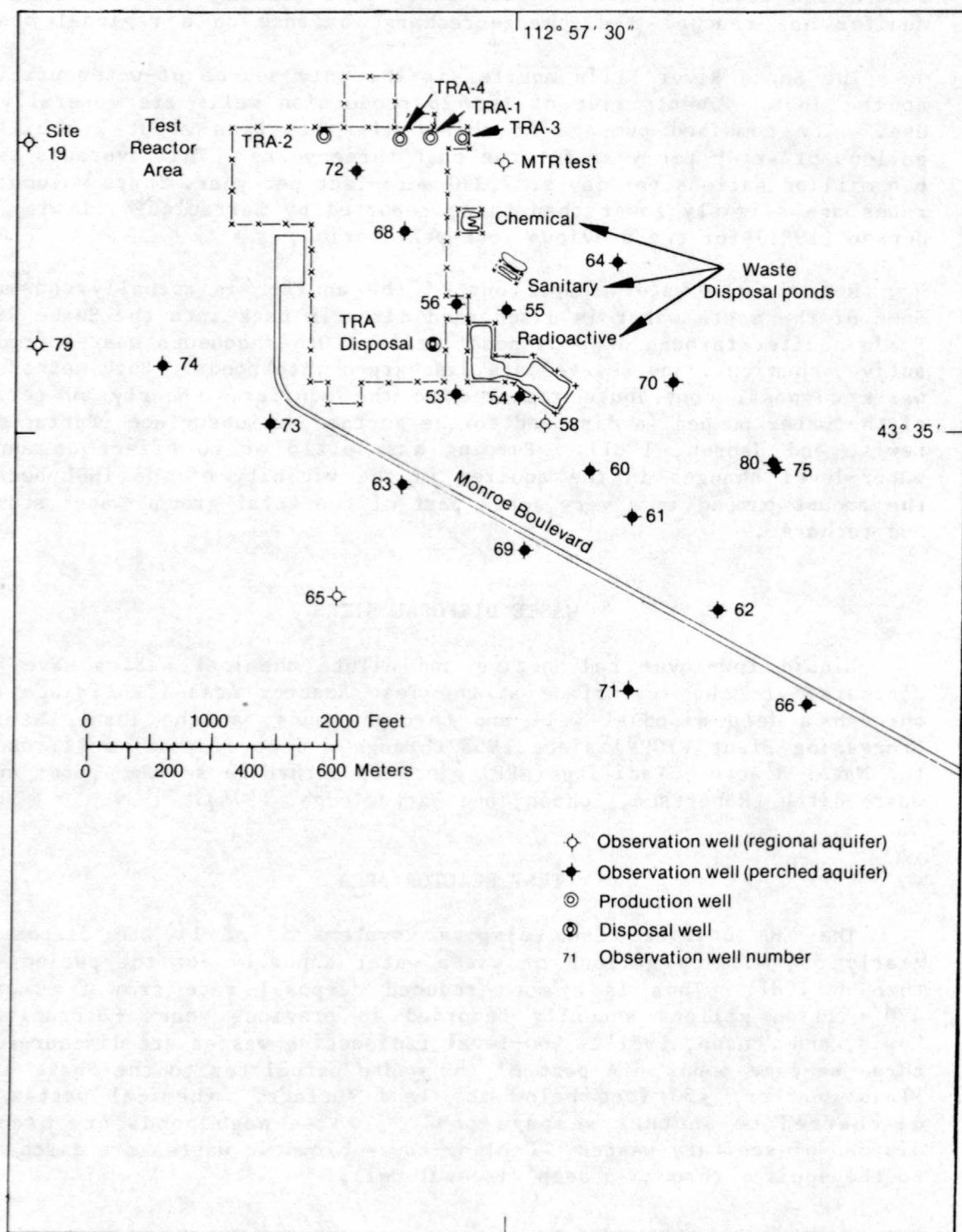


Figure 11.--Location of observation wells, production wells, waste-disposal ponds, and the disposal well at the TRA.

Radioactive-Waste Ponds

The average annual discharge to the TRA radioactive-waste ponds has been about 180 million gallons for the past twelve years. Figure 12 shows a graph of the discharge from 1959 through 1981. Monthly discharge peaks and several yearly discharge totals are depicted on the graph. The discharge to the ponds was 73 million gallons in 1979, 59 million gallons in 1980, and 55 million gallons in 1981 (fig. 12). The discharge was much below average for these three years and averaged a little more than 5 million gallons per month.

Barracough, Lewis, and Jensen (1981) showed that water discharged to the radioactive waste ponds during 1974 to 1978 contained an average of about 2,400 Ci (curies) of activation and fission products per year. During 1977 and 1978 this average was reduced to about 1,300 Ci per year due to the reduction of the yearly volume of discharged waste water. By 1980, the average curie discharge was reduced to about 210 Ci, again due to the reduction of the yearly volume of discharged waste water. In recent years, the average amount of tritium discharged to the ponds has also decreased from about 212 Ci per year to 144 Ci per year (fig. 12) but now represents a greater percentage of the total discharged radioactivity. On the average, about 70 percent of these products have a short half-life (less than several weeks) and probably move only a short distance during their half-lives.

Chemical-Waste Ponds

A pond has been utilized at the TRA since 1962 to dispose of chemical (nonradioactive) wastes from ion-exchange system regeneration. The average disposal from 1979 to 1981 was 13.1 million gallons per year; a rate much lower than the preceding 16-year average of 39.2 million gallons per year. Sulfate and sodium are the major chemical constituents in the waste water and are disposed of in annual amounts of about 824,000 lbs and 95,000 lbs, respectively. For 1979 through 1981, these discharge amounts yielded sulfate and sodium discharge concentrations of about 0.06 and 0.01 lbs per gallon (about 7,200 and 1,200 mg/L), respectively.

Deep-Disposal Well

A disposal well (1,275-feet deep) has been used at the TRA since 1964 to dispose of about 251 million gallons per year of nonradioactive waste water (fig. 12). The well discharges directly into the Snake River Plain aquifer. The water level is generally about 450 feet below the land surface. Most of the injected water is from cooling-tower blowdown; it contains a yearly average of about 518,000 lbs of sulfate and 55,000 lbs of various other chemicals. For several years, hexavalent chromium, used as a corrosion inhibitor in the cooling tower, was discharged to the well (Barracough, Lewis, and Jensen, 1981). Its average concentration in the cooling-tower blowdown was about 2.2 mg/L. This process was replaced by a polyphosphate treatment beginning in October 1972.

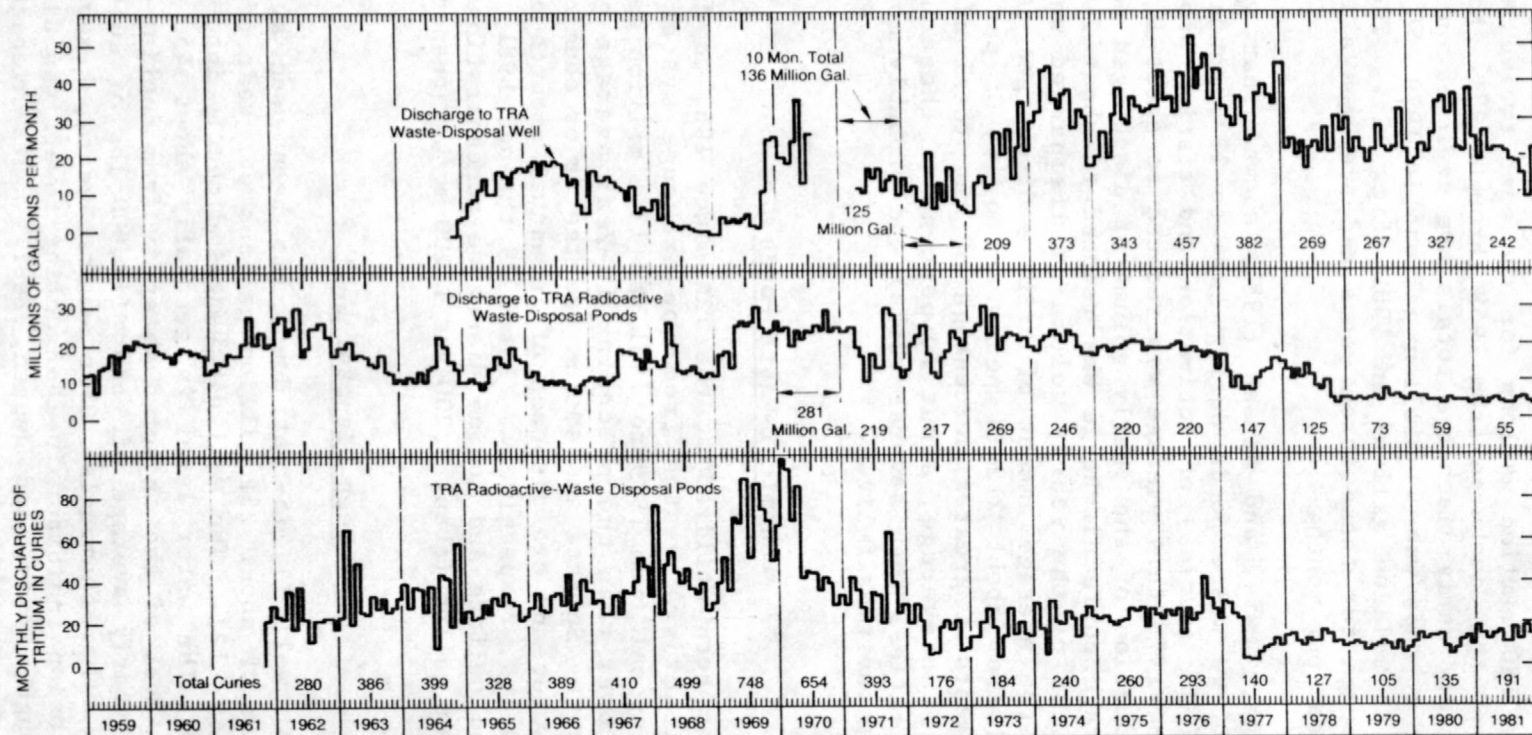


Figure 12.--Waste water discharged to a deep well and the radioactive-waste ponds at the TRA, and the quantity of tritium discharged to the TRA radioactive-waste ponds.

Figure 12 shows the monthly discharge to the waste-disposal well from 1964 through 1981 except for a brief period in 1970 and 1971. The discharge increased to a maximum of 457 million gallons in 1976, and decreased to 242 million gallons in 1981.

IDAHO CHEMICAL PROCESSING PLANT

The ICPP currently discharges low-level radioactive waste and dilute-chemical waste directly to the Snake River Plain aquifer through a disposal well 600 feet deep. The natural water level is about 450 feet below the land surface. The average yearly discharge to the well has been about 326 million gallons since disposal began in 1953 and represents an average monthly discharge of about 27 million gallons. Figure 13 shows the monthly and yearly variations in waste water discharged to the ICPP disposal well. The highest discharge year of modern record was 1981 and represents a monthly disposal rate of more than 44 million gallons, much above the overall average. More tritium, in terms of radioactivity, has been discharged than any other waste isotope.

During the past eight years, 1974 through 1981, the average curie discharge rate (all isotopes) to the ICPP well was 299 Ci per year, and the average volume of water discharged was 398 million gallons per year; resulting in an average radioactivity concentration of about 200 picocuries per milliliter (pCi/mL) in the discharge water. The amount of radioactivity discharged to the well from year to year is variable and depends on plant operations. For example, 223 Ci was discharged in 1979 and 112 Ci in 1980, below the overall discharge average, but increased to an above average 362 Ci in 1981. Nearly 99 percent of the total activity was from tritium (fig. 13), approximately 221, 109, and 359 Ci for 1979, 1980, and 1981, respectively. An average of 0.32 Ci from strontium-90 per year was discharged to the well during 1979 through 1981, but figure 13 again shows the discharge range of this isotope during the past three years, as well as the entire known record. The remainder of the discharged activity was from small quantities of various other radioisotopes.

NAVAL REACTORS FACILITY

The NRF utilizes a ditch to dispose of waste water. Nearly 125 million gallons of waste water were disposed of annually for the 1979 through 1981 time period. A part of the discharged waste percolates to the Snake River Plain aquifer, about 400 feet below land surface. The major chemical constituents in this waste water have been sodium, chloride, and sulfate for the past three years and have average annual discharge amounts of about 168,000, 217,000, and 366,000 lb, respectively. These discharge rates and amounts yield discharge concentrations of about 0.001, 0.002, and 0.003 lb per gallon (about 120, 240, and 360 mg/L) for sodium, chloride, and sulfate, respectively. It should be noted that discharge to the waste ditch has decreased significantly over the latest three-year period. For example, about 189 million gallons of waste water was disposed of in 1979, and decreased to about 69 million gallons in 1981; sodium discharge decreased from about 211,000 lbs in 1979 to 127,000 lbs in 1981; chloride

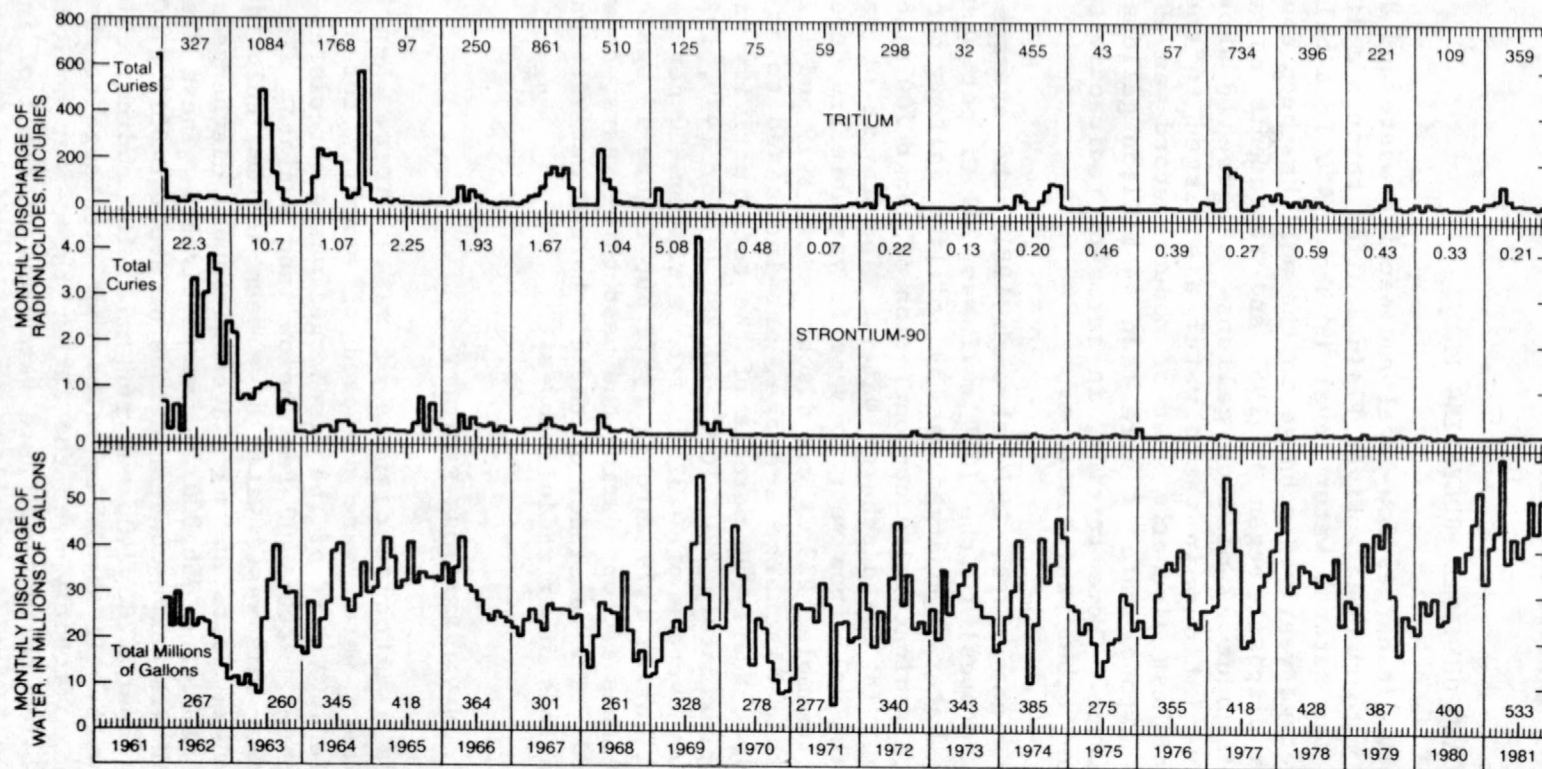


Figure 13.--Waste water discharged to the disposal well at the ICPP, and the quantities of tritium and strontium-90 discharged to the ICPP disposal well.

discharge decreased from nearly 369,000 lbs in 1979 to less than 134,000 lbs in 1981; and the disposal of sulfate decreased from nearly 519,000 lbs in 1979 to about 207,000 lbs in 1981. During each year, minor amounts of other chemical constituents made up the remainder of the waste ditch effluent. Seepage ponds are used at the NRF for sewage disposal.

DISTRIBUTION OF WASTE

About 87 percent of the total waste discharged at the INEL since 1952 has been disposed at the TRA, ICPP, and NRF facilities. The effects of this disposal have been intensively studied and are discussed in detail in the following sections.

CONSTITUENTS IN PERCHED GROUND WATER BENEATH TEST REACTOR AREA

Five perched-water zones have formed in the subsurface rocks at the TRA because of seepage from disposal ponds. A large zone of perched water has formed in the alluvium beneath and to the west of the radioactive waste-disposal ponds (see fig. 11 for pond locations). A zone of perched water has also formed in the alluvium beneath the chemical waste-disposal pond. Another much larger zone of perched water, covering an 0.2 mi² area, has formed in the basalt beneath the perched zone in the surficial alluvium (fig. 14). This saturated zone in the basalt is perched by a sediment bed approximately 150 feet below land surface.

The water that seeps from the radioactive waste ponds percolates through the surface alluvium and is perched on fine-grained sediment at the base of the alluvial deposit and at the top of the basalt surface, about 50 feet below the land surface. The extent of the perched ground water in the alluvium is about twice the pond area.

The shallow perched water percolates through the fine-grained sediment and into the basalt and moves downward until it reaches another layer of fine-grained sediment that is interbedded with the basalt. This deeper sediment layer, which averages about 50 feet in thickness and is about 150 feet below land surface, also perches the percolating water. As figure 14 shows, the extent of this deeper perched-water zone in the basalt beneath the TRA is much greater than that of the shallower perched zones. The deeper perched water is derived from seepage from all of the TRA ponds and by percolation from lawn irrigation at the TRA and from precipitation. The extent of the perched-water zone in the basalt is an area about 2,800 feet by 1,700 feet. The highest water-level contour in figure 14 is 4,850 feet above the geodetic datum, which is about 62 feet below the land surface. The extent and thickness of this large perched water zone has decreased significantly in the past three or four years. A similar depiction of the basalt perched zone for May 1978 (fig. 15) was shown by Barraclough, Lewis, and Jensen (1981). A comparison of figures 14 and 15 readily shows that the perched water body decreased laterally by more than 50 percent and its maximum thickness has thinned by about 10 feet. These reductions indicate that outflow is greater than inflow in the perched-water system. The sharp reduction in the amount of water discharged to the

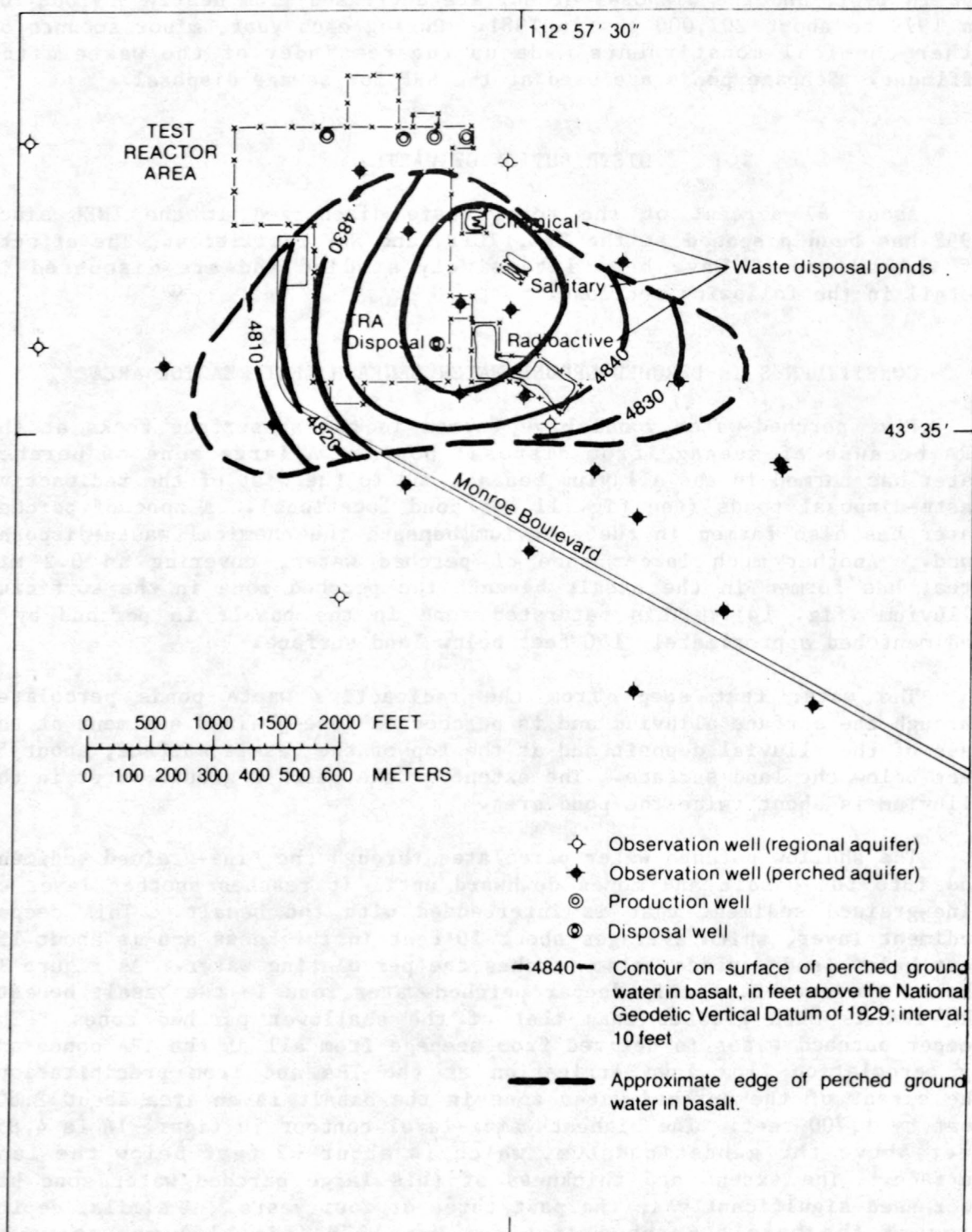


Figure 14.--Water-level contours on the surface of the perched ground water in the basalt at the TRA, October 1981.

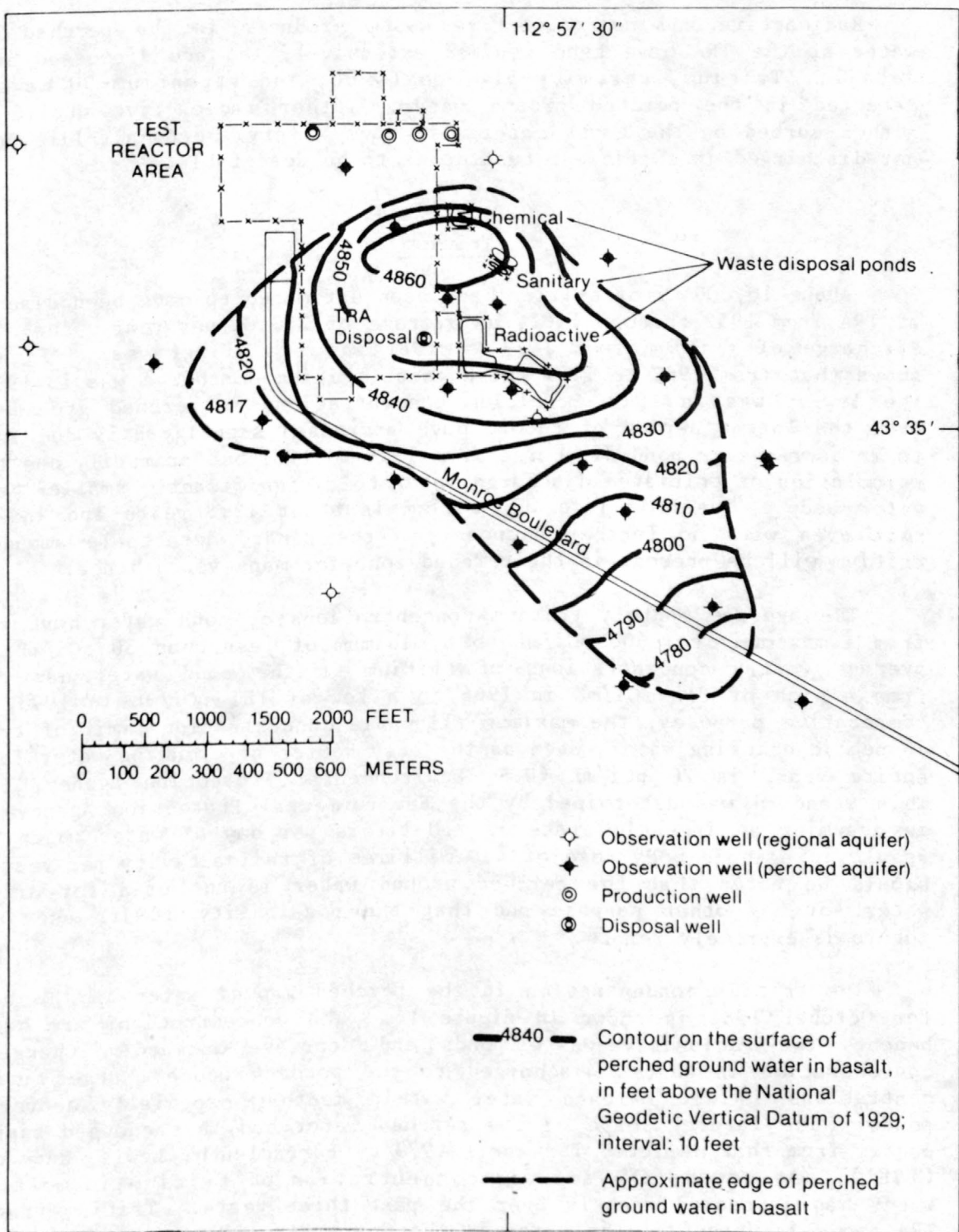


Figure 15.--Water-level contours on the surface of the perched ground water in the basalt at the TRA, May 1978 (from Barraclough, Lewis, and Jensen, 1981).

radioactive-waste ponds from 1976 to 1981 (fig. 12) plus the already mentioned water-discharge reductions associated with the chemical-waste pond have caused this hydrologic imbalance.

Radioactive and nonradioactive waste products in the perched ground water at the TRA have been studied extensively and are discussed here in detail. Tritium, chromium-51, cobalt-60, and strontium-90 have been detected in the perched ground water. Other radioactive nuclides are either sorbed on the earth materials, have a very short half-life, or are not discharged in sufficient quantities to be detectable.

Tritium

About 10,000 Ci of tritium have been estimated to have been discharged at TRA from 1952 through 1981, an average of 330 Ci per year. The average discharge of tritium from 1979 to 1981 was 144 Ci per year. Figure 12 shows that from 1962 to 1981 the highest tritium discharge was in 1969 and the lowest was in 1979. Tritium concentrations in perched ground water over the latest period of record have increased significantly due in part to an increase in pond discharge from 1979 to 1981 but primarily due to the percolation of tritiated discharge water to a significantly smaller perched water body. The half-life of tritium is about 12.3 years and indicates that even with no further disposal to the ponds, detectable amounts of tritium will be present in the perched zone for many years hence.

The average monthly tritium concentrations of pond water have ranged from a maximum of 1,600 pCi/mL to a minimum of less than 30 pCi/mL. The average yearly concentrations of tritium in the pond water has ranged from a high of 816 pCi/mL in 1966 to a low of 181 pCi/mL in 1973. For comparative purposes, the maximum allowable concentration limit of tritium in public drinking water, used as the only source of drinking water for the entire year, is 20 pCi/mL (U.S. Environmental Protection Agency, 1976). This standard was determined by the Environmental Protection Agency (EPA) in assuming an ingestion rate of 2.0 liters per day of water which would result in a whole body dose of 4.0 millirem of radioactivity per year. It should be noted that the perched ground water is not used for drinking water, or any other purpose and that the possibility of its use in the future is extremely remote.

The tritium concentration in the perched ground water in the basalt for October 1981 is shown in figure 16. The concentrations are highest beneath the radioactive-waste ponds and decrease outward. Changes in concentration in wastes discharged to the ponds produce changes in concentrations in the perched water within months, especially nearer the ponds. The lateral shape of the perched water body has changed significantly from that depicted for April 1978 by Barraclough, Lewis, and Jensen (1981). As noted, the average concentration of tritium in most well water has increased greatly over the past three years. Tritium from the TRA ponds is detectable in water in the Snake River Plain aquifer. Migration of tritium from the TRA ponds to the regional aquifer has been modeled and described by Robertson (1977); the study indicates that tritium will continue to enter the Snake River Plain aquifer as long as it is disposed to the radioactive-waste ponds.

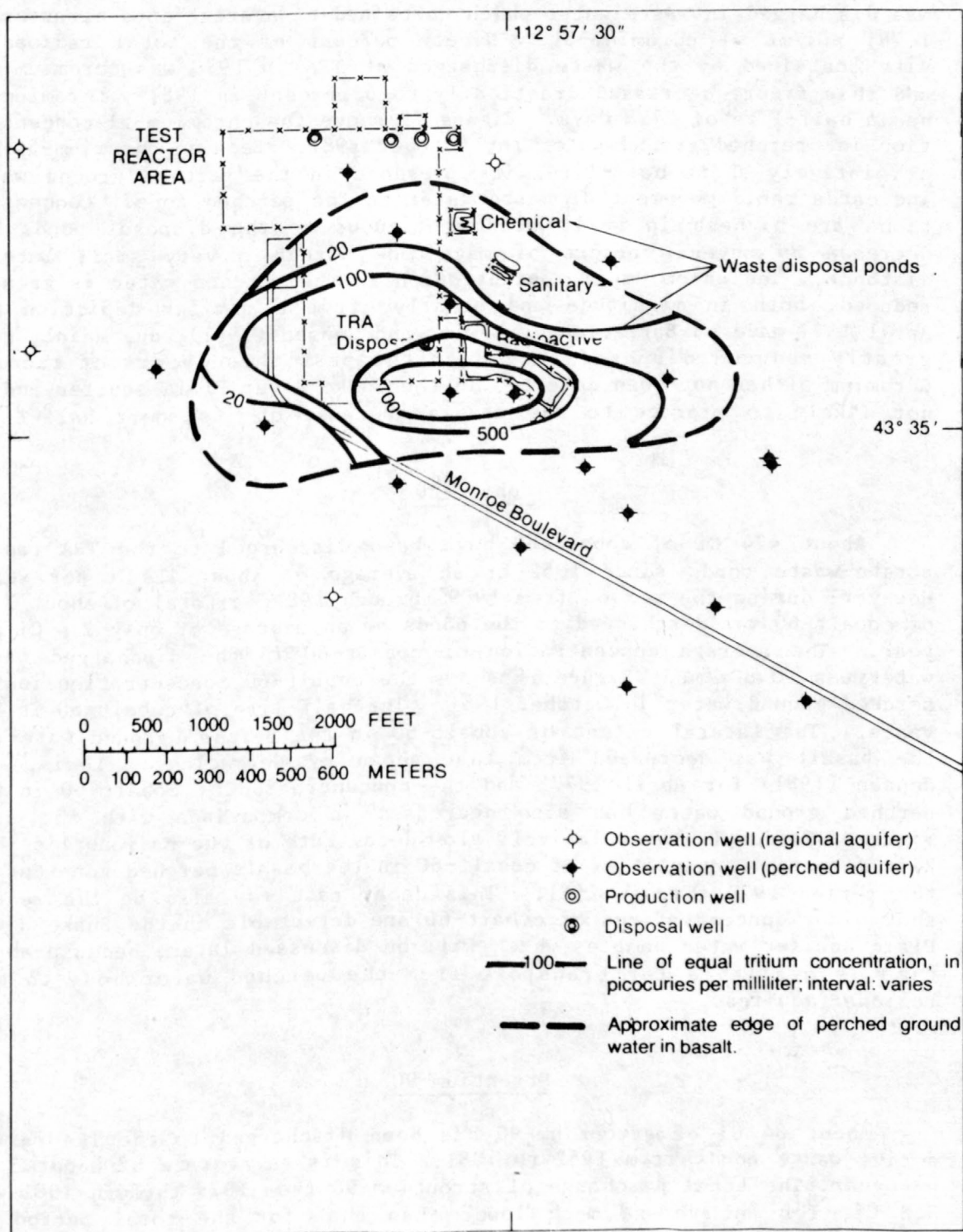


Figure 16.--Concentration of tritium in the perched ground water in the basalt at the TRA, October 1981.

Chromium-51

A total of 2,298 Ci of chromium-51 was discharged to the radioactive waste ponds in the period 1979 to 1981. An average of 403 Ci per year was discharged in waste water which contained an average concentration of 1,781 pCi/mL of chromium-51. Ninety percent of the total radioactivity contained by the waste discharged at TRA in 1979 was chromium-51, and this figure decreased drastically to 6 percent in 1981. Chromium-51 has a half-life of 27.8 days. Figure 17 shows the chromium-51 concentration in perched ground water for October 1981. Because chromium-51 has a relatively short half-life, its presence in the perched ground water indicates rapid movement of waste water to the perched zone. Concentrations are highest in well water contiguous to the disposal ponds but decrease by several orders of magnitude within a very small lateral distance. The chromium-51 concentration in the perched water is greatly reduced, both in magnitude and areally, from a similar depiction for April 1977 made by Barraclough, Lewis, and Jensen (1981), due mainly to a greatly reduced disposal rate over the past three years of record. Chromium-51 has not been detected in the Snake River Plain aquifer and is not likely to migrate to the aquifer because of its short half-life.

Cobalt-60

About 424 Ci of cobalt-60 have been discharged to the TRA radioactive-waste ponds since 1952 or an average of about 12 Ci per year. However, during the period from 1979 through 1981, a total of about 7 Ci of cobalt-60 was discharged to the ponds or an average of only 2.4 Ci per year. The average concentration of cobalt-60 in the discharged waste water was 10 pCi/mL. Figure 18 shows the cobalt-60 concentration in the perched ground water in October 1981. The half-life of cobalt-60 is 5.3 years. The lateral extent of cobalt-60 in the perched ground water in the basalt has decreased from that shown by Barraclough, Lewis, and Jensen (1981) for April 1977, and the concentration of cobalt-60 in the perched ground water has also decreased in comparison with the same figure. Evidently the relatively slow decay rate of the radionuclide has kept detectable quantities of cobalt-60 in the basalt perched zone during the period 1979 through 1981. This decay rate may also be the reason that minor concentrations of cobalt-60 are detectable in the Snake River Plain aquifer water samples which will be discussed later, because ample time is available for transport from the perched water body to the regional aquifer.

Strontium-90

About 84 Ci of strontium-90 has been discharged to the TRA radioactive waste ponds from 1952 to 1981. This is an average of about 3 Ci per year. The total discharge of strontium-90 from 1979 through 1981 was 3.8 Ci, for an average much lower than that for the total period of record. The average concentration of strontium-90 discharged to the TRA radioactive waste ponds from 1979 through 1981 was about 1,300 pCi/L.

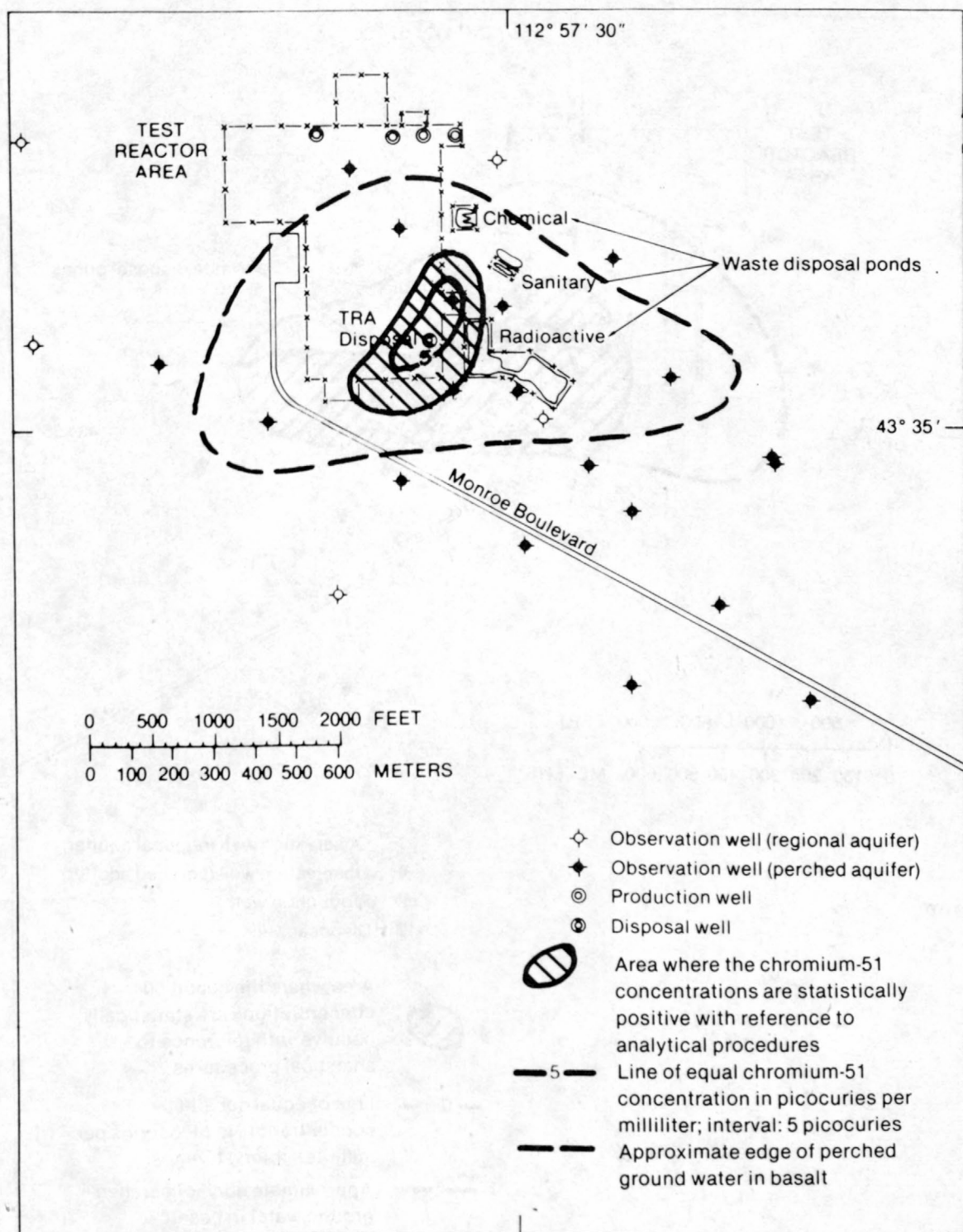


Figure 17.--Concentration of chromium-51 in the perched ground water in the basalt at the TRA, October 1981.

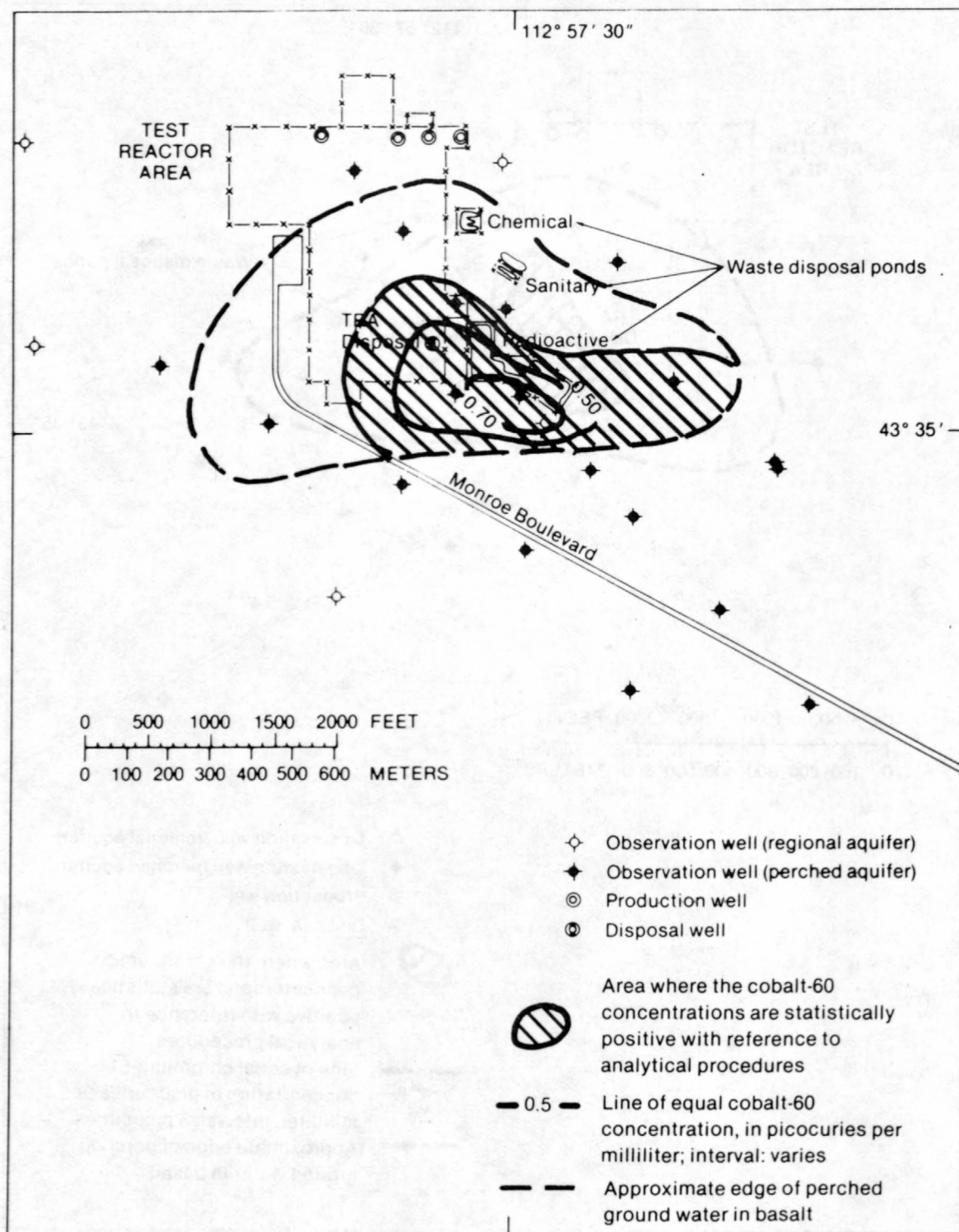


Figure 18.—Concentration of cobalt-60 in the perched ground water in the basalt at the TRA, October 1981.

The distribution of strontium-90 outward from the ponds in the perched ground-water zone in the basalt in October 1981 is shown in figure 19. The figure was constructed from the data from five shallow wells. Strontium-90 was not detected in water samples from the other wells. Strontium-90 can be detected about 1,000 feet outward from the edges of the ponds. Sorption plays an important role in removing the strontium-90 from the perched ground-water zone (Robertson, Schoen, and Barraclough, 1974, p. 108). That part of the perched ground water in which significant amounts of strontium-90 can be detected is similar to that of April 1975 (Barraclough, Lewis, and Jensen, 1981), and concentrations within this limited area have decreased since that time. Strontium-90 has a half-life of 28.6 years, and concentrations may continue to be relatively constant in the years to come. Strontium-90 has not been detected in water from the Snake River Plain aquifer near the TRA ponds. The potential for migration of strontium-90 from the TRA ponds to the regional aquifer was modeled and described in a report by Robertson (1977) who concluded that strontium-90 may reach the Snake River Plain aquifer in the future if preferential vertical flow paths exist in the unsaturated zone beneath the perched aquifer, if the strontium-90 distribution coefficients of the sediment layers are much lower than estimated, or if the sedimentary layers are much thinner than expected. This conclusion is also based on the premise that strontium-90 discharge to the waste ponds remains constant at the rate relevant at the time of the study. In fact, the discharge rate has decreased since that time, as noted earlier.

Cesium-137

Approximately 135 Ci of cesium-137 was discharged to the disposal ponds at the TRA over the period of 1952 through 1981, an average of 4.5 Ci per year. The discharge of cesium-137 totaled 6.0 Ci from 1979 through 1981 for an average of 2.0 Ci per year. Cesium-137 has a similar half life (30.2 years) to strontium-90; because of this and other similarities, such as quantities disposed, the distribution of cesium-137 in the perched ground water could be expected to be similar to the distribution of strontium-90. However, cesium-137 has never been detected in a water sample from the perched ground water in the basalt. This is due to the fact that cesium-137 is strongly sorbed to the minerals of the alluvial sediments and sediments within the basalt and is removed before reaching wells in the perched-water body (Robertson, Schoen, and Barraclough, 1974).

Specific Conductance

The chemical-waste pond water has a high specific conductance because of the large amount of dissolved chemicals discharged to it. Figure 20 shows the specific conductance of samples taken from the perched ground water in the basalt in October 1981. The specific conductance of water from the well nearest the chemical waste pond was 3,700 $\mu\text{mho/cm}$ at 25°C (fig. 20). At a greater distance from the pond, the perched water had a specific conductance as low as 120 $\mu\text{mho/cm}$ at 25°C. As the waste water moves outward from the pond to the southwest, it becomes diluted by waste water of low specific conductance from the large radioactive ponds.

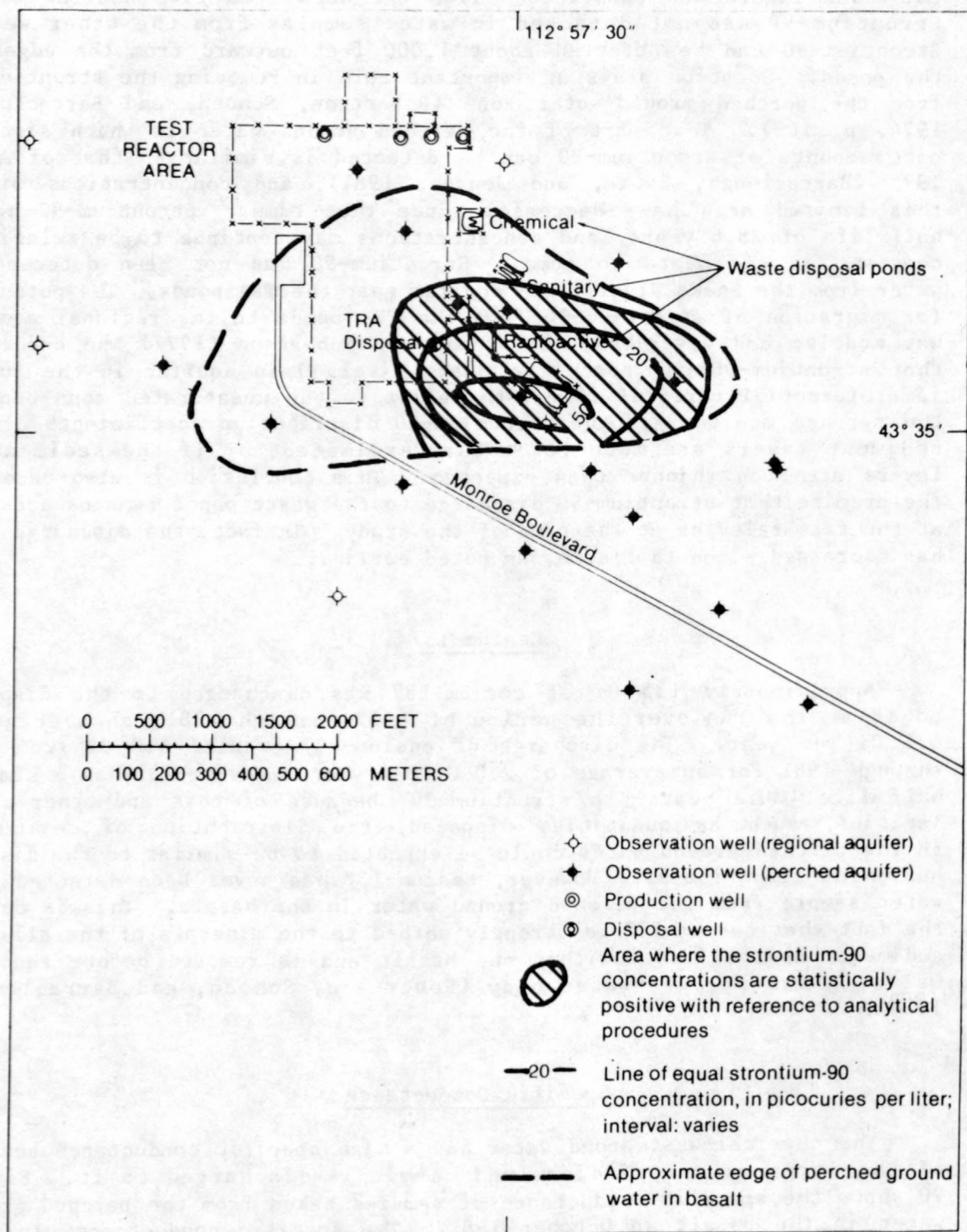


Figure 19.—Concentration of strontium-90 in the perched ground water in the basalt at the TRA, October 1981.

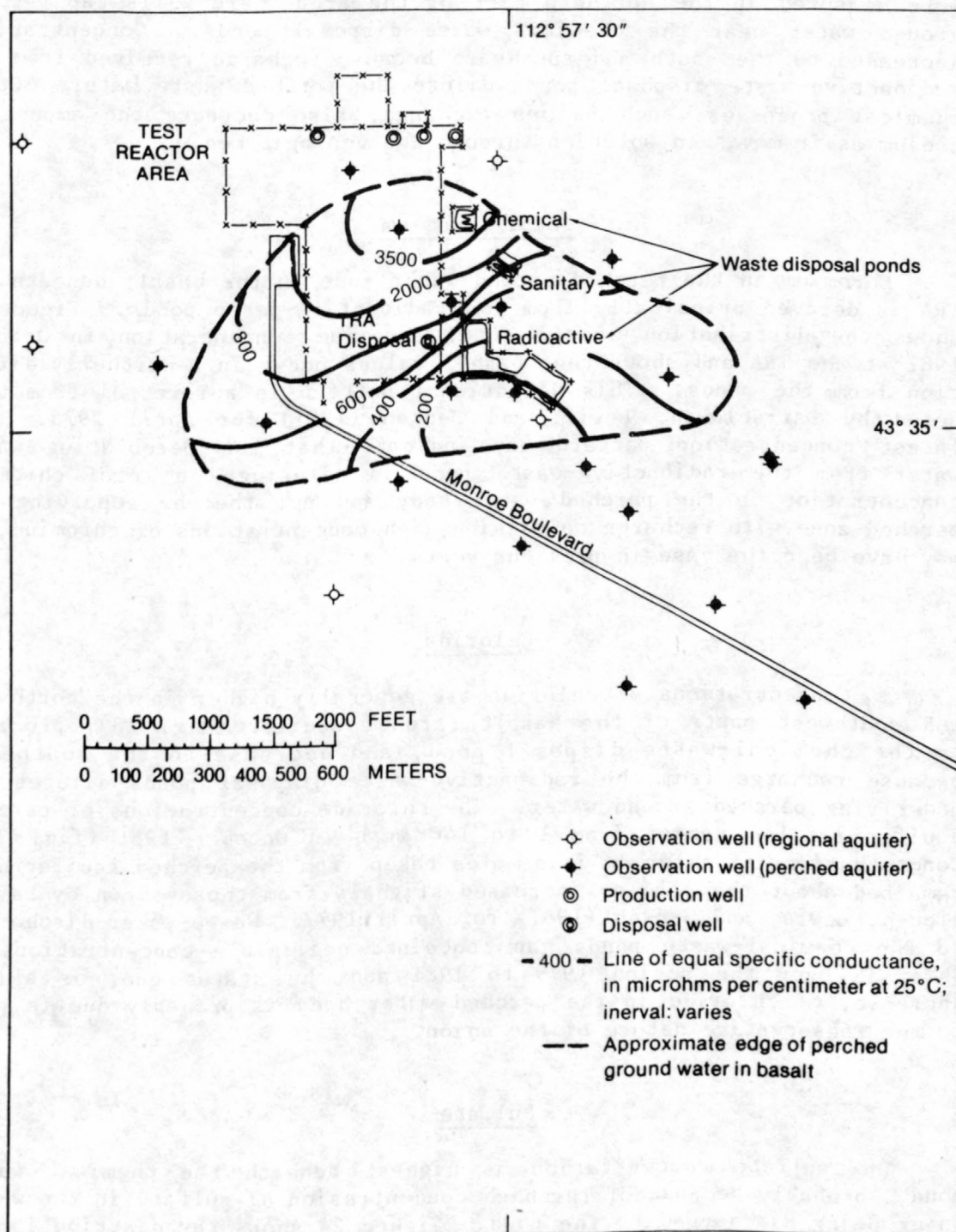


Figure 20.--Specific conductance of perched ground water in the basalt at the TRA, October 1981.

Sodium

The sodium concentration in perched ground water in the basalt at TRA ranged from 6 to 222 mg/L in October 1981 (fig. 21). Highest values were measured in the northern part of the area where wells tap perched ground water near the chemical waste disposal ponds. Concentrations decreased to the south and southeast because recharge received from the radioactive-waste disposal ponds dilute the perched waste water. Other chemical processes, such as ion exchange, also decrease the amount of sodium as it moves in solution through the geologic media.

Total Chromium

Chromium in the perched ground-water zone in the basalt beneath the TRA is derived principally from the radioactive-waste ponds. Figure 22 shows the distribution of the total chromium concentration in October 1981 at the TRA and shows that higher values occur in a northerly direction from the ponds. This directional pattern is a reversal from that noted by Barraclough, Lewis, and Jensen (1981) for April 1975. The latest concentration pattern may indicate that the percolating waste water from the radioactive-waste pond is diluting the total chromium concentration in the perched water body and not thereby supplying the perched zone with recharge containing high concentrations of chromium, as may have been the case in previous years.

Chloride

Concentrations of chloride are generally higher in the northwest and southwest parts of the basalt perched aquifer (fig. 23), proximal to the chemical-waste disposal pond, and decrease to the southeast because recharge from the radioactive-waste disposal ponds dilutes the underlying perched ground water. The chloride concentrations of perched aquifer samples ranged from 1 to 140 mg/L in October 1981 (fig. 23). Concentrations of chloride in samples taken from the perched aquifer have remained about the same or increased slightly from those shown by Barraclough, Lewis, and Jensen (1981) for April 1977. Waste water discharged to the chemical-waste ponds has contained negligible concentrations of chloride over the period 1979 to 1981 and the status quo, or slight increase, of chloride in the perched water body is probably due in part to the conservative nature of the anion.

Sulfate

The sulfate concentration is highest beneath the chemical waste pond, probably because of the high concentration of sulfate in the waste water being discharged to the pond. Figure 24 shows the distribution of sulfate in the perched ground water at TRA in December 1981. The concentrations of sulfate in water from the perched aquifer ranged from 12 to 2,700 mg/L (fig. 24). Here again, the dilution effect of recharge to the

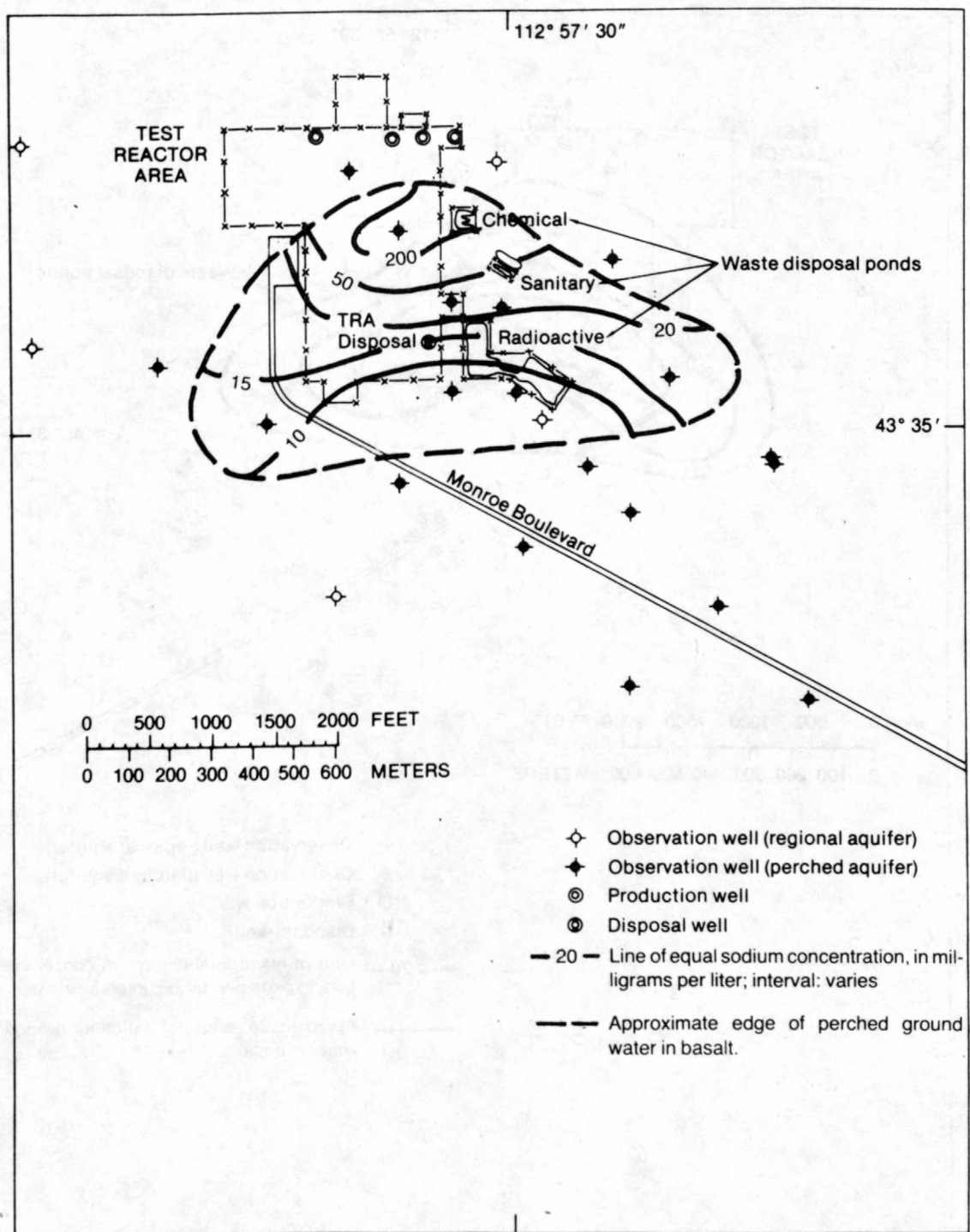


Figure 21.—Concentration of sodium in the perched ground water in the basalt at the TRA, October 1981.

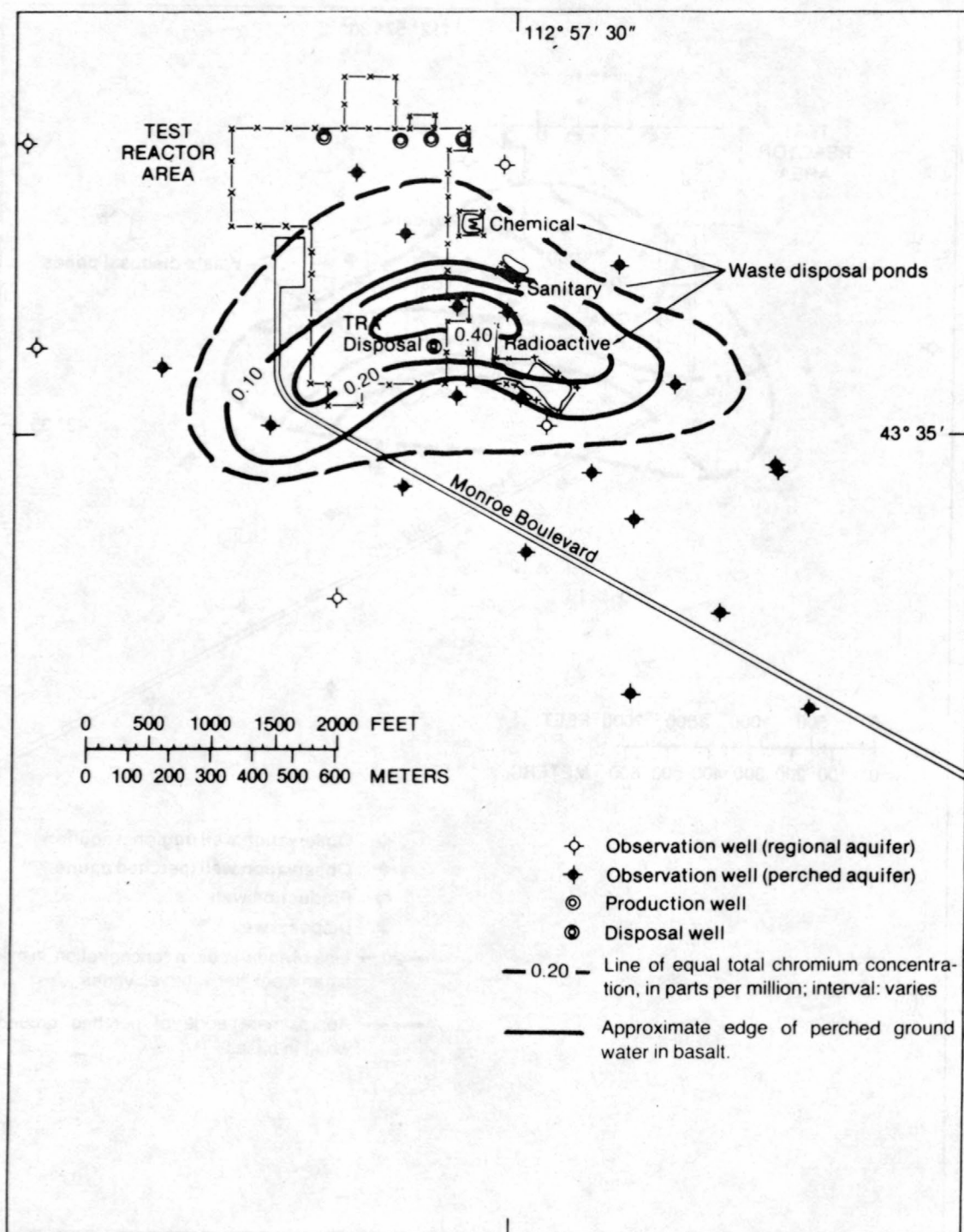


Figure 22.—Total concentration of chromium in the perched ground water in the basalt at the TRA, October 1981.

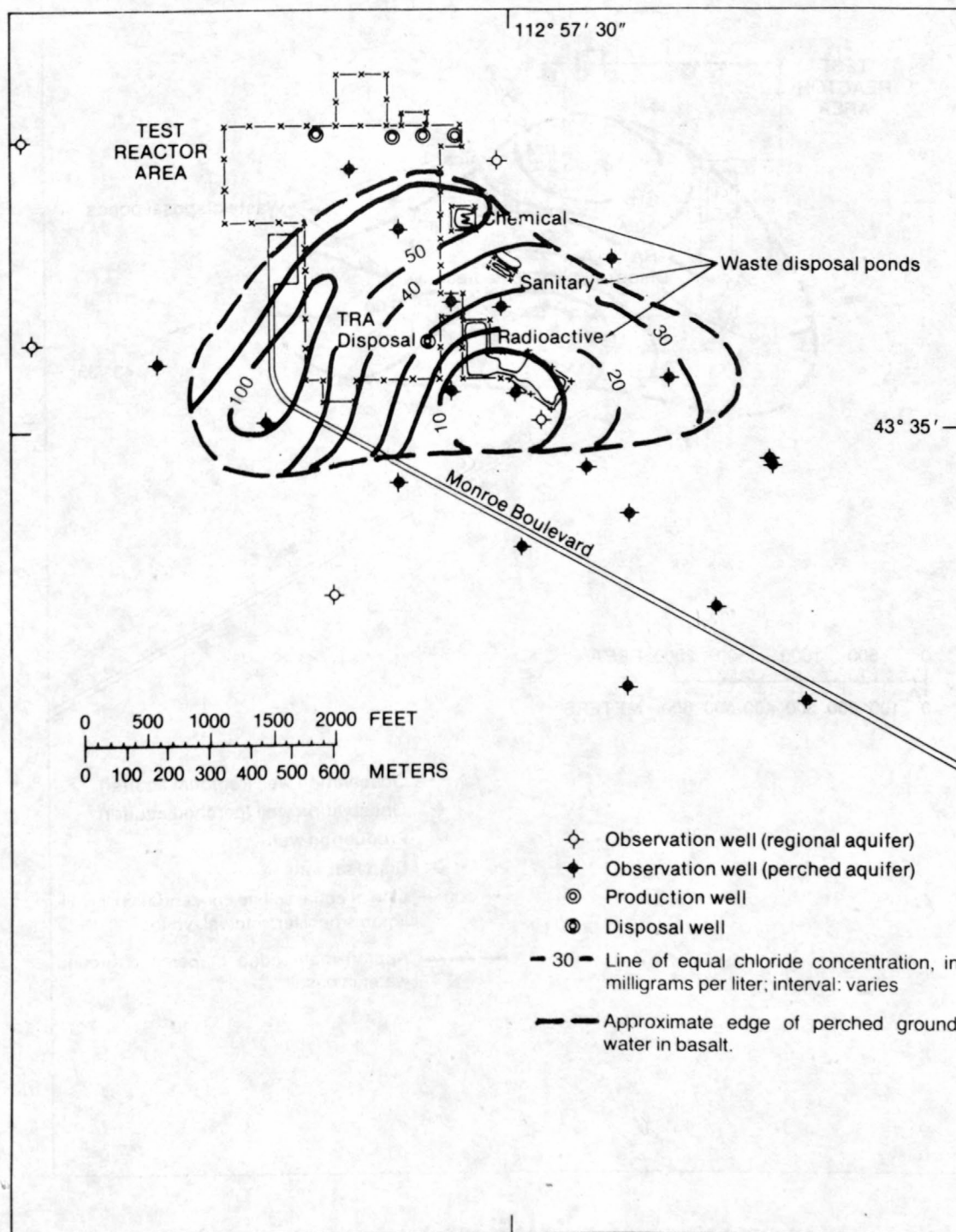


Figure 23.--Concentration of chloride in the perched ground water in the basalt at the TRA, October 1981.

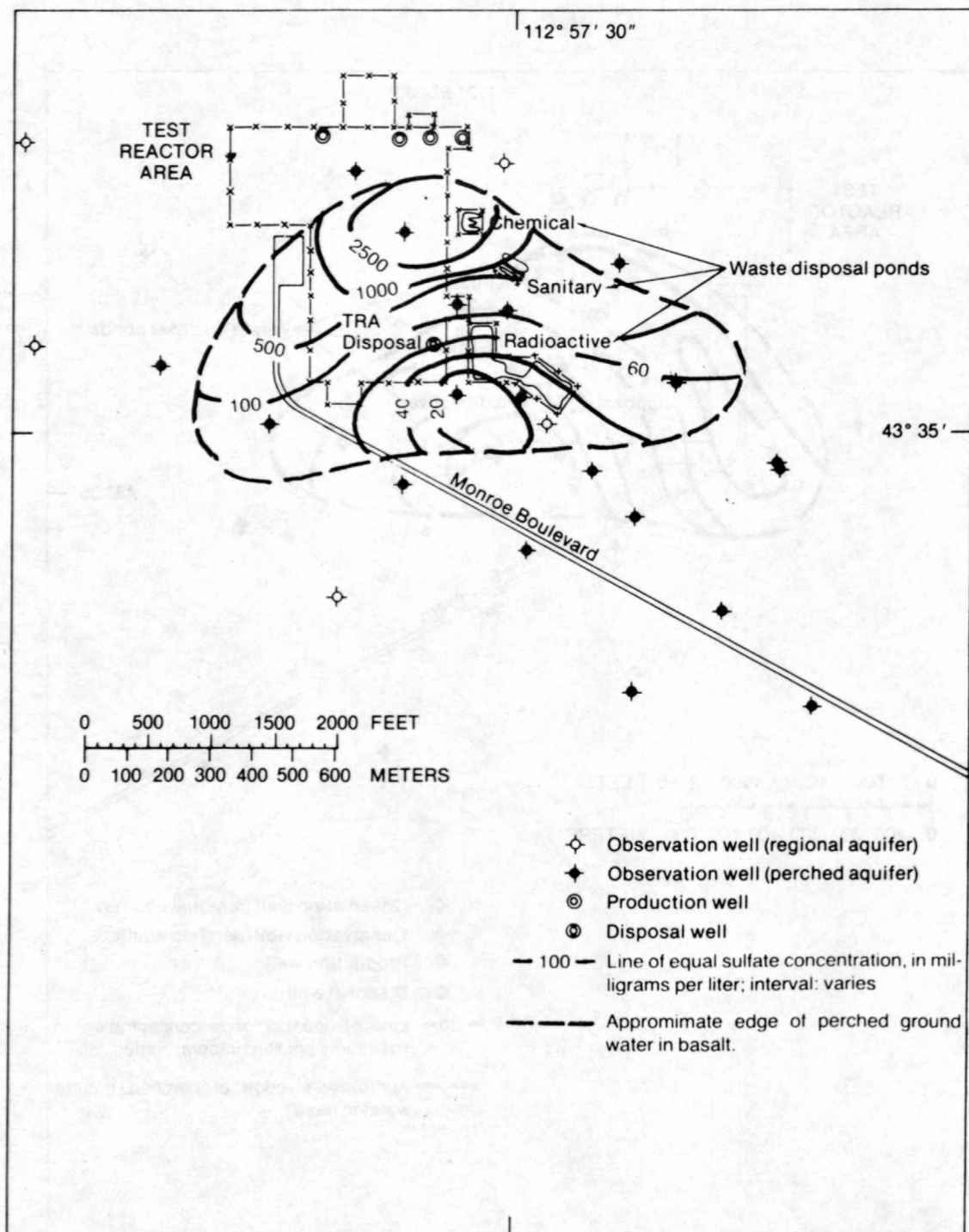


Figure 24.--Concentration of sulfate in the perched ground water in the basalt at the TRA, December 1981.

perched aquifer from the radioactive-waste disposal ponds is readily apparent by the decrease in sulfate concentration to the south. The sulfate concentration pattern for December 1981 is closely similar in appearance to a corresponding part of the October 1975 perched water body (Barracough, Lewis, and Jensen, 1981).

Nitrate

Nitrate concentration in the basalt perched aquifer is highest in the perched zone's northern part contiguous with the chemical- and sanitary-waste ponds (fig. 25). Figure 25 also shows that the nitrate concentrations (calculated as NO_3) are nearly uniform in the perched zone except for samples taken from the wells nearest the radioactive-waste disposal ponds. The diluting effect of recharge from the radioactive-waste water is again apparent and indicates that little or no nitrate is contained in the radioactive-waste disposal water.

Phosphate

The phosphate concentration in the basalt perched aquifer is generally higher in the eastern half of the zone (fig. 26) and appears to be influenced by recharge from the sanitary-waste pond and, perhaps, the radioactive-waste ponds. Recharge from the radioactive-waste ponds apparently does not dilute this waste constituent as was the case in the previously discussed situations. The reasons and causes for the relationship are at present undetermined because no known phosphate is discharged to the radioactive-waste ponds.

Phosphate chemistry is extremely complex and the concentration in the perched ground water may be influenced by geochemical factors such as the pH of the recharge and perched aquifer water, organic chemical reactions, sorptive interactions with the perching fine-grained sediment layer, and other unknown factors. Noticeable in figure 26 is that the sampled phosphate concentrations are very low, mostly less than 1 mg/L. Analytical uncertainties associated with the measurement of an ion in such low concentrations may also contribute to the complexity of determining the actual situation.

CONSTITUENTS IN SNAKE RIVER PLAIN AQUIFER

The distribution of the principal radioactive and nonradioactive waste in the Snake River Plain aquifer is discussed and illustrated in the following section, and waste product concentrations are compared and contrasted, where applicable, to the natural quality of water in the regional aquifer. Olmsted (1962) stated that the natural quality of water in the Snake River Plain aquifer in the INEL area could be divided into two general categories: 1) a calcium, magnesium, bicarbonate, and carbonate dominated water underlying the western part of the INEL reflects the abundance of these constituents from the recharge areas north and west of the INEL, which are mainly composed of limestone and

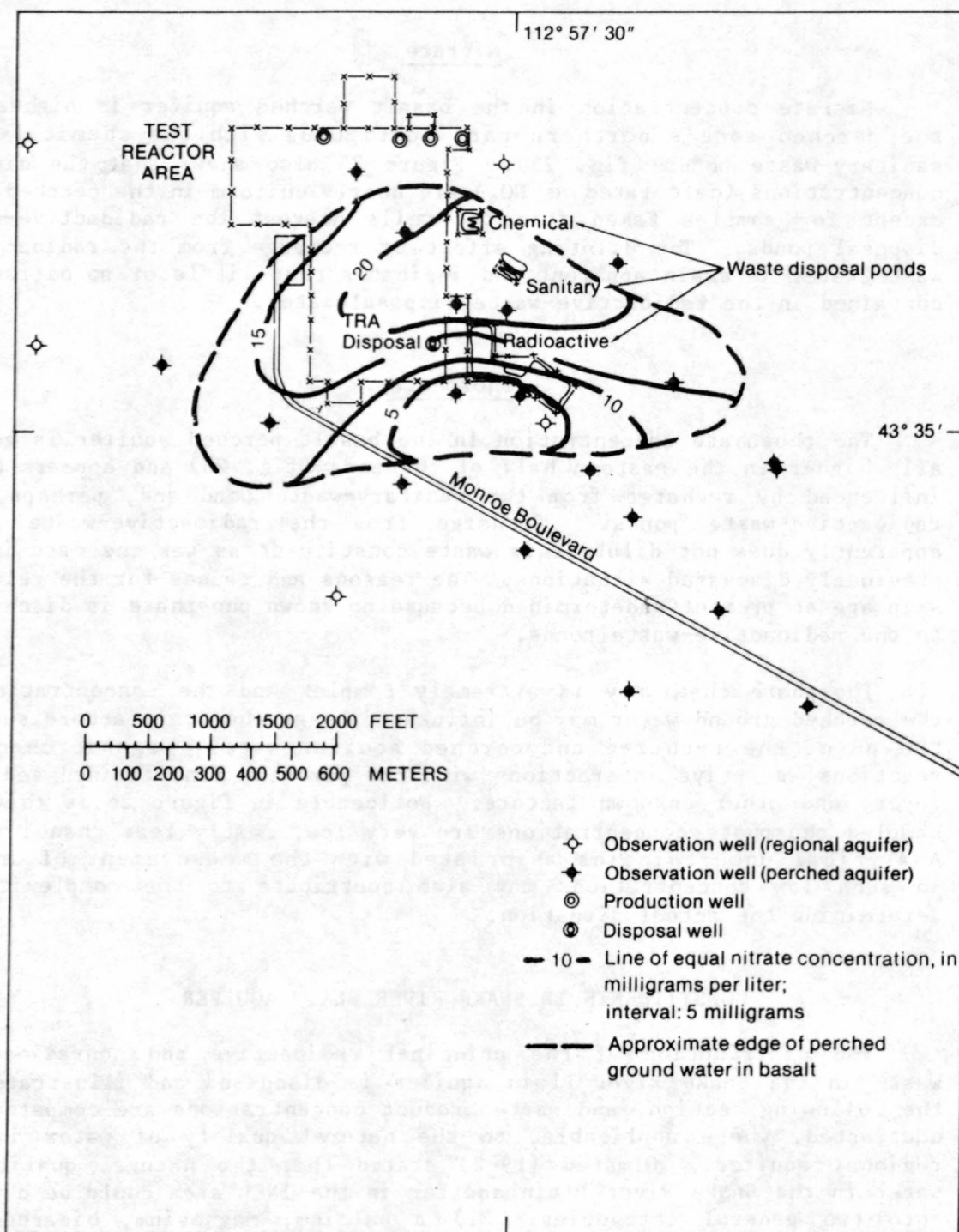


Figure 25.--Concentration of nitrate in the perched ground water in the basalt at the TRA, December 1981.

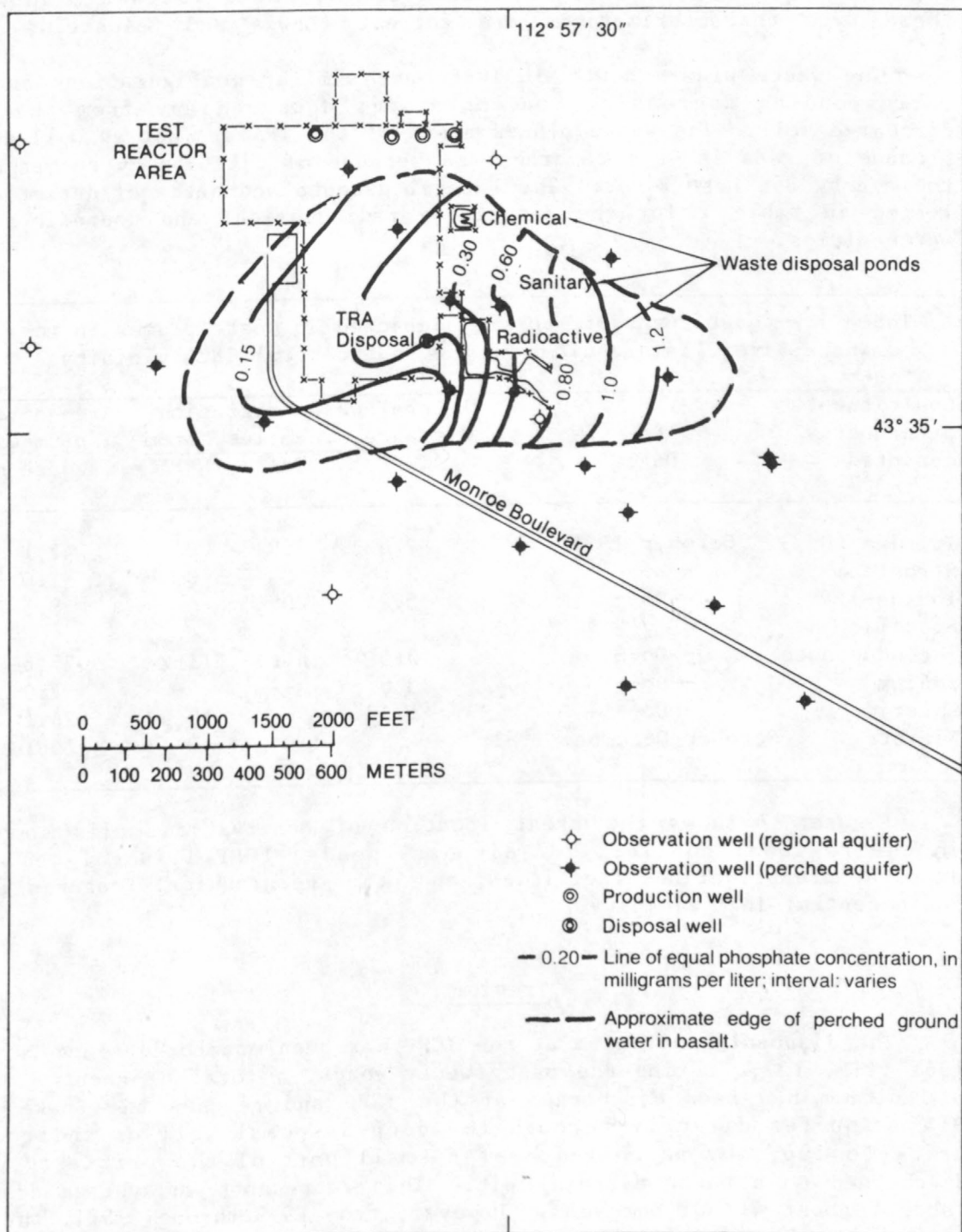


Figure 26.--Concentration of phosphate in the perched ground water in the basalt at the TRA, December 1981.

dolomite; and 2) whereas a similar type of water underlies the eastern part of the site, it contains greater percentages of sodium and potassium, indicating that recharge to this part of the aquifer originates in the mountains north and northeast of the INEL, an area predominantly composed of silicic volcanic rocks. Analyses of water samples collected from the regional aquifer, in areas not affected by waste disposal, show that these type characterizations are correct (Lewis and Goldstein, 1982).

The waste plumes south of ICPP have similar configurations and show corresponding decreasing concentrations downgradient from the waste discharge well. The waste plumes south of the TRA are not as well defined because of gaps in well coverage and because of dilution by recharge from the nearby Big Lost River. The lateral extents and dates of depiction are listed in table 1 for the detectable radiochemical and nonradiochemical waste plumes.

Table 1.--Constituent or property depicted in waste plumes in the Snake River Plain aquifer in the southcentral INEL vicinity

Constituent or property depicted	Date	Lateral waste migration distance, in miles, from			Area of waste plume, in square miles
		ICPP	TRA	NRF	
Tritium (H-3)	October 1981	7.6	7.9	0	42.1
Strontium-90	--Do--	2.1	0	0	2.0
Iodine-129	--Do--	6.2	0	0	9.5
Specific conductance	--Do--	5.5	6.1	11.2	27.6
Sodium	--Do--	3.6	--	--	7.9
Chloride	--Do--	5.3	0	10.6	26.2
Nitrate	October-December 1981	4.8	0	0	10.1

Figure 27 shows the areal location of observation wells completed in the regional aquifer, TRA disposal ponds, ICPP disposal well, NRF disposal areas, various facilities, and other geographical features in the south-central INEL vicinity.

Tritium

The disposal of tritium at the ICPP has been monitored since December 1961 (fig. 13). During the past twenty years, a total of about 8,370 Ci of tritium has been discharged at the ICPP and reaches the Snake River Plain aquifer directly through the deep disposal well or indirectly, prior to 1967, by percolation of a small part of the tritiated water discharged to a waste disposal pit. This represents an average disposal rate of about 418 Ci per year. However, from 1979 through 1981, the rate of tritium disposal of 230 Ci per year was considerably less than the overall average. This injection into the regional aquifer of waste

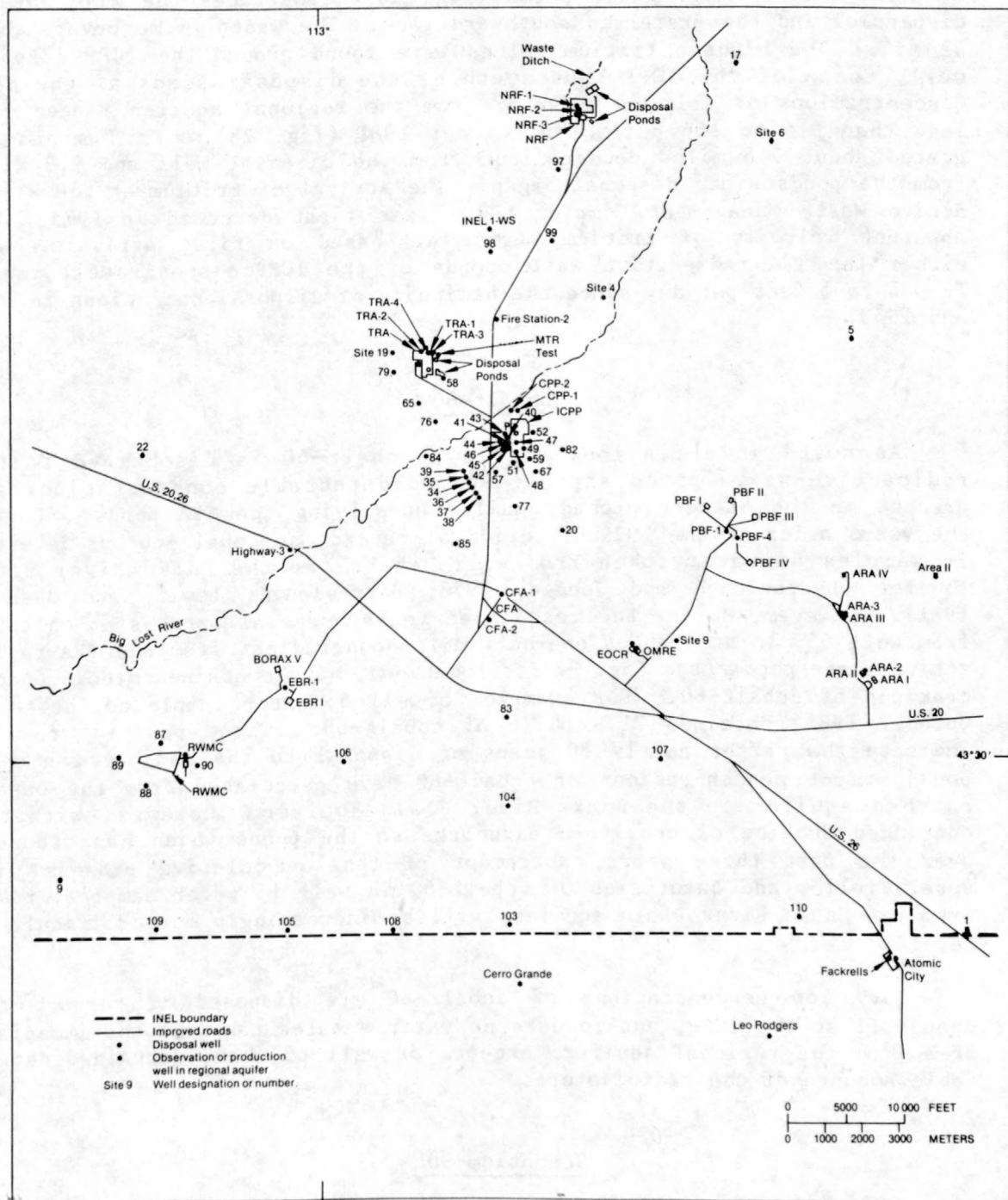


Figure 27.--Location of observation wells completed in the Snake River Plain aquifer, waste-disposal wells, and radioactive-waste-disposal ponds in the south-central INEL vicinity.

water plus the simultaneous percolation of waste water from the perched ground-water zone underlying the TRA has resulted in a large, dispersed plume of tritium in the regional ground-water system (fig. 28).

The October 1981 waste plume (fig. 28) illustrates the wide lateral dispersion and the preferred southward flow. The waste plume covers about 42 mi². The highest tritium values were found around the ICPP disposal well, south of the ICPP, and south of the disposal ponds at the TRA. Concentrations of tritium in water from the regional aquifer ranged from less than 0.4 to 156 pCi/mL in October 1981 (fig. 28). Tritium has migrated about 7.6 miles downgradient from the disposal well and 7.9 miles from the ponds since disposal began. The arrival of tritium at the Radioactive Waste Management Complex (RWMC) was first detected in 1975. The apparent velocity of tritium migration, based on first arrivals, from either the TRA radioactive waste ponds or the ICPP disposal well ranges from 4 to 5 feet per day since the beginning of disposal operations in 1952 and 1953.

Cobalt-60

As noted in a previous section, cobalt-60 is discharged to the radioactive-waste ponds at the TRA and detectable concentrations are present in the basalt perched aquifer underlying the TRA ponds. During the years prior to the 1979-81 period of record, no cobalt-60 was detected in samples of water taken from wells which tap the Snake River Plain aquifer (Barraclough and Jensen, 1976; Barraclough, Lewis, and Jensen, 1981). However, during the past three years, several water samples taken from well 65, located about one-half mile downgradient from the TRA radioactive-waste ponds (see fig. 27 for location), have contained minor concentrations of cobalt-60. For example, a well 65 water sample collected in October 1981 contained 21.9 pCi/L of cobalt-60. These positive results indicate that after nearly 30 years of disposal to the radioactive-waste ponds, minor concentrations of cobalt-60 have percolated from the basalt perched aquifer to the Snake River Plain aquifer. However, with the continued decline of cobalt-60 discharge to the ponds which has occurred over the past three years, abatement of this percolative process will surely follow and quantities of cobalt-60 in well 65 water samples, taken from the Snake River Plain aquifer, will be increasingly more difficult to detect.

Very low concentrations of cobalt-60 are disposed of through the deep well at the ICPP, but to date no water samples taken in the immediate area from the regional aquifer, except for well 65, have contained detectable amounts of the radioisotope.

Strontium-90

A total of about 21 Ci of strontium-90 has been discharged to the ICPP well from 1952 through 1981. This is an average of about 0.7 Ci of strontium-90 per year. The current discharge of strontium-90 is somewhat less. For example, in 1979 a total of 0.43 Ci was discharged to

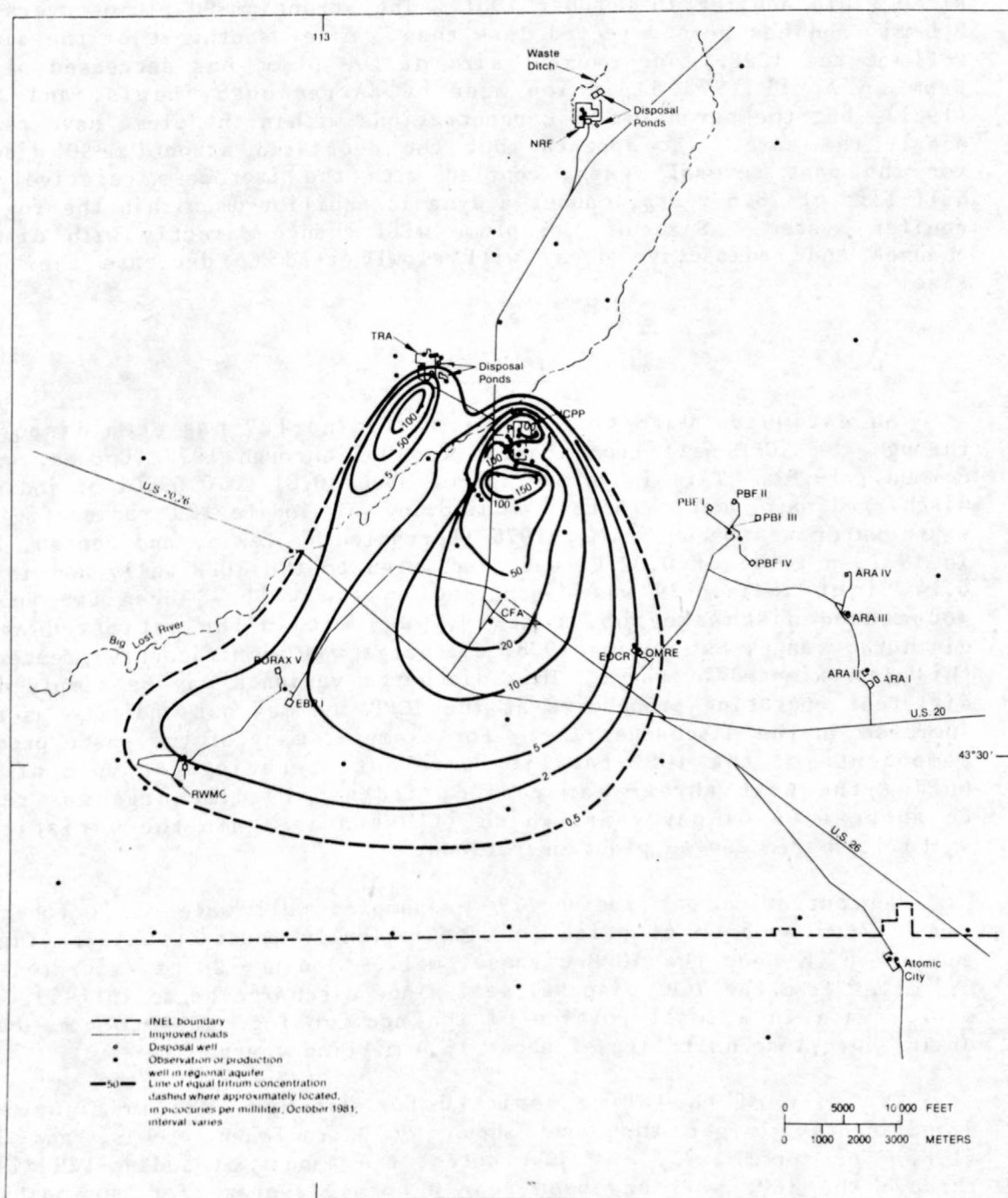


Figure 28.—Distribution of tritium in the Snake River Plain aquifer, southcentral INEL vicinity, October 1981.

the ICPP well, whereas in 1981 a total of 0.21 Ci of strontium-90 was discharged to the ICPP well. From 1979 through 1981, a total of 1.0 Ci of strontium-90 was discharged to the ICPP disposal well--an average of 0.33 Ci per year.

Figure 29 shows the distribution of strontium-90 in the Snake River Plain aquifer in October 1981. The strontium-90 plume covers about 2.0 mi² and has been detected less than 3 miles southwest of the disposal well at the ICPP. The overall size of the plume has decreased slightly from an April 1978 depiction made by Barraclough, Lewis, and Jensen (1981), but the strontium-90 concentrations within the plume have remained nearly the same. It appears that the decreased strontium-90 discharge for the past several years, coupled with the isotope's relatively long half-life of 28.6 years, causes a dynamic equilibrium within the regional-aquifer system. Size of the plume will change directly with discharge changes and radioactive decay will slowly tend to decrease the plume's size.

Iodine-129

An estimated 0.16 to 0.78 Ci of iodine-129 has been disposed of through the ICPP well from startup in 1952 through 1977 (Cordes, written commun., 1978). This is an average of about 0.01 to 0.03 Ci of iodine-129 discharged per year. Actual monitoring of iodine-129 radioactivity in waste water was begun in May 1976 (Barraclough, Lewis, and Jensen, 1981). In 1977, a total of 0.02 Ci was discharged to the ICPP well, and in 1978, 0.14 Ci of iodine-129 was discharged to the well. These two years of documented discharge show that 1977 was within the estimated average discharge range, but during 1978, discharge was significantly greater than this approximated average. This discharge variance may be simply due to different operating procedures at the ICPP and may not indicate an actual increase in the discharge rate. For example, many of the waste producing components of the ICPP facility were not operating for much of 1977. During the next three-year period, iodine-129 discharge was reduced to about 0.04 Ci per year, which illustrates again the variations in waste discharge due to plant operations.

Concentrations of iodine-129 in sampled well water in October 1981 ranged from 0.05 to 41 pCi/L for statistically positive values (fig. 30) and are high near the ICPP disposal well. Iodine-129 has migrated about 6.3 miles from the ICPP disposal well since discharge began in 1953, and it will remain in a small portion of the aquifer for years to come because of its very long half-life of about 16.4 million years.

The size of the plume depicted for October 1981 in figure 30 is significantly larger than one shown by Barraclough, Lewis, and Jensen (1981) for April 1977. As just noted, the amount of iodine-129 disposal through the ICPP well has been near a normal average for the past three years, and plume size should not have changed appreciably during that time period. However, the minimum concentration shown on the April 1977 depiction is 0.9 pCi/L (Barraclough, Lewis, and Jensen, 1981), and the comparable concentration for October 1981 is 0.05 pCi/L (fig. 30). The sample size was one liter during the 1977 sampling program and four

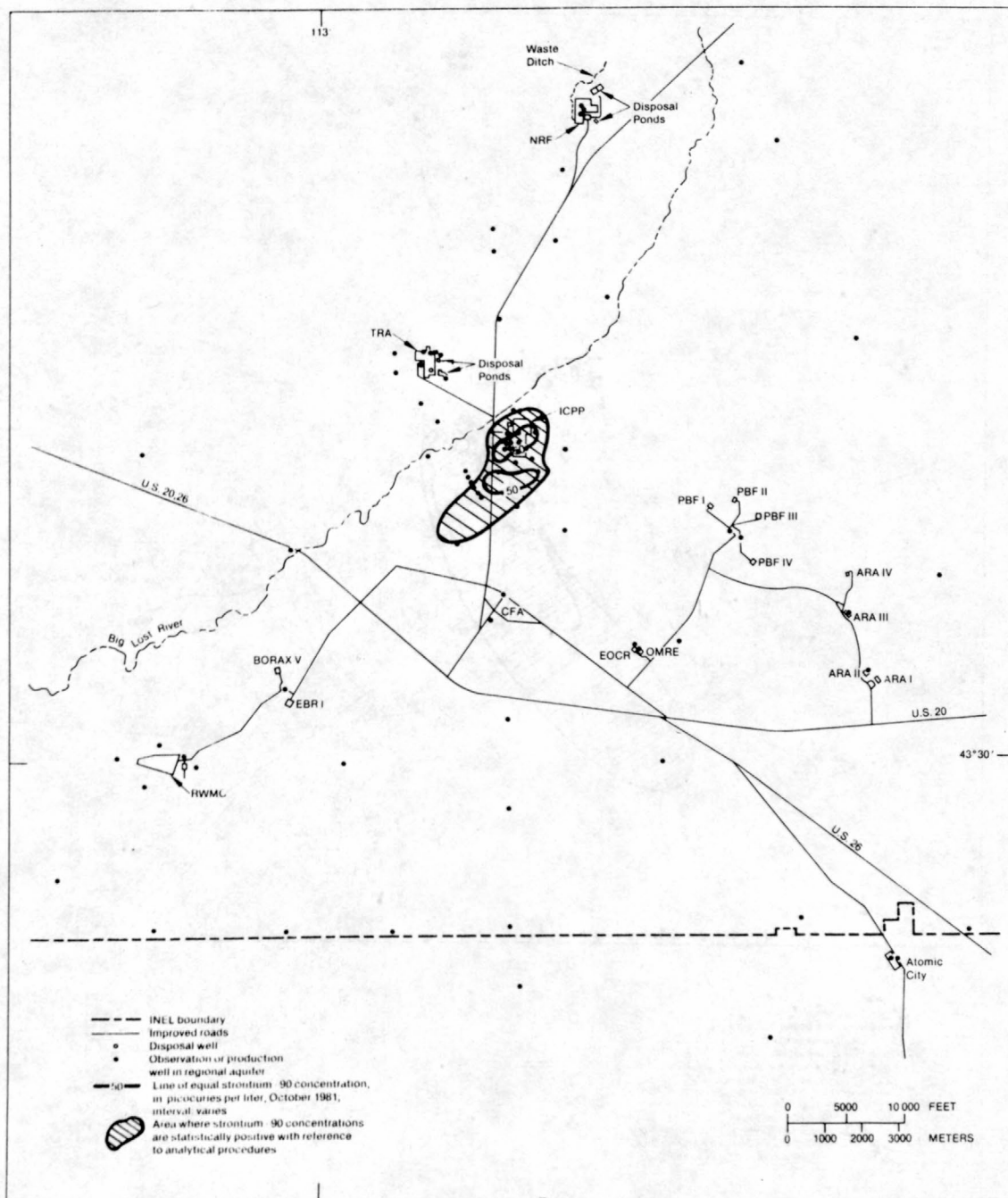


Figure 29.—Distribution of strontium-90 in the Snake River Plain aquifer, southcentral INEL vicinity, October 1981.

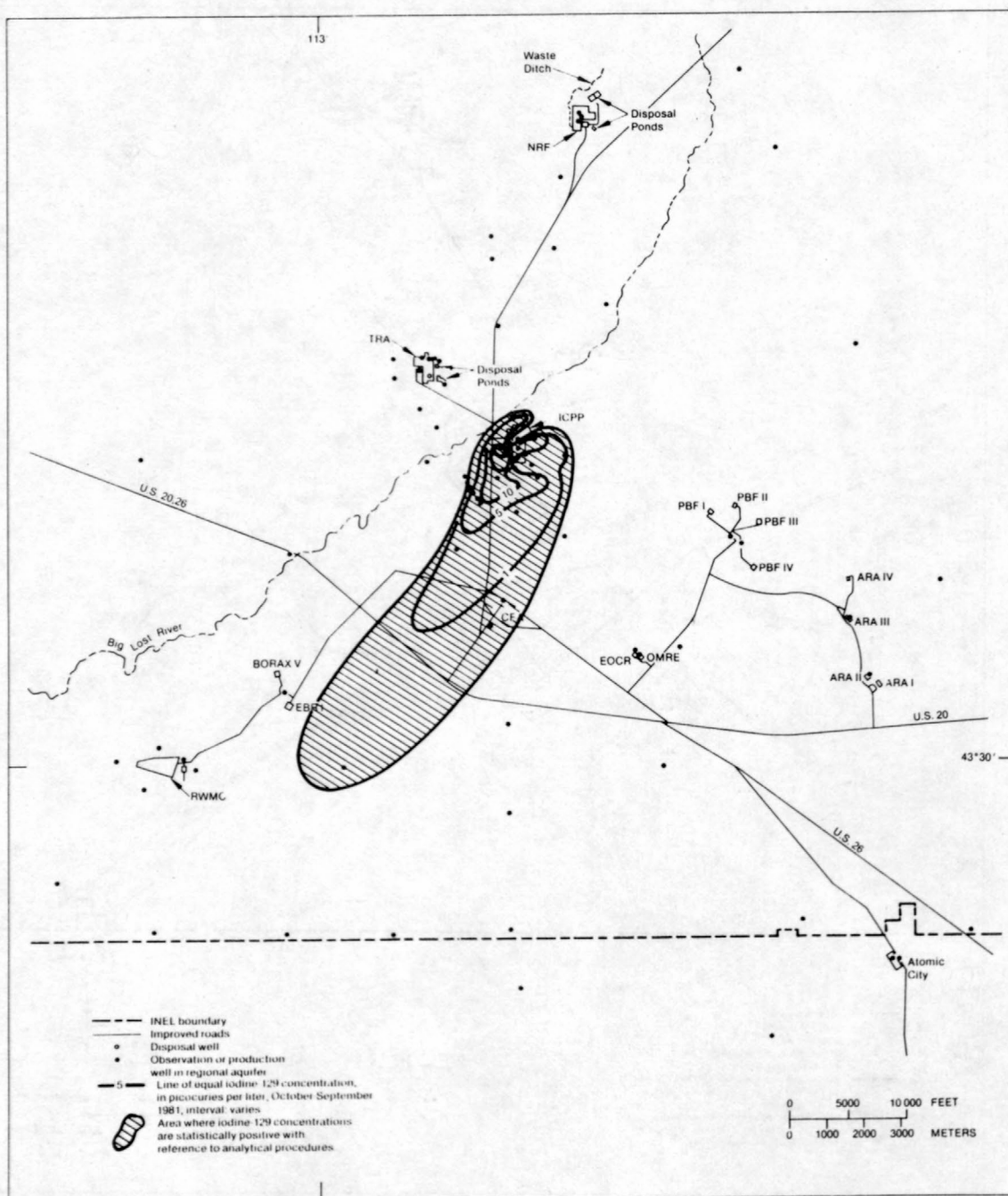


Figure 30.--Distribution of iodine-129 in the Snake River Plain aquifer, southcentral INEL vicinity, October 1981.

liters during the 1981 program. The sample size was increased to four liters to increase the sensitivity of the analyses four-fold. Also, during the past three or four years, the analytical procedures employed in determining the iodine-129 concentrations in water samples have been refined and are much more sensitive. The ultimate result is that much lower concentrations of iodine-129 are detectable than was possible in the past, and the increased size of the waste plume is primarily due to this increased sensitivity.

Generally, iodine-129 concentrations shown inside comparable parts of the two plumes have varied very little. Notable exceptions are analyses of samples from wells nearest the disposal well. The October 1981 plume (fig. 30) shows that the iodine-129 concentrations in samples from several of these "easily" waste-affected wells are much lower than those shown by Barraclough, Lewis, and Jensen (1981) for April 1977. This unexpected occurrence is not presently understood but may, in part, be due to sampling that followed several months of little or no iodine-129 disposal. Subsequent sampling programs should help to explain this situation.

Cesium-137

About 22 Ci of cesium-137 (similar to the quantity of strontium-90) has been discharged to the ICPP disposal well since disposal began. However, it is sorbed more readily than strontium-90 and is detectable in only a few wells in the immediate area of the ICPP disposal well. Well 40 contains water with the highest concentration of cesium-137, about 170 pCi/L for October 1981; and wells 43, 44, and 47 (see fig. 27 for well locations) contain water with considerably smaller concentrations--most on an order of magnitude lower than that in well 40. Therefore, after 30 years of disposal, detectable quantities of cesium-137 have migrated a maximum of about 1,800 feet from the ICPP disposal well. Cesium-137 has not been detected in any water samples from the regional aquifer near the TRA.

Plutonium Isotopes

Monitoring of plutonium-238 and of plutonium-239,-240 (undivided) radionuclides being disposed through the ICPP disposal well began in 1974. Prior to that time, they were not separable in the undifferentiated alpha activity which was measured. From 1974 through 1981, a total of about 0.13 Ci of plutonium-238 and 0.05 Ci of plutonium-239,-240 was discharged through the well. This represents a respective average discharge of 0.016 Ci per year and 0.006 Ci per year. Plutonium was disposed in waste water which contained an average concentration of 0.012 pCi/mL of plutonium-238 and 0.005 pCi/mL of plutonium-239,-240. The decay rates of plutonium-238, plutonium-239, and plutonium-240 are 89 years, 24,360 years, and 6,600 years, respectively. This indicates that very small but detectable amounts of plutonium-239,-240 may remain in part of the regional aquifer for years to come regardless of future disposal practices.

Three consecutive monthly samples were taken from ground water in well 47 (fig. 27), located 740 feet south of the ICPP disposal well, from October through December of 1975 to evaluate the effects on the Snake River Plain aquifer of the disposal of wastes containing isotopes of plutonium. Several other wells were sampled, but well 47 was the only one which contained statistically positive concentrations of the plutonium isotopes. Analysis of these samples determined that the concentration of the plutonium isotopes in the regional ground water is very low. The mean concentration of plutonium-238 in the three samples from well 47 was 6.5×10^{-6} pCi/mL, and the mean value for plutonium-239, -240 was 2.4×10^{-6} pCi/mL. These concentrations are approximately one to two million times lower than the Federal and State of Idaho concentration guides for unrestricted discharge (Polzer, Percival, and Barraclough, 1976). The concentrations of plutonium-238 and plutonium-239, -240 in the observation well samples are also several orders of magnitude lower than those for the same nuclides in the waste water being discharged through the disposal well. This concentration reduction over a relatively short distance is an indication of dilution, dispersion, and more importantly, retardation of the soluble radioisotopes by sorption. Samples from well 47 were also analyzed for americium-241, but it was not detected. This is not an unexpected result because americium-241 has not been detected in water discharged through the ICPP disposal well.

During the summer of 1980, another study was made which determined the possibility of detectable amounts of the plutonium isotopes in wells 37, 40, 43, and 67 (see fig. 27 for well locations). This study determined that the plutonium concentrations in all well waters were very low, being statistically above the detection limit of 10×10^{-6} pCi/mL only in water from well 40 (Cleveland and Rees, 1982) and, in this well, only the plutonium-238 isotope was detected. Three consecutive samples of well 40 water contained an average concentration of about 66×10^{-6} pCi/mL of plutonium-238. When compared to the previous three-month discharge rate of the radioisotope through the discharge well of about $1,037 \times 10^{-6}$ pCi/mL, the plutonium-238 concentration between the disposal well and well 40, located about 700 feet downgradient, is reduced by a factor of approximately sixteen (Cleveland and Rees, 1982). Therefore, this study also illustrates the effects of dilution, dispersion, and sorption on the soluble radioisotope over a short lateral distance.

Detectable quantities of certain plutonium isotopes were also present in water samples taken from well 90 near the RWMC (see fig. 27), but measurements thus far have been inconsistent. For example, samples collected during April 1981 contained detectable amounts of americium-241 and plutonium-238 that were determined to be about 2.0×10^{-4} and 1.1×10^{-4} pCi/mL, respectively; but an October 1981 sample contained only a detectable quantity of americium-241, which was measured at about 1.4×10^{-4} pCi/mL. Three quarterly samples prior to 1981 did not contain statistically positive amounts of any plutonium isotope. The source of the plutonium isotopes occasionally present in water from well 90 has not yet been determined, but may be due to downward migration of waste from the Radioactive Waste Management Complex (RWMC) or to introduction into the sample during the collection and analytical procedures.

Specific Conductance

Chemical wastes are also discharged to the ICPP disposal well. From 1979 through 1981, these wastes contained, on an annual average, about 397,000 lbs of sodium, 875,000 lbs of chloride, 140,000 lbs of sulfate, and 288,000 lbs of nitrate. The waste ditch and waste-disposal ponds at the NRF are also used to discharge chemical wastes. From 1979 through 1981, the NRF wastes contained an annual average of about 168,000 lbs of sodium, 228,000 lbs of chloride, 366,000 lbs of sulfate, and 4,000 lbs of phosphate. These chemical wastes increase the mineral content and, therefore, the specific conductance of the regional ground water. The specific conductance of ground water in the Snake River Plain aquifer containing no waste water generally ranges from 300 to 325 $\mu\text{mho/cm}$ (at 25°C) in the ICPP-TRA area (Robertson, Schoen, and Barraclough, 1974).

Waste water disposed through the ICPP disposal well, seepage from the TRA chemical-waste disposal ponds, and seepage from the NRF waste ditch and waste-disposal ponds have increased the specific conductance of the regional ground water significantly (fig. 31). The specific conductance plume extends south of CFA in this southern part and is similar to a plume for October 1980 shown by Lewis and Goldstein (1982). The October 1981 plume (fig. 31), however, includes a much greater area to the north of the TRA and ICPP that is a direct result of chemical-waste disposal during the past several years at the NRF and lack of recharge dilution.

During the past three years, water samples taken from the observation and production wells located between the NRF and TRA-ICPP vicinity have shown increasingly greater specific conductance values. It appears that this part of the regional aquifer is also affected by waste migration from disposal points and, therefore, must be included in the October 1981 plume (fig. 31). This restructuring of the plume with high specific conductance values has increased the affected area of the Snake River Plain aquifer to nearly 27.6 mi^2 .

Two wells penetrating the regional aquifer immediately downgradient from the RWMC also exhibit slightly higher-than-background specific conductance values. Wells 88 and 89 contain water with specific conductances of 380 and 350 $\mu\text{mho/cm}$, respectively. The cause for this anomaly is not presently known, but may result from naturally high specific conductance values that reflect normal aquifer conditions and are not affected by waste disposal. Robertson, Schoen, and Barraclough (1974) noted, however, that the dissolved solids (mineral content) of the ground water under the RWMC area, prior to INEL operations, was actually lower than the aquifer's average value. Another possibility is that part of the waste material stored at the ground surface of the RWMC has become mobilized, has been transported through the unsaturated zone, and has reached the underlying aquifer. Barraclough, Robertson, and Janzer (1976) discussed the migration of radioactive waste to the aquifer in the RWMC area and indicated that under normal climatological conditions, little migration would take place; during a significant hydrologic event, such as flooding, however, a mobilizing agent would be available and migration could take place.

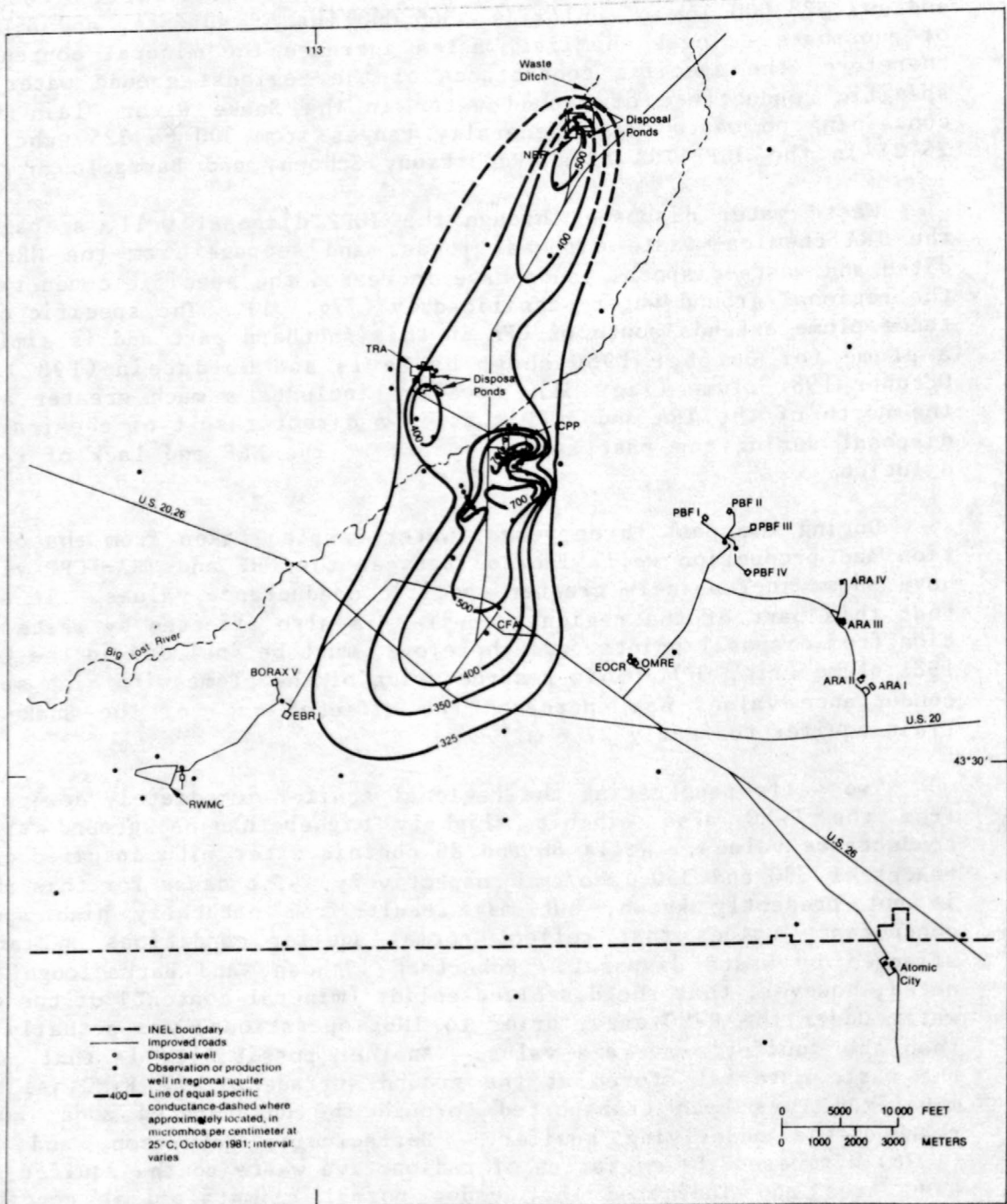


Figure 31.--Specific conductance of water samples from the Snake River Plain aquifer, southcentral INEL vicinity, October 1981.

A final possibility is that the analyzed water sample is not representative of aquifer conditions. The sampled wells in question are pumped at a low rate of about 2 gpm. During completion of the wells, pressure-cementing techniques were used to preclude the possibility of contaminants entering the sampled well water from other-than-aquifer sources. The chemical makeup of cement used could be affecting the specific conductance values of water samples collected from these wells. Subsequent sampling of these wells by an increased pumping rate to ensure a proper and reliable connection with the aquifer will determine whether or not any of these causes are verifiable.

Sodium

The rate of discharge of sodium to the ICPP disposal well has been rather uniform over the years. The average concentration of sodium in the waste water is about 103 mg/L. The background or normal concentration of sodium in water from the Snake River Plain aquifer is from 8 to 10 mg/L. Figure 32 shows the concentration of sodium in well water and the area covered by the ICPP waste plume in October 1981. Average concentrations are similar to those published for September 1977 by Barraclough, Lewis, and Jensen, (1981), but the overall size of the waste plume has decreased slightly since that time. This may in part be due to the fact that the average concentration of sodium in effluent waste water of 88 mg/L from 1974 through 1976 is 14 percent lower than the average concentration (102 mg/L) over the entire period of record. The present configuration of the waste plume's outer boundary may be affected by this low disposal concentration, but the interior contours in the plume have increased and have migrated downgradient. This relationship is likely due to an increased disposal concentration over the past few years; for example, the 1979 through 1981 average annual disposal concentration was about 112 mg/L, and the part of the plume closest to the disposal well will exhibit more readily the influence of more recent disposal practices.

The effects of sorption, ion exchange, or other chemical reactions on the migration of sodium are shown by figure 32. As noted earlier, a large amount of sodium is discharged to the chemical-waste disposal ponds at the TRA, and the waste ditch at the NRF was used during the subject three-year period which resulted in an average disposal concentration of about 176 mg/L. However, as waste water migrates downward towards the Snake River Plain aquifer from the TRA and NRF disposal areas, most of the sodium is apparently removed by the above mentioned chemical reactions. Therefore, an aquifer area affected by disposal at these facilities is very difficult to depict (fig. 32).

The regional ground water directly underlying and immediately downgradient from the RWMC again contains higher-than-background concentrations of sodium. The possible causes for the anomaly may be the same as those listed in the previous section on specific conductance (fig. 31). In the case of sodium, however, the affected aquifer area is somewhat larger. The work done by Robertson, Schoen, and Barraclough (1974) showed that the RWMC is located near two areas that exhibited anomalously high sodium concentrations prior to waste-disposal practices

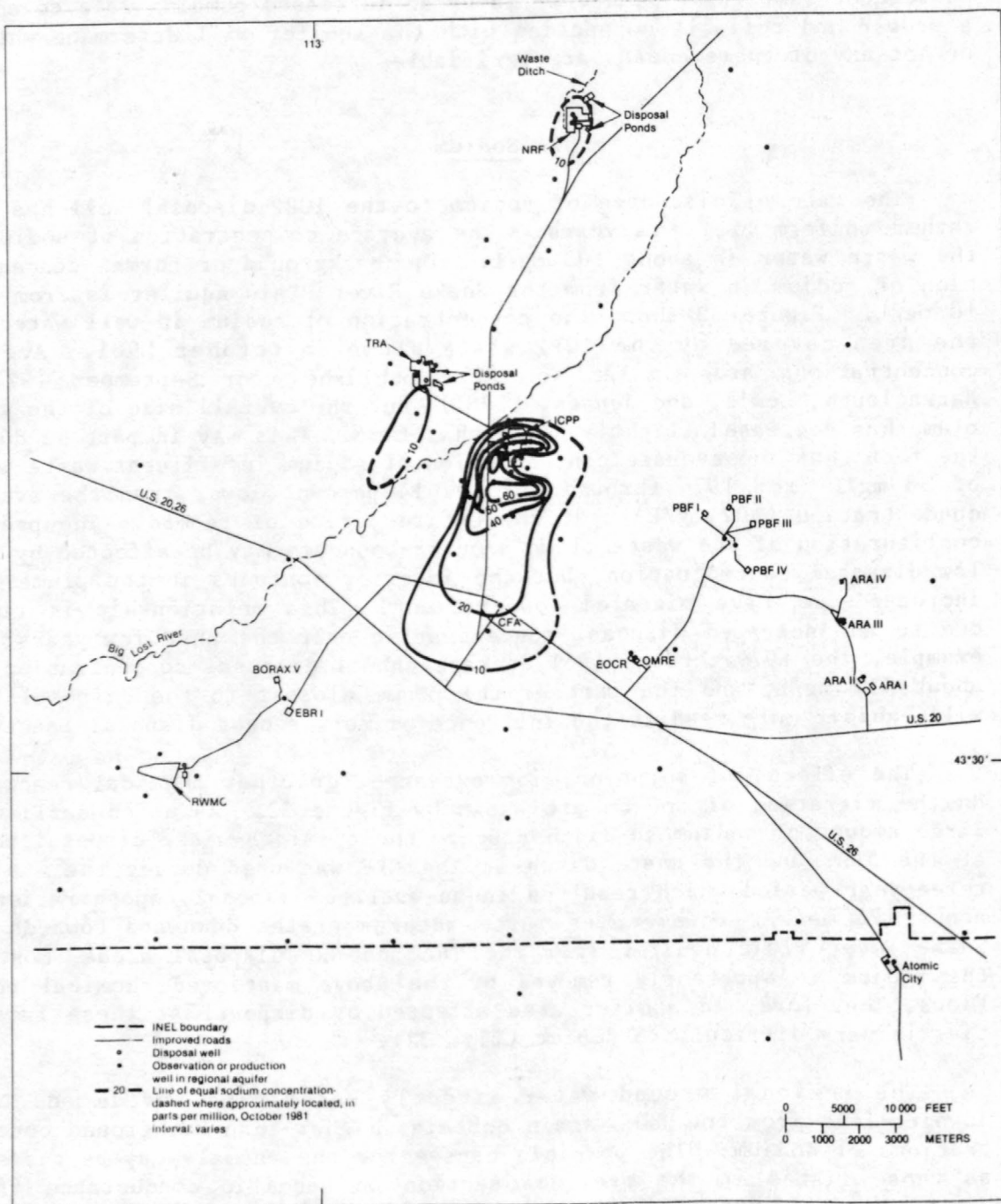


Figure 32.--Distribution of waste sodium in the Snake River Plain aquifer, southcentral INEL vicinity, October 1981.

at the INEL. Coupled with the possibility of not obtaining a representative sample by the thief-sampling method, pumping at low rates, and minor contributions from other artificial sources, a more comprehensive data base may have better delineated a naturally anomalous distribution of sodium in the underlying regional aquifer.

Total Chromium

As stated previously, chromium was discharged directly to the Snake River Plain aquifer via the TRA deep disposal well from 1964 to 1972. Since 1972, a different corrosion inhibiting process has been employed which utilizes no chromium compound. Chromium has also been discharged to the TRA radioactive waste ponds in the past and is present in the underlying perched ground water in the basalt. The total chromium content of the regional ground water was augmented by the direct disposal of waste water prior to 1972 and by percolation from the overlying perched zone. Well 65, located approximately 1,500 feet south of the TRA facility (fig. 27), is the only well which taps the regional aquifer that contained water with statistically positive total chromium concentrations for the period 1979 through 1981. Quarterly samples of water from well 65 during the latest period of record contained an average total chromium concentration of about 0.39 mg/L, and the values show little variance.

Chloride

The average concentration of waste chloride disposed through the ICPP well from 1979 through 1981 was 238 mg/L and the average concentration discharged to the NRF waste ditch was about 219 mg/L for the same three-year period. The background, or normal, concentration of chloride in the Snake River Plain aquifer in the southcentral INEL vicinity is usually between 8 and 15 mg/L. As a matter of interest, the Idaho Drinking Water Standards (1977) set the secondary quality standard for chloride concentration of drinking water at 250 mg/L. This concentration limit is based primarily on taste.

Figure 33 shows the distribution of waste chloride in the Snake River Plain aquifer in October 1981. The highest chloride values are found around the ICPP disposal well and south of the ICPP, with slightly higher-than-background concentrations being present near and immediately downgradient from the NRF and RWMC facilities. The chloride concentrations in water taken from wells near and south of the ICPP are similar to those depicted for September 1977 by Barraclough, Lewis, and Jensen (1981). Chloride concentrations in well water nearest the disposal well have, however, increased since that time and are probably due to an increasing amount of chloride disposed during the past several years. For example, from 1971 through 1973, an average of 386,000 lbs of chloride per year was discharged (Barraclough and Jensen, 1976); whereas, during the period 1974 through 1978, the average yearly discharge was 548,000 lbs (Barraclough, Lewis, and Jensen, 1981); and during the period 1979 through 1981, the average yearly discharge again increased to 875,000 lbs. This part of the October 1981 waste chloride plume is also similar to the figure depicted for October 1980 by Lewis and Goldstein

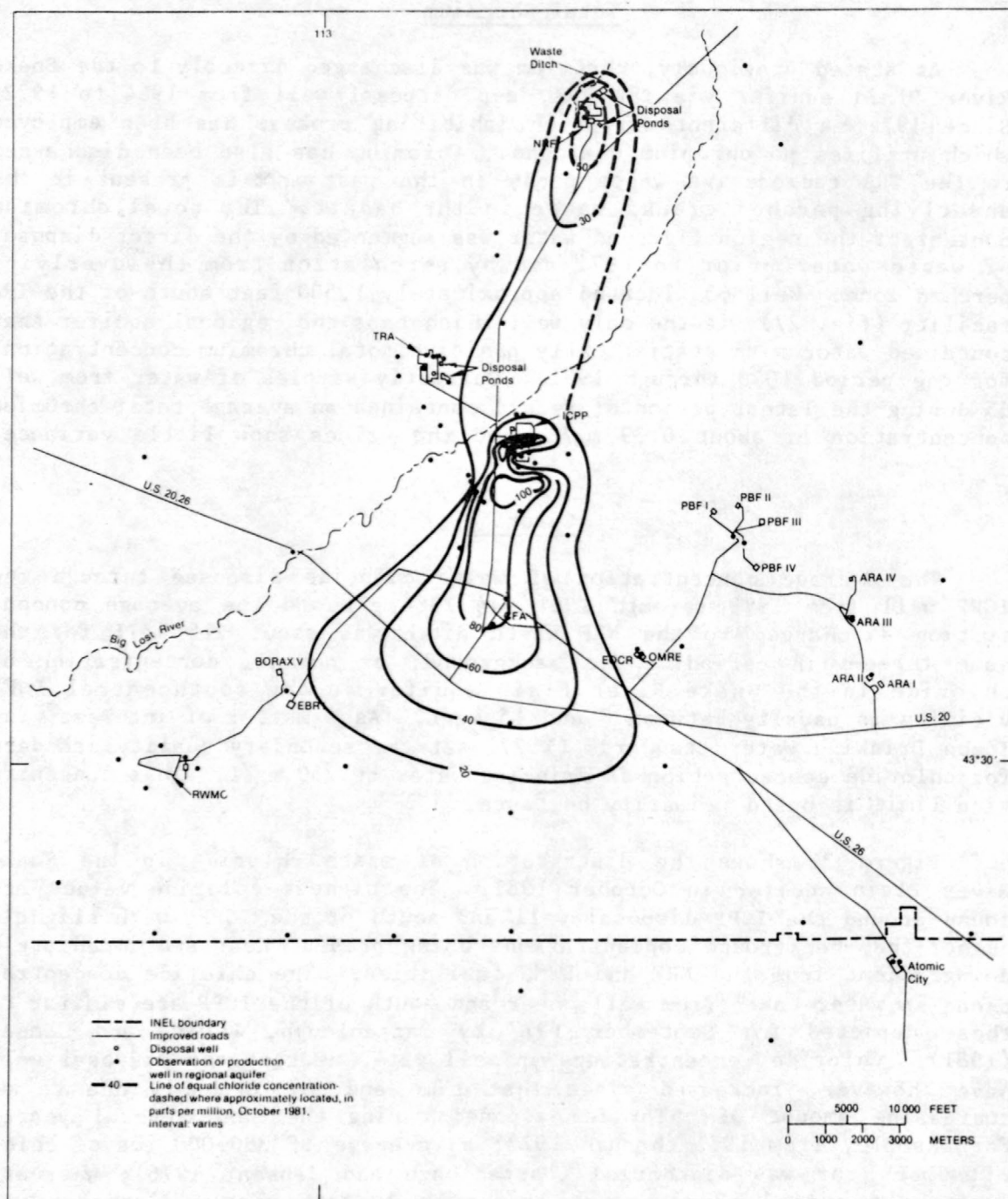


Figure 33.--Distribution of waste chloride in the Snake River Plain aquifer, southcentral INEL vicinity, October 1981.

(1982), but the concentration contours nearest the ICPP disposal well have migrated downgradient and include more area in the later figure. This also illustrates the effects of higher disposal amounts through the ICPP well.

The chloride disposed of at the NRF has increased the chloride concentration of the regional ground water to a point where the area between the NRF and ICPP must now be included with the plume created by disposal at the ICPP (fig. 33). The inclusion of the aquifer area affected by chloride disposal at the NRF has increased the overall size of the waste plume to about 26.2 mi². The plume may become two separate entities, a small one near the NRF and another larger one near and south of the ICPP, in the future because chloride disposal at the NRF has decreased significantly for each of the past few years. Recharge from the Big Lost River, which has been non-existent for the past several years, could dilute the chloride concentration in that part of the aquifer being recharged as it is located directly under the river and between the two facilities (fig. 33).

The aquifer area underlying and immediately downgradient from the RWMC also appears to contain waste chloride--which may be the result of the same three circumstances as listed in the specific conductance section. Wells 87, 88, and 89 contain water with chloride concentrations of 26, 66, and 44 mg/L, respectively. Chloride concentrations, as were noted for sodium concentrations, may be anomalously high background levels and not reflect artificial sources. The RWMC is situated over a part of the aquifer that lies between two anomalous aquifer areas which contained very high natural chloride concentrations (Robertson, Schoen, and Barraclough, 1974) and, with more comprehensive well coverage, could have been denoted as an area of similar nature. Well completion pressure cementing practices, may also influence the chloride concentration in sampled water. Proper well development, by pumping, would determine the viability of this latter supposition.

Sulfate

The average concentration of sulfate in the waste water disposed through the ICPP well from 1979 through 1981 was about 39 mg/L and amounted to a yearly average of about 140,000 lbs. At the TRA deep disposal well, the yearly average concentration of the sulfate disposed was 218 mg/L for the entire three-year period, which amounted to a yearly average of about 492,000 lbs. At the NRF, an annual average sulfate concentration of 358 mg/L was discharged to the waste ditch and amounted to about 366,000 lbs per year. The background concentration of sulfate in the Snake River Plain aquifer is less than about 20 to 30 mg/L in the southcentral INEL vicinity. A sulfate waste plume was not mapped because the only water samples above the normal level are adjacent to and immediately south of the ICPP disposal well and south of the TRA deep disposal well (see fig. 27). The area south of the TRA is the largest area affected, with a measured value slightly above normal being recorded 1.3 miles from the facility. This small plume is a result of waste sulfate disposed through the deep well and of recharge from the overlying perched

aquifer in the basalt. Apparently, the large amount and high concentration of sulfate discharge to the NRF waste ditch is negated by sorption and other chemical reactions as the waste water percolates through the unsaturated zone toward the regional aquifer because sampled wells downgradient from the NRF contain no sulfate concentrations significantly above background levels.

Nitrate

Waste water containing nitrate has been disposed through the ICPP well since 1952, but 1973 was the first year in which the concentration in waste water was reported. During that year, the average waste nitrate concentration entering the Snake River Plain aquifer was 39 mg/L (calculated as NO_3^-), and over the next five years this average increased slightly to 40 mg/L, but it increased to 47 mg/L in 1977 and to 80 mg/L during 1978 (Barracough, Lewis, and Jensen, 1981). The higher discharge rate was sustained over the next three years, 1979 through 1981, at an annual average of about 83 mg/L. This latter discharge rate amounts to about 288,000 lbs of nitrate disposal per year through the ICPP well. The normal or background level of nitrate in the regional ground water is generally less than 5 mg/L (Robertson, Schoen, and Barracough, 1974).

The first recent comprehensive sampling of the observation wells in the regional aquifer for nitrate analyses was completed in January 1979 (Barracough, Lewis, and Jensen, 1981) and indicated that a large nitrate waste plume existed. The January 1979 waste plume covered an area of about 8.7 mi^2 and was elongated to the south of the ICPP disposal well (Barracough, Lewis, and Jensen, 1981). A second recent comprehensive sampling program for nitrate analyses was conducted between October and December of 1981. Figure 34 shows the plume revealed by this sampling program and subsequent nitrate analyses. The 1981 plume is similar in shape and in interior nitrate concentrations to the January 1979 depiction shown by Barracough, Lewis, and Jensen (1981); however, the nitrate plume size has increased to 10.1 mi^2 over the past three years, and the nitrate concentrations in the sampled water from wells nearer the ICPP disposal well have generally increased over the same time period. The expanded plume size and concentration increases are results of the sustained higher nitrate disposal rate.

A notable difference in the figures is the abatement of nitrate concentrations in samples from wells south of the TRA. A small part of the aquifer near the RWMC also contains higher-than-background nitrate concentrations. Well 89 contains water with a nitrate concentration of 7.1 mg/L. No nitrate disposal to the TRA disposal ponds or through the facilities' deep disposal well was recorded during 1979 through 1981. Apparently, recharge received from the overlying perched aquifer was not sufficient to sustain the small waste plume present in the regional aquifer as shown by the January 1979 figure (Barracough, Lewis, and Jensen 1981); dilution, dispersion, and other chemical or physical processes have significantly reduced nitrate concentrations in this small part of the regional aquifer south of the TRA. All of the possible causes noted in the preceding sections for anomalous concentrations of other chemicals, in the aquifer near the RWMC area, could also apply here; but data are insufficient to make a reasonable analysis.

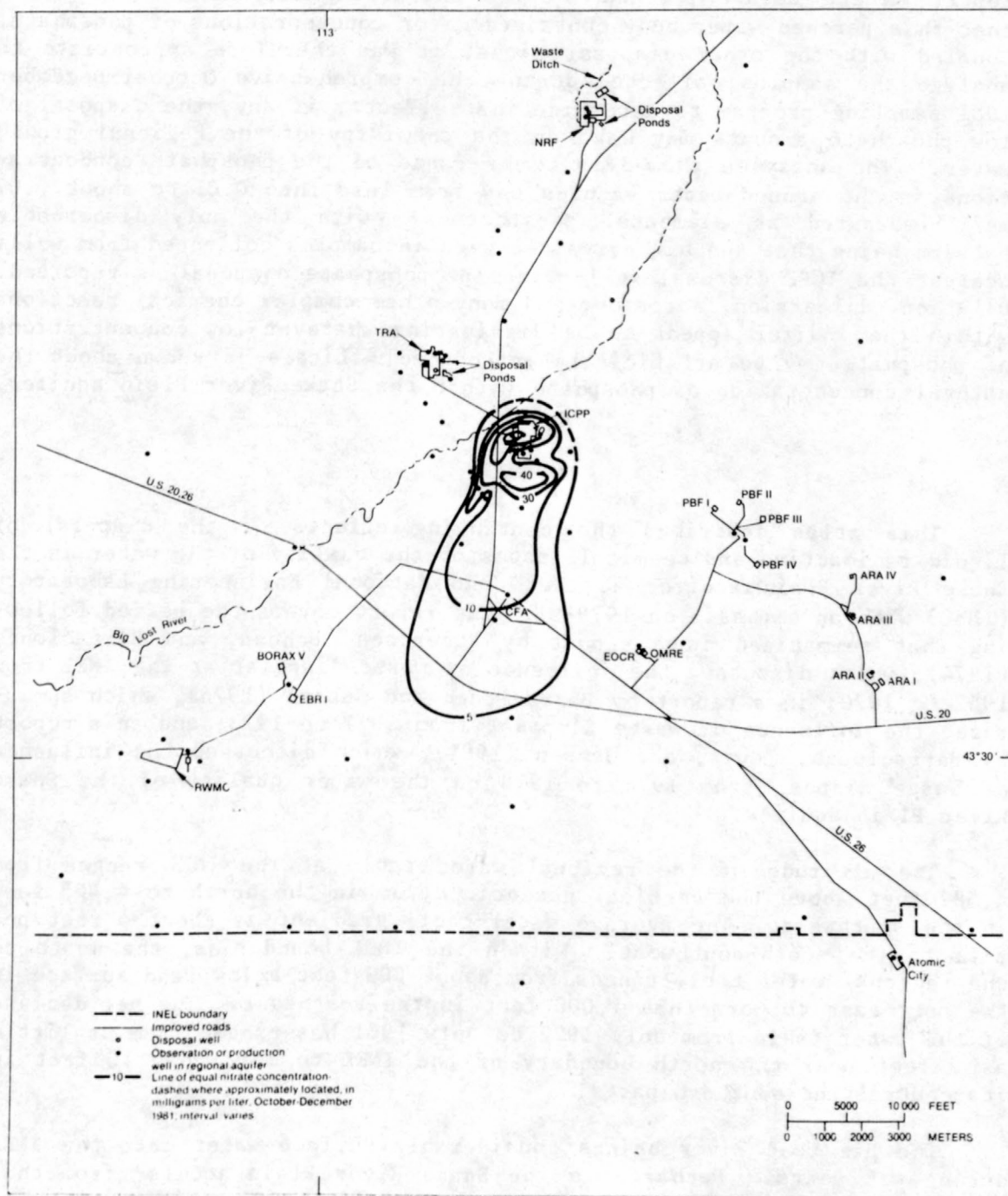


Figure 34.--Distribution of waste nitrate in the Snake River Plain aquifer, southcentral INEL vicinity, October-December 1981.

Phosphate

The average concentration of phosphate in the waste water disposed through the TRA disposal well and to the NRF waste ditch from 1979 through 1981 was 4.0 mg/L and 1.3 mg/L (concentrations measured as elemental phosphorous), respectively. In an earlier section of this report on the basalt perched aquifer underlying the TRA, it was noted that this perched water body contained minor concentrations of phosphate. Coupled with the other disposal sites, it was therefore appropriate to analyze the samples collected during the comprehensive October-December 1981 sampling program to determine what effects, if any, the disposal of low phosphate amounts may have on the chemistry of the regional ground water. The analyses showed that the range of the phosphate concentrations in the ground-water samples was from less than 0.01 to about 0.07 mg/L (measured as elemental phosphorous), with the only discernable pattern being that the higher values were in samples collected from wells nearest the ICPP disposal well--where no phosphate disposal is reported. Dilution, dispersion, sorption, and many other complex chemical reactions within the aquifer appear to be dissipating whatever low concentrations of phosphate may be artificially introduced. Little is known about the natural concentration of phosphate within the Snake River Plain aquifer.

SUMMARY

This atlas describes the continuing effects of the disposal of liquid radioactive and chemical wastes on the quality of the water in the Snake River Plain aquifer at the Idaho National Engineering Laboratory (INEL) with an emphasis on 1979-81. The report covers the period following that summarized in a report by Robertson, Schoen, and Barraclough (1974), which discussed the influence of waste disposal at the INEL from 1952 to 1970; in a report by Barraclough and Jensen (1976), which summarized the influence of waste disposal from 1971 to 1973; and in a report by Barraclough, Lewis, and Jensen (1981), which discussed the influence of waste disposal from 1974 to 1978 on the water quality of the Snake River Plain aquifer.

The altitude of the regional water table at the INEL ranges from 4,582 feet above the vertical geodetic datum in the north to 4,423 feet in the southwest. The average water-table gradient is about 4 feet per mile to the south-southwest. Within the INEL boundaries, the depth to the regional water table ranges from about 200 feet below land surface in the northeast to more than 1,000 feet in the southeast. The net decline of the water table from July 1972 to July 1981 has ranged from as little as 2 feet near the north boundary of the INEL to more than 10 feet in its central and southern parts.

The Big Lost River brings considerable surface water onto the INEL during wet years. Recharge to the Snake River Plain aquifer from this flow has been significant. The average flow of the Big Lost River below Mackay Reservoir has been about 215,000 acre-feet yearly for the 64 years of recorded discharge. In 1979 the discharge was a below average 202,400

acre-feet; in 1980 the discharge rose to an above-average 249,500 acre-feet; and in 1981 the discharge fell slightly to 240,100 acre-feet. However, little or no flow was recorded at gaging stations on the INEL since 1977.

Recharge from the Big Lost River and other streams, to the north of the INEL, caused the water table in the aquifer to rise to record highs in 1972 over much of the INEL. The water level in one well rose 21.5 feet from 1964 to 1972. This is the largest fluctuation in water level in the Snake River Plain aquifer that has been observed at the INEL. Water levels have declined in many of the observation wells which penetrate the regional aquifer from the record high levels of 1972 to record lows by the end of 1981.

Twenty-five INEL production wells pumped 2.4 billion gallons of water per year from 1979 to 1981, an average of 6.6 million gallons per day. About 60 percent of this pumpage was returned to the aquifer.

The Test Reactor Area (TRA) utilized ponds and a deep well to dispose of about 354 million gallons of dilute waste water per year from 1979 through 1981. Infiltration from the radioactive-waste ponds has formed a large perched-water zone in the underlying basalt. The perched ground-water contains tritium, chromium-51, cobalt-60, strontium-90, and several non-radioactive chemicals. The lateral extent of the perched water body has decreased over the past few years due to decreases in the amount of waste water discharged to the various ponds. The concentrations of the radionuclides in the perched ground water have generally decreased during 1979 through 1981 also due to a reduction in their rates of disposal to the ponds. A notable exception is the tritium concentration which has increased significantly. This increase may be due in part to a slight increase in the overall yearly discharge rate to the ponds but may primarily be due to recharge water being restricted to and contained by a small perched water body.

The Idaho Chemical Processing Plant (ICPP) discharges low-level radioactive waste and chemical waste directly to the Snake River Plain aquifer through a disposal well 600 feet deep. During 1979 to 1981, the well was used to dispose of 697 Ci of radioactivity of which 689 Ci was as tritium (99 percent). The average yearly discharge was about 440 million gallons of waste water.

The Naval Reactors Facility (NRF) utilizes a waste ditch to discharge about 125 million gallons of dilute waste water annually. During 1979 through 1981, the waste ditch was used to dispose of about 168,000 lbs of sodium, 217,000 lbs of chloride, and 366,000 lbs of sulfate annually. The amount of waste water discharged yearly and the amounts of chemicals therein have decreased significantly over the past three years.

Radionuclides are subject to radioactive decay, sorption, and dilution by dispersion in the regional aquifer. Chemical wastes are subject to sorption and dilution by dispersion. Waste plumes in the southcentral INEL vicinity containing tritium, iodine-129, sodium,

chloride, and nitrate have been mapped, and all have similar configurations. The plumes generally follow southerly flow lines and are laterally dispersed in that part of the aquifer underlying the INEL.

Tritium is distributed in the Snake River Plain aquifer over about 42 square miles. Since disposal began in 1952, tritium has migrated as much as 8 miles downgradient from discharge points.

The waste plume containing strontium-90 covers a much smaller area of the regional aquifer, about 2.1 square miles. Based on the relatively small size of the plume, it would appear that strontium-90 is sorbed from solution as it moves through the Snake River Plain aquifer. Cesium-137 has been discharged in quantities similar to those of strontium-90 but has not been detected in the perched-water zone and has been detected in only a few wells which tap the Snake River Plain aquifer and are located very near the ICPP disposal well. Following 30 years of disposal, detectable quantities of cesium-137 are measurable no farther than about 1,800 feet from the disposal well. Cesium-137 is strongly sorbed to the minerals in the alluvial sediments, basalt, and clay-to-silt interbeds.

Detectable plutonium radioisotopes and total chromium concentrations have been found in three wells which penetrate the Snake River Plain aquifer. Plutonium-238 and plutonium-239,-240 were detectable in well 47 south of the ICPP but in very minute quantities, and very low concentrations of plutonium-238 were detected in well 40. Both of these wells are located very near the ICPP disposal well. The low concentrations indicate that the effects of dilution, dispersion, and sorption reactions on this soluble radioisotope are significant. Total chromium concentrations were measurable at consistent levels in well 65 south of the TRA.

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