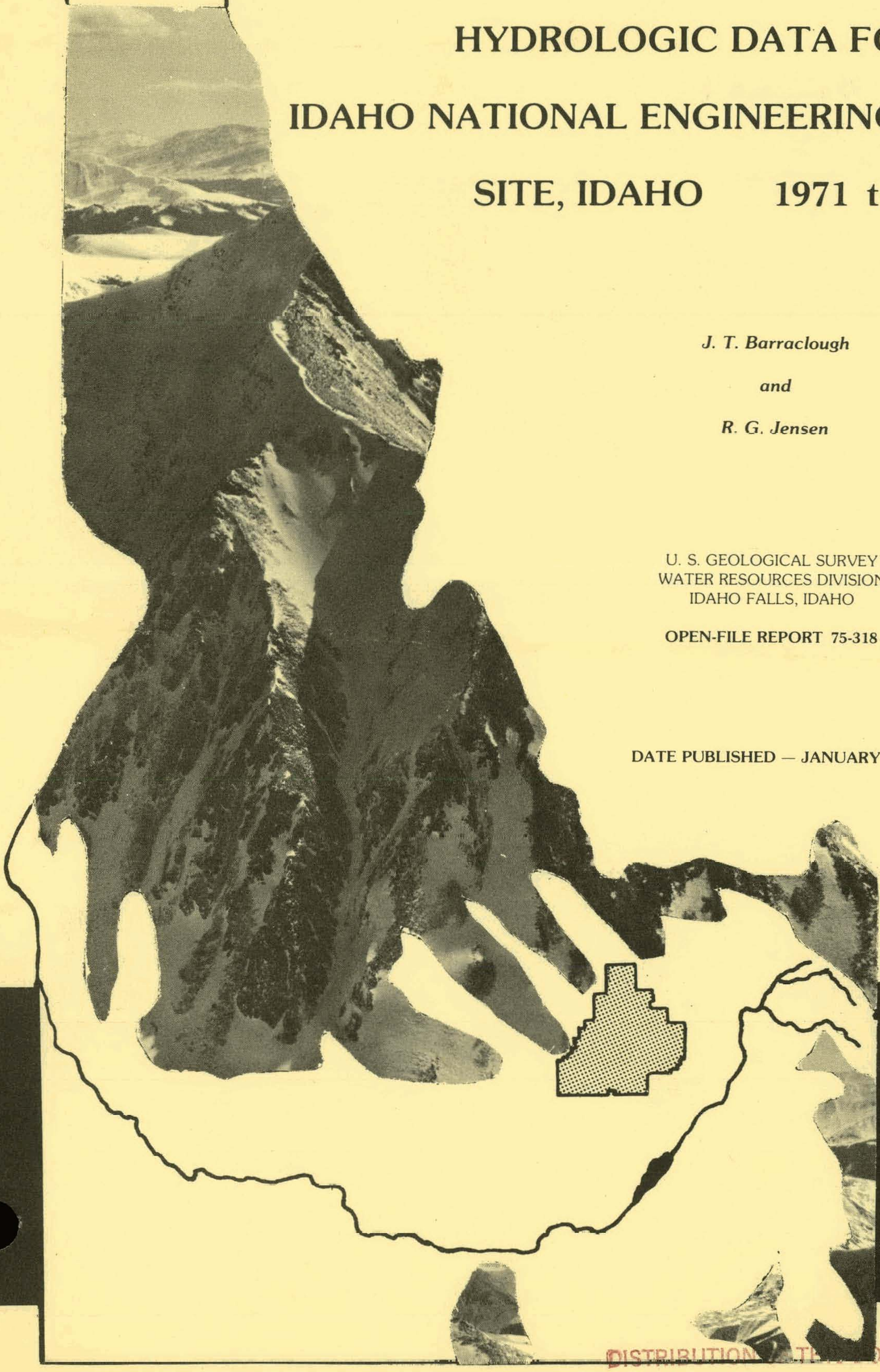
HYDROLOGIC DATA FOR THE IDAHO NATIONAL ENGINEERING LABORATORY SITE, IDAHO 1971 to 1973



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U. S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
IDAHO FALLS, IDAHO

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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SUMMARY

This report describes the influence of liquid radioactive and chemical waste disposal on the Snake River Plain aquifer at the Idaho National Engineering Laboratory (INEL). This report follows the period summarized by a report by Robertson, Schoen, and Barraclough (1974) which discussed the influences of waste disposal at the INEL from 1952 to 1970.

The chemical quality of the ground water in the Snake River Plain aquifer is the primary concern. Ground-water samples were collected to determine the migration and the concentration of radioactive wastes in the subsurface. In 1971 to 1973, an average of 237 water samples was collected annually, and an average of 600 chemical and radiometric determinations was made annually. An annual average of 817 water-level measurements was made in wells to determine the relations of water-level fluctuations to the movement of wastes. Water-level fluctuations within both the regional and perched water systems were monitored and mapped.

The altitude of the regional water table at the INEL ranges from about 4,584 feet (1,400 meters) above sea level in the north to about 4,419 feet (1,350 meters) near the southwest. The average water table gradient is about 5 feet per mile (1 meter per kilometer) to the south-southwest. Within the INEL boundaries, the depth below the land surface to the regional water table ranges from 200 feet (61 meters) in the northeast to 900 feet (275 meters) in the southwest. From July 1962 to July 1972, the net changes of ground-water levels ranged from zero to a 16-foot (5 meter) rise. In the northern part of the INEL, the water levels remained relatively constant, exhibiting only a slight rise.

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 from 1965 through 1973 has been the highest for the period of record. The four years with the highest annual discharge occurred in 1965, 1969, 1967, and 1971, in order of decreasing discharge. High and low discharge cycles of the Big Lost River are outlined.

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 or 1973 over much of the INEL. The water level in one well rose 21.5 feet (6.5 meters) from 1964 to 1972. This is the largest fluctuation of the water level in the Snake River Plain aquifer that has been observed at the INEL.

The 25 INEL production wells pumped an annual total of 2.5 billion gallons of water during 1971 to 1973 (9.5×10^9 liters) or an average of 7 million gallons (2.6×10^7 liters) per day. About 50% of this pumpage was returned to the aquifer.

The Test Reactor Area utilizes ponds and a deep well to dispose of about 400 million gallons (1.5×10^9 liters) of dilute wastes per year. About half of the liquid waste is discharged to a radioactive waste pond. Infiltration from the ponds has formed a large

perched-water body in the basalt. The perched ground-water body contains tritium, chromium-51, cobalt-60, and strontium-90. The extent and concentration of these radionuclides are shown on maps in the report.

The Idaho Chemical Processing Plant (ICPP) discharges low-level radioactive waste and chemical waste directly to the Snake River Plain aquifer through a 600-foot (180 meter) disposal well. Most of the radioactivity is removed by distillation and ion exchange prior to being discharged into the well. During 1971 to 1973, the well was used to dispose of 404 curies of radioactivity, of which 389 curies were tritium (96%). The average yearly discharge was about 300 million gallons (1.1 x 10^9 liters).

The distribution of waste products in the Snake River Plain aquifer covers about 15 square miles (30 square kilometers). Since disposal began in 1952, the wastes have migrated about 5 miles (8 kilometers) downgradient from discharge points.

Radionuclides are subject to radioactive decay, sorption, and dilution by dispersion in the aquifer. Chemical wastes are subject to sorption and dilution by dispersion. Waste plumes south of the ICPP containing tritium, sodium, and chloride have been mapped and all cover a similar area. The plumes follow generally southerly flow lines and are widely dispersed in the aquifer.

The waste plume of strontium-90 covers a much smaller area of the aquifer, about 1.5 square miles (4 square kilometers). Based on the relatively small size of the plume, it would appear that the strontium-90 is sorbed from solution as it moves through the Snake River Plain aquifer.

USE OF METRIC UNITS

The International System (SI) of units is being adopted for use in reports prepared by the Geological Survey. To assist readers of this report in understanding and adapting to the new system, the measurements used in the well descriptions are reported in English units and, in parentheses, International System units. Factors used to convert English units to SI units are as follows:

Multiply English units	By	To obtain SI units
inches (in)	2.54	centimeters (cm)
feet (ft)	0.3048	meters (m)
miles (mi)	1.609	kilometers (km)
acres	4,047	square meters (m^2)
square miles (mi^2)	2.590	square kilometers (km^2)
gallons (gal)	3.785	liters (l)
gallons (gal)	3.785×10^{-3}	cubic meters (m^3)
million gallons (10^6 gal)	3,785	cubic meters (m^3)
acre-feet (acre-ft)	1,233	cubic meters (m^3)
ton (short)	907.1848	kilograms (kg)

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HYDROLOGIC DATA FOR THE IDAHO NATIONAL ENGINEERING LABORATORY SITE, IDAHO 1971 to 1973

I. INTRODUCTION

The Idaho National Engineering Laboratory (INEL), formerly the National Reactor Testing Station (NRTS), was established in 1949 so that the United States Atomic Energy Commission (AEC), now the Energy Research and Development Administration (ERDA), could build, operate, and test various types of nuclear reactors. The reactors are built primarily to develop peacetime uses of atomic energy. Fifty reactors have been constructed to date.

In 1949, the AEC (now ERDA) requested the U.S. Geological Survey to investigate and describe the water resources of the INEL and adjacent areas. Information was collected which gave the geohydrologic conditions prior to any reactor operations at the station. Current investigations serve to determine natural changes in the geohydrology and also to determine changes resulting from activities at the Laboratory.

The INEL site covers 894 square miles (2,320 km^2) on the eastern Snake River Plain (Figure 1) and has an average altitude of 4,900 feet (1,500 m) above sea level. This plain is underlain by a vast body of ground water that is 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 shallow or deep wells. The pond and shallow-well wastes infiltrate into the ground, form perched bodies of water, and then percolate downward to the Snake River Plain aquifer.

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

This report covers the water level and water quality data collected by the U.S. Geological Survey during the calendar years 1971, 1972, and 1973. The report covers a period following that covered by a previous report by Robertson, Schoen, and Barraclough (1974), which summarized the influences of waste disposal from 1952 to 1970. Reports on previous Geological Survey investigations describing geologic and hydrologic studies of the area and related reports by the ERDA staff are listed in the references and may be obtained from the INEL library or from the offices of the Geological Survey at Central Facilities Area (CFA) (Figure 2).

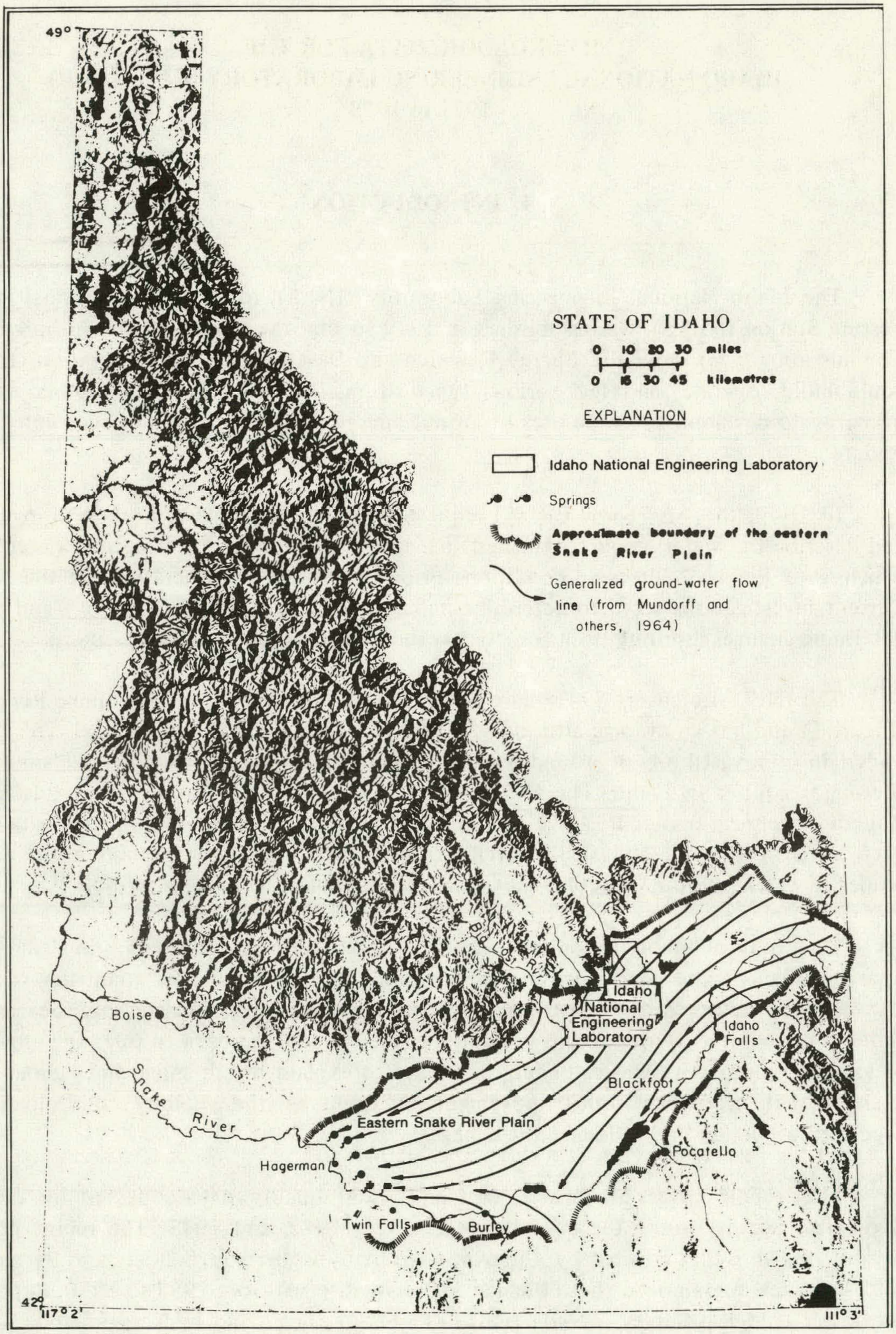
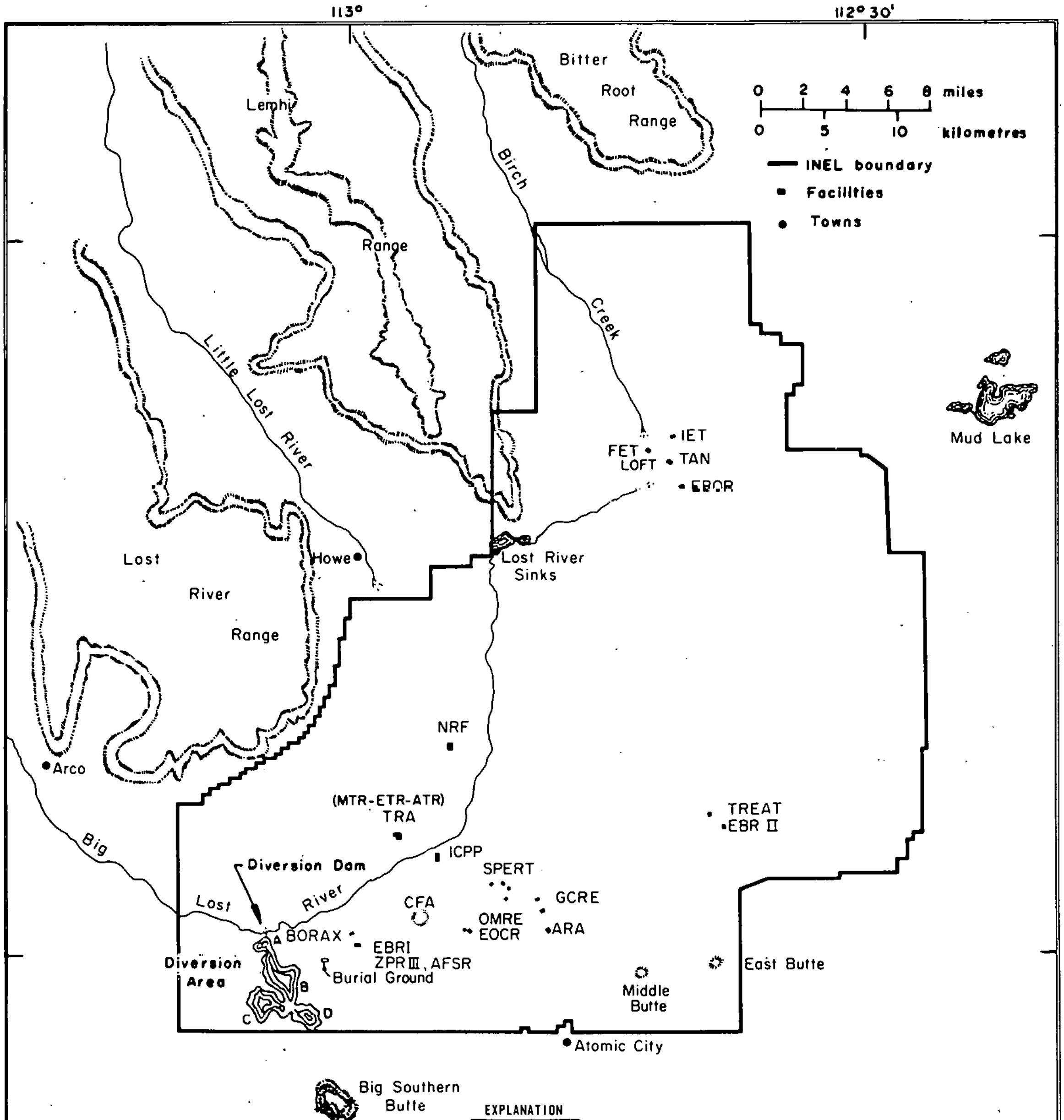


Fig. 1 Relief map of Idaho showing the location of the INEL, the Snake River Plain, and generalized ground-water flow lines of the Snake River Plain aquifer.



EXPLANATION

TABULATION OF FACILITIES AT THE IDAHO NATIONAL ENGINEERING LABORATORY

Name	Abbreviation	Name	Abbreviation
Advanced Test Reactor	ATR	Idaho Chemical Processing Plant	ICPP
Argonne Fast Source Reactor	AFSR	Initial Engineering Test Facility	IET
Army Reactor Area	ARA	Loss of Fluid Test Facility	LOFT
Boiling Water Reactor	BORAX	Materials Testing Reactor	MTR
Central Facilities Area	CFA	Naval Reactors Facility	NRF
Engineering Test Reactor	ETR	Organic Moderated Reactor Experiment	OMRE
Experimental Beryllium Oxide Reactor	EBOR	Special Power Excursion Reactor Test	SPERT
Experimental Organic Cooled Reactor	EOCR	Test Area North	TAN
Experimental Breeder Reactor No. 1	EBR-1	Test Reactor Area	TRA
Experimental Breeder Reactor No. 2	EBR-2	Transient Reactor Test Facility	TREAT
Field Engineering Test Facility	FET	Zero Power Reactor No. 3	ZPR-III
Gas Cooled Reactor Experiment	GCRE		

Fig. 2 Location of the facilities.

II. REGIONAL HYDROLOGY

1. INTRODUCTION

The eastern Snake River Plain is a large graben or downwarped structural basin 12,000 mi^2 (31,000 km^2) in area (Figure 1). It has been filled to its present level with 2,000 to 7,000 ft (600 to 2,000 m) of thin basaltic lava flows and interbedded sediments. A more detailed description of the geology is found in Robertson, Schoen, and Barraclough (1974). Nearly all of 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-ft (1,230 km^3) of water. The flow of ground water in the aquifer is principally to the south-southwest (Figure 1) at relatively high velocities (generally 5 to 25 ft/d or 1.5 to 8 m/d) [Robertson, Schoen, and Barraclough (1974)]. Transmissivity of the aquifer is high, generally ranging from 1 million to 100 million gal/d/ft (134,000 to 13,400,000 ft^2/d or 1 x 10^4 to 1 x $10^6 m^2$/d) [Robertson, Schoen, and Barraclough (1974)].

The basaltic volcanic rocks and interbedded sediments composing the aquifer are all included in the Snake River group. The "basement rocks" are probably composed of older volcanic and sedimentary rocks. The basalt is the principal aquifer. The water-bearing openings 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 complicates the direction of ground-water movement locally throughout the aquifer.

Ground-water recharge to the INEL is derived primarily as 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 Laboratory, moves south or southwestward through the aquifer, and discharges at springs along the valley of the Snake River near Hagerman (Figure 1). Lesser amounts of recharge are derived from direct precipitation on the plain. Some of the precipitation evaporates, and some percolates directly into the subsurface and downward to the regional water table.

2. COLLECTION OF RECORDS

2.1 Water Table Data

The water table observation program is operated to record the ground-water fluctuations in or near the INEL to determine the gradient changes that influence the rate and direction of 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 water body and in the perched-water bodies. In 1971 to 1973, there was an average of 9 wells in which continuous water-level recorders were operated; water levels in 33 to 40 wells were measured monthly, 2 semiannually, and 39 to 45 annually in order to study the regional water table. Two wells were equipped with water-level recorders, and water levels in 1 well were measured weekly; 13 were measured monthly; 8 were measured semiannually; and 82 were measured annually to study perched-water bodies. A total of 700 water-level measurements was made in 1971, 820 in 1972, and 932 in 1973.

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

2.2 Water Quality Data

The study of the chemical and radiometric character of ground water in the INEL area is based on analysis of water samples collected for a comprehensive sampling program. The type, frequency, and depth of sampling generally depends upon the information needed in a specific area. The program includes analyses for tritium, strontium-90, cobalt-60, chromium-51, cesium-137, chromium, specific conductance, sodium, chloride, and the standard chemical analysis (28 determinations of the more common chemical constituents per water sample).

Water samples have been collected throughout the site and in adjacent areas to define the 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 follow the migration of wastes in both the perched and the regional ground-water bodies.

The locations and the frequency of sampling of wells on or near the INEL are shown in Figures 5 and 6. Water samples for tritium analyses are collected from wells near ICPP and TRA on a quarterly and semiannual basis. Water samples for tritium and specific conductance analyses are obtained from three wells which intercept ground-water underflow near areas of recharge at the north end of the Laboratory. Nearby surface-water samples also are collected at about the same time. Water from wells near the ICPP is analyzed for tritium and strontium-90. Water from wells near the TRA is analyzed for tritium, chromium, specific conductance, and gamma radiation. During 1971 to 1973, a total of 137 samples was collected from production wells, 532 from observation wells, 41 from streams on and near the INEL, and 2 from waste effluent streams. From these samples, 1,586 analyses were made for chemical or radiometric determination. Surface-water samples were collected from the following locations: Big Lost River near Moore, Idaho; Birch Creek near Reno, Idaho; Fall River near Squirrel, Idaho; Henry's Fork below Island Park Reservoir, Idaho; Little Lost River near Howe, Idaho; Mud Lake near Terreton, Idaho; Snake River near Heise, Idaho; Snake River below Jackson Reservoir, Wyoming; and Snake River near Alpine, Wyoming. The total number and type of analyses are given in Table I.

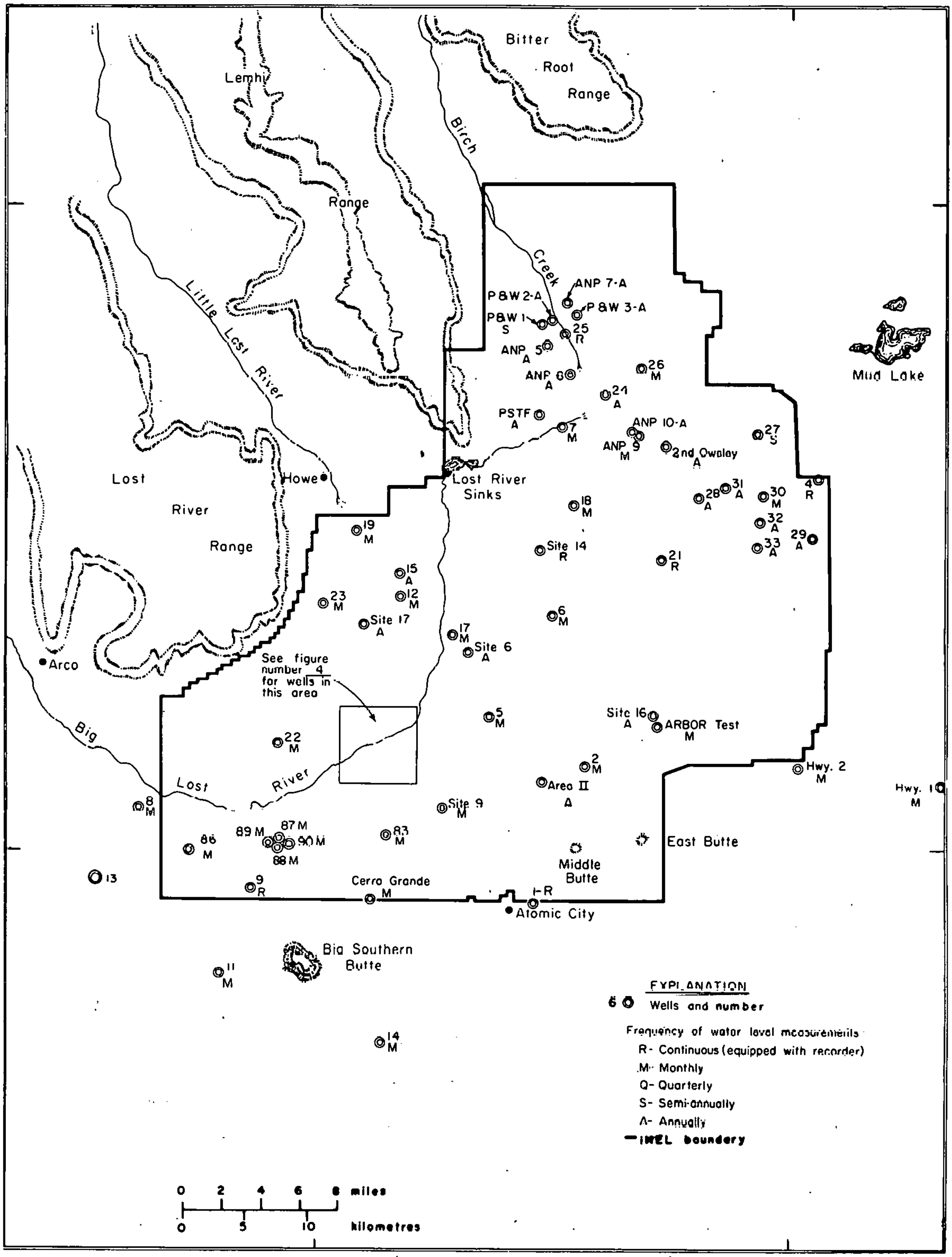


Fig. 3 Location of wells and the frequency of water-level measurements.

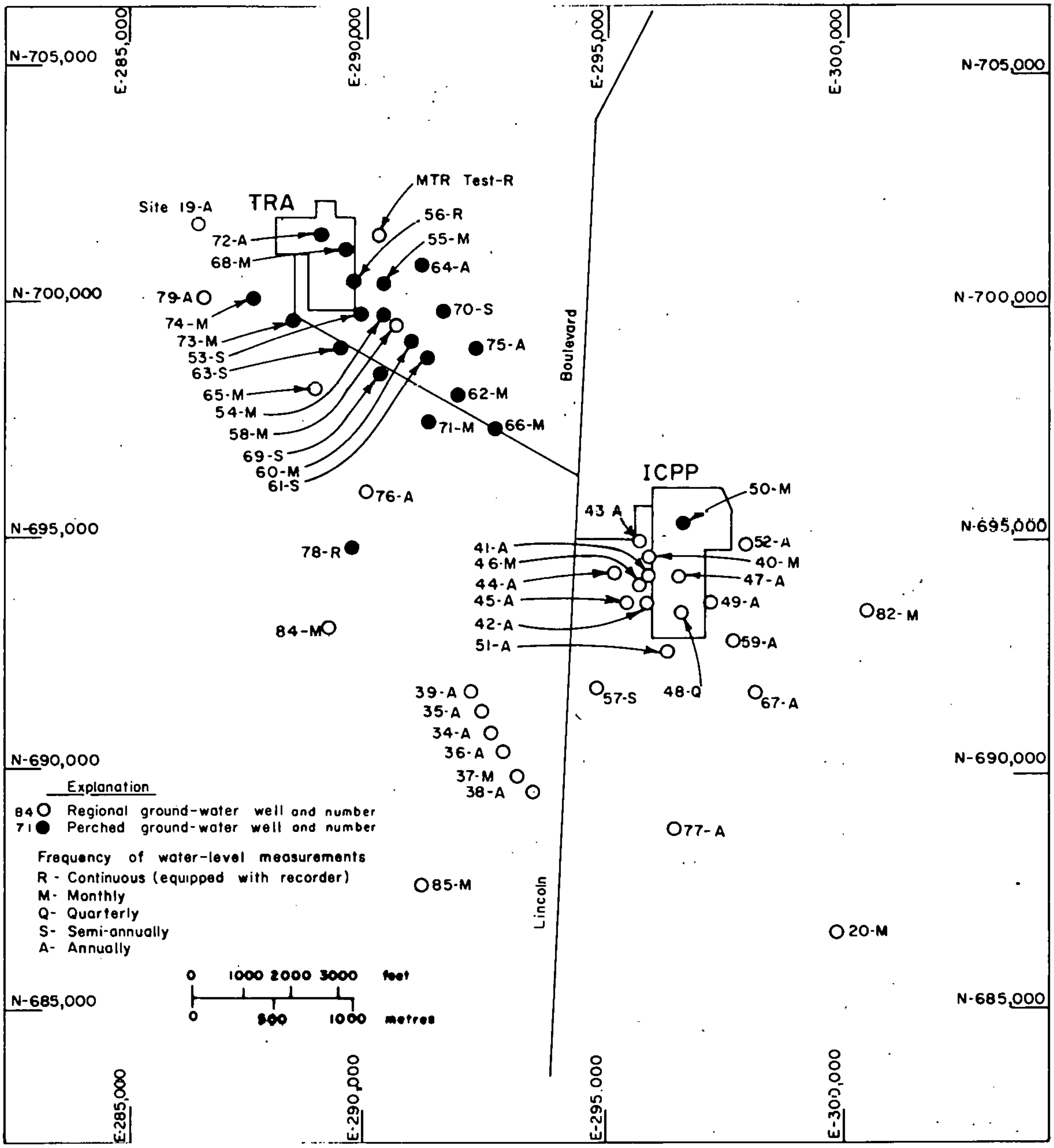


Fig. 4 Location of wells and the frequency of water-level measurements in the TRA-ICPP area.

During 1971 to 1973, a detailed study was conducted at the radioactive solid-waste burial ground. The basic data for this study are available in the files of the U.S. Geological Survey, and the interpretive report is under technical review. The following is a summary of the number of samples collected and the determinations made for that study:

(1) 17 water samples, U.S. Geological Survey laboratory, Salt Lake City, Utah, 35 determinations per sample

(2) 59 sediment samples, U.S. Geological Survey laboratory, Lakewood, Colo., 27 determinations per sample

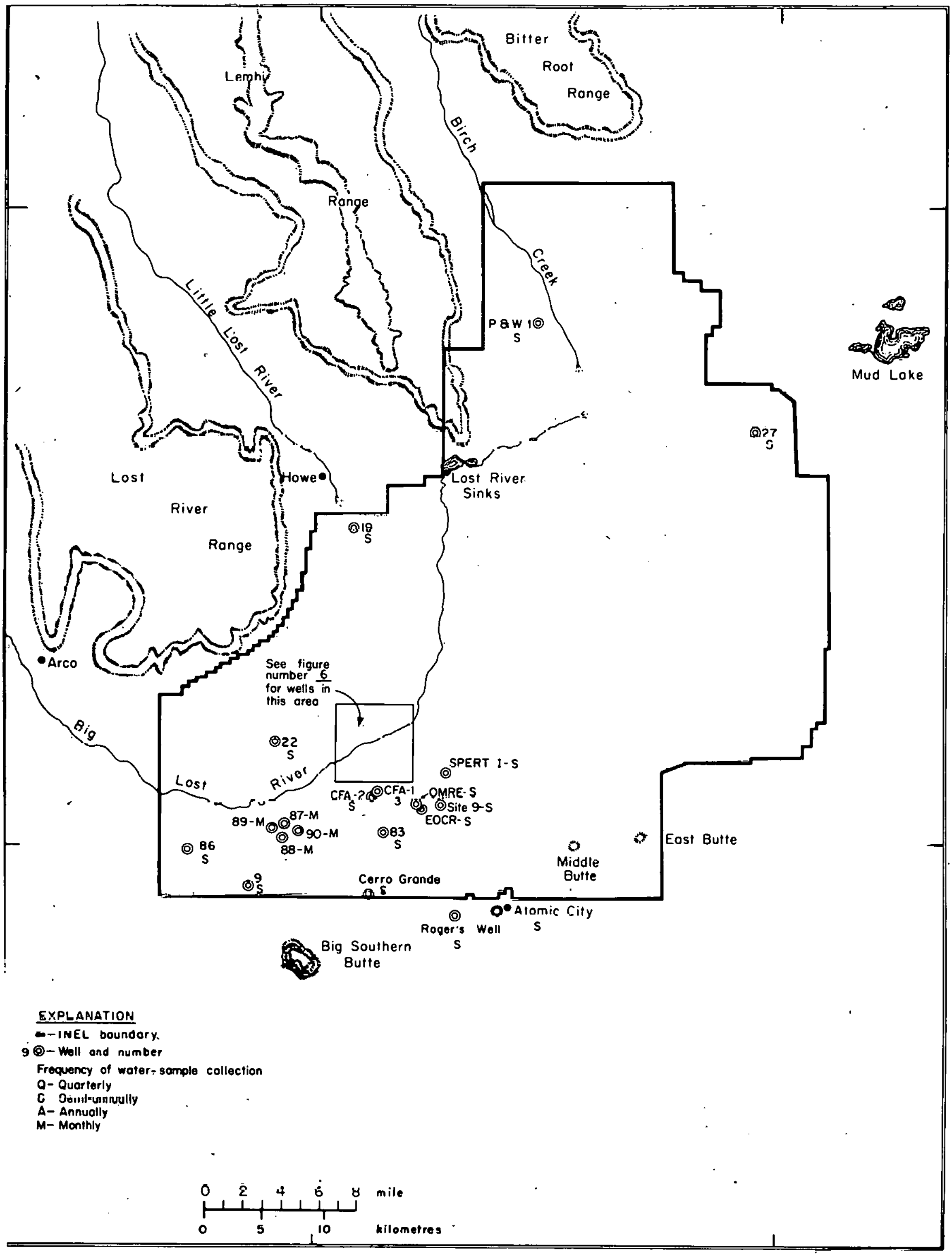


Fig. 5 Location and frequency of water-sample collection.

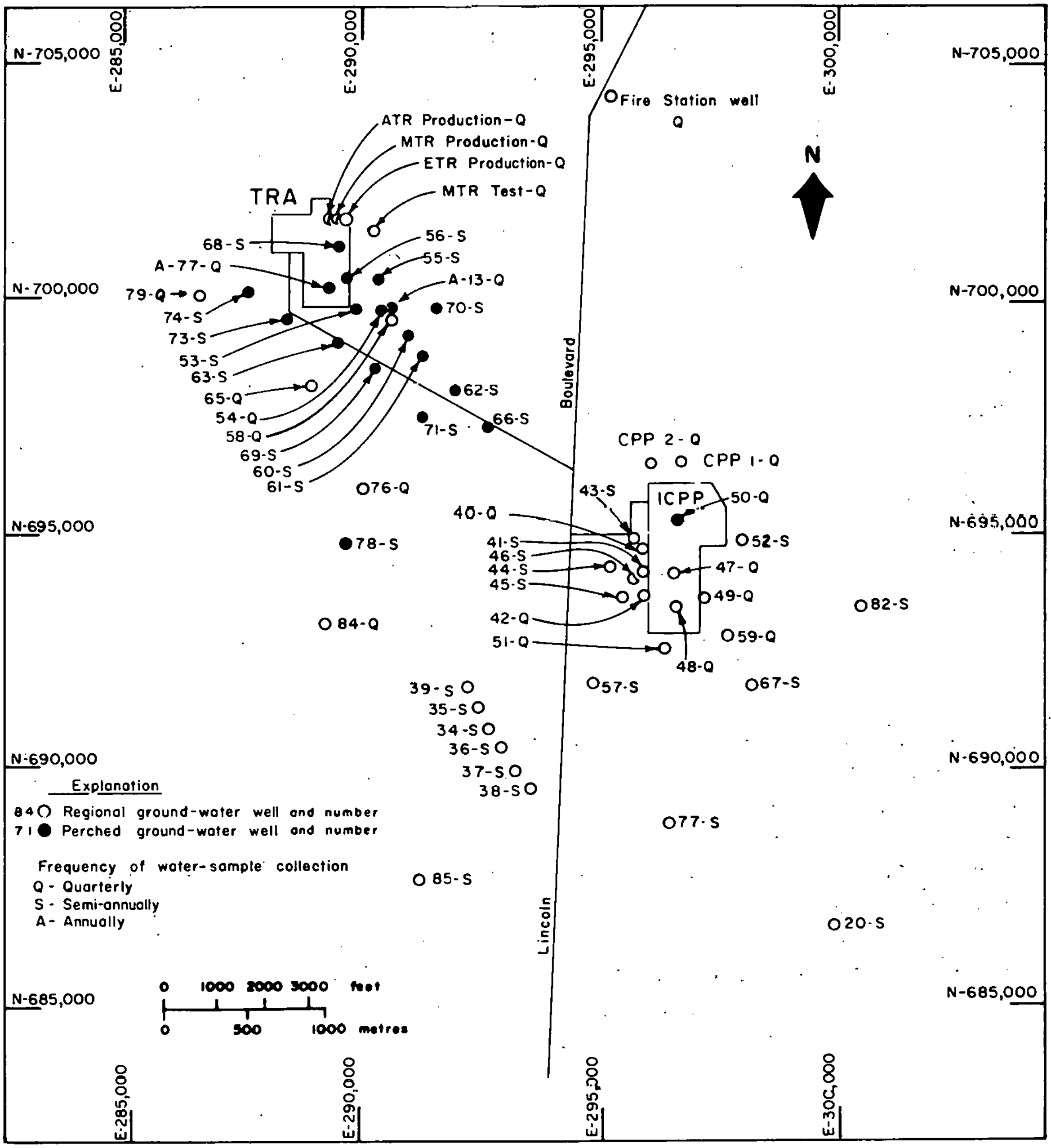


Fig. 6 Location of wells from which water samples are collected and the frequencies of water-sample collection in the TRA-ICPP area.

(3) 82 sediment samples, AEC-HSL, about 15 radiometric determinations per sample

(4) 68 water samples, AEC-HSL, about 15 radiometric determinations per sample.

TABLE I

NUMBER AND TYPE OF RADIOMETRIC OR CHEMICAL ANALYSES OF GROUND-WATER SAMPLES DETERMINED DURING 1971 to 1973

Analysis	Number and Year		
	1971	1972	1973
Tritium	173	219	213
Sodium	5	50	4
Chloride	5	52	11
Specific Conductance	77	146	106
Strontium-90	59	101	63
Cobalt-60	0	18	3
Chromium-51	0	18	0
Cesium-137	0	3	0
Total Chromium	21	39	80
Standard Chemical	5	14	1
Gross γ	16	10	3
Gross β	14	6	1

3. POSITION AND FORM OF THE WATER TABLE

Figure 7 is a map of the INEL and adjacent areas showing contours on the water table of the Snake River Plain aquifer for July 1972 and inferred directions of the ground-water movement. The altitude of the water table ranges from 4,584 ft (1,400 m) in the northern part of the site to 4,419 ft (1,350 m) above mean sea level 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 5 ft/mi (1 m/km) and the depth to water within the Laboratory boundaries ranges from 200 ft (61 m) below the land surface in the northeast to 900 ft (275 m) below the land surface in the west-southwest. In the northern part of the INEL, near the Birch Creek valley, the water-table gradient is relatively low. It slopes southward about 4 ft in 7 mi (0.1 m/km) (Figure 7). This low gradient is a result of relatively greater aquifer permeability or thickness than in the Birch Creek valley. Although a significant amount of underflow enters the area [Mundorff and others (1963)], the head gradient required to transport the water is slight.

Figure 8 is a map showing the net change of the regional ground-water levels for INEL from July 1962 to July 1972. The net changes of ground-water levels ranged from zero to a rise of more than 16 ft (5 m). Near Test Area North, the water levels remained relatively constant, exhibiting only a very slight rise.

The 16-ft (5 m) rise in the west-central part of the station can be attributed to cumulative recharge effects of the Big Lost River and the Little Lost River. The effects of the recharge decrease eastward and southward across the station. Data in the figure show that recharge from the streams to the west of INEL has the major effect on long-term water-level changes in the aquifer.

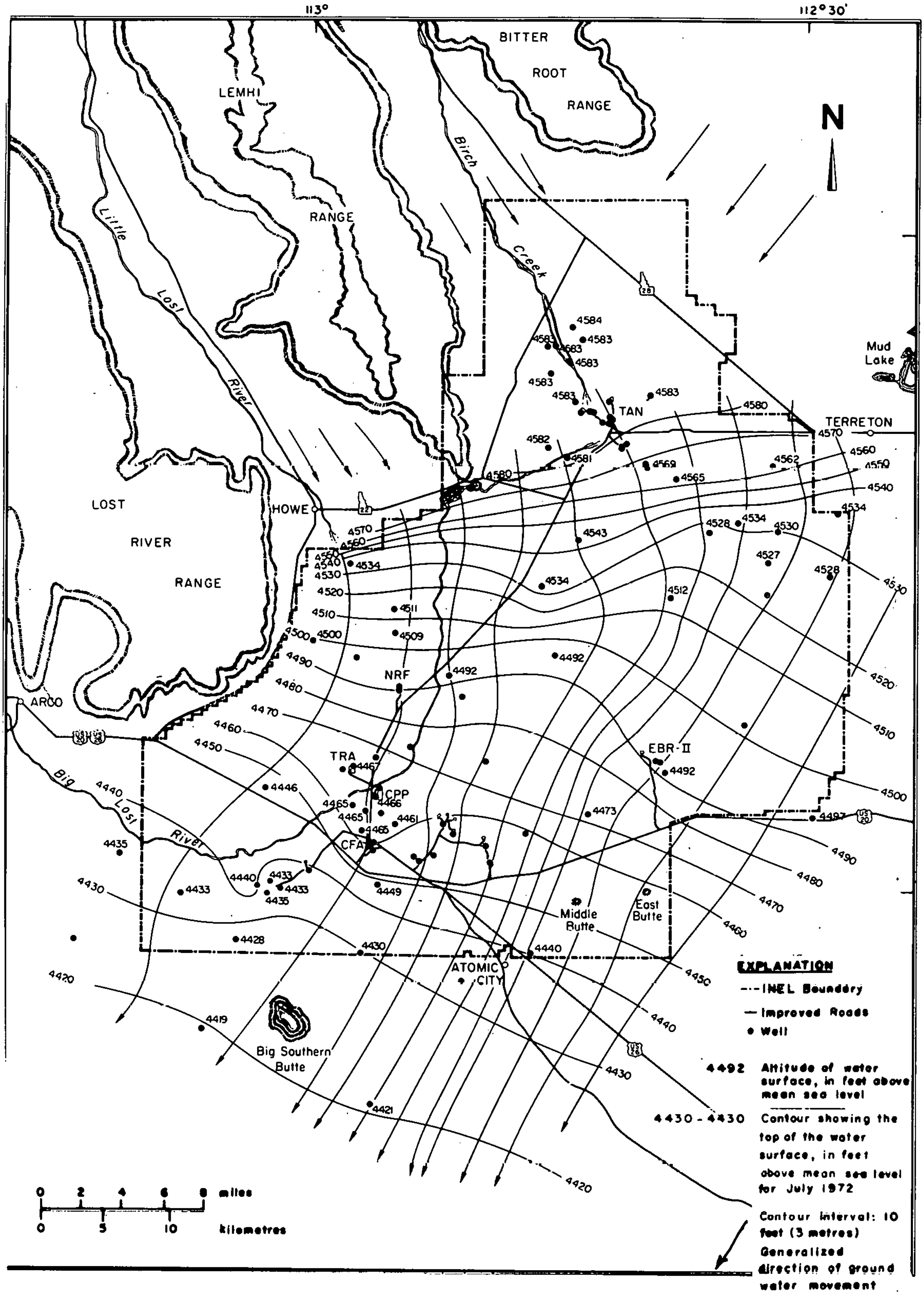


Fig. 7 Contours on the regional water table and the inferred directions of ground-water movement, July 1972, INEL and vicinity.

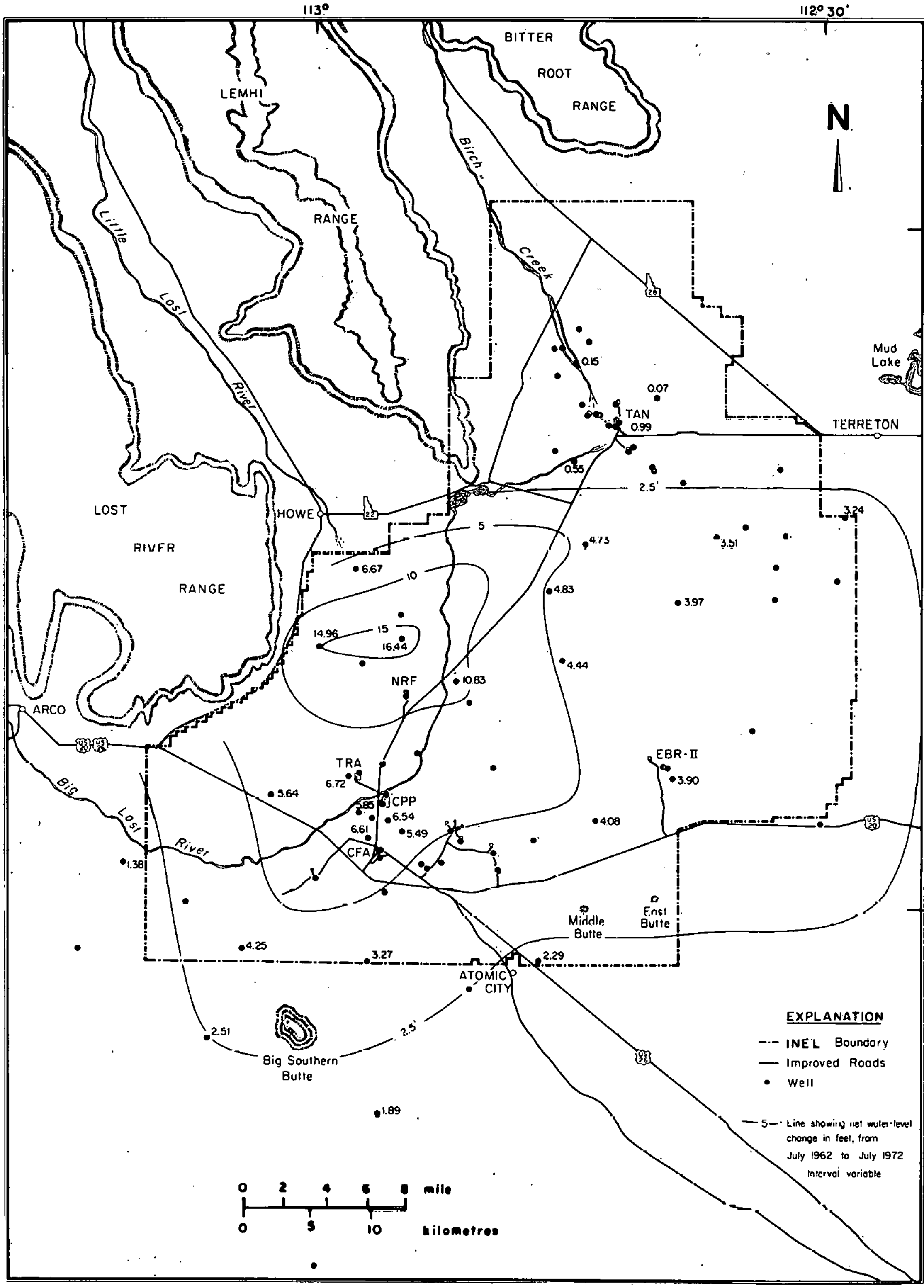


Fig. 8 Net change of the regional water table from July 1962 to July 1972.

4. GROUND-WATER PUMPAGE

The Snake River Plain aquifer is the only source of water utilized at the INEL. Twenty-five of the 28 production wells were generally used in 1971 to 1973. The combined pumpage of these wells was about 2.5 billion gal of water (9.5 x 10^9 l) per year for 1971 to 1973. This averages about 7 million gallons (2.6 x 10^7 l) per day or about 8,000 acre-ft (10^7 m^3) per year.

Figure 9 illustrates the pumpage of water by the major facilities at the INEL [U.S. Atomic Energy Commission (1975)]. The TRA (Figure 2) is the largest user of ground water at the INEL. The quantity of water used at TRA is more than half of the total pumpage, but it has been significantly reduced from 1971 to 1973. The quantity of water used at the ICPP has remained rather constant while the quantity of water used at the Naval Reactor Facility (NRF) has increased. The quantity of water used at all the other facilities is a rather small percentage of the total (less than 10%).

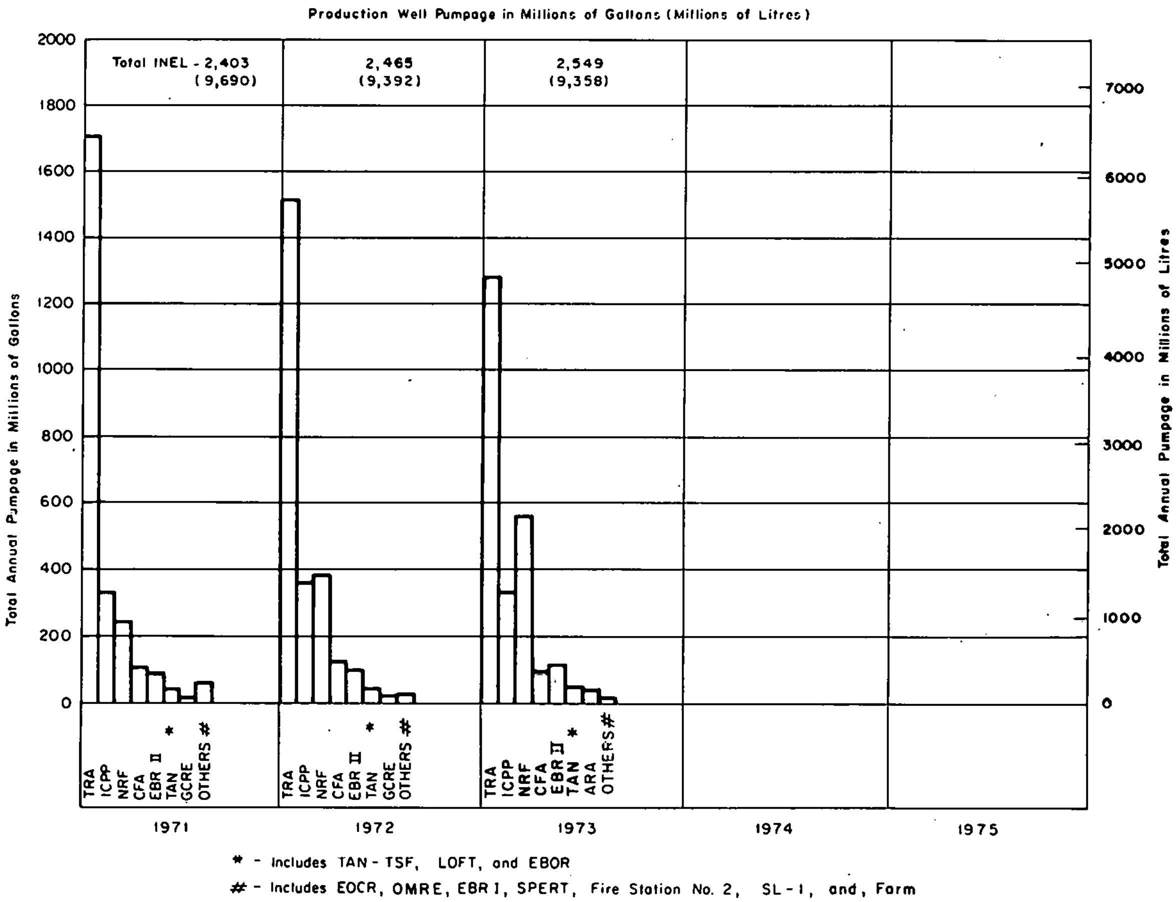


Fig. 9 Production well pumpages for selected INEL facilities, 1971 to 1973.

Not all of the water pumped is actually consumed. Some of the waste water is discharged directly into the Snake River Plain aquifer through deep wells. Other aqueous wastes (radioactive, chemical, and sewage) are discharged into ponds or shallow wells. Both methods of waste disposal contribute recharge to the aquifer. An AEC report [U.S. Atomic Energy Commission (1975)] gives the volumes disposed to the air, surface, subsurface, and sewage. During 1971 to 1973, an average of 47% of the water pumped was disposed of to the surface or subsurface. Pumpage has a limited effect on long-term water-level changes in the aquifer because the amount pumped is a very small amount of the total storage and recharge.

5. SURFACE WATER

Surface water is derived mainly from streams draining through the valleys to the west and north of the INEL. Snowmelt and rain also contribute to surface water, especially in the spring. Water from the Big Lost River, the Little Lost River, and Birch Creek enters the INEL during wet years. Most of the flow of the Little Lost River and Birch Creek is diverted for irrigation before it reaches INEL.

The Big Lost River is the most important source of surface water. During wet years, the Big Lost River brings considerable surface water onto the INEL, and the recharge to the Snake River Plain aquifer from this flow has been significant.

The Big Lost River flows southeastward down the Big Lost River valley past Arco, out onto the Snake River Plain, and then turns northward through the INEL to its termination in playas (or "Lost River Sinks"). On the plain, the river loses water by infiltration through the channel bottom. During dry times, flow does not even reach the INEL. As flow approaches the playas, the channel branches into many distributaries, and the flow spreads over several flooding and ponding areas [Barraclough and others (1967)].

Two major artificial controls affect the river in addition to irrigation diversions. These are Mackay Dam, 30 mi (48 km) above Arco, and the INEL flood diversion system in the southwestern part of the Laboratory (Figure 2). The INEL flood-control diversion system was constructed in 1958 to reduce the threat of floods from the Big Lost River. The diversion dam can divert flow out of the main channel to spreading 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 downstream on the Laboratory.

All flow of the Big Lost River that enters onto the Snake River Plain is recharged to the subsurface, except for evaporation and transpiration losses. Recharge effects from the Big Lost River are very pronounced in the Snake River Plain aquifer and in perched water beneath the river.

During water year 1971, the flow of the Big Lost River below Mackay Reservoir was 311,500 acre-ft ($3.8 \times 10^8 m^3$), the fourth highest discharge of record. The flow during water year 1972 was above average, and the flow during water year 1973 was about average (Table II). The hydrographs in Figure 10 show the flow rates on the INEL during 1971 to 1973.

Figure 11 illustrates the wet and dry cycles that are shown by annual discharge of the Big Lost River below Mackay Reservoir. The last 50 years, 1924 through 1973, can be divided into four periods. From 1924 through 1941 was a very dry period. The average discharge was 164,000 acre-ft (2.0 x $10^8 m^3$), which is only about 78% of the 57-year average discharge. During these 18 years, the flow was below the average for 16 of the years.

The flow from the Big Lost River was above average for 13 years of the 17-year wet period from 1952 through 1958. The average for this period was 237,000 acre-ft (2.9 x $10^8 m^3$), which is 113% of the 57-year average discharge.

A brief but severe dry period occurred from 1959 through 1962. The average discharge from 1959 through 1962 was 155,500 acre-ft (1.9 x $10^8 m^3$), which is 74% of the 57-year average discharge.

The wettest period and the highest flows of record occurred in the 11 years from 1963 to 1973. The flow of the Big Lost River in 8 of these years has been above the long-term average. The flow in the other 3 years was only slightly below average. The average annual discharge from 1963 through 1973 was 275,000 acre-ft (3.4 x $10^8 m^3$), or 131% of the 57-year average.

The discharge of the Big Lost River during the last decade is unusually high as compared to the period of record. The lowest flow for a 9-year period was from 1929 through 1937 when the average annual discharge was 141,000 acre-ft (1.7 x $10^8 m^3$). The highest flow of record for 9 years was from 1965 through 1973 when the average annual discharge was 284,000 acre-ft (3.5 x $10^8 m^3$), more than double the flow during the dry period.

TABLE II

DISCHARGE OF THE BIG LOST RIVER BELOW MACKAY, IDAHO

Water Year	Discharge (acre-ft)	Cubic meters (m^3)
1971	311,500	3.8 x 10^8
1972	267,300	3.3 x 10^8
1973	205,300	2.5 x 10^8
1965 (maximum)	397,000	4.9 x 10^8
57-Year Average	211,000	2.6 x 10^8

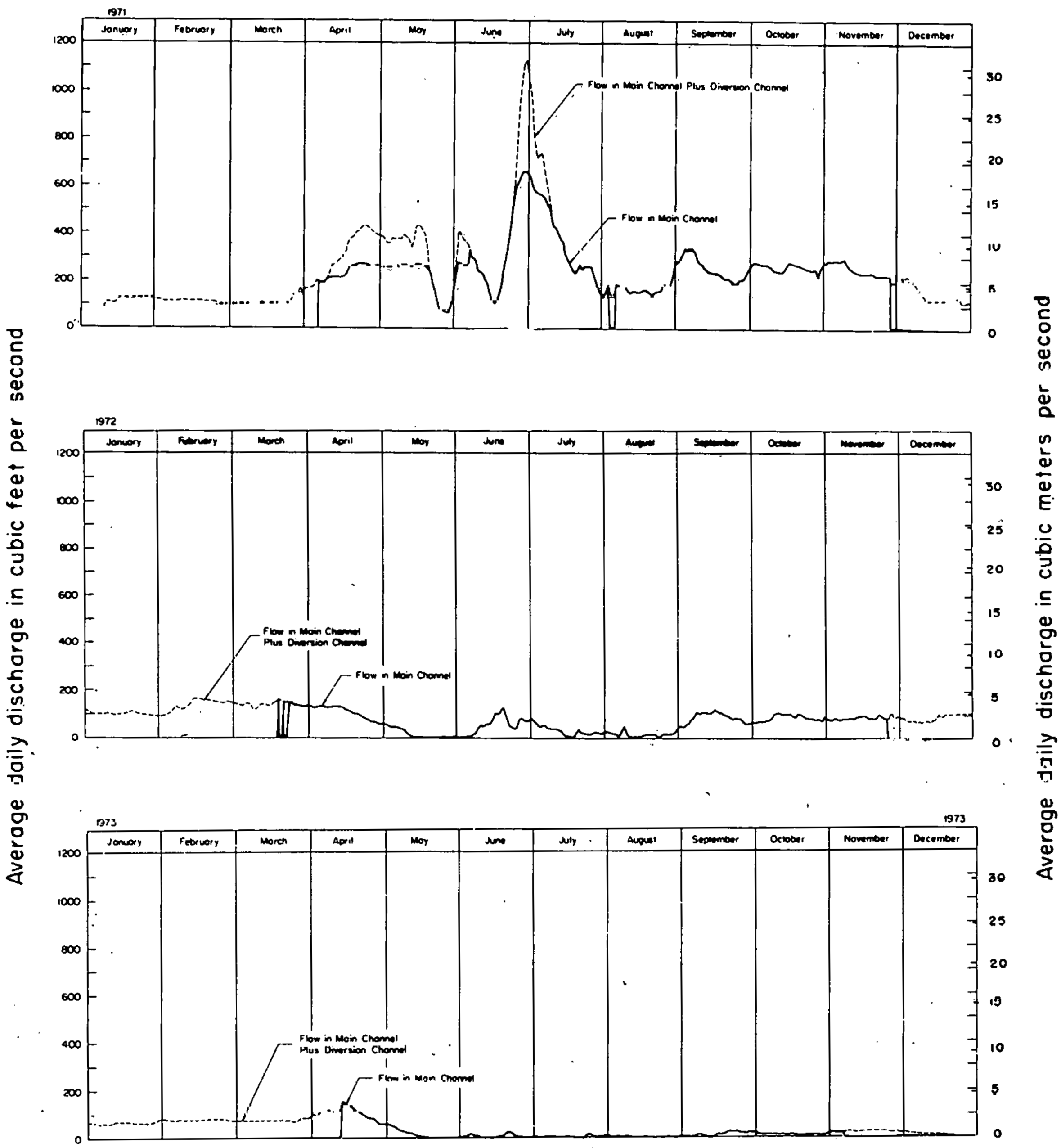


Fig. 10a Average daily discharge of the Big Lost River during 1971, 1972, and 1973 at the INEL diversion.

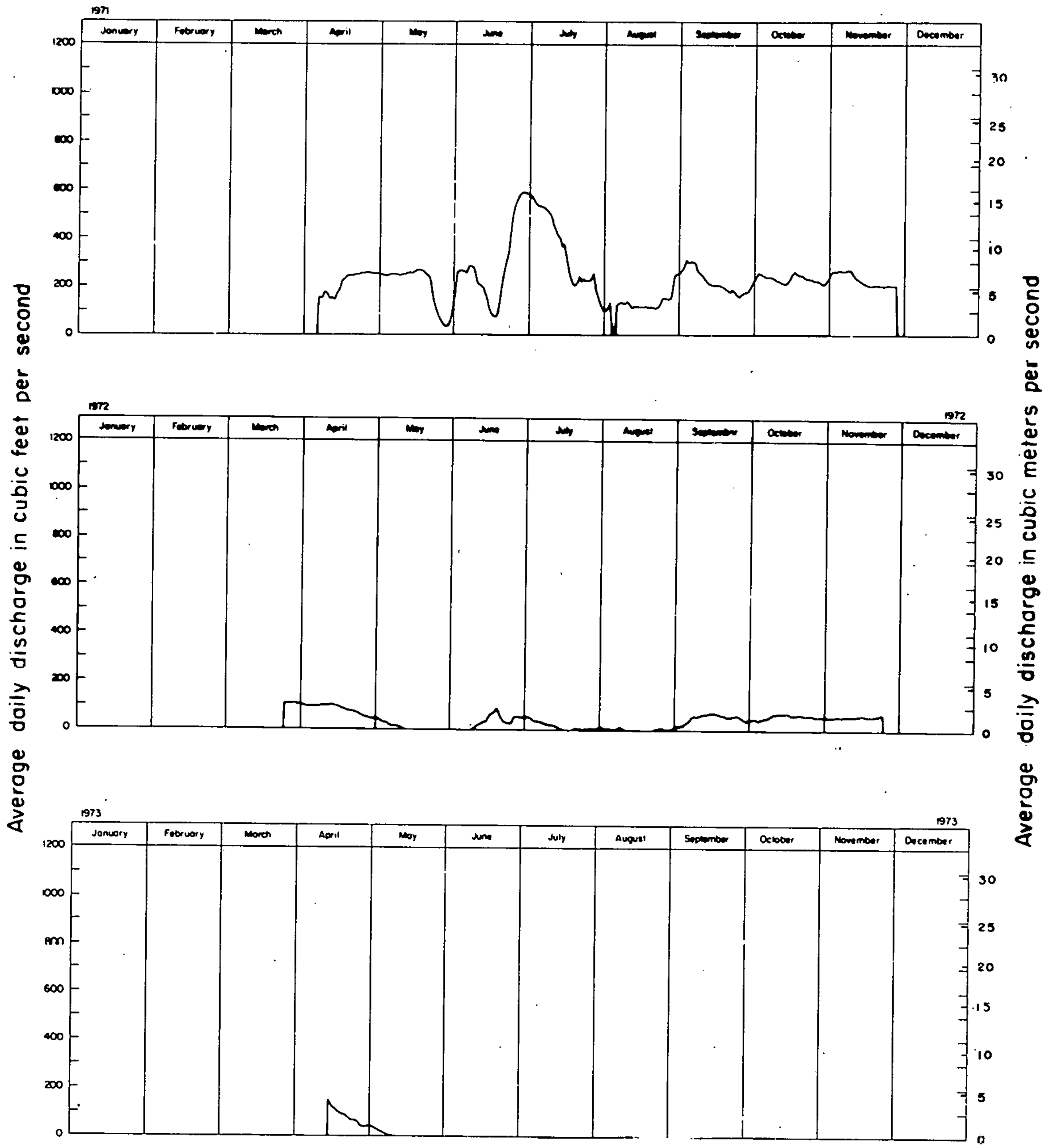


Fig. 10b Average daily discharge of the Big Lost River during 1971, 1972, and 1973 at Lincoln Boulevard Bridge near TRA.

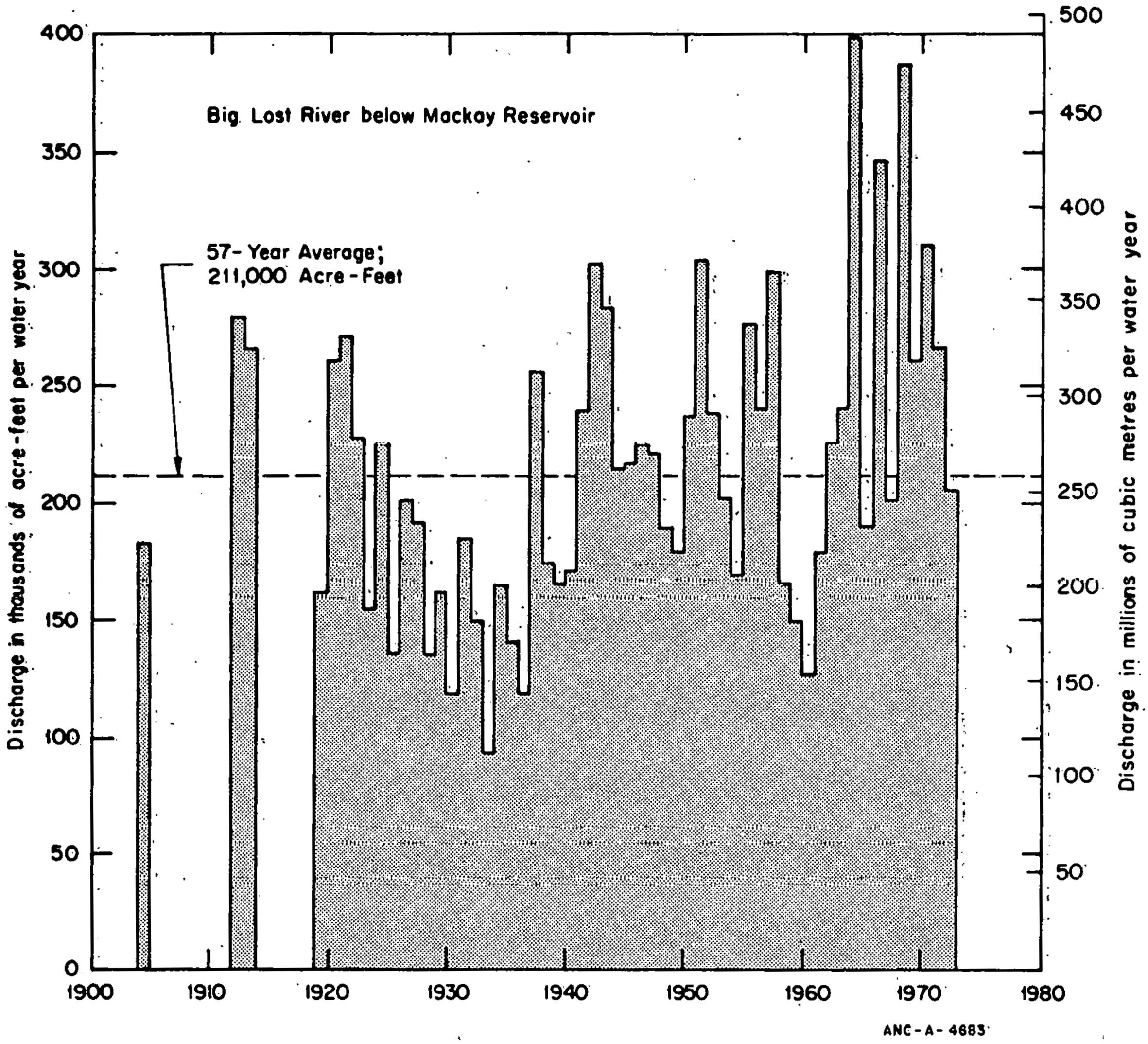


Fig. 11 Discharge of the Big Lost River below Mackay Reservoir.

6. GROUND-WATER RECHARGE AND WATER-LEVEL FLUCTUATIONS

The Big Lost River flows intermittently on the INEL. When flowing, water infiltrates from the river and percolates downward toward the Snake River Plain aquifer. Layers of sediment of low permeability between the basalt flows slow the downward percolation and sometimes form perched bodies of water beneath the River.

Figure 12 shows the hydrograph of well 78 and the discharge of the Big Lost River near the Test Reactor Area. Well 78 is 235 ft (72 m) from the river and 203 ft (62 m) deep and does not penetrate the Snake River Plain aquifer. About 4-1/2 days after flow starts in the river, the water level in well 78 begins an abrupt rise because of recharge from the river.

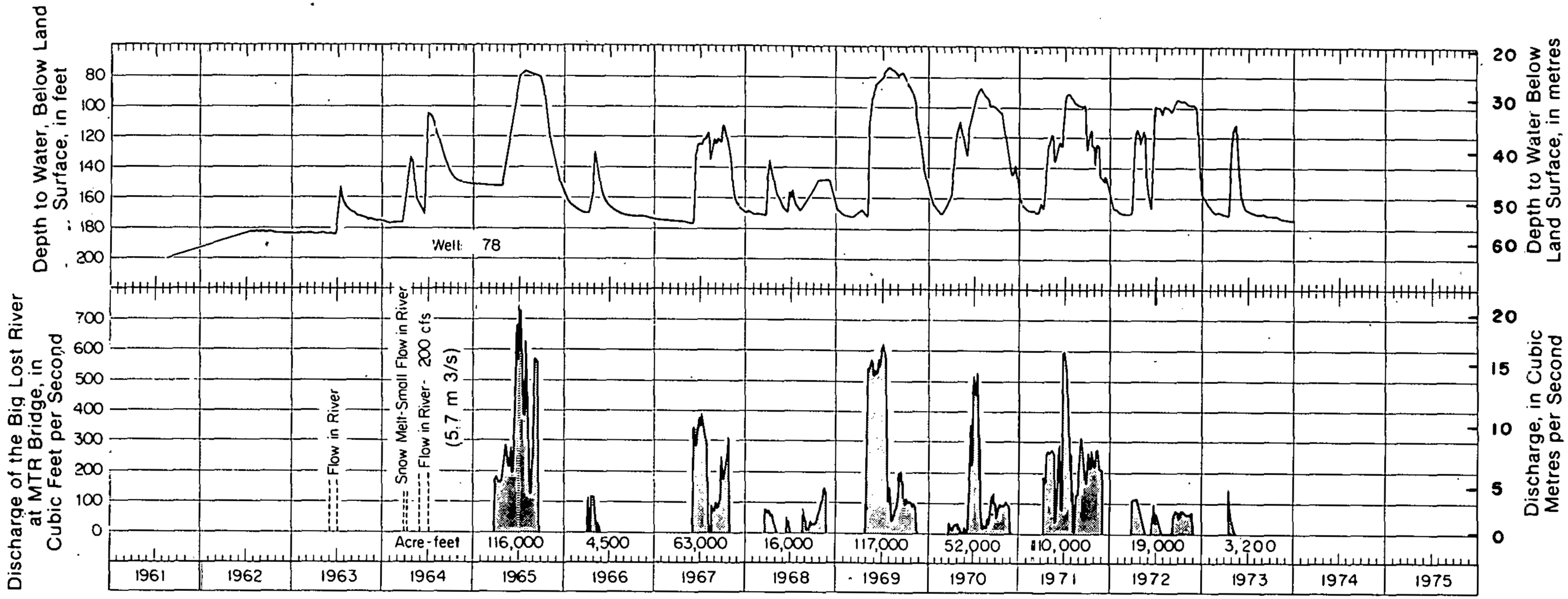


Fig. 12 Correlation between water-level fluctuations in well 78 and discharge of the Big Lost River at the Lincoln Boulevard Bridge near the TRA.

The water level may rise almost 100 ft (30 m) within a few months. The water level in the well is very sensitive to river stage and as stream flow declines or ceases, the perched-water level declines abruptly. Declines of 60 to 90 ft (18 to 27 m) have been measured within 3 or 4 months.

A significant but unknown amount of recharge from the Big Lost River has caused a regional ground-water level rise over much of the INEL for several periods. The water levels in some wells rise as much as 6 ft (2 m) in a few months following a very high flow in the river.

Figure 13 shows the hydrographs of well 18, site 14 well, and well 6 in the central part of the Laboratory. The water level in these wells is influenced by recharge from high flows of the nearby Big Lost River. The hydrograph of well 18 and site 14 well show very rapid water-level rises following the recharge from high flows in 1965, 1967, 1969, and 1971. The water levels all rose from the low of record in 1964 to highs of record in 1972 and 1973.

Figure 14 shows the hydrographs of wells 9, 11, 8, 13, and 86. These wells are near the southwest corner of the Laboratory near the Big Lost River, and recharge from the river and from the nearby diversion areas causes sharp rises in the water level. The effects of high flows in recent years are clearly shown on the graphs. The lowest water levels occurred in 1964 and the highest water levels occurred in 1969 for wells 9, 8, and 86 and in 1972 for well 11.

The water-level changes in four wells in the western part of the INEL are shown in Figure 15. The water levels in these wells are also influenced by recharge from the Big Lost River. The lowest water levels on record occurred in 1964. The highest water levels for more than 20 years of record occurred in 1972 for wells 17, 23, and 12.

The water level in well 12 rose 21.5 ft (6.5 m) in 8 years from 1964 to 1972. This is the largest fluctuation of the water level in a well in the Snake River Plain aquifer that has been measured at the INEL. The water level in well 23 rose 18 ft (5.5 m) in this same period, which is the second largest rise that has been measured. The water levels have started to decline from the highs caused by recharge from the Big Lost River because of decreased recharge.

The water level in well 20 rose only about 6 ft (1.8 m) from 1964 to 1972. Nearby pumping at the ICPP, CFA, and TRA during the past 20 years may have influenced the water level preventing as sharp a rise as occurred in nearby wells.

The hydrographs of wells 1, 2, 14, and Cerro Grande well are shown in Figure 16. The water levels in these wells are influenced by underflow from the northeast and the recharge from the Big Lost River. Well 1 and Cerro Grande well are at the Laboratory boundary, well 14 is 8 mi (13 km) south, and well 2 is 7 mi (11 km) north of the southern boundary. The water levels in these four wells have fluctuated from 4 to 6 ft (1.2 to 1.8 m) during the

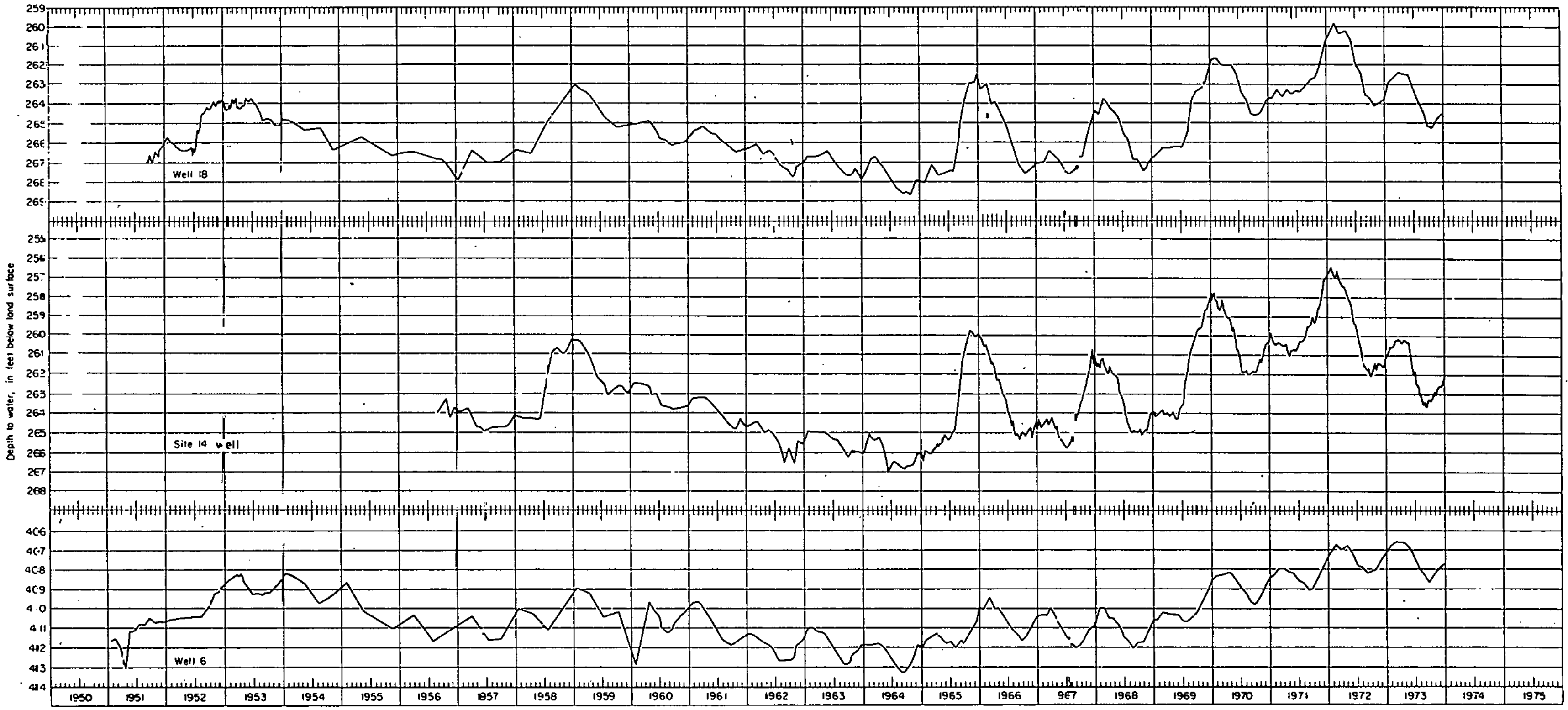


Fig. 13 Hydrographs of three wells in the central part of the INEL.

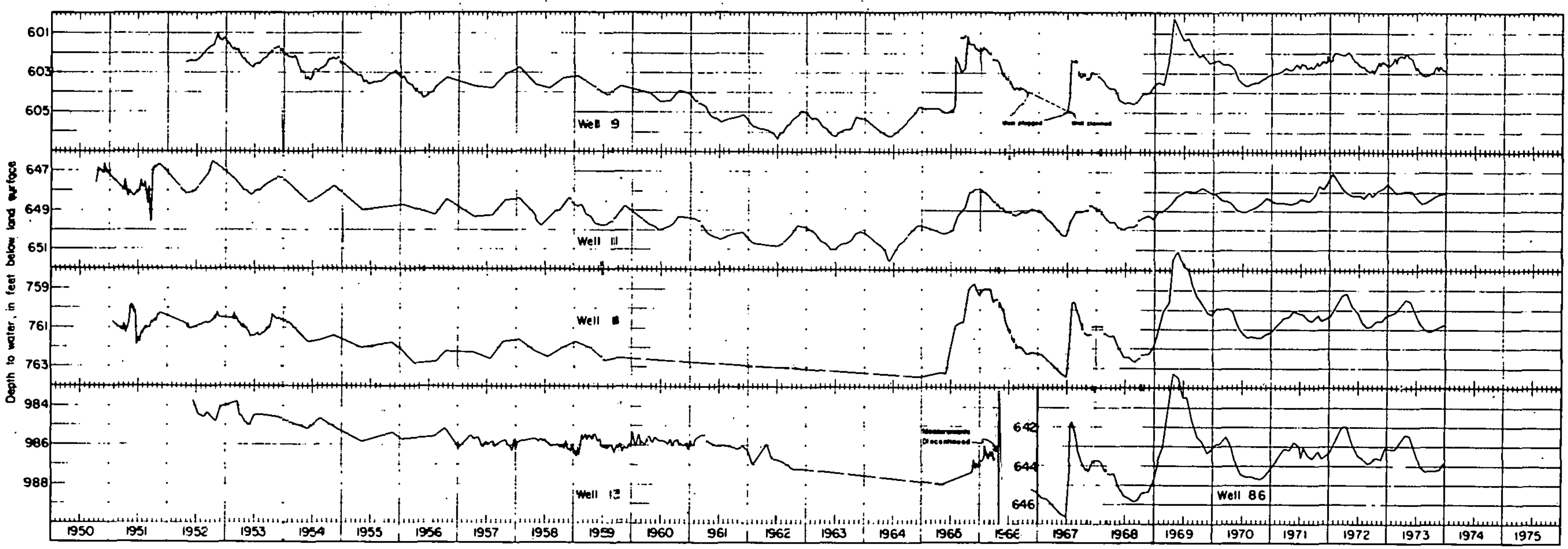


Fig. 14 Hydrographs of five wells near the southwest corner of the INEL.

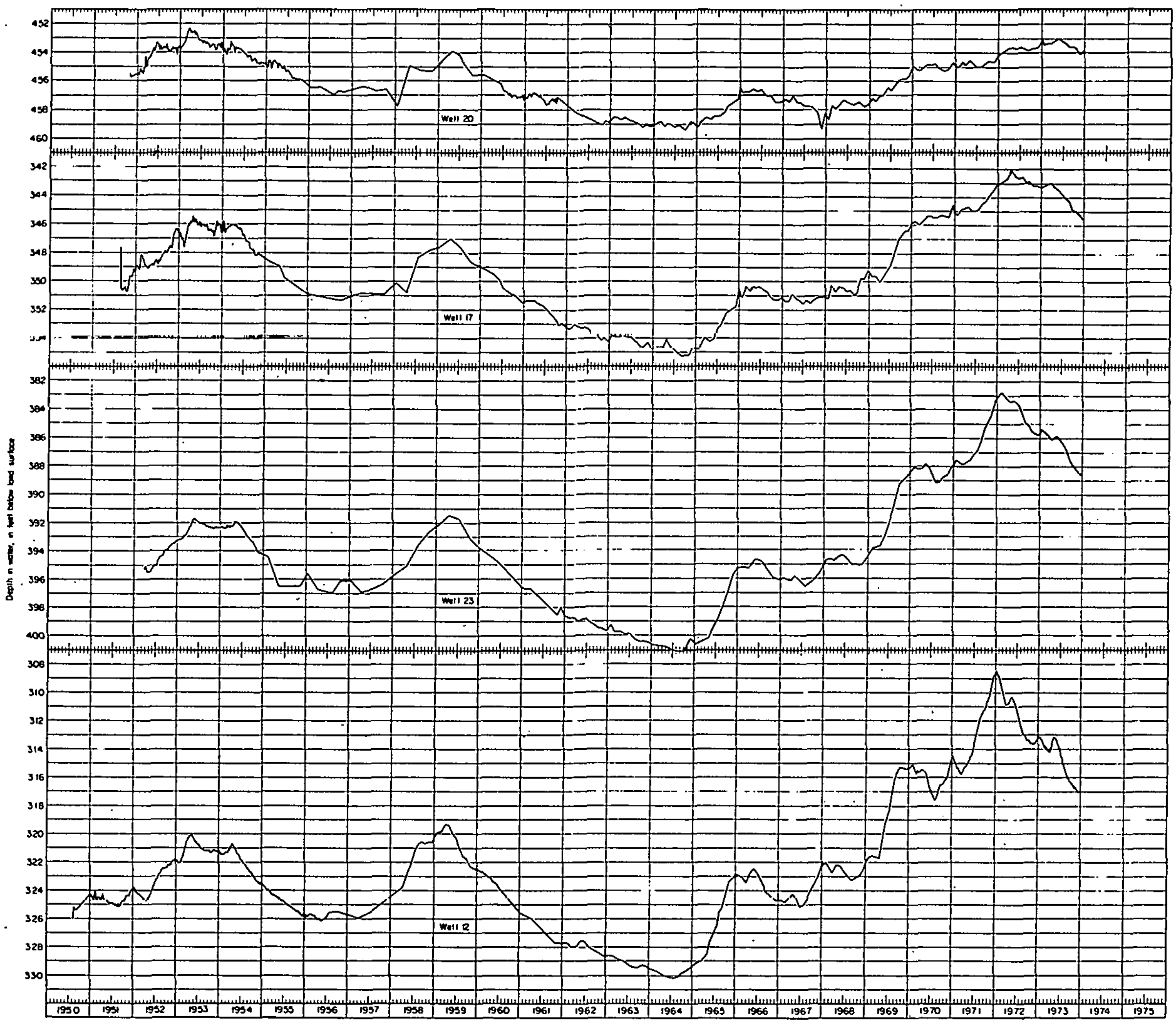


Fig. 15 Hydrographs of four wells in the western part of the INEL.

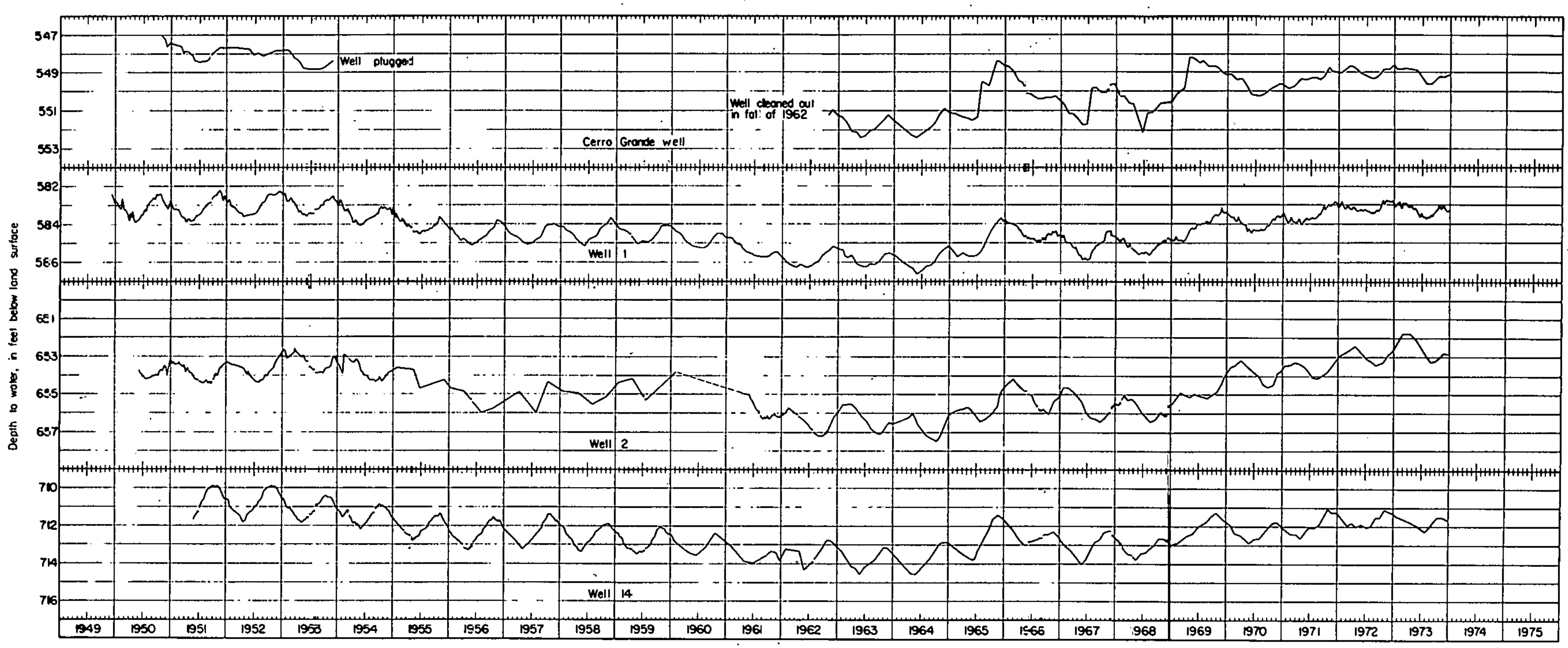


Fig. 16 Hydrographs of four wells in the southeast corner of the INEL.

period of record. The water levels have risen from 3 to 5 ft (0.9 to 1.5 m) in the wells from the low in 1964 to 1973. The water levels are now within 1 ft (0.3 m) of the water levels measured in 1950 or 1951.

Figure 17 shows hydrographs of well 4, Highway 2 well, well 21, and Arbor Test well, located near the eastern boundary of the Laboratory. The highest water levels during the period of record of these four wells occurred in 1973, and the lowest water level was in 1964. The total water-level fluctuations ranged from 6 to 8 ft (1.8 to 2.4 m). The water levels have an annual fluctuation of 2.5 to 5 ft (0.8 to 1.5 m). The annual high is usually in January or February and the annual low is in July or August.

The changes in water levels in these four wells respond to changes in recharge from Mud Lake and from the northeastern part of the Snake River Plain. Recharge from the Big Lost River also influences the water levels in the wells.

The hydrographs for wells 25, 26, and ANP 9, for the northern part of the Laboratory, are shown in Figure 18. Wells in this area are influenced by recharge from Birch Creek and other streams to the northeast. The total fluctuation of the water level for the period of record for these three wells ranged from 4 to 5 ft (1.2 to 1.5 m). The annual fluctuation is from 1 to 2.5 ft (0.3 to 0.8 m). The highest water levels of record occurred in 1973, and the lowest water levels occurred in 1966 or 1967.

The water levels in 14 of the 22 wells were the highest in 1972 or 1973. Almost two-thirds of these wells had the highest water level of record in 1972 or 1973 which is a result of the increased recharge, principally from the Big Lost River. The water levels in the wells have a blending effect on all sources of recharge. The net result is the sum of all the recharge and discharge effects.

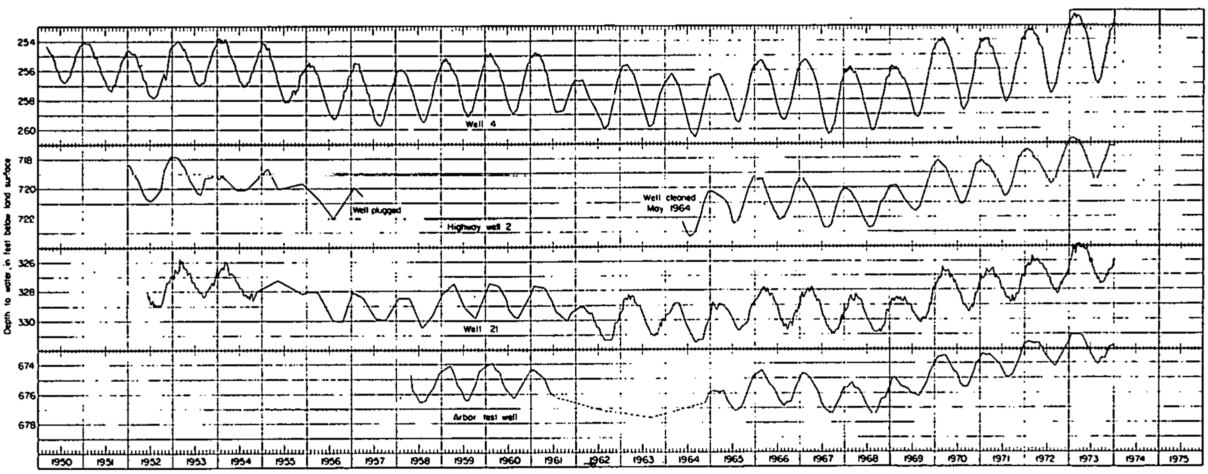


Fig. 17 Hydrographs of four wells in the eastern part of the INEL.

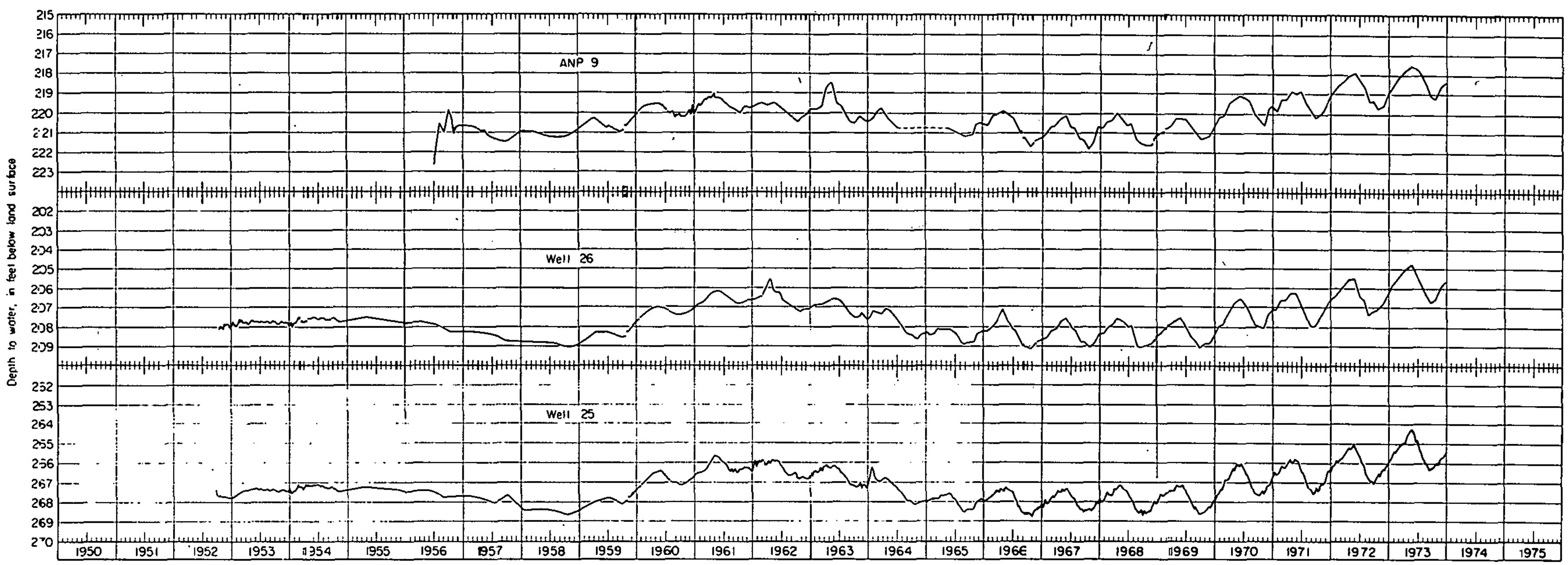


Fig. 18 Hydrographs of three wells in the northern part of the INEL.

III. WASTE DISPOSAL

Liquid low-level radioactive and dilute chemical wastes have been discharged to the subsurface at the TRA and ICPP since 1952 through wells and ponds. The TRA and ICPP have discharged more than 75% of the total waste at the INEL. Therefore, the effects of this disposal on the Snake River Plain aquifer have been intensively studied.

1. TEST REACTOR AREA

The TRA utilizes four disposal systems. Low-level radioactive wastes are discharged to three seepage ponds and allowed to percolate to the Snake River Plain aquifer, 450 ft (137 m) below the land surface. Chemical wastes are discharged to another seepage pond. Two seepage ponds are used to dispose of sanitary wastes (Figure 19). Cooling tower blowdown wastes are discharged to the aquifer through a deep disposal well. Four perched-water bodies have formed in the alluvium (Figure 19). A small perched-water body has formed beneath the chemical waste disposal pond and a larger perched-water body has formed beneath the radioactive waste disposal pond. Two smaller perched-water bodies have formed west of the radioactive waste disposal pond because of leakage. A much larger perched-water body in the basalt covering about 0.5 mi^2 (1.3 km^2) has formed beneath the TRA on a sediment bed approximately 150 ft (46 m) deep (Figure 21).

1.1 Radioactive Waste Ponds

The average discharge to the TRA radioactive waste ponds has been about 200 million gal (757,000 m^3) per year since 1952. Figure 20 shows a graph of the discharge from 1959 to 1973. The discharge to the ponds in 1971 was 191 million gal (723,000 m^3), in 1972 was 217 million gal (821,000 m^3), and in 1973 was 269 million gal (1,020,000 m^3) (Figure 20). The discharge was slightly above average for these years and averaged 644,000 gal (2.44×10^6 l) per day.

The water discharged to the radioactive waste ponds percolates downward into the surface alluvium and is perched on fine-grained sediment and the top of the basalt surface, about 50 ft (15 m) below the land surface. The extent of the perched ground water in the alluvium on July 27, 1973 is shown in Figure 19. The perched water covers about twice the pond area.

The shallow perched water percolates into the basalt and moves downward until it reaches a fine-grained sediment layer that is interbedded in the basalt. This extensive sediment layer averages about 60 ft (18 m) in thickness and is about 150 ft (46 m) below the land surface. Figure 21 shows the extent of the perched waste water beneath the TRA on July 1972. The water is derived from all the TRA ponds. The extent of the perched-water body in the basalt is about 6,000 ft (1,800 m) by 2,500 ft (760 m). The highest water-level contour in Figure 21 is 4,860 ft (1,480 m) above sea level which is about 60 ft (18 m) below the land surface. The extent and thickness of this large perched-water

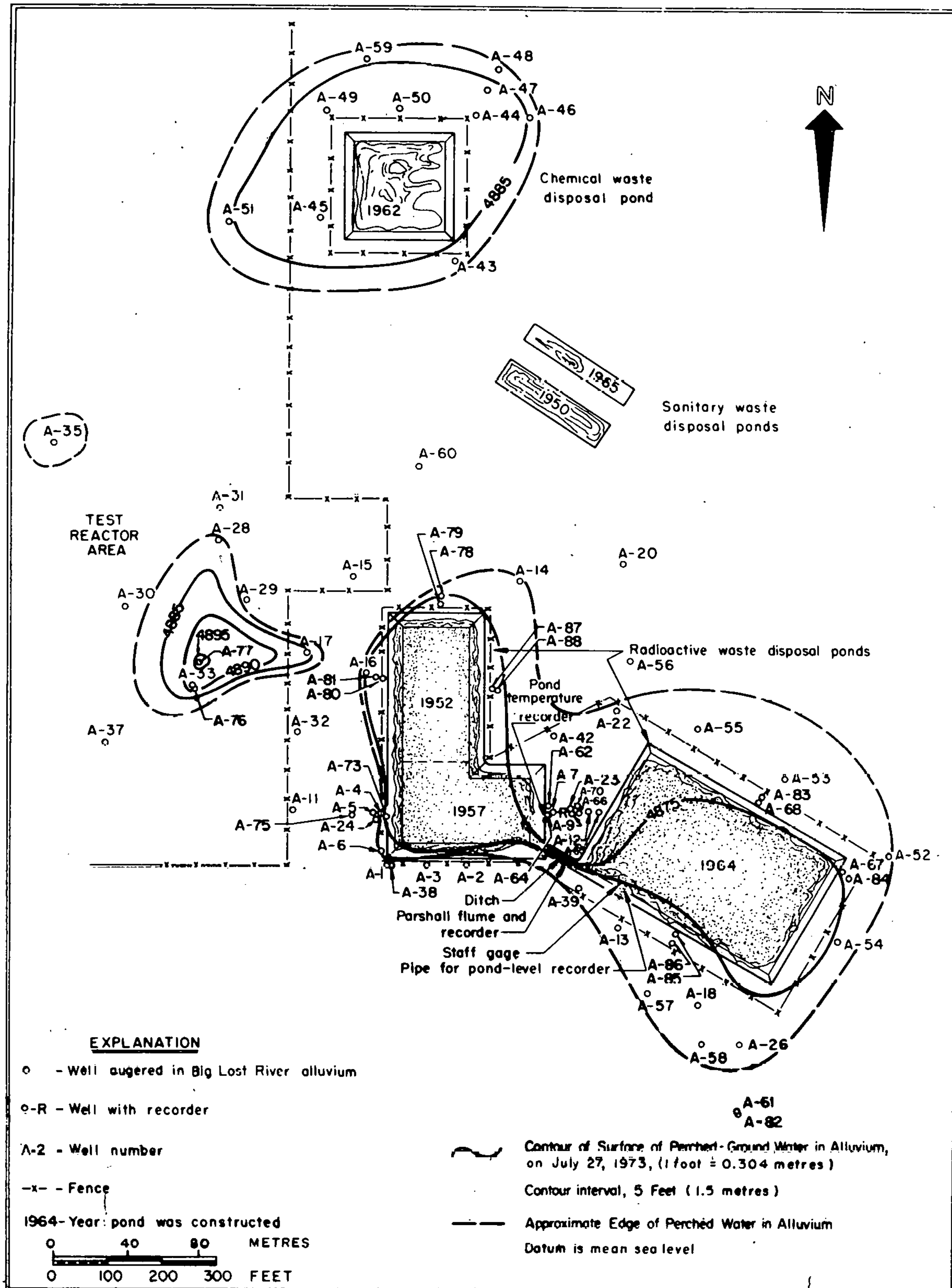


Fig. 19 Location of disposal ponds, well, and the extent and water-level contours of the perched ground water in alluvium, July 1972, at TRA.

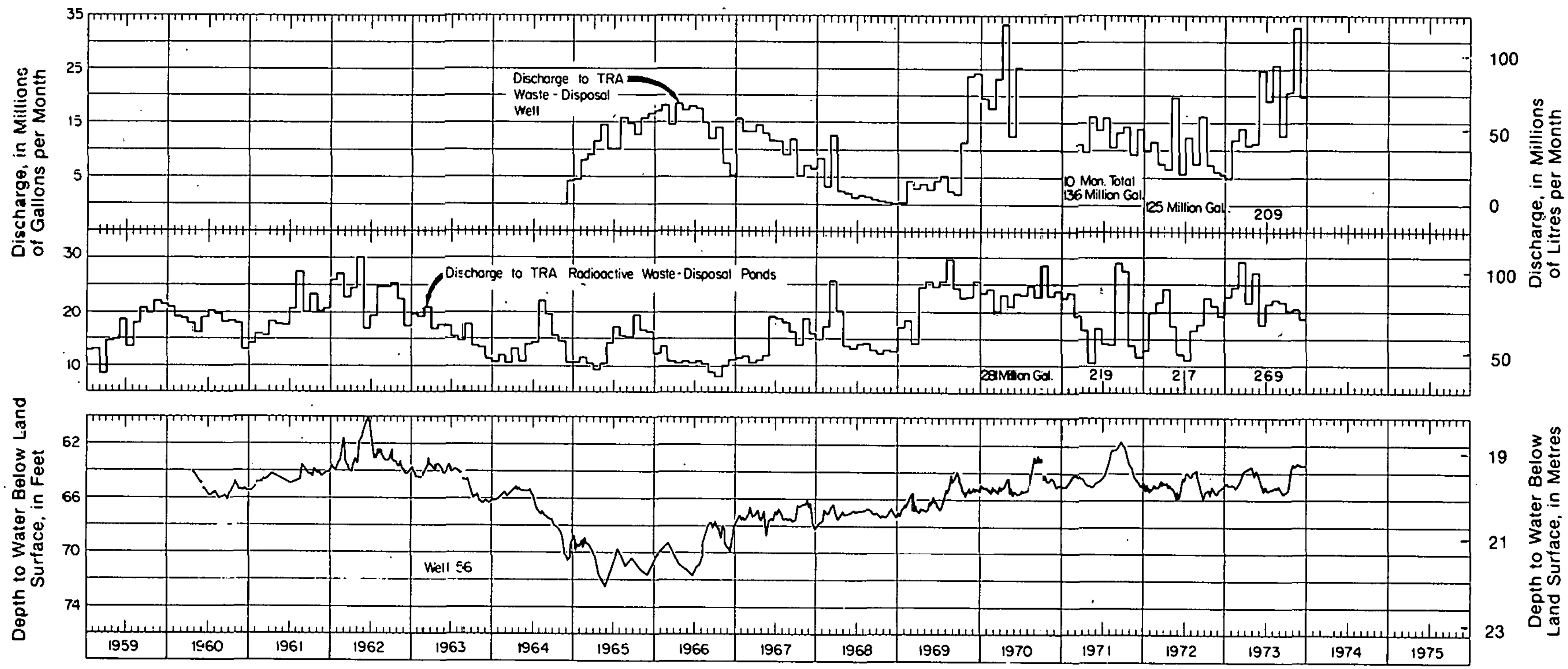


Fig. 20 Waste discharged to the radioactive waste ponds and to a well in the TRA, and hydrograph of well 56, tapping the perched ground water in the basalt.

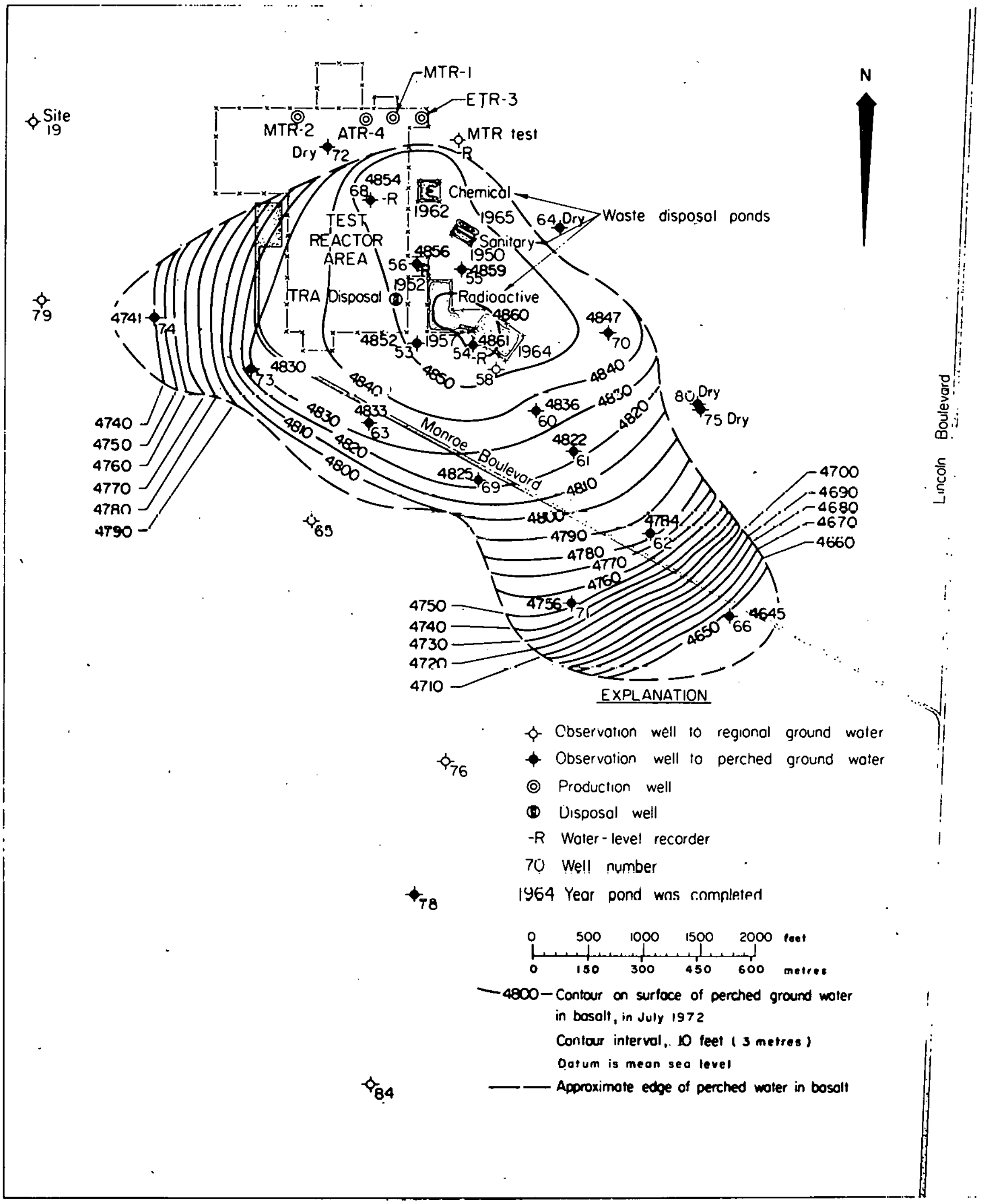


Fig. 21 Water-level contours on the surface of the perched ground water in the basalt, July 1972, at TRA.

body has not changed much in the past 12 years, indicating that the inflow is approximately balanced by the outflow.

Figure 22 illustrates two hydrographs of wells that tap the major perched-water body at the TRA. The water level in well 60 has fluctuated a total of 25 ft (7.6 m) during the 14 years of record. The water level in well 54 has fluctuated about 18 ft (5.5 m). The water-level fluctuations are compared to those in the Materials Test Reactor test well that penetrates the Snake River Plain aquifer and shows that fluctuations of water levels in the perched-water table are not related to fluctuations in the regional water table.

The fluctuations of the water level in three wells that tap the perched-water body are shown in Figure 23. These water levels reflect recharge from the nearby Big Lost River, especially from record flows in 1965 and 1969, and also reflect changes in the quantity of water discharged to the ponds. The recharge effects from the Big Lost River are shown within a few weeks in the water-level peaks in wells 62 and 71. The same effects of recharge are shown in water-level peaks in well 66 about four or five months later. The delay is apparently caused by the time required for the water to percolate downward through basalts and sediments.

The water discharged to the radioactive waste ponds contained an average of about 1,700 Ci (curies) per year of activation and fission products from 1971 to 1973. About 70% of these have a short half-life and are of little consequence because of their rapid decay. The amounts of some of the nuclides with longer half-lives which have been discharged at the TRA are shown in Table III.

About 8,500 Ci of tritium has been discharged at TRA from 1952 through 1973, an average of 386 Ci per year. The average discharge of tritium from 1971 to 1973 was 234 Ci per year. Figure 24 shows that from 1962 to 1973 the highest tritium discharge was in 1969 and the lowest was in 1972. Figure 24 also shows the tritium concentrations of water from four wells that tap the perched ground water in the basalt.

Figure 25 shows a graph of the average monthly tritium concentrations discharged to the TRA radioactive waste ponds from 1961 through 1973. The average monthly tritium concentrations have ranged from a high of 1,600 pCi/ml (picocuries per milliliter) to a low of less than 100 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. The maximum allowable concentration limit of tritium in public drinking water is 3,000 pCi/ml [Kansas State Board of Health, Radiation Protection Regulations (1961)].

The graphs of the tritium concentrations of water from two wells that tap the perched ground water in the basalt at the TRA are shown in Figure 25. Figure 26 also shows the tritium concentrations of five other wells that penetrate the same perched-water body at the TRA. The tritium concentrations reached a high value in 1970 and have generally decreased since then.

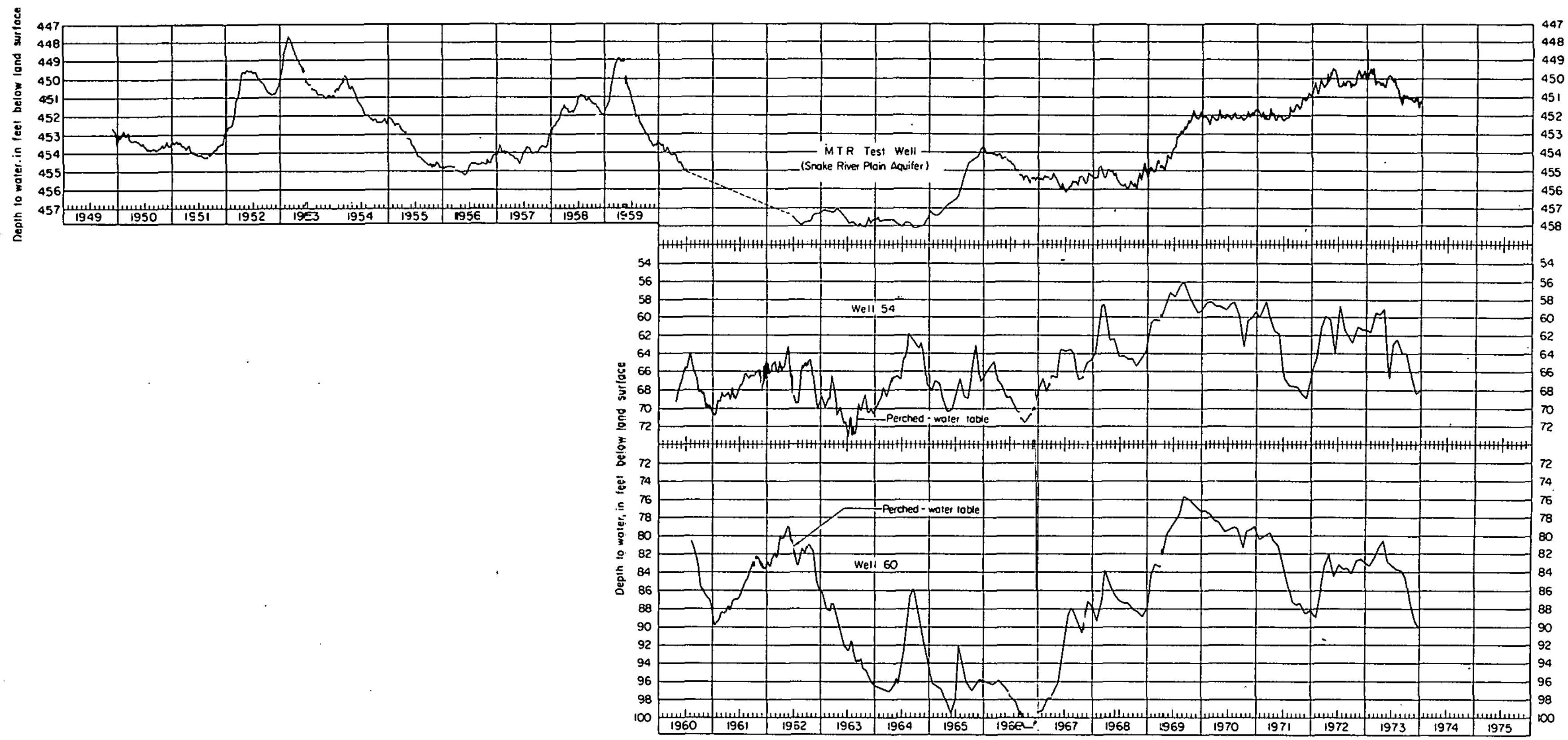


Fig. 22 Hydrographs of wells MTR Test, 54, and 60.

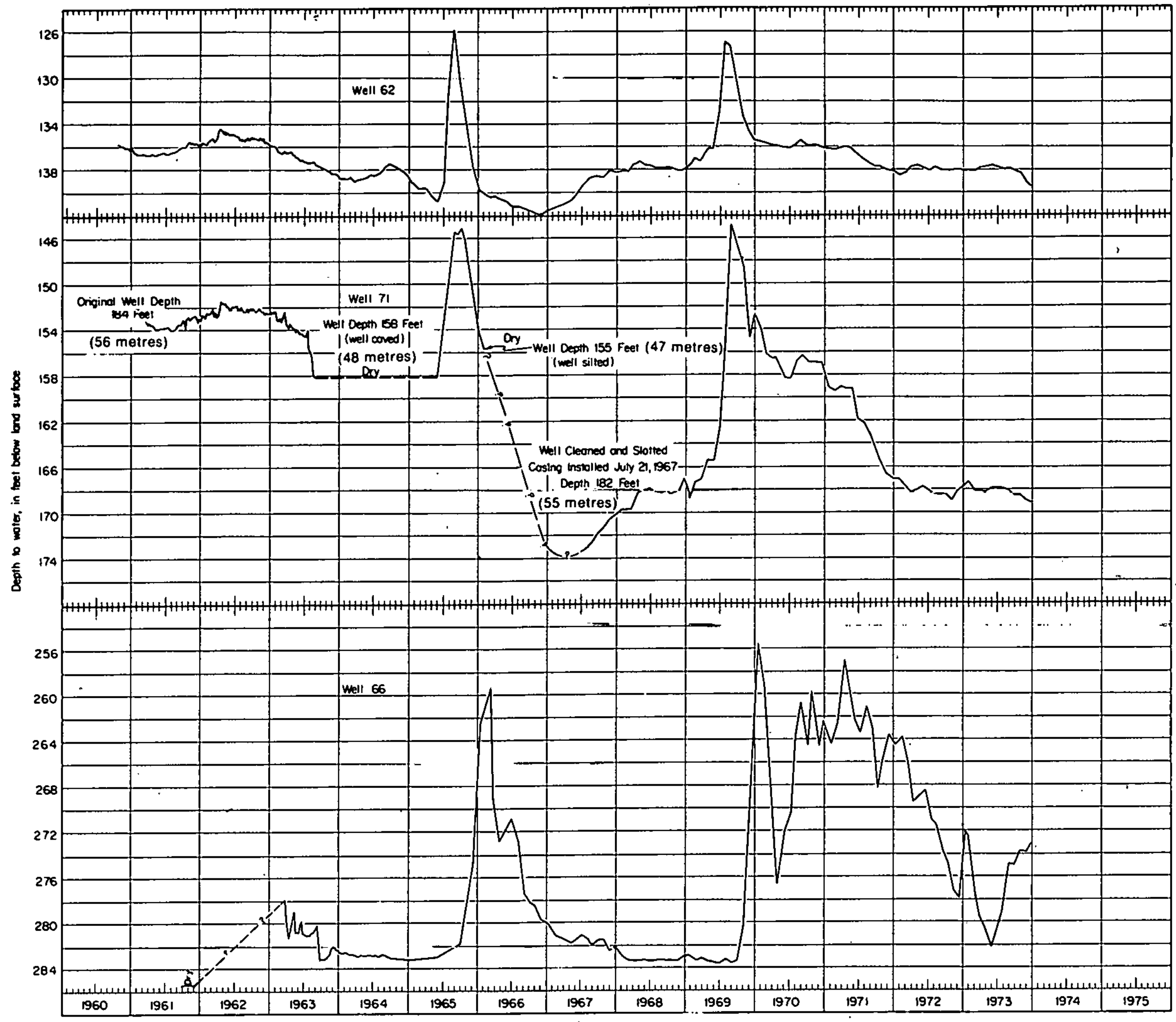


Fig. 23 Hydrographs of wells 62, 71, and 66, tapping the perched ground water in the basalt.

The tritium concentration in the perched ground water in the basalt for April 1971 is shown in Figure 27. The concentrations are highest beneath the radioactive waste ponds and decrease outward. The tritium concentration for October 1972 is shown in Figure 28. In 18 months, the tritium concentrations near the ponds have been reduced by about one-half. These and previous figures illustrate the dynamic nature of the perched-water body in the basalt. Changes in waste concentrations discharged to the ponds produce changes in waste concentration in the perched water within months, especially nearer the ponds.

The relatively rapid movement of waste water from the ponds to the major perched-water body is illustrated in Figure 29. This figure shows the chromium-51 concentration in perched water for October 1972. During 1972, a total of 250 Ci of chromium-51 was discharged to the pond. The average concentration of chromium-51 discharged to the TRA radioactive waste ponds was 305 pCi/ml during 1972. The maximum permissible concentration of chromium-51 in drinking water is 2,000 pCi/ml [Kansas State Board of Health, Radiation Protection Regulations (1961)]. Chromium-51 discharge was

TABLE III

SELECTED RADIONUCLIDES DISCHARGED TO THE TRA RADIOACTIVE WASTE PONDS

Radionuclide	Curies (Ci) 1971[a]	1972[b]	1973[c]
Tritium	342	176	184
Strontium-90	14.7	9.36	4.23
Cesium-137	10.1	6.57	3.93
Cobalt-60	4.34	1.86	3.97
Total of all radionuclides	2,406	1,397	1,518

[a] U.S. Atomic Energy Commission (1974) (a)
[b] U.S. Atomic Energy Commission (1974) (b)
[c] U.S. Atomic Energy Commission (1974) (c)

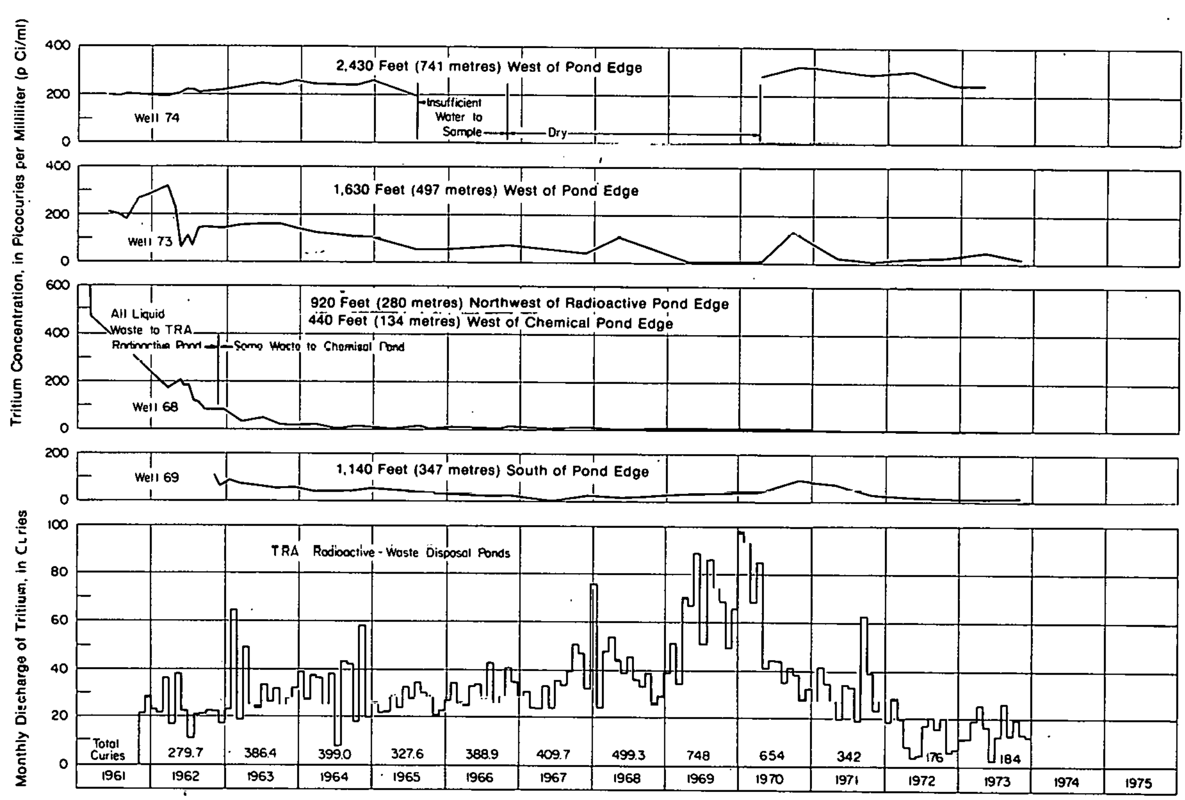


Fig. 24 Quantity of tritium discharged to the TRA ponds and the tritium concentrations of water from wells 74, 73, 68, and 69, tapping the perched ground water in the basalt.

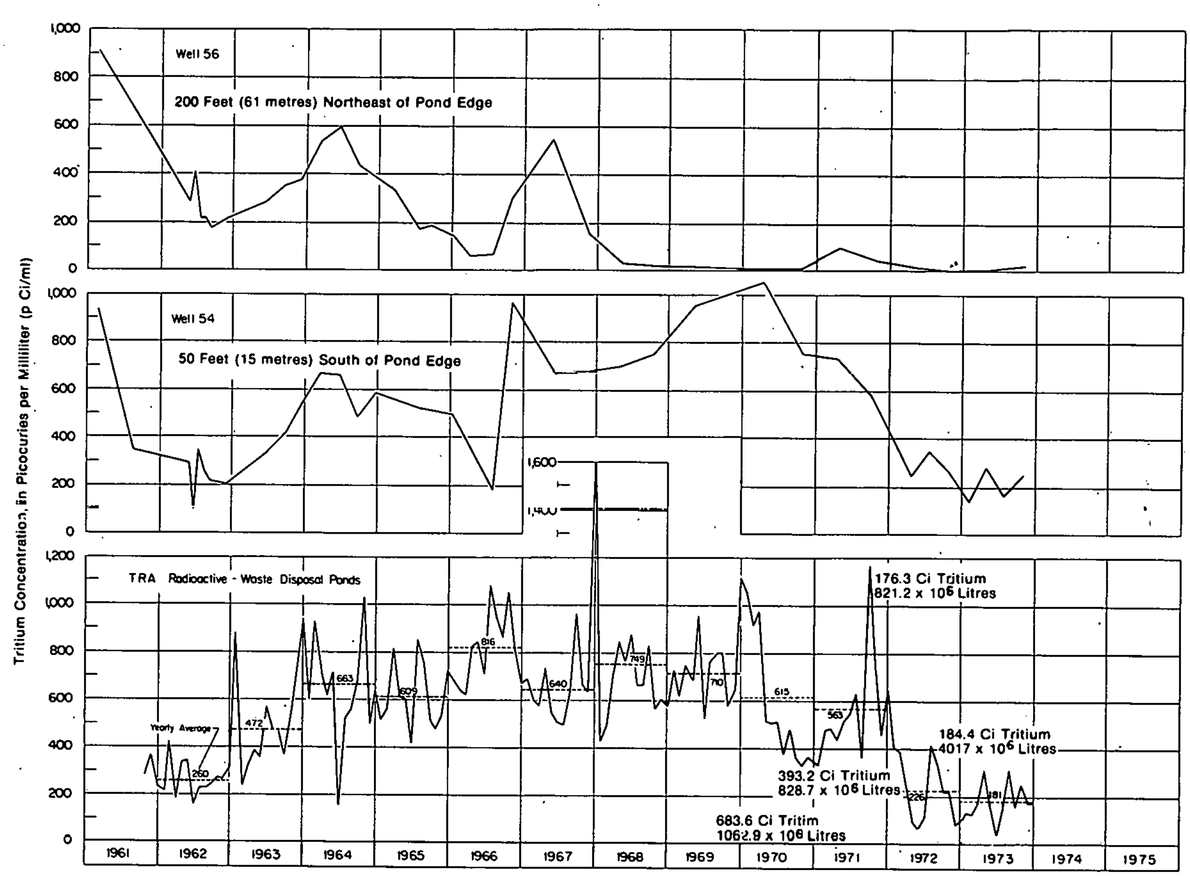


Fig. 25 Tritium concentrations of water from the TRA ponds and wells 56 and 54, tapping the perched ground water in the basalt.

18% of the total radioactive waste discharge at the TRA in 1972. Chromium-51 has a half-life of 27.8 days. Almost all of the chromium-51 would decay by seven half-lives (195 days, 6-1/2 months). Therefore, the waste chromium-51 percolates into the alluvium, through the perched ground water in the alluvium, into the perched ground water in the basalt, and as far as 0.25 mi (0.4 km) outward from the ponds all in less than seven months.

About 400 Ci of cobalt-60 have been discharged to the TRA radioactive waste ponds since 1952. This averages about 18 Ci per year. In 1972, less than 2 Ci of cobalt-60 were discharged to the ponds. In 1972, the average concentration of cobalt-60 discharged to the TRA radioactive waste ponds was about 2.3 pCi/ml. Figure 30 shows the cobalt-60 concentration in perched ground water for October 1972. The highest concentration of cobalt-60 (6.4 pCi/ml) is southeast of the pond and is probably a remnant of higher cobalt-60 discharges in the past. In 1972, the cobalt-60 discharge was 0.14% of the total radioactive discharge to the TRA ponds. The half-life of cobalt-60 is 5.3 years. The

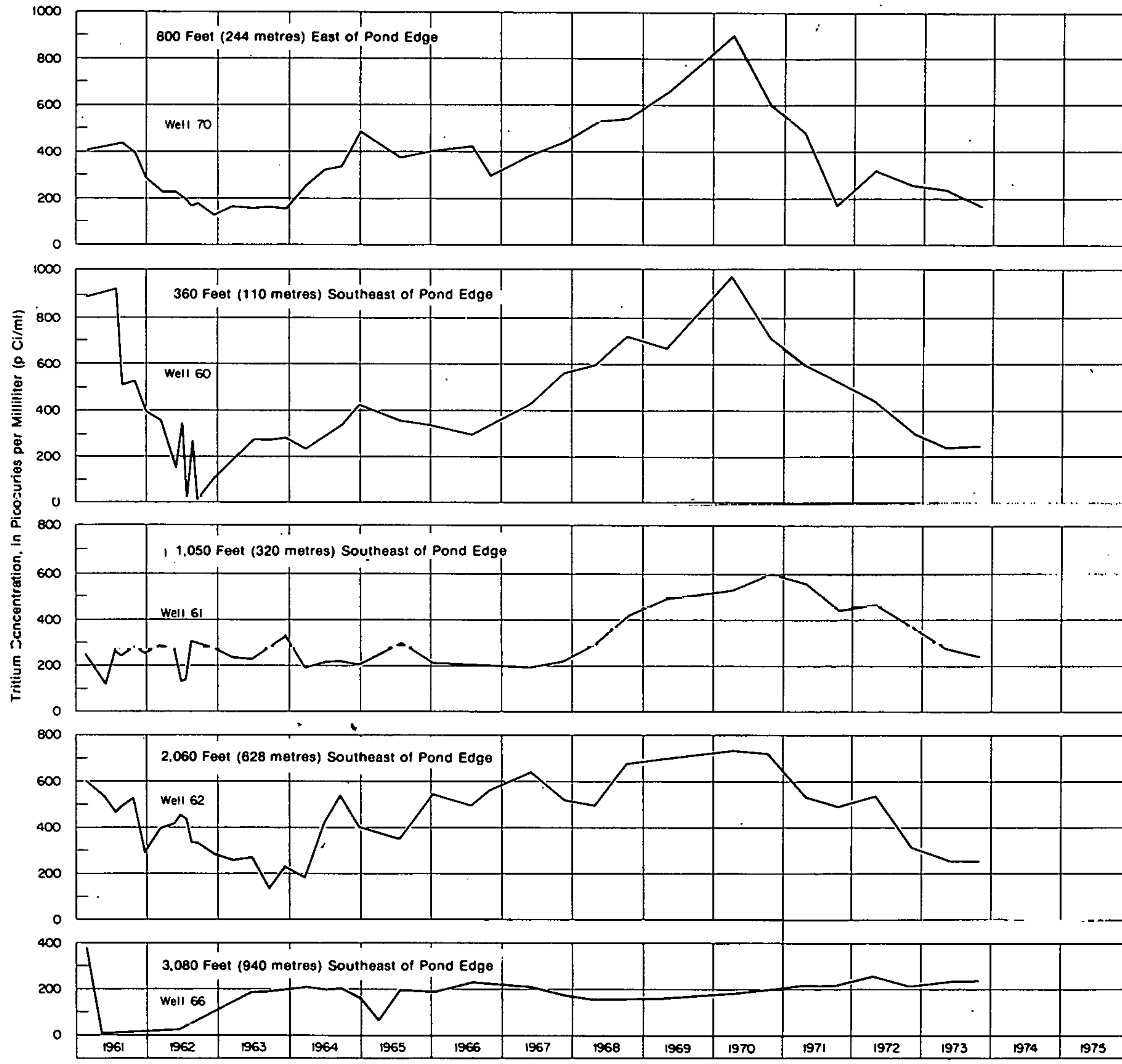


Fig. 26 Tritium concentrations of water from wells 70, 60, 61, 62, and 66, tapping the perched ground water in the basalt.

maximum permissible concentration of cobalt-60 in drinking water is 50 pCi/ml [Kansas State Board of Health, Radiation Protection Regulations (1961)].

About 65 Ci of strontium-90 has been discharged to the TRA radioactive waste ponds from 1952 to 1973. This is an average of about 3 Ci of strontium-90 per year. The discharge of strontium-90 was 15 Ci in 1971, 9 Ci in 1972, and 4 Ci in 1973. The average discharge over this three-year period was 9 Ci per year.

In 1972, the average concentration of strontium-90 discharged to the TRA radioactive waste ponds was 11 pCi/ml. On October 1972, the water from well 54 contained 0.817 pCi/ml of strontium-90. The Idaho Drinking Water Standards (1964) list the maximum permissible concentration of strontium-90 in drinking water as 0.01 pCi/ml.

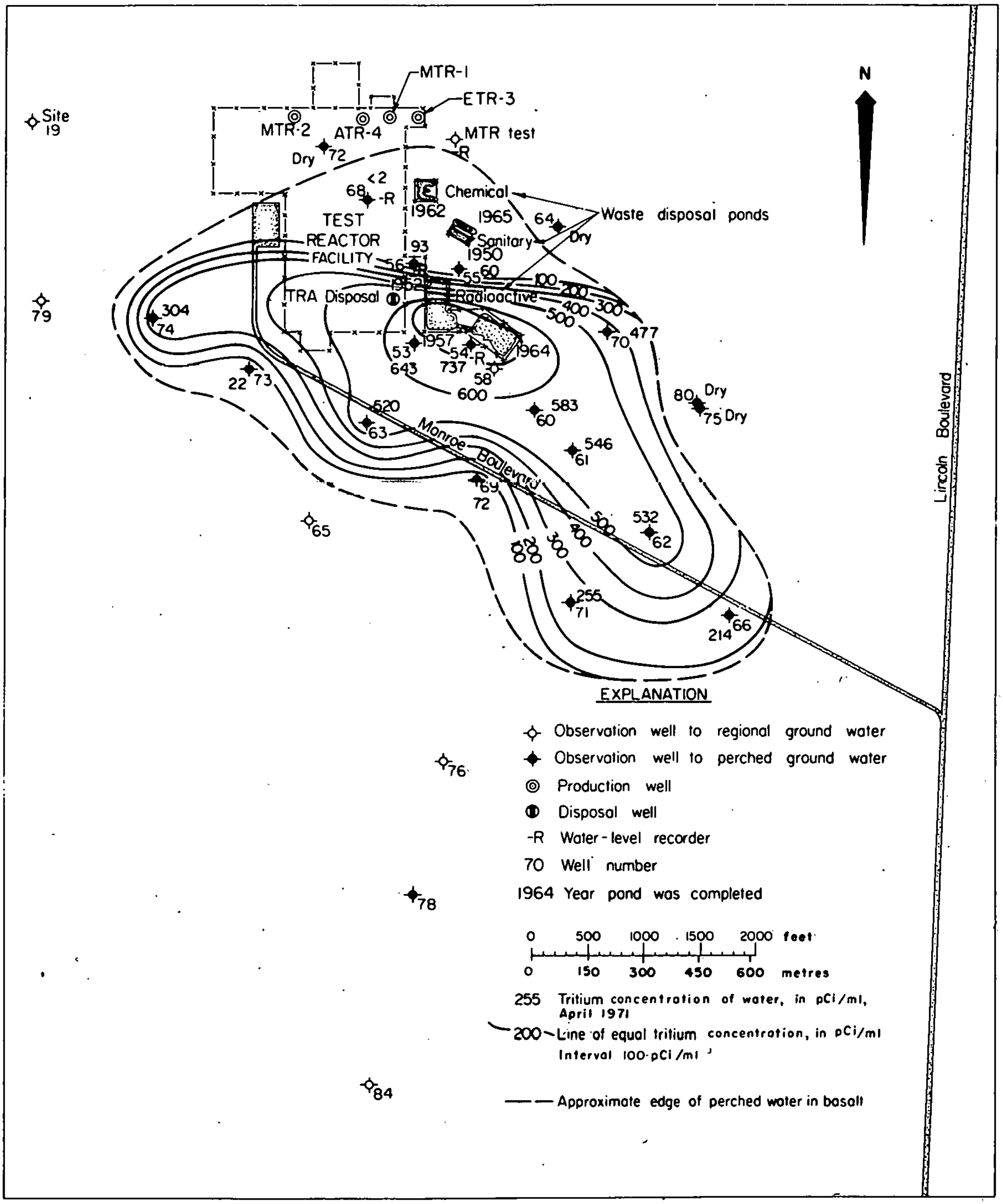


Fig. 27 Tritium concentration in the perched ground water in the basalt, April 1971, at TRA.

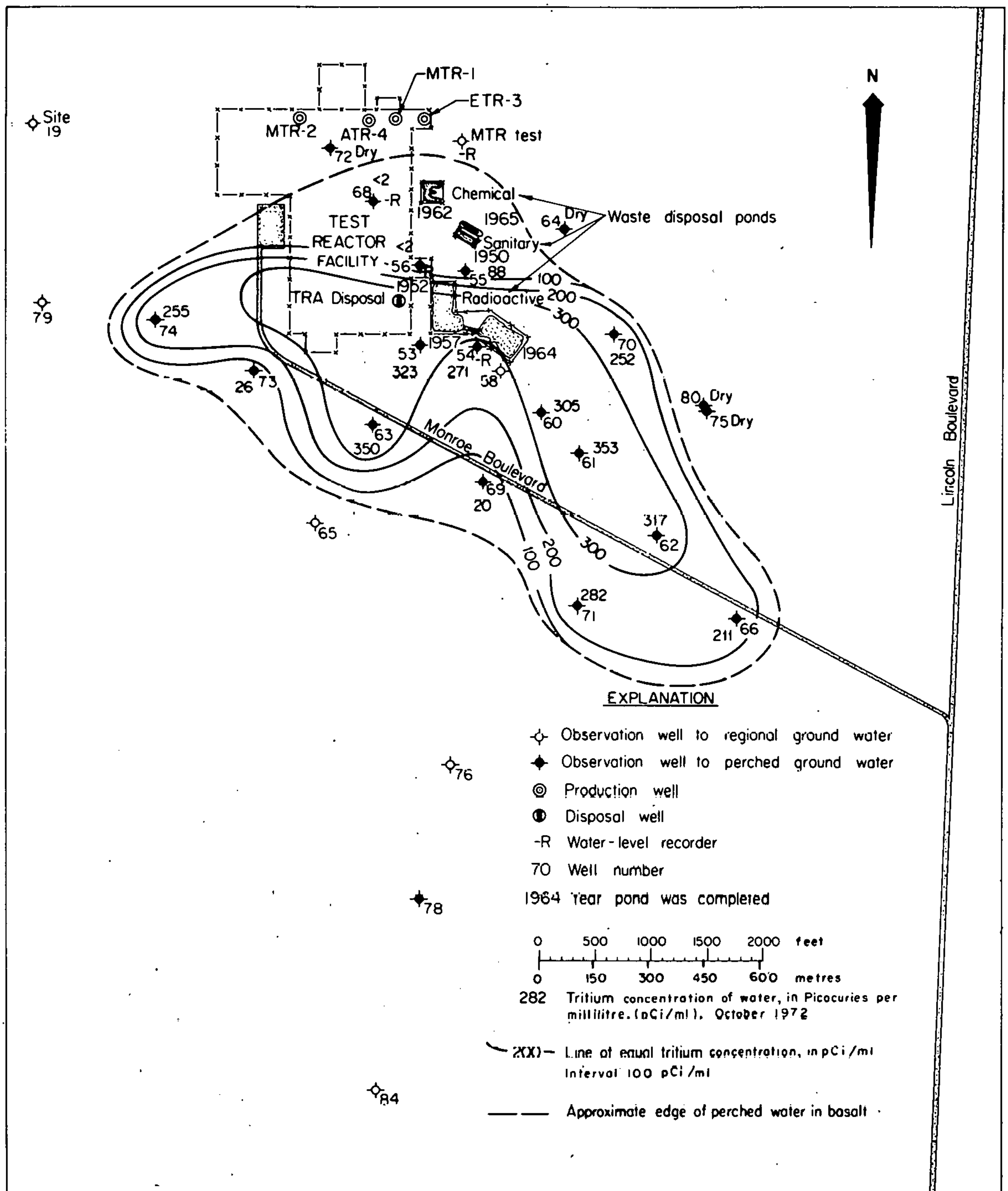


Fig. 28 Tritium concentration in the perched ground water in the basalt, October 1972, at TRA.

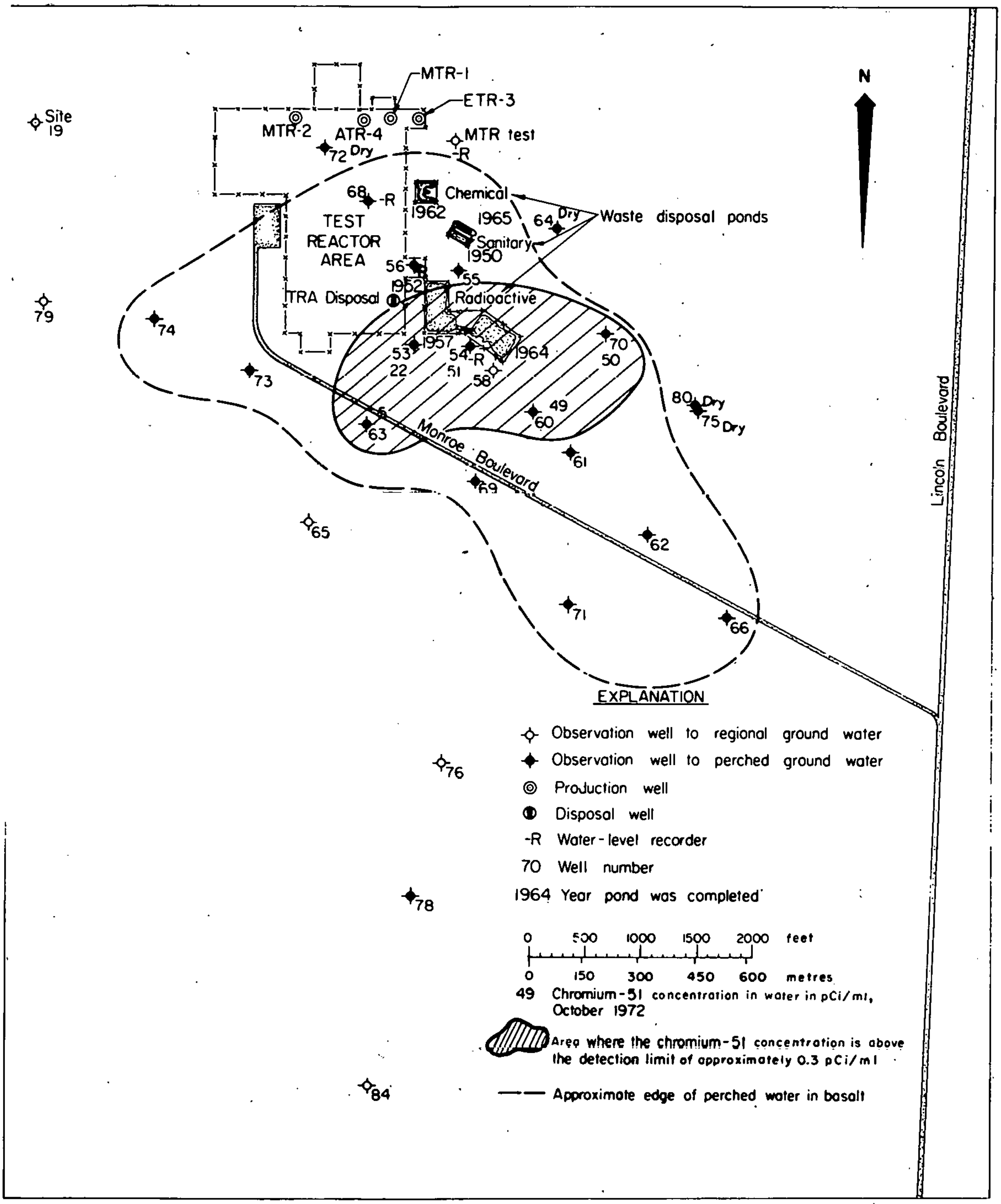


Fig. 29 Chromium-51 concentration in the perched ground water in the basalt, October 1972, at TRA.

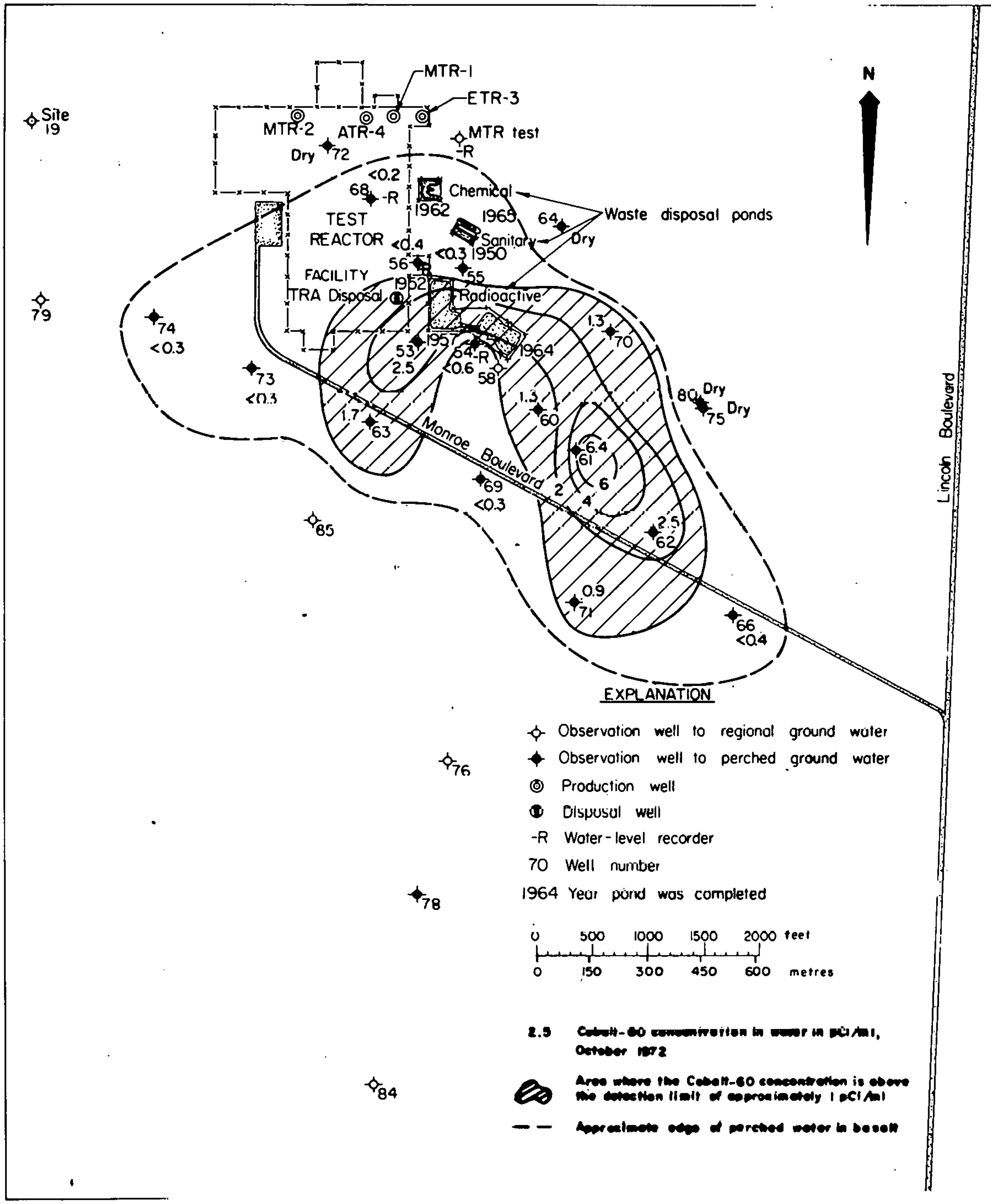


Fig. 30 Cobalt-60 concentration in the perched ground water in the basalt, October 1972, at TRA.

The distribution of strontium-90 in the perched ground water in the basalt for October 1972 is shown in Figure 31. Strontium-90 extends outward from the ponds and was determined in water samples from six shallow wells. The strontium-90 concentration of water samples from the other wells was below the detection limit. Strontium-90 can be detected about 1,000 ft (305 m) outward from the edges of the ponds. Sorption plays an important role in removing the strontium-90 from the perched-water body [Robertson, Schoen, and Barraclough (1974)].

Cesium-137 has been discharged at TRA in slightly larger quantities than strontium-90 over the period of 1952 through 1973. Approximately 111 Ci has been discharged during this period. The discharge of cesium-137 was 10.1 Ci in 1971, 7 Ci in 1972, and 4 Ci in 1973. This is an average of about 7 Ci per year. Cesium-137 has a slightly longer half-life (30.2 years) than strontium-90.

Because of the similar half lives, quantities disposed, and other properties, one would expect distribution of cesium-137 in the perched water would be similar to the distribution of strontium-90, as shown in Figure 29. However, cesium-137 has never been detected in a water sample from the perched ground water in the basalt. Cesium-137 is strongly sorbed to the minerals in the alluvial sediments, basalt, and interbeds before reaching the perched-water body [Robertson, Schoen, and Barraclough (1974)].

No other radioactive waste nuclides have been detected in the perched ground water. They are either sorbed on the earth materials, have too short a half-life, or are not discharged in sufficient quantities to be detectable.

1.2 Chemical Waste Ponds

A pond has been utilized since 1962 to dispose of chemical (nonradioactive) wastes from ion-exchange system regeneration. The average disposal during 1971 to 1973 was 50 million gal (1.9×10^8 l) per year. During 1971 to 1973, the wastes consisted of a yearly average of 1,194,000 lb (542,000 kg) of sulfate, 188,000 lb (85,000 kg) of sodium, 54 lb (24 kg) of sulfite, and 28 lb (13 kg) of phosphate [U.S. Atomic Energy Commission (1975)].

The chemical waste pond water has a high specific conductance because of the amount of dissolved chemicals. Figure 32 shows the specific conductance of samples from the perched ground water in basalt for October 1972. The higher specific conductance values are from water which has infiltrated to the perched aquifer from the chemical waste pond which moves outward and then to the southwest. The specific conductance of the fluid in the radioactive waste pond is low and that water dictates the contour of the high conductance water.

1.3 Deep Disposal Well

A 1,275-ft (388 m) deep disposal well has been used at the TRA since 1964 to dispose of about 150 million gal (5.7×10^8 l) per year of nonradioactive waste water. Most of this

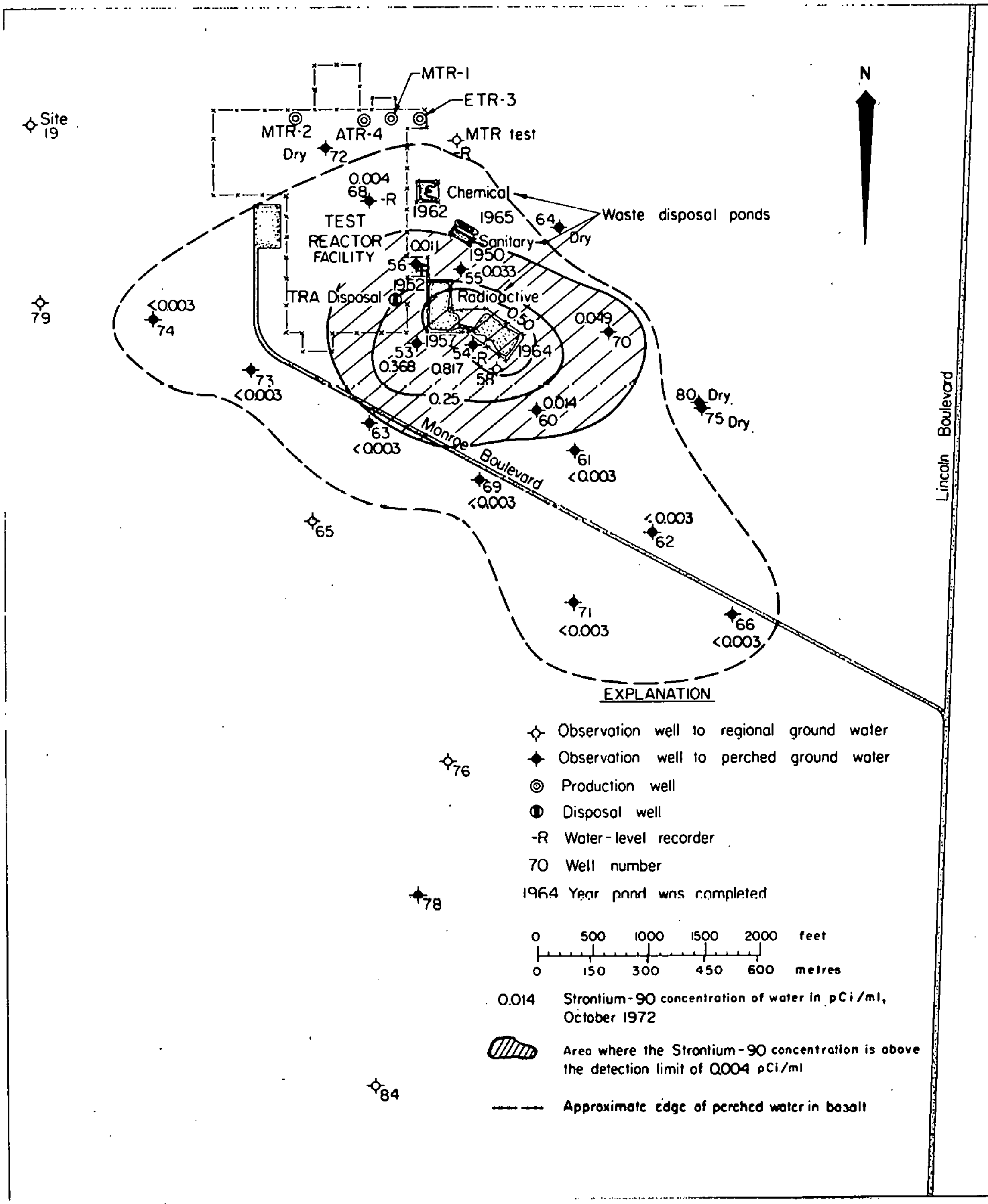


Fig. 31 Strontium-90 concentration in the perched ground water in the basalt, October 1972, at TRA.

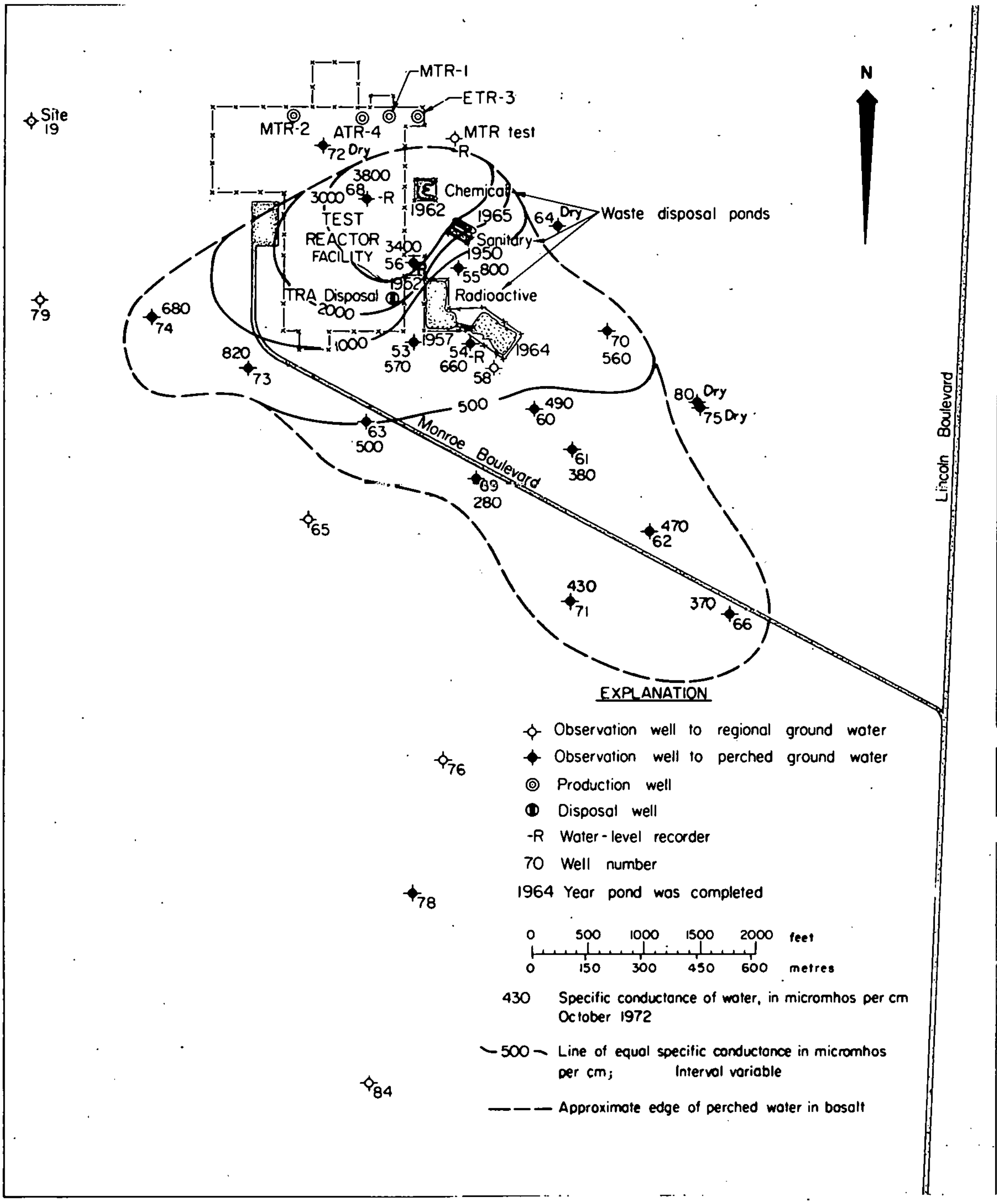


Fig. 32 Specific conductance of samples from the perched ground water in the basalt, October 1972, at TRA.

water is derived from cooling tower blowdown and contains a yearly average of 617,000 lb (280,000 kg) of sulfate and 22,000 lb (10,000 kg) of various other chemicals [U.S. Atomic Energy Commission (1975)]. From January 1971 until October 1972, a total of 4,800 lb (2,200 kg) of hexavalent chromium was discharged. The average concentration of hexavalent chromium was about 2.2 mg/l. The chromium was used as a corrosion inhibitor. This has been replaced by a polyphosphate treatment which began in October 1972.

Figure 20 shows the monthly discharge to the waste-disposal well from 1964 through 1973 except for a brief period in 1970 and 1971. The average discharge from 1971 through 1973 was 158 million gal (6.0×10^8 l) per year. The discharge increased to 209 million gal (7.9×10^8 l) in 1973.

The well discharges directly into the Snake River Plain aquifer. The water level is about 450 ft (137 m) below the land surface. Some of the effects of this discharge on the Snake River Plain aquifer is similar to that discussed in the following section on the ICPP and shown in Figures 35, 36, and 37. Because of this similarity, the details that apply to the ICPP well also apply to the TRA disposal well.

2. 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 600-ft (180 m) disposal well. The natural water level is about 450 ft (137 m) below the land surface. The average yearly discharge to the well was about 300 million gal (1.1×10^9 l).

Most of the radioactivity of this waste is removed by distillation and ion exchange before it is discharged into the well. More tritium has been discharged than any other waste isotope.

During the period of 1971 through 1973, the ICPP well was utilized to discharge 404 Ci of radioactivity in 960 million gal (3.63×10^9 l) of water. The average curie concentration was 135 Ci per year, and the average water discharge was 320 million gal (1.21×10^9 l) per year. The discharged in 1971 containcd 62 Ci; in 1972, 308 Ci; and in 1973, 34 Ci. About 96% of the activity was tritium, and 0.10% was strontium-90. The remainder was unidentified beta and gamma activity.

The distribution of waste tritium in the Snake River Plain aquifer for October 1972 is shown in Figure 33. The waste plume illustrates the wide dispersion angle and the preferred southward flow. The waste plume from the ICPP well covers about 15 mi^2 (30 km^2). The highest tritium values were found around the ICPP disposal well, south of the ICPP and south of the TRA. The maximum allowable concentration limit of tritium in public drinking water is 3,000 pCi/ml [Kansas State Board of Health, Radiation Protection Regulations (1961)]. The map also shows the tritium plume as a result of infiltration from the TRA ponds. Since disposal began, the wastes have migrated about 5 mi (8 km) downgradient from the disposal well and ponds.

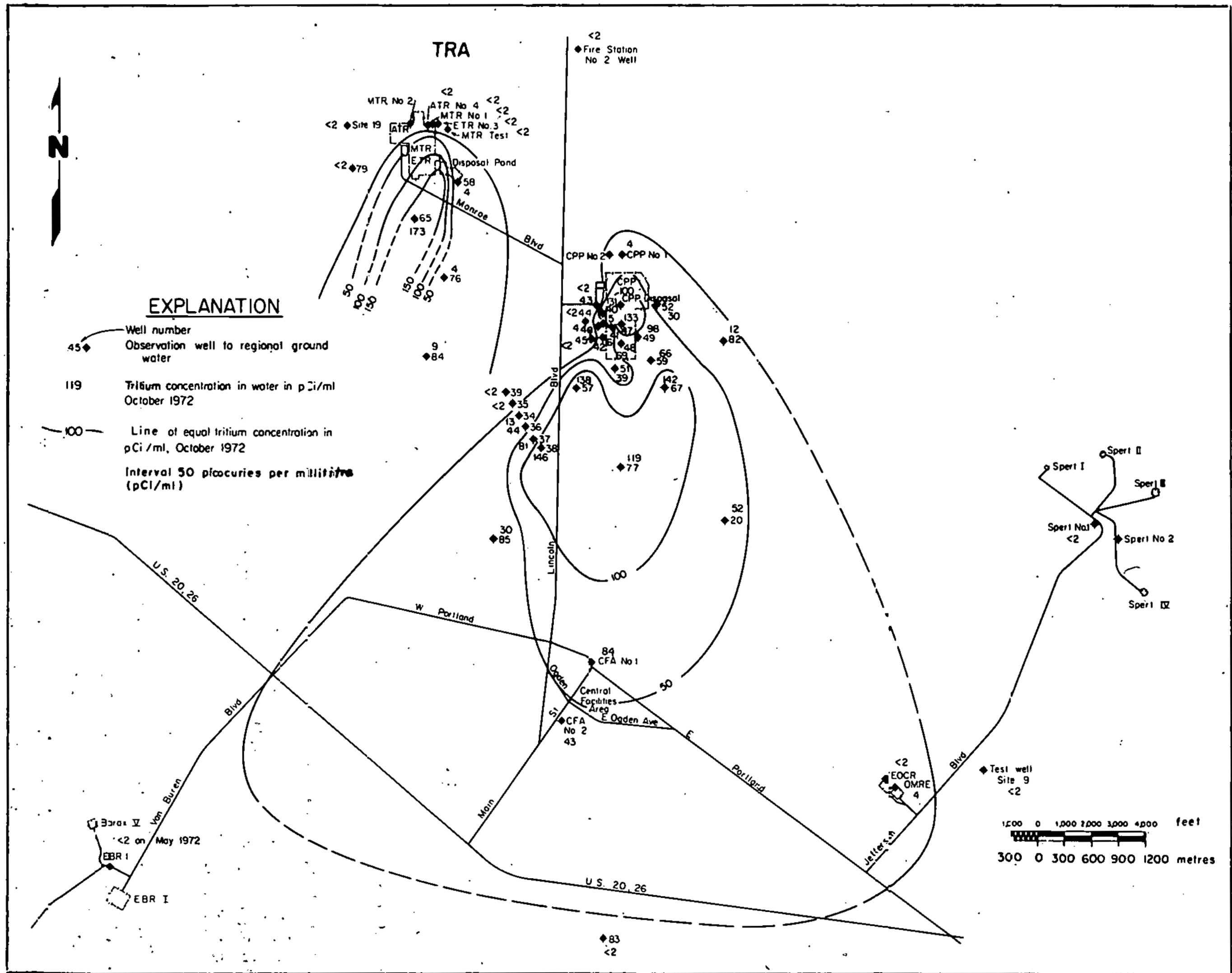


Fig. 33 Distribution of tritium in the Snake River Plain aquifer, October 1972, ICPP-TRA vicinity.

The decay of tritium in the Snake River Plain aquifer slightly exceeds addition of tritium to the aquifer resulting from recent discharges; thus the total quantity of tritium in the ground water is being reduced. The concentrations of tritium between ICPP and CFA have been reduced over the past several years.

A total of about 18 Ci of strontium-90 has been discharged to the ICPP well from 1952 through 1973. The current discharge of strontium-90 is even less. For example, in 1971, a total of 0.068 Ci of strontium-90 was discharged to the ICPP well (0.11% of the radioactivity discharged).

Figure 34 is a map of the strontium-90 distribution in the Snake River Plain aquifer as a result of discharge to the ICPP disposal well. The strontium-90 plume covers about 1.5 mi^2 (4 km^2) and has been detected about 1 mi (1.6 km) southwest of the disposal well.

More strontium-90 has been discharged to the TRA ponds than to the ICPP well. The strontium-90 appears to be sorbed out of solution as the waste moves from the ponds through the sediments and basalts down to the Snake River Plain aquifer. No strontium-90 has ever been detected in water from the aquifer near the TRA (Figure 34).

A quantity of cesium-137 similar to that of strontium-90 has been discharged to the ICPP disposal well. However, it is sorbed more readily than strontium-90. Cesium-137 has never been detected in any aquifer samples near the ICPP or TRA. After 21 years of disposal, detectable quantities of cesium-137 have not migrated as far as 700 ft (213 m) away from the well.

Chemical wastes are discharged to the ICPP disposal well. During 1971 to 1973, the annual average discharge of these wastes contained 320 tons (290,000 kg) of sodium chloride, 73,000 lb (33,000 kg) of sulfate, and 1,360 lb (617 kg) of sulfite and phosphate. During 1973, 101,000 lb (45,800 kg) of nitrate was discharged [U.S. Atomic Energy Commission (1975)]. These wastes increase the specific conductance of the water.

Figure 35 shows the distribution of the specific conductance in the Snake River Plain aquifer for October 1972. The plume of specific conductance is similar to the waste plume of tritium (Figure 33). The highest concentrations occur around the ICPP well and south of the ICPP. Figure 35 also shows the increase in specific conductance around the TRA.

During 1971 to 1973, an average of 254,500 lb (115,400 kg) of sodium was discharged to the ICPP disposal well annually. The discharge has been rather uniform over the years. The average concentration of sodium in the waste water is around 103 mg/l. The background or normal concentration of sodium in water from the Snake River Plain aquifer that does not contain any waste products is 8 to 10 mg/l. Figure 36 shows the sodium concentration in the Snake River Plain aquifer for October 1972. The sodium concentration is almost 50 mg/l near the well and the sodium plume covers much of the area covered by the tritium plume. A slight increase in sodium is noted at the TRA in Figure 36. The sodium in the water is subject to sorption and the ratio of sodium to chloride decreases downgradient.

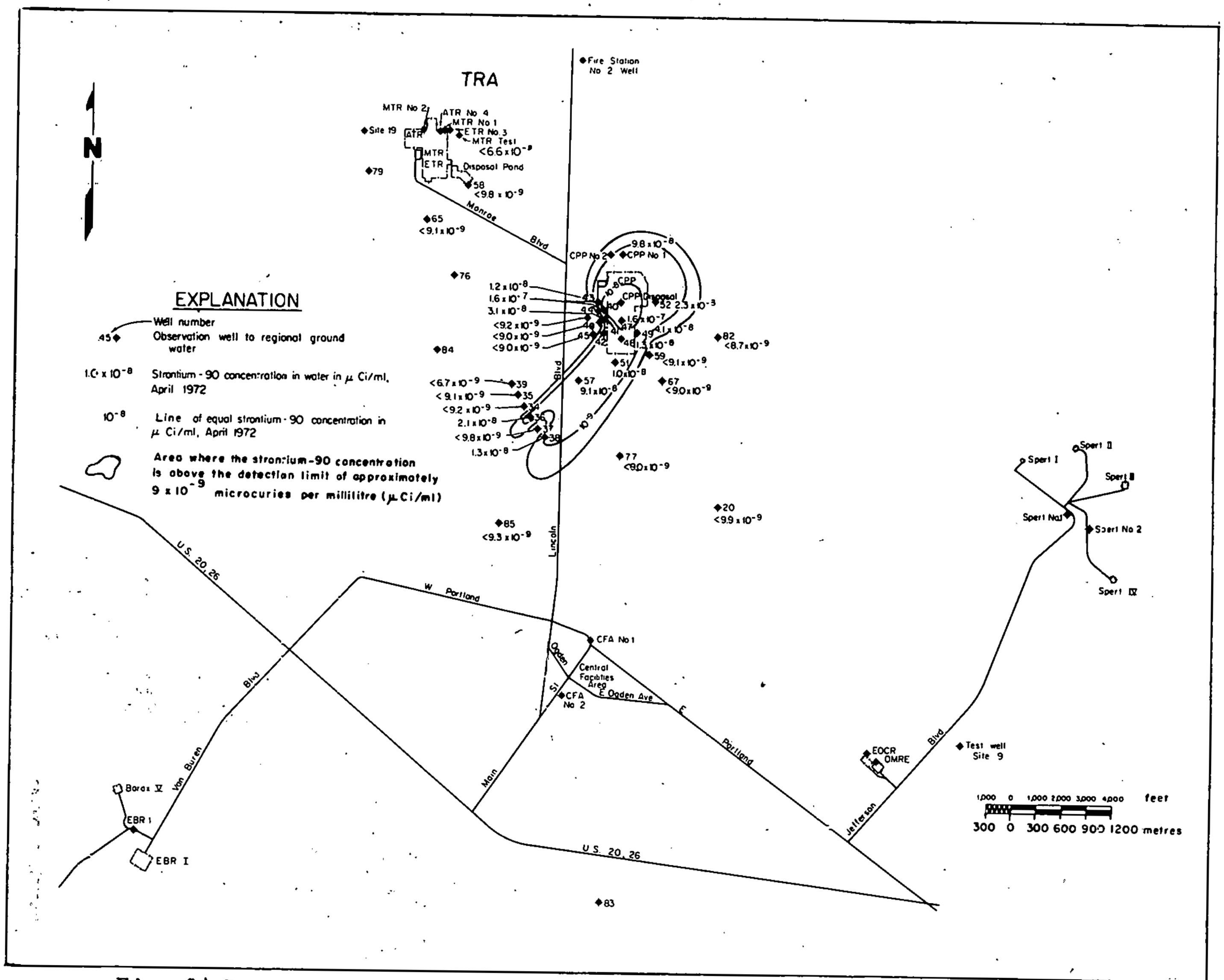


Fig. 34 Distribution of strontium-90 in the Snake River Plain aquifer, April 1972, ICPP-TRA vicinity.

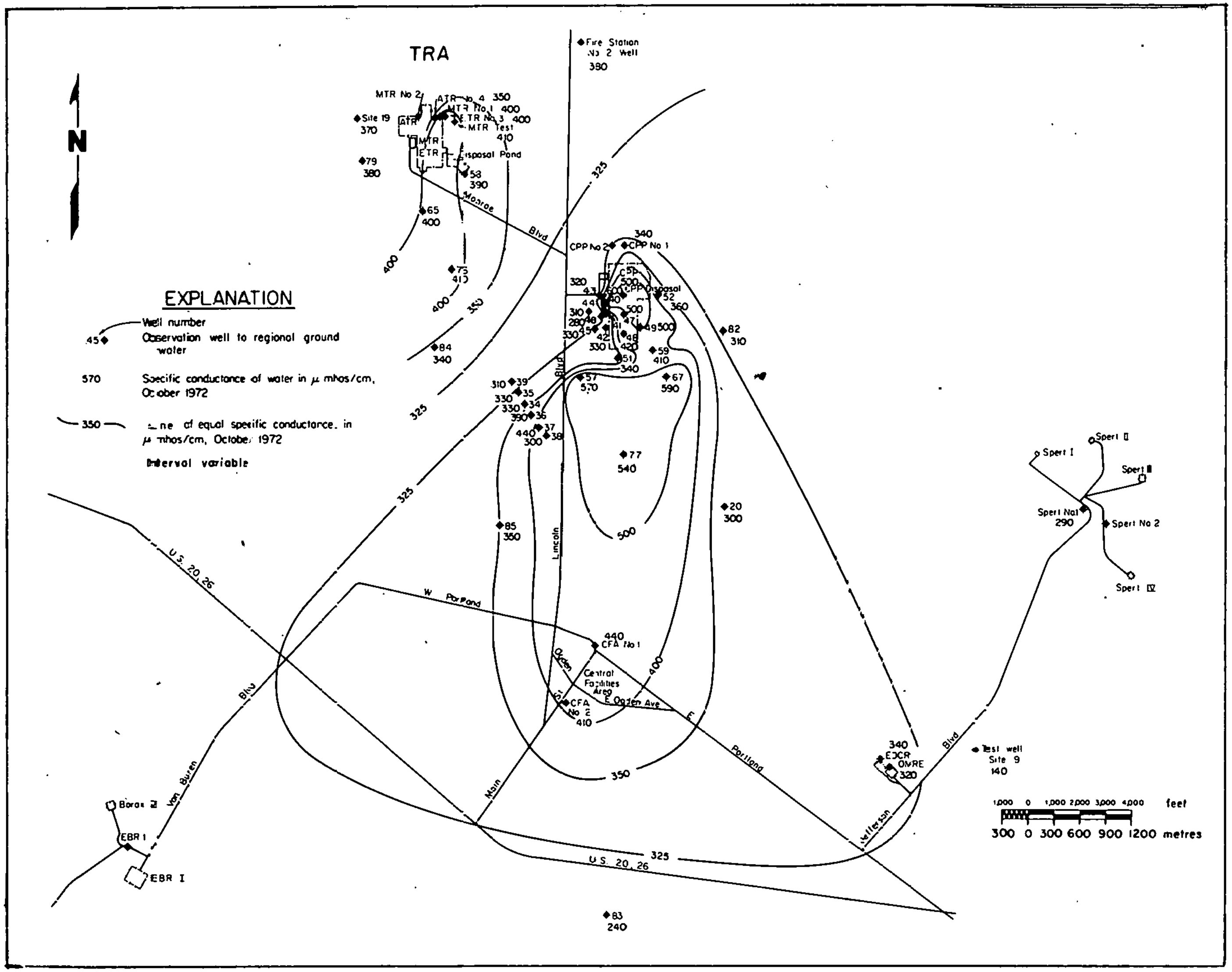


Fig. 35 Distribution of specific conductance in the Snake River Plain aquifer, October 1972, ICPP-TRA vicinity.

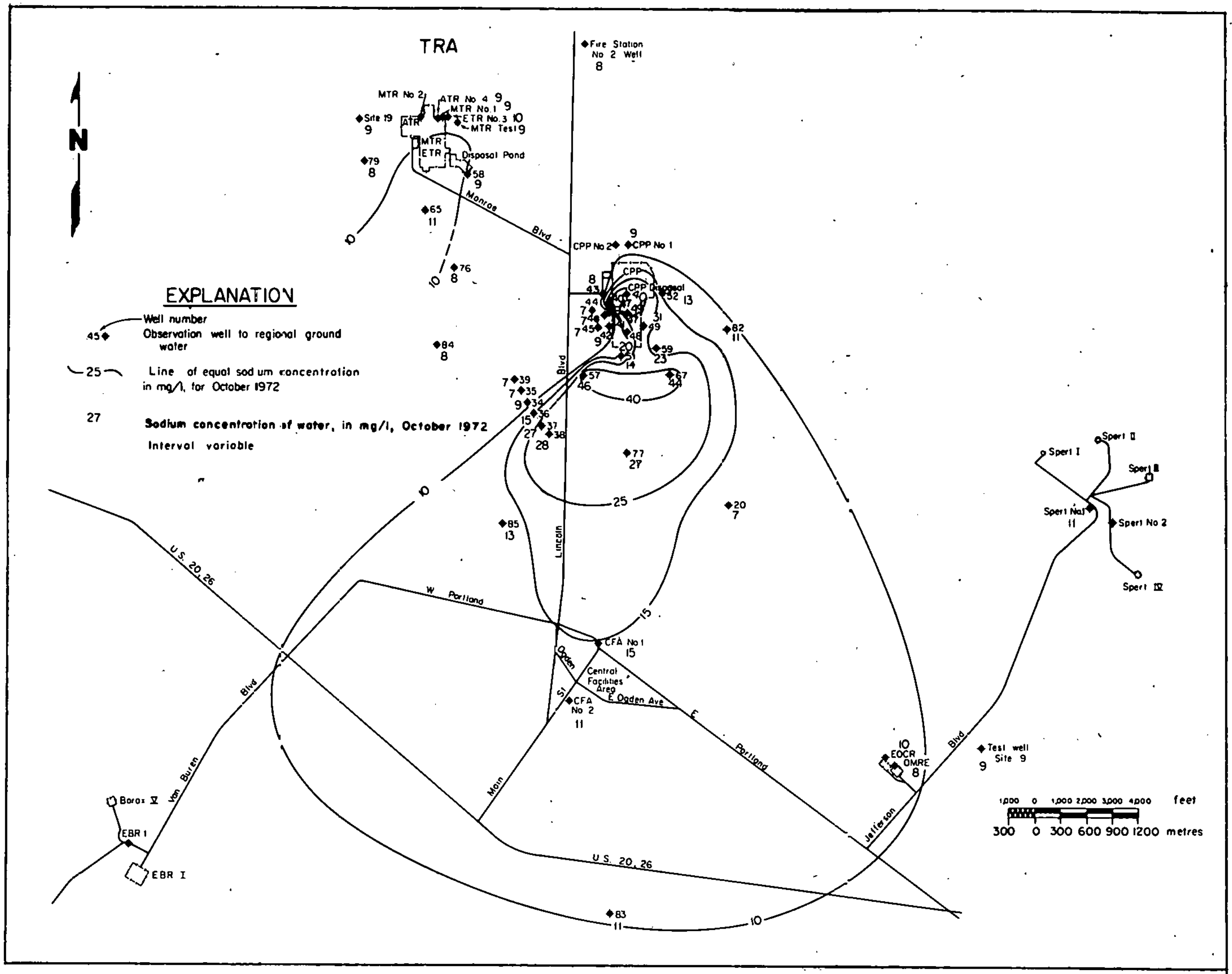


Fig. 36 Distribution of waste sodium in the Snake River Plain aquifer, October 1972, ICPP-TRA vicinity.

During 1971 to 1973, an average of 386,000 lb (175,000 kg) of waste chloride was discharged to the ICPP disposal well. The average concentration was 156 mg/1. The background or normal concentration of chloride in the Snake River Plain aquifer not containing waste chloride is between 8 and 15 mg/1. The Idaho Drinking Water Standards (1964) list the maximum permissible concentration of chloride in drinking water at 250 mg/l.

Figure 37 shows the distribution of waste chloride in the Snake River Plain aquifer on October 1972. The highest chloride values are found around the ICPP disposal well and south of the ICPP. Figure 37 also shows the increase in chloride around the TRA.

The waste plumes south of the ICPP containing tritium, sodium, chloride, and the specific conductance all cover nearly similar areas and show corresponding concentrations. This redundancy of data implies that the waste plumes have been mapped in general detail and follow the southerly flow lines with a wide dispersion angle. The waste plumes south of the TRA are generally similar but not very well defined because of the lack of observation wells and recharge from the nearby Big Lost River.

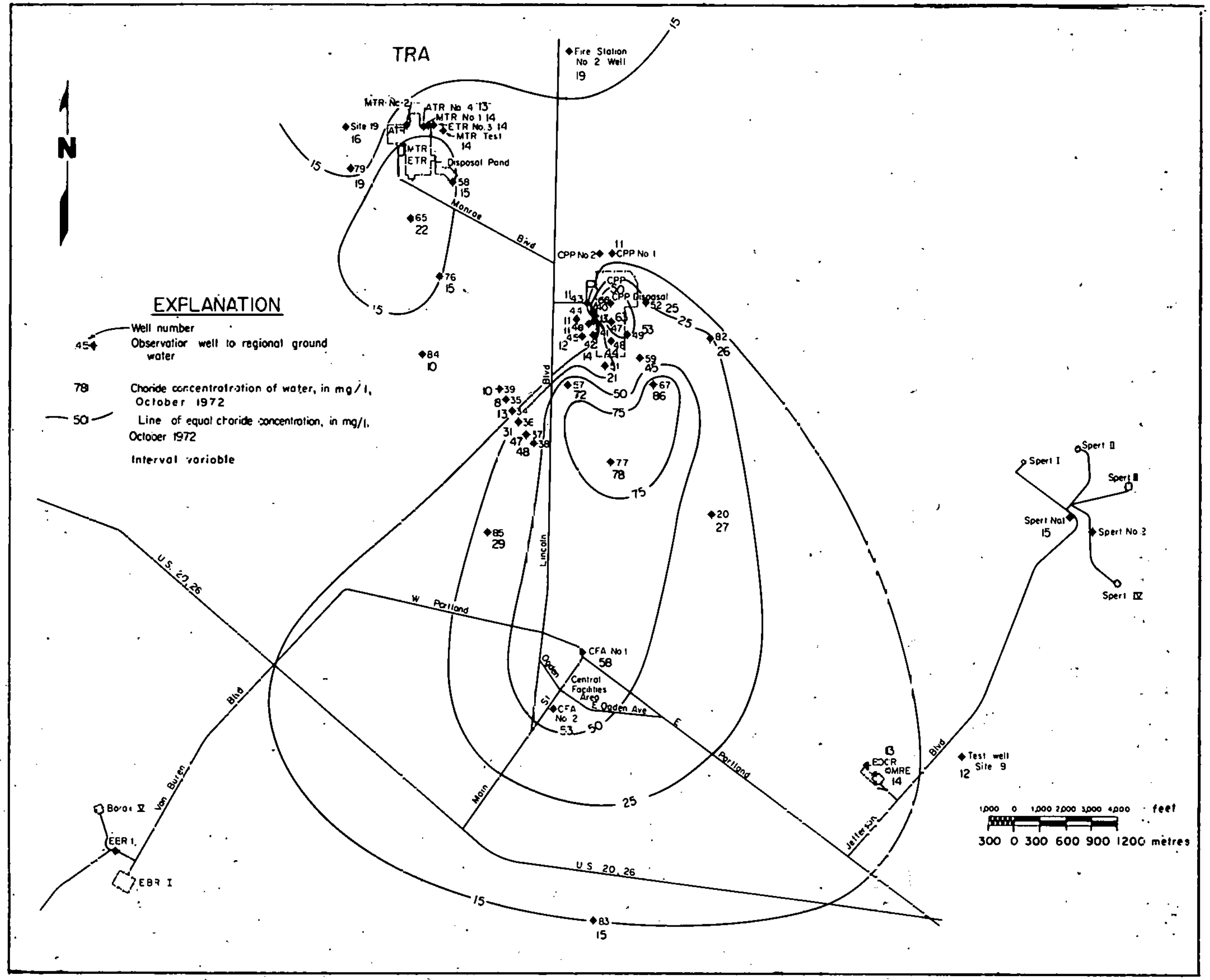


Fig. 37 Distribution of waste chloride in the Snake River Plain aquifer, October 1972, ICPP-TRA vicinity.

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