UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

LOW-LEVEL RADIOACTIVE CONTAMINATION FROM A COLD-SCRAP RECOVERY OPERATION, WOOD RIVER JUNCTION, RHODE ISLAND

Open-File Report 84-066

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By Barbara J. Ryan and Kenneth L. Kipp, Jr.

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TABLE OF CONTENTS

(for review purposes only)

Low-Level Radioactive Ground-Water Contamination from a Cold Scrap Recovery Operation Wood River Junction, Rhode Island

Barbara J. Ryan and Kenneth L. Kipp, Jr.

ABSTRACT

Liquid wastes from a uranium-bearing cold scrap recovery plant at an industrial site in Wood River Junction, Rhode Island were discharged to the environment through evaporation ponds from 1966-1980. Leakage from the polyethylene- and polyvinylchloride-lined ponds resulted in a plume of contaminated ground water that extends from the ponds northwestward to the Pawcatuck River through a highly permeable sand and gravel aquifer of glacial origin.

Electrical conductivities, determined by electromagnetic methods, were used to delineate the plume areally before observation wells were installed. These data, in combination with water quality data from more than 100 observation wells, indicate that the plume is approximately 2300 feet long, 300 feet wide, and is confined to the upper 80 feet of saturated thickness where sediments consist of medium to coarse sand and gravel. No contamination has been detected in fine sands and silts underlying the coarser materials. Piezometric-head and water-quality data from wells screened at multiple depths on both sides of the river indicate that contaminants discharge both to the river and to a swampy area at the west edge of the river. Dilution precludes detection of contaminants once they have entered the river, which has an average flow of 193 cubic feet per second.

Water quality data collected from April 1981 to June 1983 indicate strontium 90, technetium 99, boron, nitrate, and potassium exceed background concentrations by an order of magnitude in much of the plume. Concentrations of gross beta emitters range from 5 to 500 picoCuries per liter. No gamma emitters above detection levels have been found. Electrical conductivity of the water ranges from 150 to 4500 micromhos per centimeter at 25 degrees Celsius. Water quality sampling shows zones of concentrated contaminants at both ends of the plume, separated by a zone of less contaminated water. Laboratory tests of exchangeable cations indicate little capacity for uptake on the coarse sediments.

INTRODUCTION

Liquid wastes containing both radionuclides and other chemical solutes from an enriched uranium cold scrap recovery plant have leaked from polyethylene- and polyvinylchloride-lined ponds and trenches into a highly permeable sand and gravel aquifer in southern Rhode Island. The resultant plume of ground-water contamination extends about 2300 feet from the lagoons to the Pawcatuck River and contiguous swamp into which ground-water discharge occurs. In 1981, the U.S. Geological Survey began a three-year study of this ground-water contamination at a plant at Wood River Junction, Rhode Island (fig. 1). The objectives of the study are to: (1) identify constituents in the plume, (2) determine solute interaction with aquifer materials, (3) model ground water flow and solute tranport in the study area, and (4) use the model to predict residence times in the aquifer and fate of contaminants in the plume.

Contaminated ground water at this site moves through a highly permeable glacial outwash aquifer which yields water readily to wells. The Rhode Island Water Resources Board has done test drilling around Wood River Junction and has considered developing ground water from the Meadow Brook Pond area for use both within and outside the basin. The possibility that supply wells might be contaminated as a result of migration of contaminated water beneath the Pawcatuck River is of concern to the Water Resources Board.

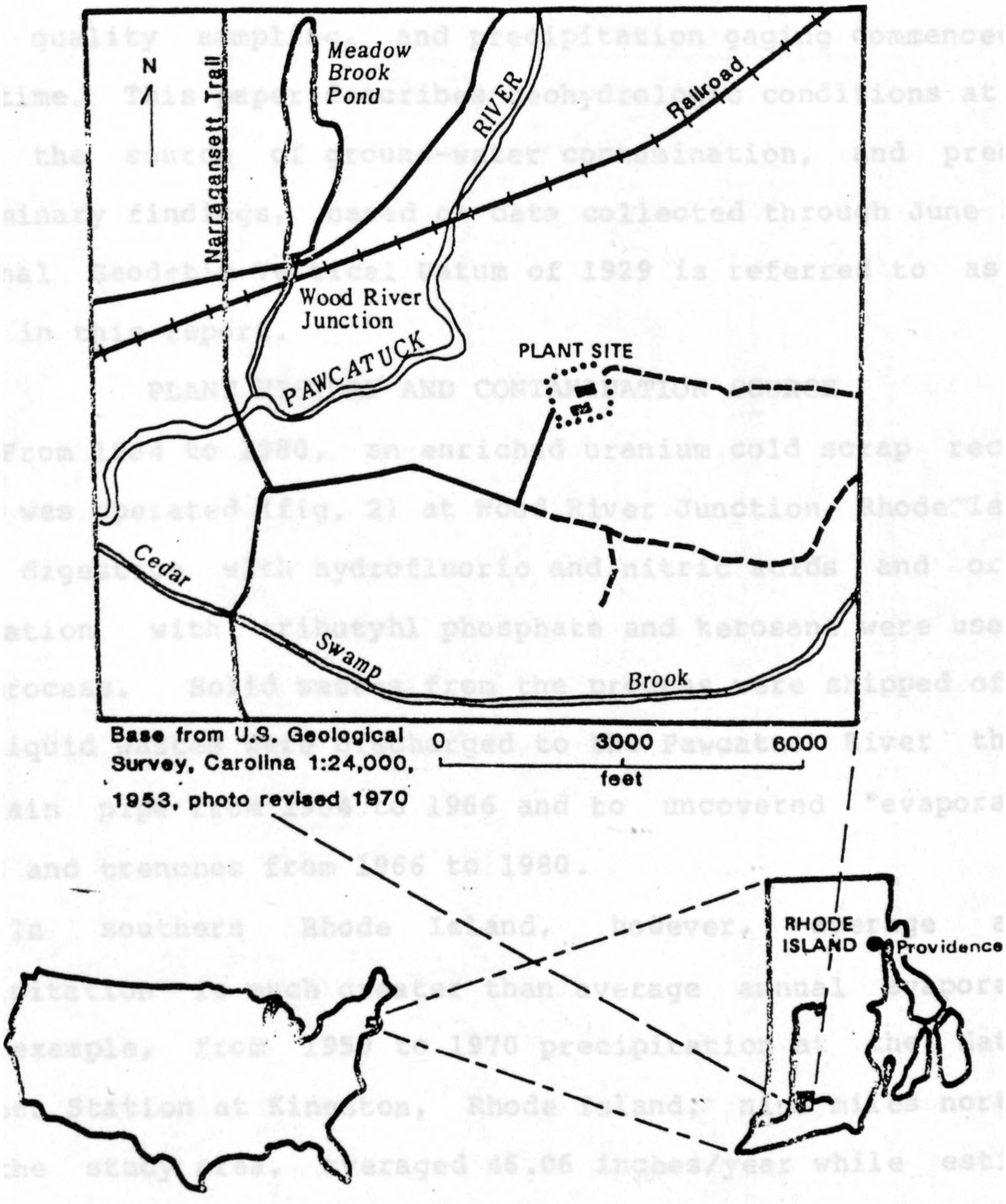


Figure 1. Location of study area.

By October 1982 most of the data collection network for the investigation was in place and routine water level measurements, water quality sampling, and precipitation gaging commenced at that time. This paper describes geohydrologic conditions at the site, the source of ground-water contamination, and presents preliminary findings, based on data collected through June 1983. National Geodetic Vertical Datum of 1929 is referred to as sea level in this report.

PLANT HISTORY AND CONTAMINATION SOURCE

From 1964 to 1980, an enriched uranium cold scrap recovery plant was operated (fig. 2) at Wood River Junction, Rhode Island. Acid digestion with hydrofluoric and nitric acids and organic separation with tributyhl phosphate and kerosene were used in the process. Solid wastes from the process were shipped offsite and liquid wastes were discharged to the Pawcatuck River through a drain pipe from 1964 to 1966 and to uncovered "evaporation" ponds and trenches from 1966 to 1980.

In southern Rhode Island, however, average annual precipitation is much greater than average annual evaporation. For example, from 1950 to 1970 precipitation at the National Weather Station at Kingston, Rhode Island, nine miles northeast of the study area, averaged 46.06 inches/year while estimated annual free water surface evaporation for the same period was only 29 inches/year (NOAA Technical Report NWS 33). This fact, and the fact that highly permeable sediments occur beneath the ponds, indicates that much of the liquid waste discharged to the ponds and trenches did not evaporate but rather percolated into unconsolidated deposits beneath the site.

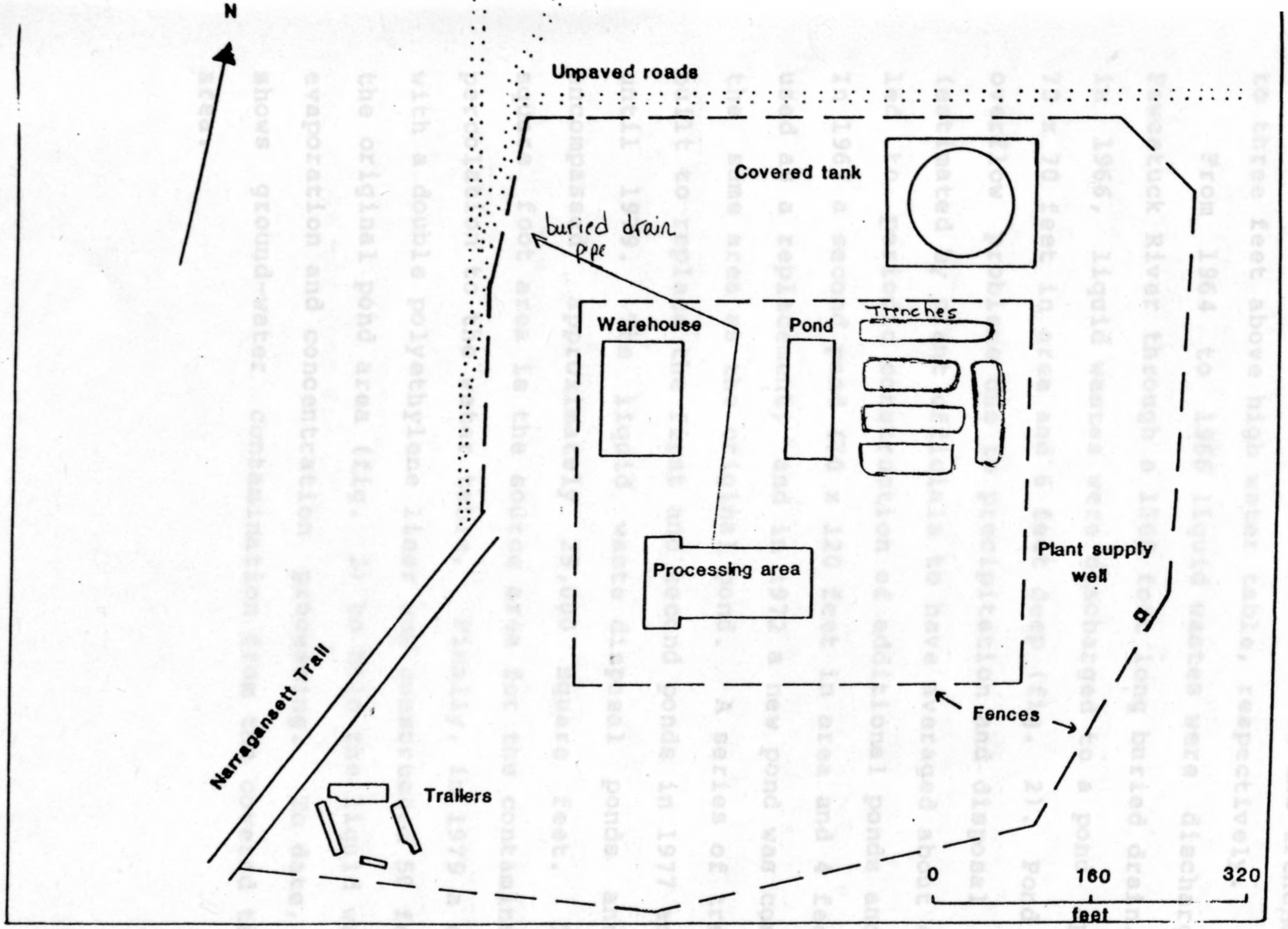


Figure 2. Location of processing area, evaporation pond, trenches, and covered tank, 1979

The depth of the ponds and trenches ranged from three to fifteen feet below land surface; the bottoms of the ponds were nine to thirteen feet and the bottoms of the trenches were one to three feet above high water table, respectively.

From 1964 to 1966 liquid wastes were discharged to the Pawcatuck River through a 1500 foot long buried drain. Beginning in 1966, liquid wastes were discharged to a pond approximately 70 x 70 feet in area and 6 feet deep (fig. 2). Pond capacity or overflow problems due to precipitation and disposal flow rates (estimated by plant officials to have averaged about 400 gal/day) led to periodic construction of additional ponds and trenches. In 1967 a second pond (70 x 120 feet in area and 4 feet deep) was used as a replacement, and in 1972 a new pond was constructed in the same area as the original pond. A series of trenches were built to replace the first and second ponds in 1977 and were used until 1979. The liquid waste disposal ponds and trenches encompassed approximately 25,000 square feet. This 25,000 square foot area is the source area for the contaminated liquid percolation to the water table. Finally, in 1979 a covered tank with a double polyethylene liner was constructed 50 feet north of the original pond area (fig. 2) to hold the liquid waste during evaporation and concentration processing. To date, no evidence shows ground-water contamination from the covered tank storage area.

Data on chemical composition and physical properties of the liquid wastes are limited and because concentrations of chemical and radiochemical constituents in waste discharges changed with time, defining the actual source loadings is not possible. In addition to hydrofluoric and nitric acids, tributyl phosphate, and kerosene, the following chemicals were used in the recovery process and were present in the liquid wastes in varying concentrations: aluminum nitrate, calcium hydroxide, mercury, sodium carbonate, sodium hydroxide, and potassium hydroxide. Although primarily non-irradiated fuel elements were processed over the period 1964 to 1980, slightly irradiated fuel elements from test reactors were processed from 1967 to 1980. This could account for the strontium 90 and technetium 99 that are in the contaminated water.

Processing at the plant ended in August 1980, and it is currently being decommissioned. Material from the bottom of the ponds and trenches and sediment from below the ponds and trenches was removed and combined with a cement-like mixture and shipped offsite for burial. No sampling of the sediments in the unsaturated zone between the pond and trench bottoms and the water table was done for this study.

PREVIOUS SITE INVESTIGATIONS

From 1974 to 1977 the Rhode Island Water Resources Board drilled approximately 20 test holes on the plant property to obtain lithologic and water quality data for evaluating potential areas for ground-water development. Water quality data obtained as part of the Water Resources Board investigation indicate ground water of high conductivity (5,500 umhos/cm at 25 degrees Celsius), high nitrate (225 mg/L) and significant gross alpha (43 pC/L) and gross beta (489 pC/L) emitters 1100 feet from the source area (Dickerman and Silva, 1980, p. 177 - 178). In 1977 the company installed ten observation wells between the plant and river that ranged in depth from approximately 50 to 80 feet. Water quality data obtained by the company from one of these wells indicate ground water of high conductivity (14,500 umhos/cm at 25 degrees Celsius) high nitrate (2,200 mg/L) and significant gross beta emitters (1518 pC/L) 200 feet from the source area (Dickerman and Silva, 1980, p. 177 - 178).

Resistivity surveys were conducted in 1977 by David Huntley, University of Connecticut and by Daniel Urish, University of Rhode Island. Results of these surveys indicated a plume of ground water with high conductivity between the plant area and the Pawcatuck River. Adjacent to the source area, depth below land surface of the highest conductance water was estimated to be 40 feet (D. Huntley, written commun., 1981). Maximum known extent of contamination at the start of the present study was approximately 1200 feet from the source area.

STUDY AREA DESCRIPTION

Geology

The study area is underlain by the Hope Valley Alaskite gneiss, a metamorphic rock unit of possible Devonian or older age (300-400 million years old). The gneiss was an igneous rock unit that underwent one and possibly two episodes of metamorphism (Moore, 1959). The bedrock crops out east, northeast, west, and southwest of the study area and unconsolidated glacial deposits of Pleistocene age (less than 1 million years old) have been deposited on top of the bedrock.

Glacial till deposits (poorly sorted, clays, silts, sands, gravels, and boulders) form a relatively thin (less than 20 foot) mantle over the bedrock (Lasala and Hahn, 1960) and appear at land surface east of the plant site (fig. 3). Glacial outwash deposits (well-sorted, silts, sands, and gravels) were deposited in the bedrock valley (fig. 4) and range in thickness from 0 to 300 feet in some parts of the valley.

The outwash deposits consist of predominantly medium to coarse sands and gravels to about 80 feet below land surface and mostly fine sands and silts below a depth of 80 feet. A glacial terminal moraine (till with some stratified deposits) approximately three miles south of the study area may be responsible for the fine sands and silts at depth. Slow moving glacial meltwater flowing into a lake behind the moraine apparently resulted in the deposition of the fine-grained sediments.

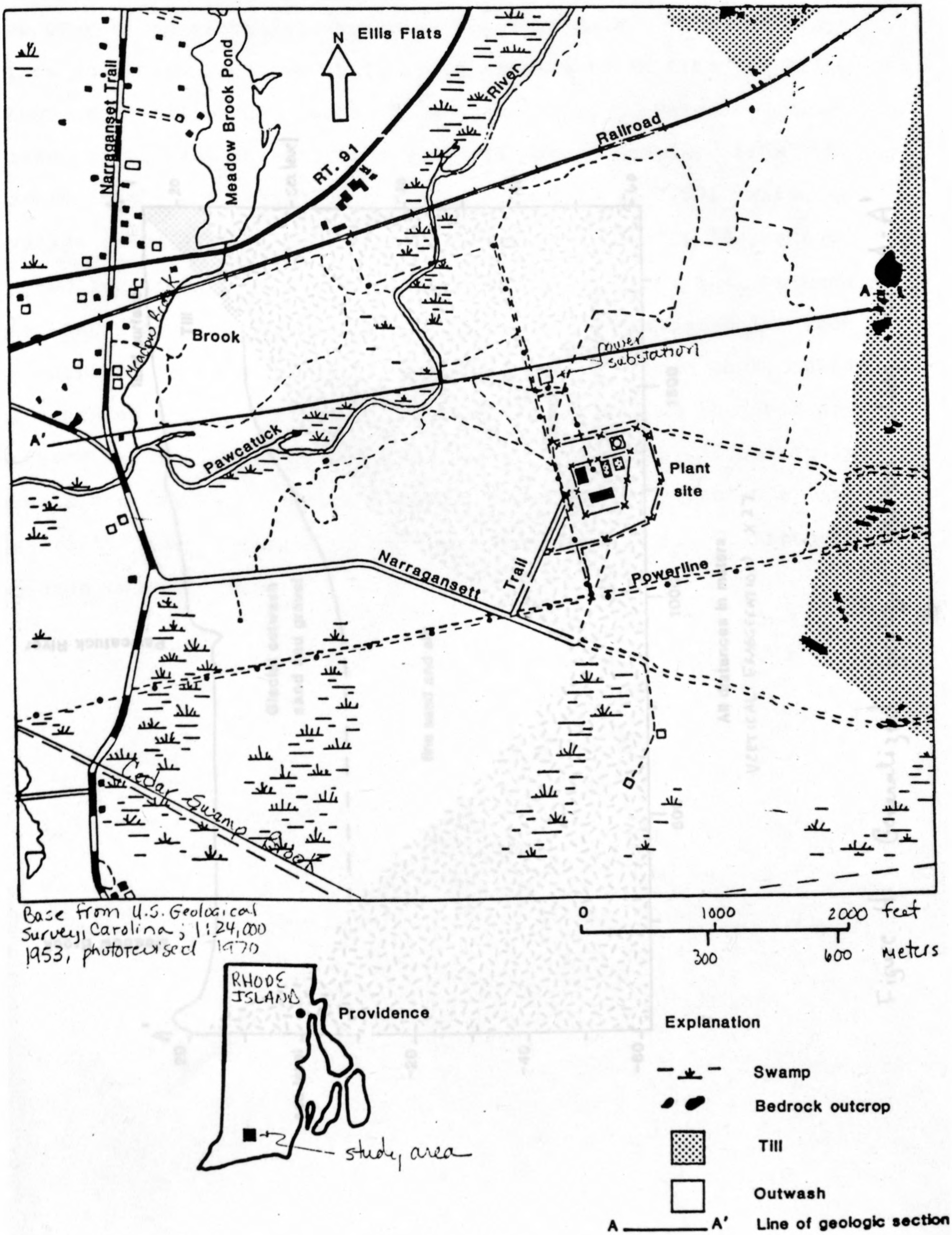


Figure 3: Generalized surficial geologic map of the study area and location of cross section line A–A'

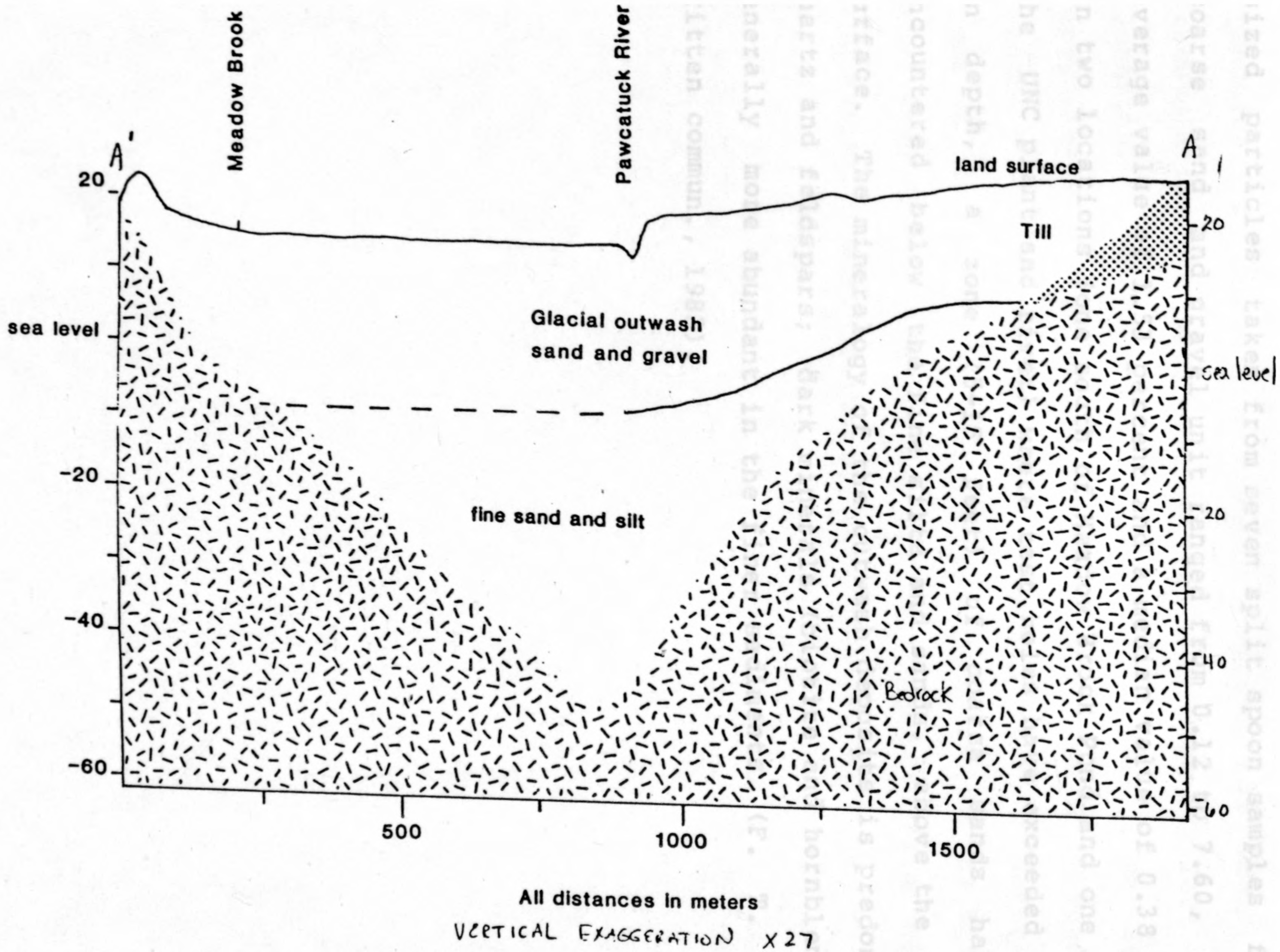


Figure 4. Generalized geologic section along line A-A'

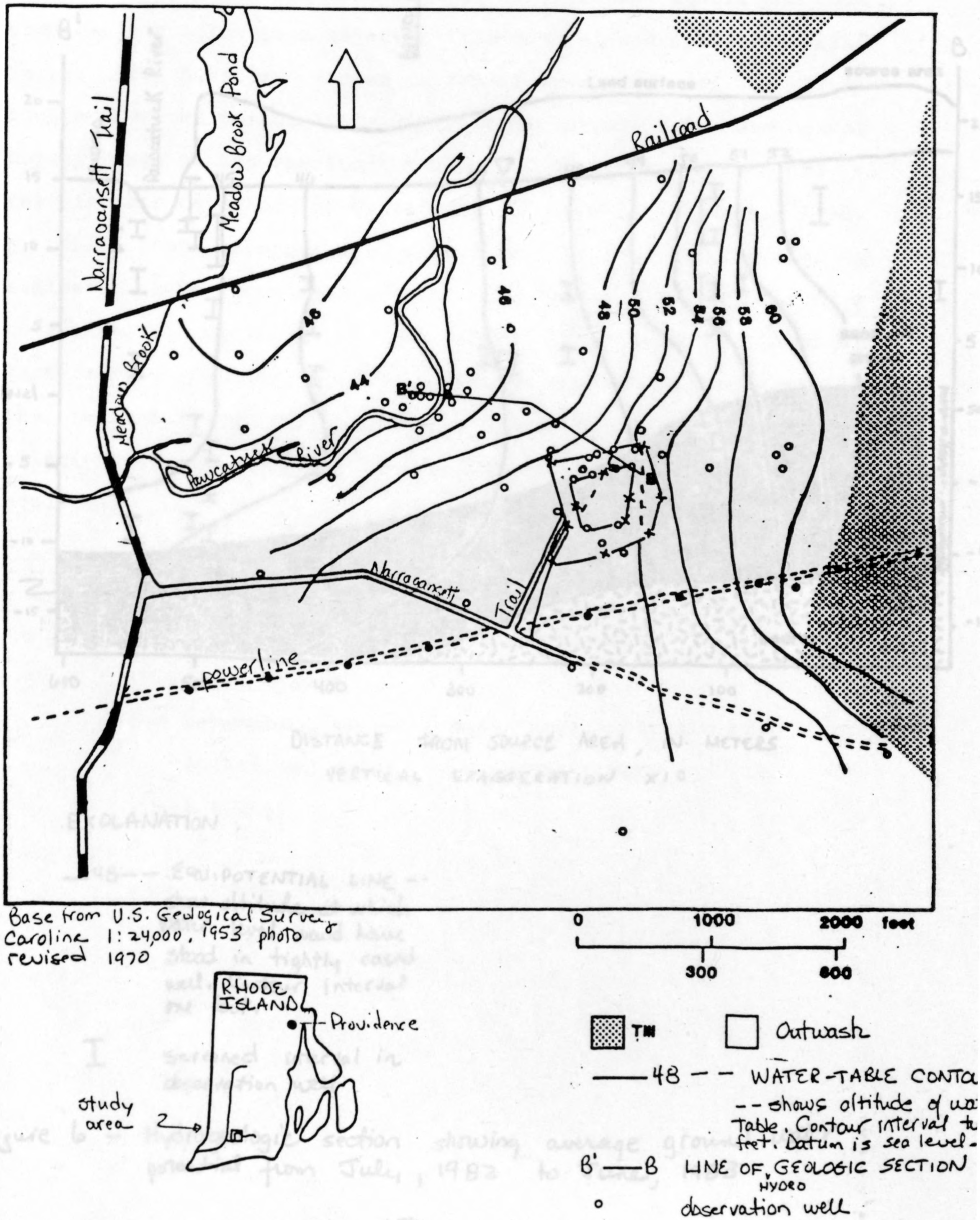
The fine sands and silts are cohesive in places; however, few clay-sized particles have been found to date. Percent clay-sized particles from two split spoon samples taken from the fine sand and silt unit were 2.94 and 3.07. Percent clay-sized particles taken from seven split spoon samples from the coarse sand and gravel unit ranged from 0.12 to 7.60, with an average value of 1.53 percent and a median value of 0.38 percent. In two locations (one south of Meadow Brook Pond and one between the UNC plant and river) where test holes have exceeded 150 feet in depth, a zone (5-15 feet) of coarse sands has been encountered below the fine silts and sands, above the bedrock surface. The mineralogy of the outwash deposits is predominately quartz and feldspars; dark minerals (biotite and hornblends) are generally more abundant in the finer sediments (F. T. Manheim written commun., 1983).

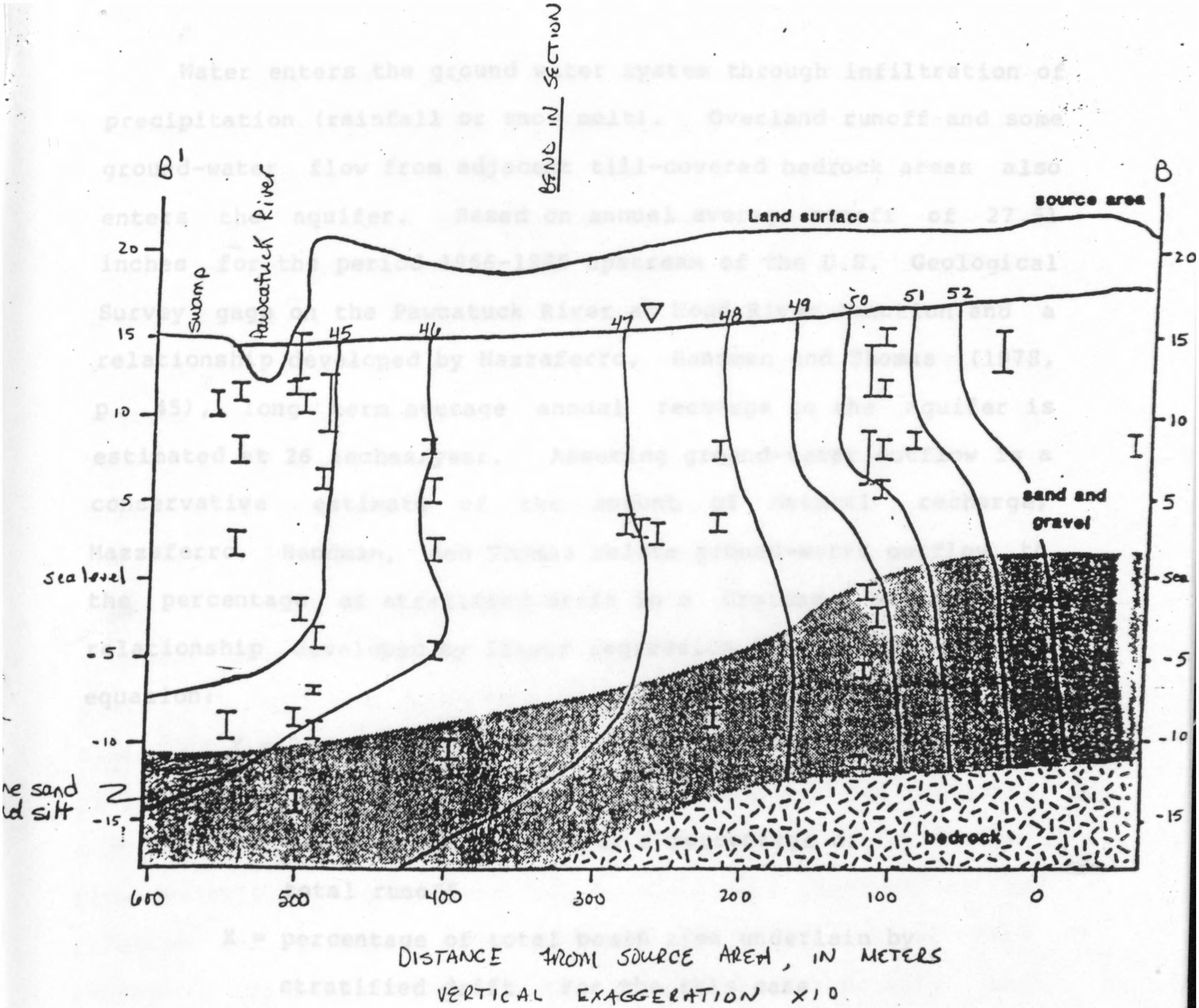
Hydrology

The plant site, located within the lower Pawcatuck River Basin, is approximately two miles east of the junction of the Pawcatuck and Wood Rivers. Unconsolidated deposits near the junction of these two rivers comprise the most extensive accumulation of sediments in the lower Wood aquifer (Gonthier, Johnston, and Malmberg, 1974, p. 7). The aquifer is approximately 8 miles long and ranges from 2000 to 8000 feet in width with the majority of it extending north, northwest, and west of the plant site. Saturated thickness in the Ellis Flats area exceeds 290 feet. Swamp and till deposits form the southern and eastern limits of the aquifer, respectively.

The aquifer is unconfined with a water table that slopes westward from the plant site at an average gradient of 28 feet/mile. The lower boundary of the aquifer is the bedrock surface (fig. 4). Generally, ground water movement in the aquifer is from the lateral boundaries or till upland areas toward the Pawcatuck River (fig. 5). Ground water discharges to the Pawcatuck River which is the major surface water drainage from the study area. Ground water potentials (fig. 6) show upward vertical movement of water into the Pawcatuck River and contiguous swampy area west of the river.

Figure 5 - Average water table altitude from July, 1982 to June, 1983





EXPLANATION

—48—— EQUIPOTENTIAL LINE -- show altitude at which water level would have stood in tightly cased well. Contour interval one foot.

I screened interval in observation well

Figure 6 - Hydrogeologic section showing average ground water potential from July, 1982 to June, 1983

Water enters the ground water system through infiltration of precipitation (rainfall or snow melt). Overland runoff and some ground-water flow from adjacent till-covered bedrock areas also enters the aquifer. Based on annual average runoff of 27.51 inches for the period 1966-1980 upstream of the U.S. Geological Survey gage on the Pawcatuck River at Wood River Junction and a relationship developed by Mazzaferro, Handman and Thomas (1978, p. 45), long term average annual recharge to the aquifer is estimated at 26 inches/year. Assuming ground-water outflow is a conservative estimate of the amount of natural recharge, Mazzaferro, Handman, and Thomas relate ground-water outflow to the percentage of stratified drift in a drainage basin. The relationship developed by linear regression is described by the equation:

$$Y = 35 + 0.6X$$

Where:

Y = ground-water outflow as a percentage of total runoff

X = percentage of total basin area underlain by stratified drift. For the this case X = 100.

Discharge of water from the aquifer occurs through groundwater runoff and also through evapotranspiration, primarily where the water table is near the land surface. Hydraulic conductivity of till is estimated to average about 1 foot/day like the till in the nearby upper Pawcatuck River basin (Allen, Hahn, Brackley,. 1966, p. 9) whereas, hydraulic conductivity of outwash deposits at the plant, estimated from lithologic logs,is about 180 feet/day (Gonthier, Johnston, and Malmberg, 1974, plates 2 and 4). Hydraulic conductivity determined from analyses of three aquifer tests made within a one-mile radius of the site, including an aquifer test on the plant supply well (fig. 2), ranged from 140 to 190 feet/day (D. C. Dickerman, oral commun., 1983). Hydraulic conductivity of the fine sands and silts at depth probably falls somewhere in between that of the tills and coarse outwash deposits. Fractures in the bedrock also yield water to wells, but generally only enough for domestic supplies (5 gal/min or less) (Allen, 1953, p. 26). Ground-water flow velocities, calculated from a water table gradient of 28 ft/mile, an estimated aquifer porosity of 0.38 (obtained from averaging porosity values from six sediment samples), and hydraulic conductivity estimates that ranged from 140 to 190 feet/day, ranged from 1.95 to 2.65 feet/day.

Uncontaminated ground and surface water in the study area generally meet 1976 U.S. Environmental Protection Agency drinking water standards. Specific conductance, an indication of dissolved minerals in the water, is generally less than 100 umhos/cm at 25 degrees Celsius. Principal cations, sodium, calcium, potassium, and magnesium are present in concentrations of 14 mg/L or less; principal anions, sulfate, chloride, and nitrate, are present in concentrations of 20 mg/L or less. Some naturally occurring radionuclides are found in the water. Potassium 40 (1 pC/L), radium 226 (3 pC/L), radium 228 (2 pC/L), and strontium 90 (3 pC/L) have been detected in ground and surface water in the study area.

EXPLORATION TECHNIQUES

Geophysical techniques and well drilling were used between April 1981 and June 1983 to define the hydrogeologic system and contamination plume. Geophysical techniques included: seismic refraction to determine depth to bedrock, geophysical well logging (gamma gamma, natural gamma, and neutron) to determine relative lithologic differences within a given well and from well to well, and electromagnetic (inductive) conductivity surveys to locate areas within the aquifer containing water of high specific conductance.

More than 135 observation wells ranging in depth from 10 to 230 feet were installed during six drilling phases using hollow-stem auger, mud rotary, and drive and wash methods. Wells were generally constructed of 1-1/4" to 1-1/2" diameter flexible polyethylene or rigid polyvinyl chloride (PVC) plastic pipe. Two wells were constructed with 5" diameter rigid PVC for geophysical logging purposes and two wells were constructed with 1-1/4" diameter galvanized steel for continuous water level recording. Screened intervals or well points ranged from 2 to 10 feet in length and were either #10 (0.010 inches) or #12 (0.012 inches) slot. The first drilling phases were used to install relatively shallow (less than 30 feet) observation wells to determine water table configuration. Later phases were devoted to the installation of wells generally ranging in depth from 10 to 100 feet to locate the contamination plume both horizontally and vertically. Ten split spoon samples were taken for sediment analyses that included cation exchange capacities, mineralogic descriptions, porosity tests, and sieve analyses.

CONTAMINATION PLUME

The plume of contaminated ground water extends from the source area northwestward approximately 1500 feet to the Pawcatuck River and southwestward approximately 800 feet in a downstream direction through the swampy area west of the river, a total distance of 2300 feet (fig 7 and 8). Dilution precludes detection of contaminants once they have entered the river which has an average discharge of 193 cubic feet per second. The plume is approximately 300 feet wide and is confined to the upper 80 feet of saturated thickness (fig. 9) where sediments consist of medium to coarse sand and gravel. The top of the contamination plume is depressed below the water table, and its depth increases as it moves away from the source area. The plume obtains a maximum depth (80 feet below land surface) between 1400 and 1500 feet from the source area. Beneath the discharge area (river and adjacent swamp), the plume rises to land surface.

Specific gravity of three samples of contaminated ground water collected in 1981 ranged from 1.000 to 1.001 g/cm^3 (Urish, written commun., 1982). It is therefore assumed that freshwater recharge on top of the plume is probably responsible for increased depth of the plume away from the pond area. Seasonal variations in hydrologic conditions may affect dimensions of the plume. For example, high precipitation in the spring of 1983 depressed the contamination plume below the water table at the river/swamp interface (fig. 10).

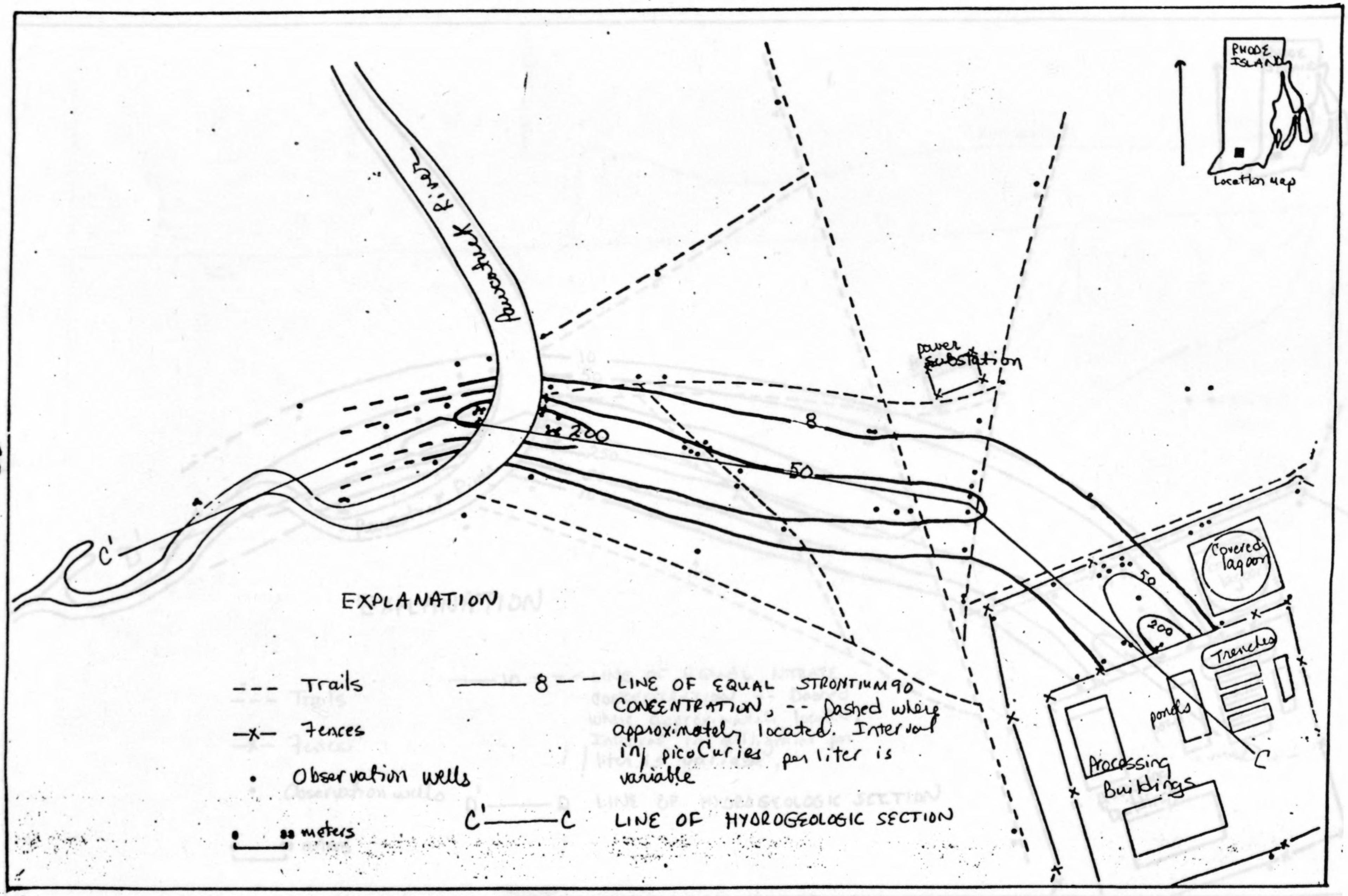


Figure 7. -- Strontium 90 concentrations in ground water at the plant site, October 1982.

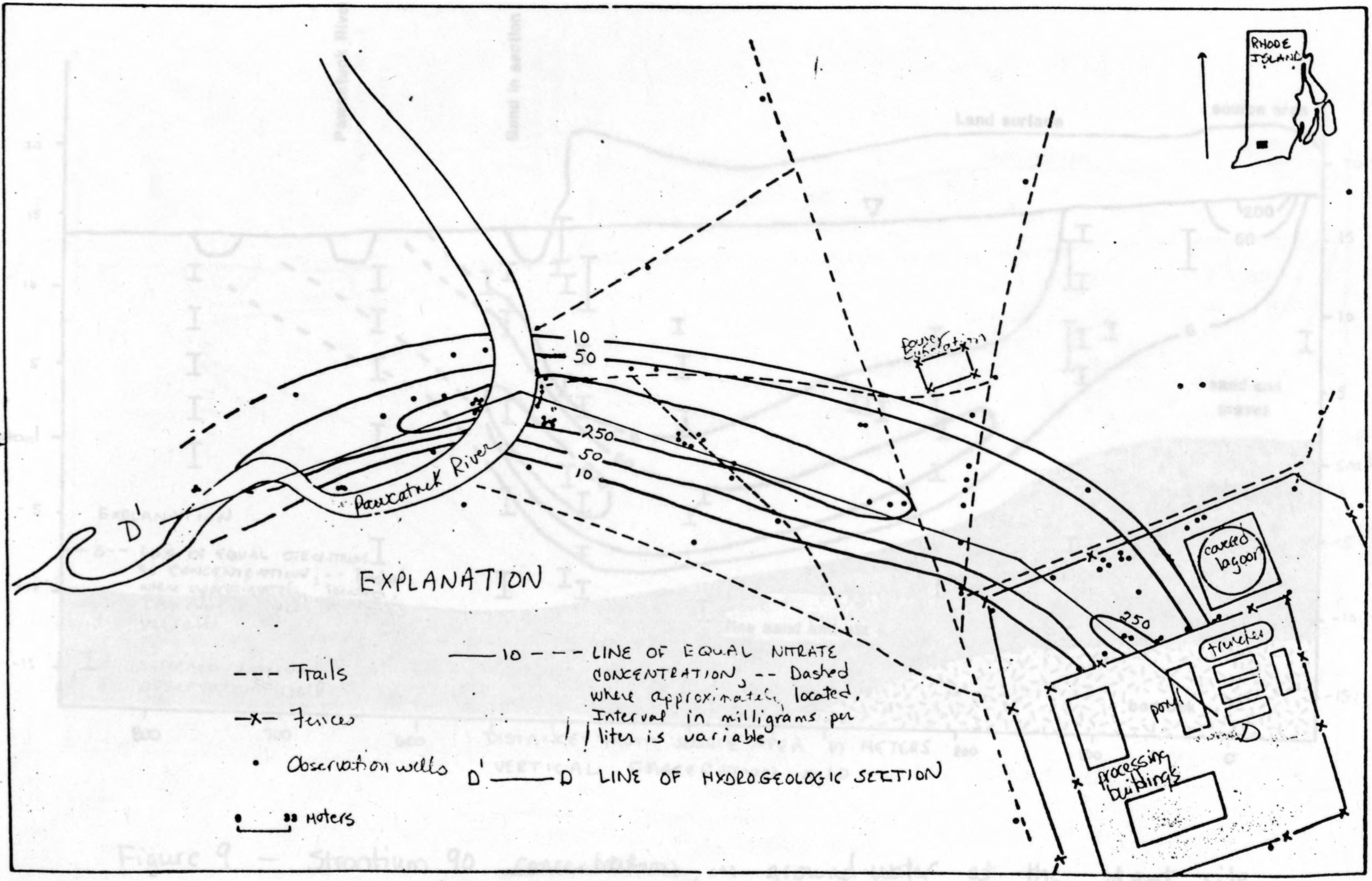


Figure 8. -- Nitrate concentration in ground water at the plant site,
Ma. 1982

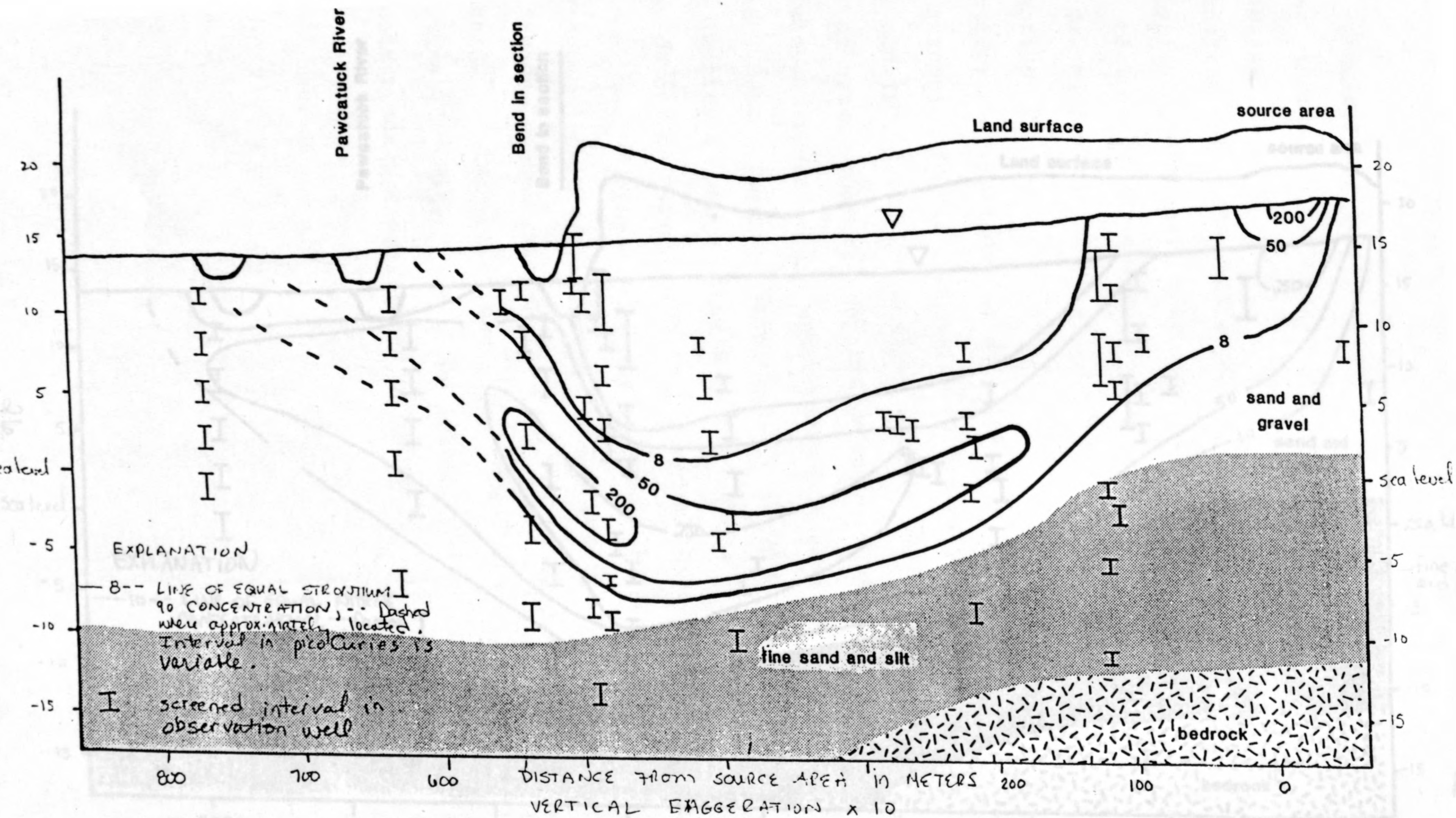


Figure 9 – Strontium 90 concentration in ground water at the plant site, October 1982.

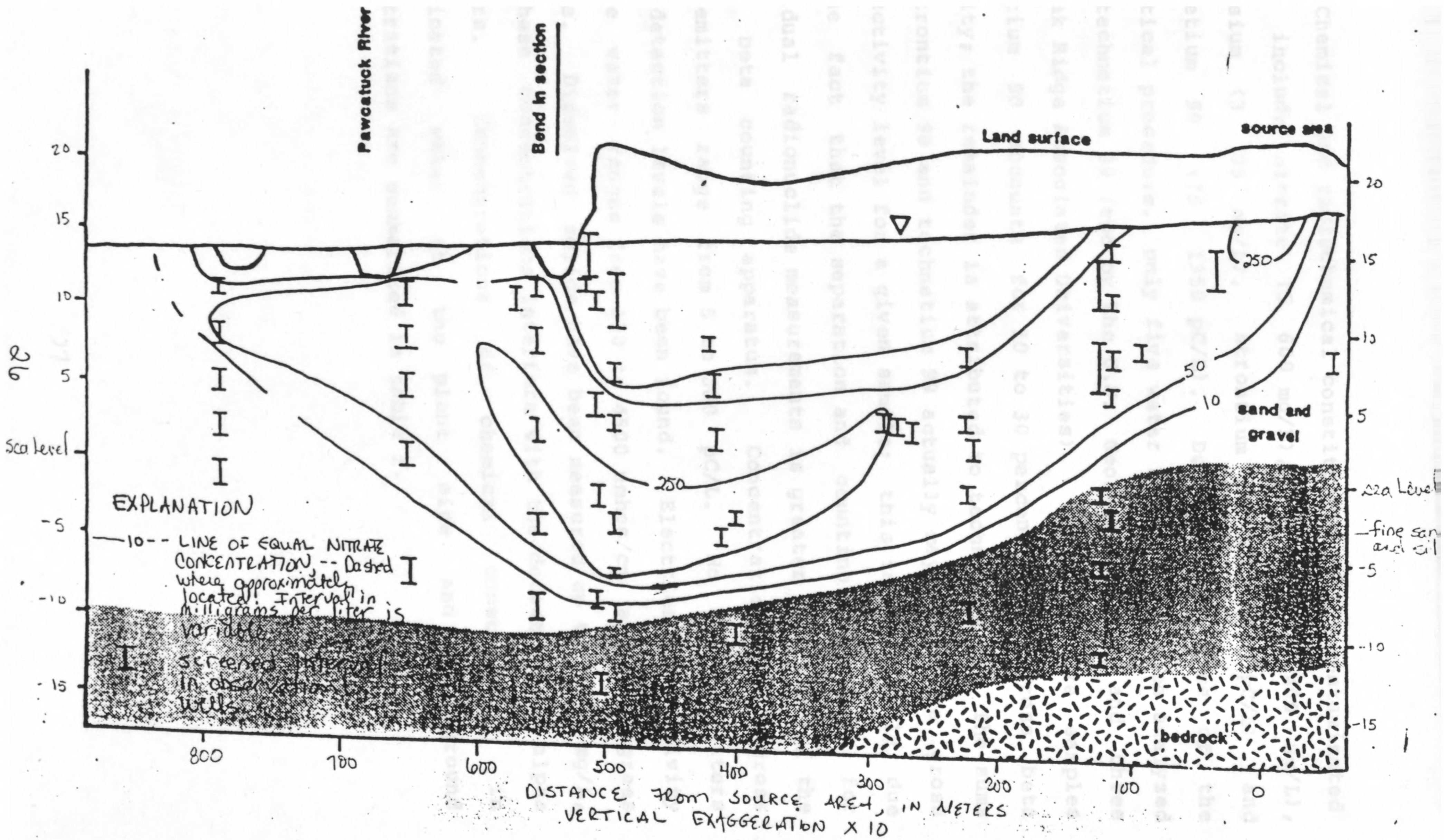


Figure 10. -- Nitrate concentration in ground water at the plant site, May 1983

Chemical and radiochemical constituents in the contaminated water include nitrate (5 600 mg/L), boron (20 400 ug/L), potassium (3 25 mg/L), strontium 90 (4 250 pC/L) and technetium 99 (75 1350 pC/L). Due to the expense of the analytical procedure, only five water samples have been analyzed for technetium 99 (two by the U.S. Geological Survey and three by Oak Ridge Associated Universities). In these five samples strontium 90 accounts for 10 to 30 percent of the gross beta activity; the remainder is attributed to technetium 99. The sums of strontium 90 and technetium 99 actually may exceed the gross beta activity level for a given sample; this is most likely due to the fact that the separation and counting efficiency for individual radionuclide measurements is greater than that of the gross beta counting apparatus. Concentrations of gross beta emitters range from 5 to 500 pC/L. No gamma emitters above detection levels have been found. Electrical conductivity of the water ranges from 150 to 4500 umhos/cm at 25 degrees Celsius. Dissolved solids have been measured up to 3500 mg/L, and these concentrations interfere with the detection of alpha emitters. Concentrations of chemical constituents in contaminated water at the plant site and background concentrations are summarized in table 1.

Table 1.-Representative chemical analyses of water from observation wells near the middle, edge, and outside the contaminant plume.

Chemical constituent	Observation well in middle of plume Feb. 17, 1982	Observation well on edge of plume Feb. 3, 1982	Observation well outside of plume Dec. 23, 1981
Alkalinity-$CaCO_3$ (mg/L)	7	3	9
Boron (ug/L)	230	50	< 10
Cadmium (ug/L)	1	2	< 1
Calcium (mg/L)	720	50	4.1
Chloride (mg/L)	180	9.2	5.0
Copper (ug/L)	4	2	5
Fluoride (mg/L)	< 0.1	< 0.1	< 0.1
Hardness (mg/L)	1900	130	16
Iron (ug/L)	250	20	310
Lead (ug/L)	5	6	1
Magnesium (mg/L)	23	1.5	1.4
Manganese (ug/L)	600	67	1600
Nickel (ug/L)	14	1	2
Nitrate (NO_2+NO_3) (mg/L)	580	37	0.18
pH (units)	5.6	5.7	5.6
Phosphorus (ortho as P) (mg/L)	< 0.01	< 0.01	< 0.01
Potassium (mg/L)	21	3.4	2.5
Silica (mg/L)	< 0.1	11	6.9
Sodium (mg/L)	25	7.8	4.4
Specific conductance (umhos)	4260	376	77
Strontium 90 (pC/L)	222	6.7	2.9
Sulfate (mg/L)	50	14	14
Water temperature (deg.C)	12.0	11.5	10.5
Zinc (ug/L)	50	11	16

From 1982 to 1983 two zones of concentrated contaminants were present at both ends of the plume, separated by a zone of less contaminated water. The zone near the Pawcatuck River resulted from infiltration of contaminants while the plant was processing material (1964-1980). The zone near the source area apparently resulted from flushing of additional contaminants from the unsaturated zone while the sediment below the ponds and trenches was being excavated for site-decommissioning (1981-1982).

Sediment- and water-quality analyses from sampling locations from the plant to the river indicate chemical and radiochemical constituents are not being sorbed by aquifer materials. Cation exchange capacities from five split spoon samples ranged from 0.1 to 4.2 meq/100 gms, with a median value of .5 meq/100 gms. Technetium 99 and strontium 90 have been detected in water from observation wells 1500 and 2000 feet, respectively, from the plant. In the swamp, however, reducing conditions may promote observable solute interaction with sediments or organic material once the plume rises to land surface. Additional sediment- and water-quality analyses are being conducted on materials from the swamp.

SUMMARY

Liquid wastes from an enriched uranium cold scrap recovery plant have leaked into a highly permeable sand and gravel aquifer in southern Rhode Island. The resultant plume of contamination extends 2300 feet from the source area (evaporation ponds and trenches) to the aquifer's discharge area (the Pawcatuck River and swampy area west of the river). Dilution, however, precludes detection of contaminants once they have entered the river. Chemical and radiochemical constituents in the plume include nitrate, boron, potassium, strontium 90 and technetium 99. Unconsolidated deposits comprising the aquifer, contain few clay-sized particles and contaminants do not appear to be significantly interacting with the sediments. In the swamp, reducing conditions may promote observable solute interaction with sediments or organic material.

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