GEOCHEMICAL DATA FOR THE WELDON SPRING CHEMICAL PLANT SITE AND VICINITY PROPERTY, ST. CHARLES COUNTY, MISSOURI--1989-90

By J.G. Schumacher

U.S. GEOLOGICAL SURVEY

Open-File Report 90-351
Revised in 1991

Prepared in cooperation with the

U.S. DEPARTMENT OF ENERGY

Rolla, Missouri

1990

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS

Multiply	By	To obtain
inch	25.4	millimeter
foot	0.3048	meter
mile	1.609	kilometer
acre	0.4047	hectare
cubic foot per second	0.02832	cubic meter per second
million gallons per day	0.04381	cubic meter per second
cubic yard	0.7646	cubic meter
gallon	0.003785	cubic meter
ton, short	907.2	kilogram

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

GEOCHEMICAL DATA FOR THE WELDON SPRING CHEMICAL PLANT SITE AND VICINITY PROPERTY, ST. CHARLES COUNTY, MISSOURI--1989-90

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ABSTRACT

This report presents geochemical data collected during an investigation of contaminant attenuation within the unconsolidated overburden and shallow bedrock at the Weldon Spring chemical plant site. The data consist of chemical analyses of water samples from 20 ground-water and 5 surface-water sites, mineralogic and chemical analyses of about 70 overburden samples, results from laboratory sorption experiments, and chemical and mineralogic characterization of sludge and interstitial water samples from raffinate pit 3.

Concentrations of dissolved nitrite plus nitrate ranging from 24 to 1,100 milligrams per liter as nitrogen were detected in samples from four shallow (less than 110 feet deep) bedrock monitoring wells near the raffinate pits. The samples from these wells generally had increased concentrations of calcium, magnesium, sodium, sulfate, dissolved solids, lithium, and strontium. Concentrations of dissolved uranium (3 to 110 micrograms per liter) were detected in samples from all four of these wells.

Samples from unconsolidated overburden units at the site consist mainly of silt-size particles (as much as 82 percent of the less than 2-millimeter size fraction) with lesser quantities of clay- and sand-size particles. The predominant mineral in the bulk (less than 2 millimeters) fraction is quartz (36 to 98 percent) with lesser quantities of feldspars, clay minerals, and calcite. Quartz also was the predominate mineral in the clay-size (less than 2 micrometers) fraction. Generally, clay minerals comprise less than 10 percent of the overburden, with the clay till containing the largest average quantities. The predominant clay type is montmorillonite (50 to 95 percent of the total clay minerals). Calcite and other carbonate minerals constitute between an average of 0.7 percent (Ferrelview Formation) and 20 percent (residuum) of the overburden mineralogy. Average contents of iron ranged from 1.4 percent in the loess to 2.4 percent in the Ferrelview Formation and clay till.

More than 95 percent of the lead and 89 percent of the vanadium in a simulated leachate was removed from solutions equilibrated with the Ferrelview Formation or clay till at fixed pH values ranging from 4.5 to 9.0 in laboratory experiments. The maximum sorption of molybdenum (greater than 97 percent) occurred at a fixed pH 4.5 in solutions in contact with either unit. Less than 41 percent of molybdenum was removed at a fixed pH of 7.0 in solutions in contact with either unit and less than 5 percent was removed at a fixed pH of 9.0. At fixed pH values, the maximum sorption of uranium (greater than 97 percent) occurred in solutions at pH 4.5 in contact with the clay till. Slightly larger quantities of sorption (more than 98 percent) occurred in unadjusted solutions in contact with the Ferrelview Formation at initial pH values of 4.5 and 7.0. Conditions least conducive to uranium sorption were at a fixed pH of 7.0 in contact with the clay till where only 52 percent of uranium was removed. Less than 15 percent of sulfate, 19 percent of nitrite plus nitrate as nitrogen, and 30 percent of lithium were removed from solutions at a fixed pH of 4.5, 7.0, or 9.0.

A composite sample of sludge collected from raffinate pit 3 at a depth of 4.5 feet below the water-sediment interface was composed of apatite (more than 99 percent) with minor quantities of quartz, hornblende, and amorphous iron oxides, and trace flakes of graphite. The sludge contained as much as 1,290 milligrams per kilogram thorium and 1,700 milligrams per kilogram uranium. Scattered grains of carnotite $K_2 (UO_2)_2 (VO_4)_2 \cdot 3H_2O$ also were detected.

Concentrations of most constituents increased with increasing depth below the water-sediment interface in raffinate pit 3. Concentrations of calcium and nitrite plus nitrate as nitrogen increased from 490 and 1,500 milligrams per liter just above the water-sediment interface to 9,500 and 9,600 milligrams per liter in interstitial water at a depth of 4.5 feet below the interface. Manganese and selenium

concentrations increased from 10 and less than 1 microgram per liter just above the water-sediment interface to 28,000 and 3,700 micrograms per liter at a depth of 4.5 feet below the interface. Uranium concentrations had no trends with depth; concentrations varied locally from 33 to 360 micrograms per liter.

INTRODUCTION

The Weldon Spring chemical plant was operated as a uranium feed materials plant under contract for the U.S. Atomic Energy Commission from 1957 to 1966. The plant processed uranium-ore concentrates and recycled scrap to obtain uranium tetrafluoride, uranium trioxide, and pure uranium metal (Kleeschulte and Emmett, 1987). Some thorium residues also were processed. Uranium-ore concentrates were dissolved in a solution of nitric acid to oxidize uranium to the hexavalent uranyl ion UO_2^{2+} in solution (Harrington and Ruehle, 1959). Various processes and reagents then were used to extract and convert the uranium to product materials from this acid stream. Wastes from the plant, referred to as raffinate, were slurried to four large pits at the site (hereafter referred to as raffinate pits). Immediately before being discharged to the pits, the acidic waste was neutralized with lime to near neutral pH (Harrington and Ruehle, 1959).

Small quantities of irrecoverable uranium were discharged along with other impurities and contaminants to the raffinate pits during operation. An estimated 150 tons of uranium, 76 tons of thorium, and 1.5 tons of enriched uranium were discharged to the raffinate pits (Lenhard and others, 1967). The liquids from the pits continuously overflowed into the plant sewer system. Lenhard and others (1967) estimated the sewer discharge at 1 Mgal/d (million gallons per day) during plant operation; one-half of this was from the raffinate pits. The sewer discharged into a small, unnamed, intermittent drainage southeast of the site, and this discharge flowed approximately 1 mi (mile) before entering the Missouri River. Approximately 196,300 cubic yards of radiologically contaminated wastes are present within the raffinate pits (MK-Ferguson Co. and Jacobs Engineering Group, 1989b). A detailed description of the site is given in Kleeschulte and Emmett (1986).

The disposal of low-level radioactive wastes at the site has resulted in increased concentrations of calcium, magnesium, sodium, sulfate, nitrate, lithium, strontium, and uranium in shallow ground water and surface water near the site (Kleeschulte and Emmett, 1987). Radiologic contamination of the shallow ground water generally is limited to wells adjacent to the raffinate pits, a perennial spring north of the site, and a small drainage to the southeast. Increased concentrations of various other contaminants are present in the shallow ground water throughout the site.

Reconnaissance water-quality and ground-water-level data have been collected by the U.S. Geological Survey (USGS) since 1984 at the Weldon Spring chemical plant site and vicinity property. These data are given in Kleeschulte and others (1986) and Kleeschulte and Cross (1990). During 1989 and 1990, the USGS investigated the attenuation mechanisms for various contaminants within the overburden and shallow bedrock aquifer and the geochemical conditions within the raffinate pits, overburden, and shallow bedrock aquifer. This investigation was funded by the U.S. Department of Energy's (USDOE) surplus facilities management program. This report describes the methods used and presents water-quality and soil-sample data and the results of laboratory sorption experiments.

Special contributions from the students and faculty of the Department of Civil Engineering, University of Missouri-Rolla made this investigation possible. Laboratory sorption experiments were performed by Stephen Bader, Craig Borgmeyer, and Steven Fink as part of their graduate studies under the direction of Dr. Purush TerKonda. Significant contributions to sample preparation were made by Robert Ford and Ralph Lemongelli as part of their undergraduate studies. Special acknowledgment also is given to Kenneth Stollenwerk of the U.S. Geological Survey in Denver, Colorado, for his assistance in developing and reviewing the experimental methods used in this study.

STUDY AREA

The study area is located in the south-central part of St. Charles County in eastern Missouri (fig. 1). For purposes of this report the Weldon Spring chemical plant site refers to approximately 220 acres owned by the USDOE and consists of the abandoned Weldon Spring chemical plant and associated raffinate pits. The site is situated near the boundary of the Dissected Till Plains of the Central Lowland to the north and the Springfield-Salem Plateaus of the Ozark Plateaus to the south (Fenneman, 1938). Average annual precipitation is 34 in. (inches) per year (National Oceanic and Atmospheric Administration, 1988).

The site is situated on the shallow ground-water and surface-water divide, trending northeast across the site, between the Mississippi River and Missouri River basins. Surface drainage on the northern part of the site, including most of the chemical plant and raffinate pit areas, flows to the north into lakes within the August A. Bush Memorial Wildlife Area, then into Schote Creek, then into Dardenne Creek (fig. 2), and eventually into the Mississippi River. Drainage from the southern part of the site flows to the south through a small, unnamed, intermittent drainage before reaching the Missouri River approximately 1 mi to the south. Ground-water flow beneath the site generally reflects the surface-water drainage and is towards the north in the vicinity of the raffinate pits and towards the south in the southern most parts of the site (Kleeschulte and Emmett, 1987). Surficial materials at the site consist of thin, dissected, and reworked glacial deposits. Underlying the glacial deposits are the Keokuk and Burlington Limestones of Mississippian age. Solution features within the limestone, such as swallow holes and losing streams, have been identified adjacent to the site, and highly permeable zones, possibly solution features, such as enlarged joints, exist in the upper few feet of the bedrock beneath the site.

Surficial deposits, composed of glacial till and derived deposits, range in thickness from 0 to 50 ft (feet) in the vicinity of the site. The overburden can be subdivided into six principal units (MK-Ferguson Co. and Jacobs Engineering Group, 1990); (1) a sandy, organic-rich top soil (0 to 30 ft thick); (2) modified loess (0 to 11 ft thick) having gradational bedding and a larger than average clay content; (3) a discontinuous clay-rich zone (Ferrelview Formation) that contains iron-rich nodules (0 to 20 ft thick); (4) clay till (0 to 30 ft thick) composed of clay with variable quantities of sand and gravel having blocky structure; (5) basal till (0 to 11 ft thick) containing clay with broken chert fragments; and (6) cherty clay or residuum (0 to 26 ft thick) that is a highly heterogeneous unit consisting of gravelly clay to clayey gravel with abundant sand- to gravel-size chert nodules. The overburden thickness in the vicinity of the raffinate pits is approximately 20 to 30 ft.

Immediately underlying the glacial deposits are the undifferentiated Mississippian Keokuk and Burlington Limestones. These limestones are coarsely crystalline and medium-to-thickly bedded. Previous geochemical investigations indicated a highly weathered residual layer developed within the upper part (0 to 26 ft) of these formations results in an uneven "pinnacled" surface that contains many clay-filled voids (Bechtel National, Inc., 1984). The residual layer can be highly permeable, often resulting in a 100-percent loss of drilling fluids (MK-Ferguson Co. and Jacobs Engineering Group, 1990). Below the Keokuk and Burlington Limestones are the lower Osagean Fern Glen Limestone and Kinderhookian Chouteau Limestone.

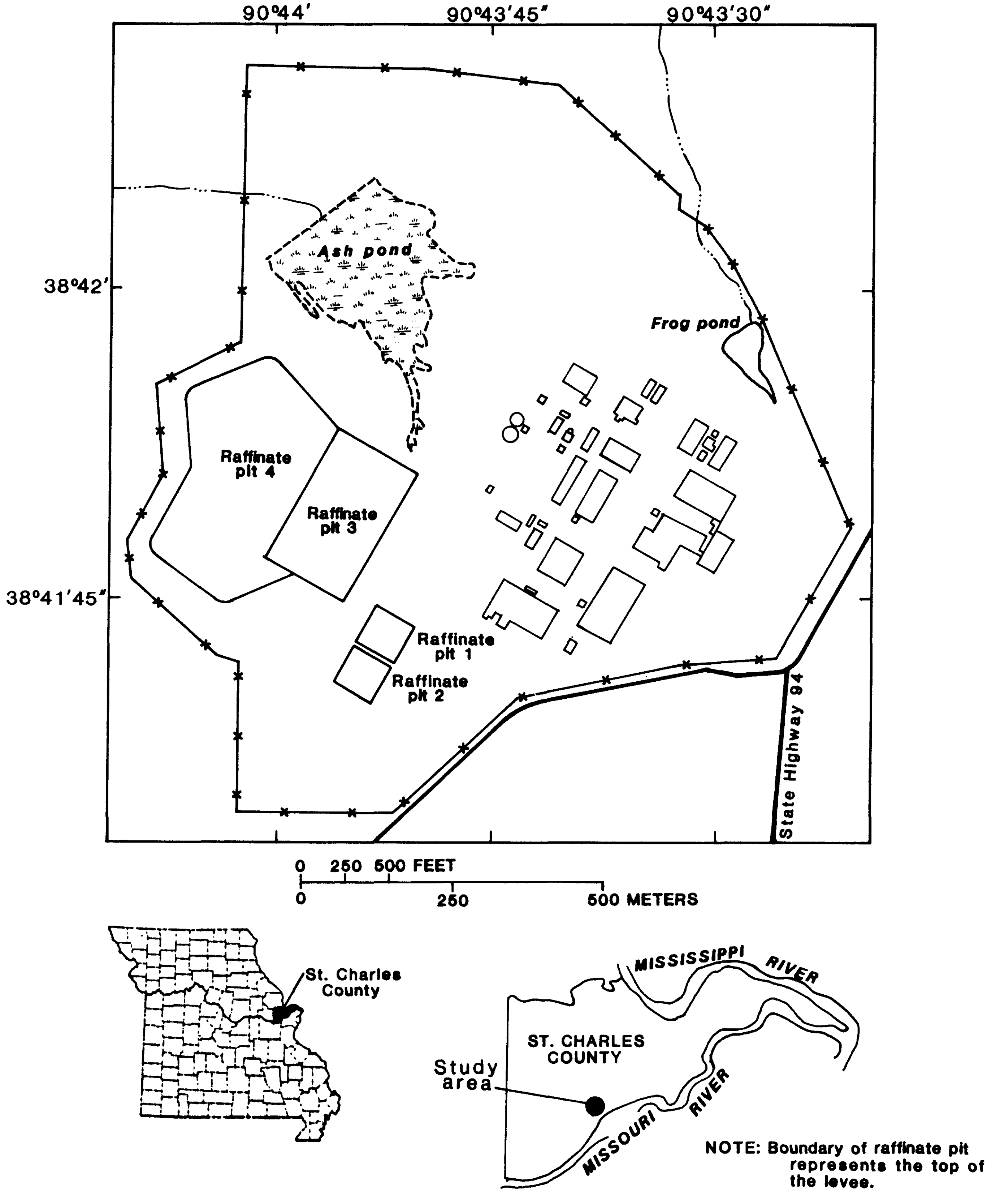

Figure 1.--Location of the Weldon Spring chemical plant site (modified from MK-Ferguson Co. and Jacobs Engineering Group, 1989a).

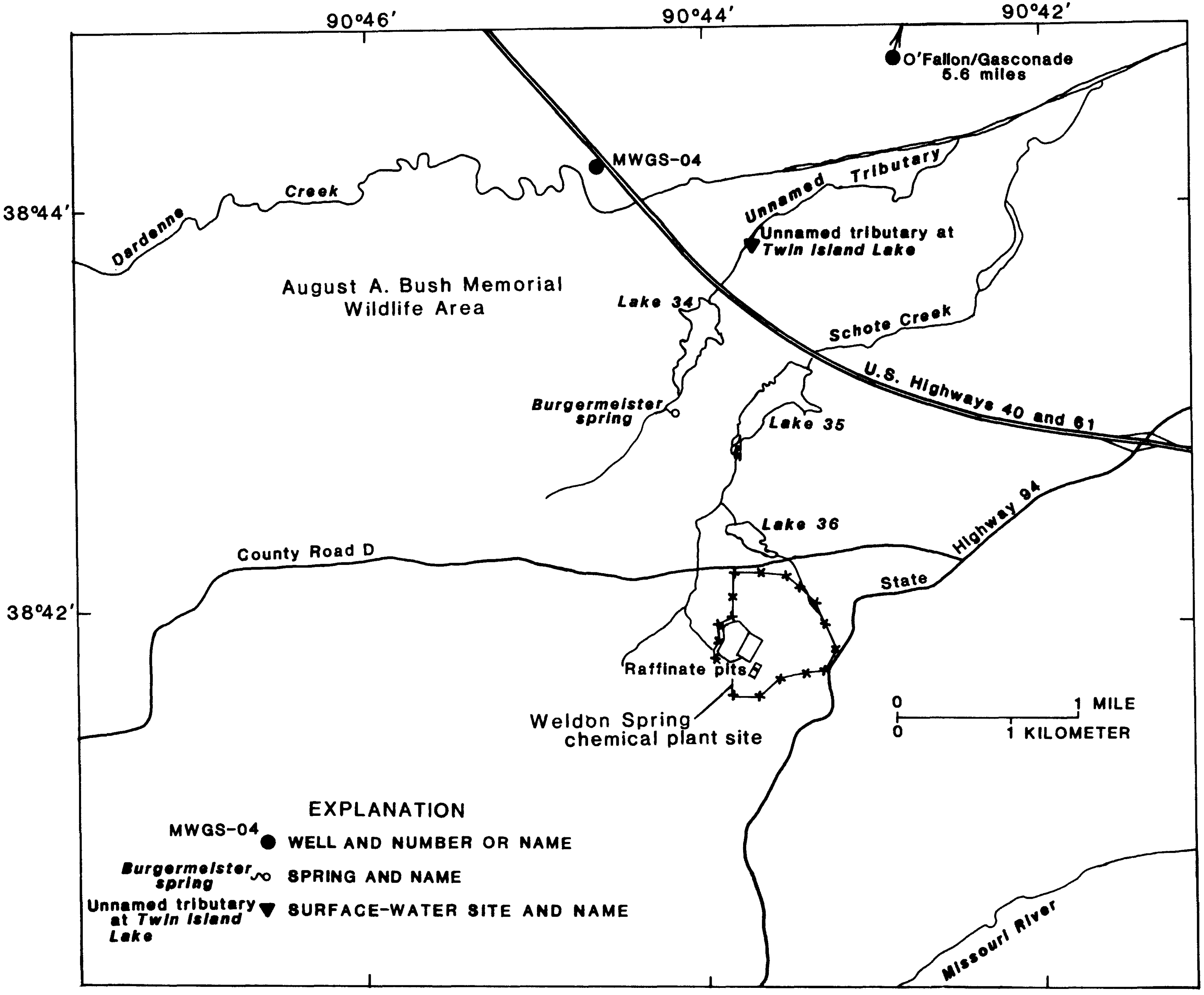

Figure 2.--Location of water-quality sampling sites in the vicinity of the Weldon Spring chemical plant site.

Solutioned enlarged joints, conduit flow of ground water, losing streams, springs, and solution collapse features are typical in karst environments. These features are present in the vicinity of the Weldon Spring chemical plant. The development of solution collapse features, such as swallow holes, is restricted to an isolated area near lake 35 in the August A. Bush Memorial Wildlife Area (fig. 2).

WATER QUALITY

Water-quality samples were collected at 20 ground-water and 5 surface-water sites (table 1, at the back of this report). Most sites were located in the vicinity of the raffinate pits (fig. 3); those that were not are shown in figure 2. These samples were collected to provide adequate data suitable for use in geochemical-modeling efforts.

Methodology

Specific conductance of water samples was measured using a portable conductivity meter with temperature compensation designed to express values in µS/cm at 25 °C (microsiemens per centimeter at 25 °Celsius). The meter was calibrated before each measurement using standards prepared by the USGS water-quality laboratory in Ocala, Florida. The pH was measured using a portable pH meter calibrated with standard buffers bracketing the expected sample pH before each measurement. Oxidation-reduction potentials (Eh) were determined by measuring the voltage potential developed at the surface of a platinum electrode emersed in the sample. Values were corrected to the standard hydrogen electrode. Water temperature was measured to the nearest 0.1 °C (degrees Celsius) by a thermistor attached to a pH meter. Dissolved-oxygen concentrations were determined by using a portable meter calibrated to air saturation daily. Alkalinity was determined by using incremental titration of 0.16 N (normal) standardized sulfuric acid to 25 mL (milliliters) of sample past the carbonate/bicarbonate inflection point (approximately pH 8.3) and the bicarbonate/carbonic-acid inflection point (approximately pH 4.5). Concentrations of carbonate, bicarbonate, and carbonate alkalinity were later computed using a computer program to integrate the rate of pH change to the equivalence of acid added. Ferrous-iron concentrations were determined by using a modification of the Phenanthroline Method developed by HACH[1]. Values were determined in the field using a portable spectrophotometer calibrated and set at a 510-nm (nanometer) wavelength. A field scanning procedure was used to test for the presence of sulfide by using a field test kit that converts aqueous sulfide to hydrogen sulfide. The hydrogen sulfide was then purged from the sample through a lead-acetate paper filter.

Water-quality samples from most wells onsite (the use of the term onsite refers to the 220-acre chemical plant property) were obtained by using dedicated bladder pumps installed in each well by the USDOE. A small, portable air compressor or compressed air tank was used as the pressure source to operate the bladder pumps. Monitoring well MWGS-04 (fig. 2) was sampled using a 3-in. diameter submersible pump. The public-supply well (O'Fallon/Gasconade) had been in operation several hours prior to sample collection. Each well was purged before sampling. During purging, specific conductance, pH, Eh, temperature, and dissolved-oxygen concentrations were monitored in a flow-through cell attached to the discharge line of the pump and water-quality samples were not collected until these measurements stabilized. However, a minimum of three pipe-volumes of water was removed from each well before sampling. Concentrations of alkalinity, ferrous iron, and sulfide were determined immediately after sample collection. During alkalinity titrations, a second pH and temperature measurement was made for comparison with flow-through-cell values. Samples were collected from monitoring well MW-

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[1] The use of trade or firm names in the report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

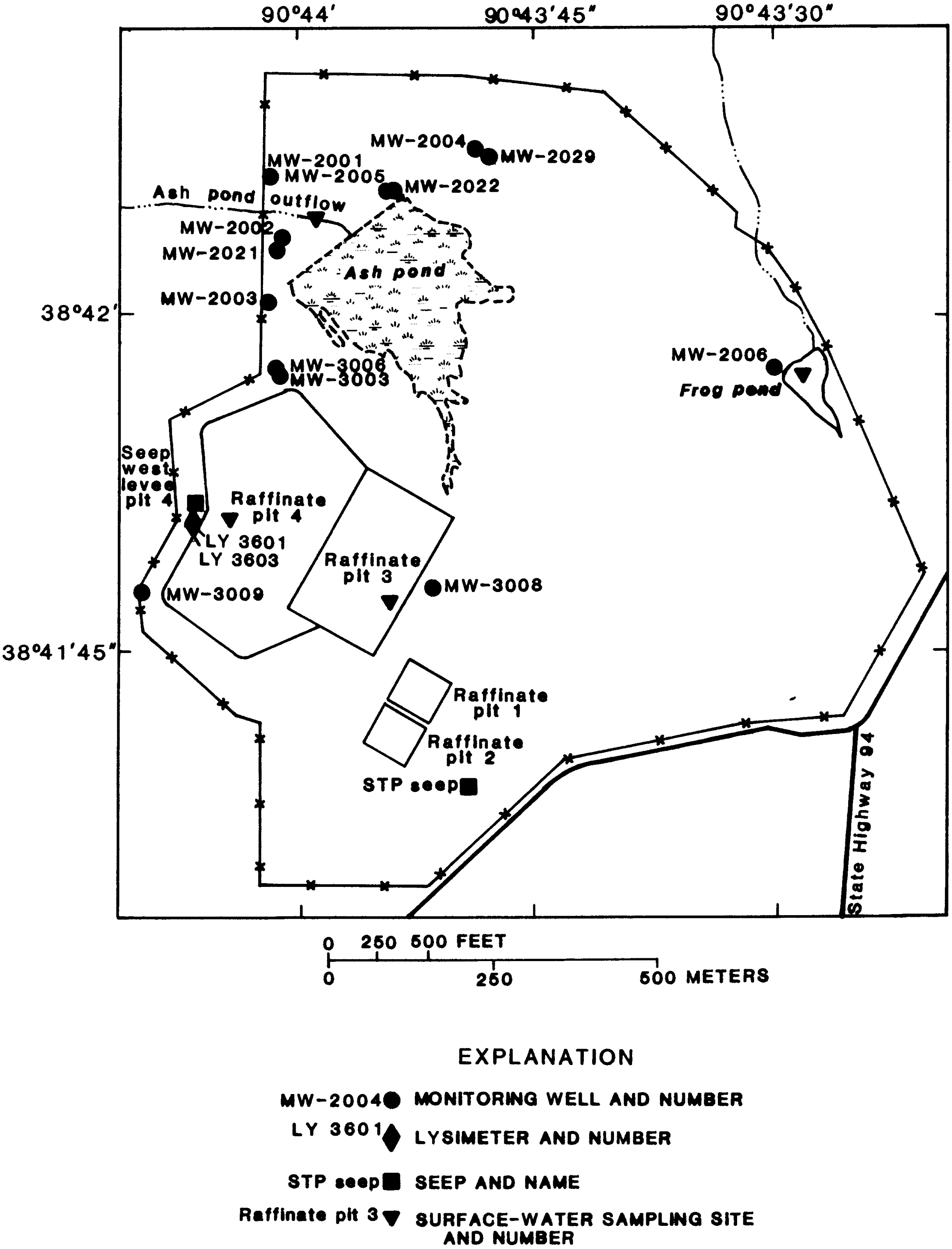

Figure 3.--Location of water-quality sampling sites at the Weldon Spring chemical plant site (modified from MK-Ferguson Co. and Jacobs Engineering Group, 1989a).

3006 (fig. 3) using a stainless-steel bailer after three pipe-volumes had been removed from the well. Values of specific conductance, pH, Eh, temperature, dissolved oxygen, alkalinity, ferrous iron, and sulfide were determined immediately after sample collection.

Lysimeters were sampled by applying a vacuum to the sampling hose of each lysimeter for several minutes using a hand-operated vacuum pump. The sample was removed from the lysimeter by applying pressure to the pressure hose using a hand-operated air pump. The samples were collected in clear, 1-L (liter) polyethylene bottles and aliquots were immediately removed for the determination of specific conductance, pH, Eh, temperature, and concentrations of dissolved oxygen, alkalinity, ferrous iron, and sulfide.

Specific conductance, pH, Eh, temperature, and dissolved-oxygen concentrations were measured at seeps and Burgermeister spring where surface flow was first observed. Water samples were collected by immersing a 500-mL polyethylene bottle into the surface flow. After filling, the bottle was emptied into a standard USGS churn splitter and the process repeated until a sufficient sample volume had been collected. Determinations of alkalinity, ferrous iron, and sulfide were made immediately after sample collection.

Water-quality samples were collected from the raffinate pits by submerging a 3.5-L polyethylene jug (affixed to a 10-ft steel pole) about 10 ft from the bank. Samples were collected along the east levee of raffinate pit 3 and the southwest levee of raffinate pit 4. Other surface-water sites were sampled by immersing a 500-mL polyethylene bottle (inorganic constituents) or a 250-mL baked glass bottle (organic constituents) near the centroid of flow. Specific conductance, pH, Eh, temperature, and dissolved-oxygen concentrations were measured at the time of sample collection. Alkalinity, ferrous-iron, and sulfide determinations were made shortly after sample collection.

Inorganic chemical constituents referred to as "dissolved" were filtered through a 142-mm (millimeter) diameter, 0.1-μm (micrometer) pore size cellulose-nitrate membrane filter placed in a lucite holder. A peristaltic pump was used as the pressure source for filtration. After filtration, samples for dissolved cations were placed in acid-washed polyethylene bottles and preserved with ultrapure nitric acid to a pH less than 2. Samples for dissolved anions were placed into clean polyethylene bottles. Dissolved nutrient samples (nitrogen and phosphorus species) were placed in amber polyethylene bottles and preserved by adding 1 mL of 10^{-4} molar mecuric chloride and chilling to 4 °C. Total organic carbon samples were collected in 250-mL amber glass bottles and preserved by chilling to 4 °C. Dissolved organic-carbon samples were filtered through a 0.45-μm silver filter placed in a stainless-steel filter holder. The filtrate was collected in amber glass bottles and chilled to 4 °C. A tank of dry nitrogen was used as the pressure source. Samples for tritium determinations were collected in 1-L glass bottles by filling from the bottom using a silicon hose to exclude any contact with the atmosphere. Samples for strontium isotopic determinations were filtered and preserved as described above for "dissolved" inorganic cations. All samples were submitted to the USGS national water-quality laboratory in Arvada, Colorado. Inorganic constituents and tritium determinations were made according to the methods described by Fishman and Friedman (1989). Total and dissolved organic-carbon determinations were made according to the procedures outlined in Wershaw and others (1983). Strontium isotopic determinations were made at the Department of Geology, Kansas State University using mass spectrometry (MS).

Summary of Data

Dissolved-oxygen measurements were made at 12 of the 20 ground-water sites sampled. Only the sample from monitoring well MW-2022 had dissolved-oxygen concentrations less than 1 mg/L (milligram per liter; table1). Generally, concentrations of ferrous iron determined onsite were small except in a sample from lysimeter LY 3601 (880 μg/L; micrograms per liter) and samples from two deeper monitoring wells--MW-2022, 40 μg/L, and MW-3006, 90 μg/L (fig. 3). No positive sulfide results were detected in any samples during these investigations. The sample from lysimeter LY-3603 near the west levee of raffinate pit 4 had large concentrations of calcium (290 mg/L), sodium (250 mg/L), sulfate (160 mg/L), strontium (630 μg/L), and uranium (21 μg/L). Except for uranium, these concentrations were greater than those detected in raffinate pit 4, but were less than those in raffinate pit 3. Burgermeister spring (fig. 2) had increased concentrations of nitrite plus nitrate as nitrogen (8.2 to 21 mg/L), lithium (10 to 35 μg/L), and uranium (84 to 180 μg/L).

Raffinate pit 3 contained large concentrations of calcium (490 mg/L), magnesium (360 to 370 mg/L), sodium (1,100 to 1,300 mg/L), sulfate (570 to 630 mg/L), dissolved solids (8,820 to 9,550 mg/L), and nitrite plus nitrate as nitrogen (1,400 to 1,500 mg/L as nitrogen). Raffinate pit 3 also contained large concentrations of lithium (3,000 to 3,600 μg/L), molybdenum (4,700 μg/L), selenium (less than 1 to 200 μg/L), vanadium (290 to 520 μg/L), and uranium (320 μg/L). Raffinate pit 4 contained small concentrations of calcium (11 mg/L), magnesium (37 mg/L), sodium (190 mg/L), sulfate (110 mg/L), dissolved solids (733 mg/L), nitrite plus nitrate as nitrogen (7.4 mg/L), lithium (520 μg/L), molybdenum (740 μg/L), selenium (7 μg/L), and vanadium (70 μg/L) relative to raffinate pit 3. Raffinate pit 4, however, contained the largest concentration of uranium (2,800 μg/L). The two seeps sampled onsite in the vicinity of the raffinate pits contained variable concentrations of uranium ranging from 13 μg/L in the seep west levee pit 4 to 1,900 μg/L in the STP seep (fig. 3).

Dissolved-solids concentrations in wells sampled were less than 500 mg/L except for five monitoring wells (MW-2003, MW-2006, MW-3003, MW-3008, MW-3009; fig. 3) located onsite. Of these, only one, monitoring well MW-2006, is not in the vicinity of the raffinate pits. Concentrations of dissolved solids in shallow monitoring wells near the pits ranged from 387 mg/L in monitoring well MW-3009, to 6,470 mg/L in monitoring well MW-3008. These wells also contained among the largest concentrations of calcium, magnesium, sodium, sulfate, nitrite plus nitrate as nitrogen, lithium, strontium, and uranium in shallow groundwater at the site. Concentrations of nitrite plus nitrate as nitrogen ranged from 24 mg/L in monitoring well MW-3009 to 1,100 mg/L in monitoring well MW-3008. Lithium concentrations ranged from 8 μg/L in monitoring well MW-3009 to 1,000 μg/L in monitoring well MW-2003, and uranium concentrations ranged from 3 μg/L in monitoring well MW-2003 to 110 μg/L in monitoring well MW-3009.

OVERBURDEN CHARACTERIZATION

Sixty-six individual samples from the various overburden units at the site were collected and analyzed for mineralogic and chemical contents. Mineralogic determinations were made on the bulk (less than 2 mm) and clay-size (less than 0.002 mm) fractions. Chemical analyses were performed on the coarse or sand-size (less than 2 mm but greater than 0.063 mm) and the fine or clay/silt-size (less than 0.063 mm) fractions. A subset of these samples was used to construct a composite sample of each overburden unit. To investigate the mechanisms of contaminant attenuation within the overburden beneath the raffinate pits, composite samples of the Ferrelview Formation and clay till were selected to be used in laboratory sorption experiments. A simulated leachate derived from raffinate-pit water was used in the experiments. Results from these experiments will be used in constructing models of contaminant movement from the raffinate pits and by the USDOE in assessing the suitability of these materials for use in remedial activities at the site.

Methodology

To characterize spatial and vertical homogeneities in overburden grain-size distribution, mineralogy, and chemistry, and to provide fresh samples for laboratory experiments, samples were collected from each overburden unit penetrated during geotechnical drilling at the site. Drilling was done by USDOE contractors as part of ongoing geotechnical-characterization efforts of the overburden and upper bedrock. The location of drillholes from which samples were obtained are shown in figure 4. A CME-55 drill rig was used and each drillhole was logged and sampled by a geologist. Holes were drilled by advancing either a split spoon or Shelby tube sampler 2 to 2.5 ft ahead of a 7 5/8-in.-outside-diameter hollow-stem auger. The retrieved core was logged and divided by a site geologist and subsamples were placed in sealed plastic bags for transport to the Environmental Research Laboratory at the Department of Civil Engineering, University of Missouri-Rolla.

In the laboratory, sample bags from each drillhole were compared against drillers' logs to verify field labels. Subsamples of approximately similar size were collected from two or three field samples selected to represent the upper, middle, and lower part of each unit from a given drillhole. Because of uncertainties between some overburden-unit boundaries, subsamples were not collected from samples that represented intervals within 12 in. of unit boundaries. Each subsample was split into two equal fractions. One fraction was submitted to a USGS geochemistry laboratory in Denver, Colorado, for detailed mineralogic determinations. Each of these samples was sieved, centrifuged, and split into three size fractions: sand (0.063 mm to 2 mm), silt (0.002 mm to 0.063 mm), and clay (less than 0.002 mm). Particles larger than 2 mm composed a small part of the samples and were discarded. Mineralogic determinations and semiquantitative elemental analyses were performed on the sand-size and clay/silt-size fractions. These analyses included X-ray diffraction of bulk powder samples and X-ray diffraction of individual grains using a Gandolfi camera, optical microscopy, clay mineralogy, and emission spectrometry. Results of these analyses are listed in tables 2, 3, and 4, at the back of this report. Clay mineralogy was determined by X-ray diffraction of the less than 0.002-mm size fraction.

The remaining fraction was retained and processed for laboratory sorption experiments. A stainless-steel knife was used to divide each sample into quarters. These were then placed on a 6.35-mm-thick by 50-cm (centimeters)-square glass plate and disaggregated by hand (using nonpowdered plastic gloves) into smaller pieces and allowed to dry at room temperature for several hours. Further manual disaggregation was performed several times until the samples could not be disaggregated further. The final steps of overburden preparation involved the use of a rubber-sleeved rolling pin to lightly disaggregate the remaining clumps of soil. By following this procedure, the materials were not allowed to fully dry and become brittle, thus minimizing the breakage of the larger individual particles. After rolling, each sample was allowed to completely air dry and a final rolling was performed. Each sample was then sieved through a number 12 (1.70 mm) stainless-steel sieve to remove the larger particles and rock fragments. The material retained on the sieve was stored separately in sealed plastic bags. Material passing through the sieve was collected and stored in sealed plastic bags for use in sorption experiments.

After all overburden samples were processed in the above manner, a separate composite sample of the Ferrelview Formation and of the clay till was prepared. The composite samples were prepared by removing approximately 5 g (grams) of processed material from each bag for each of the two units and placing this into separate 1-gallon polyethylene jugs. The bags were then stirred and the process repeated until a sufficient quantity of material, about 2 kg (kilograms), was obtained for each unit.

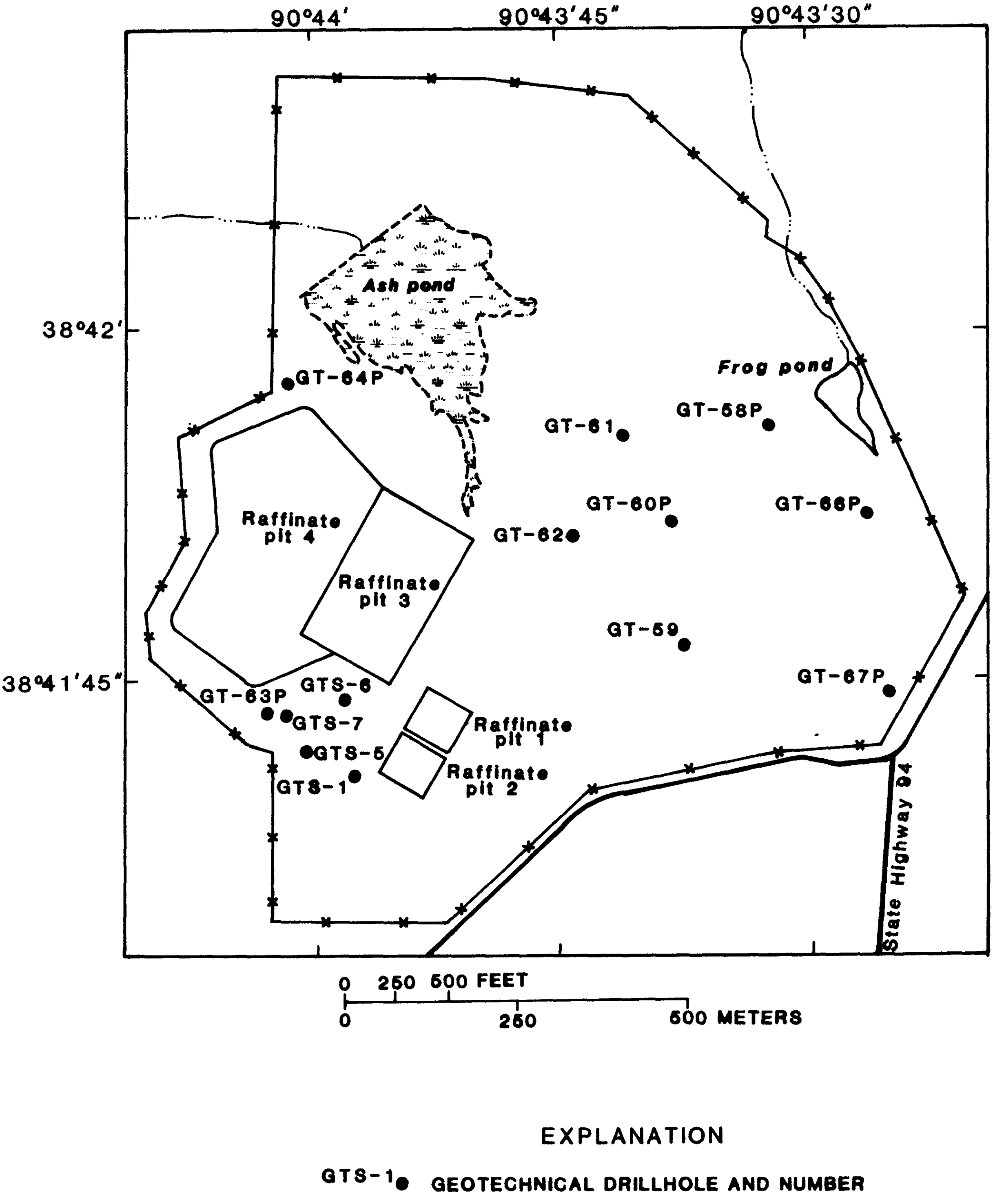

Figure 4.--Location of geotechnical drillholes from which overburden samples were collected at the Weldon Spring chemical plant site (modified from MK-Ferguson Co. and Jacobs Engineering Group, 1989a).

To investigate the attenuation of contaminants within the overburden, a matrix of laboratory "batch-type" experiments was constructed. Two of the overburden units, the Ferrelview Formation and clay till, were selected for these experiments based on their large relative thicknesses in the vicinity of the raffinate pits and the potential use of these units in remediation strategies at the site. These experiments were conducted by mixing 22.0 g of each overburden unit with 220 mL of a simulated leachate. The simulated leachate was prepared using surficial water collected from raffinate pit 3 that was spiked with aluminum, chromium, lead, nickel, and uranium. About 40 L of raffinate pit 3 water were collected during June 1989. This water was filtered through a 0.1-μm cellulose-nitrate filter in the field into 25-L polyethylene carboys that were transported to the Environmental Research Laboratory at the University of Missouri-Rolla where they were stored in an environmental room at 4 °C.

Because of uncertainties in the range of pH within the raffinate-pit sludges and underlying overburden, and advective transport of contaminants beneath the raffinate pits, pH and reaction time were selected as independent variables to be evaluated in the experiments. Three pH values (4.5, 7.0, and 9.0) were selected to represent the plausible ranges expected in the field. Experiments were carried out at each pH value for five time periods; 24, 48, 120, 240, and 480 hours in 200-mL polyethylene centrifuge bottles. A total of four reaction bottles for each pH time-period combination were used for each of the two overburden units evaluated. The four bottles were labeled A through D. A bottles were used to monitor pH fluctuations and determine the quantity of acid or base needed to adjust the pH in bottles A, B, and C. The B bottles were designated for analysis by the USGS national water-quality laboratory. The C bottles also were analyzed by the USGS national water-quality laboratory to test for reproducibility of experimental results. The D bottles were not pH adjusted and their solutions were shipped to the USGS national water-quality laboratory for analyses. The physical properties and constituents analyzed in each of the bottles are listed in table 5, at the back of this report. To minimize cross-contamination, pH was measured only in the A bottle and the appropriate quantity of hydrochloric acid or sodium hydroxide was titrated to adjust the pH to the desired value. The same quantity of acid or base was then added to the B and C bottles. Various strengths of standardized acids and bases were used to minimize the total volume of titrants added: 0.01 N, 0.1 N, 0.99 N, and 6 N hydrochloric acid and 0.0199 N, 0.199 N, and 1 N sodium hydroxide. The volume of titrants added did not exceed 5 mL, or approximately 2 percent of the total volume in the reaction bottles.

The experiments were divided into two series, the Ferrelview series (FP) and clay till series (CP). Within each series, three individual experiments were performed simultaneously at each of the three specified pH values. Each bottle was labeled according to its series, pH value, bottle designation, and equilibration time. For example, sample bottle FP45B-3 would refer to Ferrelview Formation, initial solution pH of 4.5, B bottle (pH adjusted to maintain pH 4.5), and time period 3 (120 hours).

Before each individual experiment, 22.0 g of composite material was added to each centrifuge bottle. A small Teflon-coated spoon was used to remove a small part of composite material from the storage jugs by passing the spoon through the entire depth of material. The material was stirred and the process repeated alternating between bottles until each bottle had the appropriate quantity of material. A stock solution of simulated leachate was prepared for each sample experiment by placing 5 L of filtered raffinate-pit 3 water into an acid-washed container. This was then spiked with 0.350 mL of a 1,000-mg/L aluminum standard, 0.250 mL of a 1,000-mg/L chromium standard, 0.450 mL of a 1,000-mg/L lead standard, 0.250 mL of a 1,000-mg/L nickel standard, and 15.75 mL of a 1,000-mg/L uranium standard. The resultant solution contained approximately 100 μg/L of aluminum and lead, 50 μg/L of chromium and nickel, and 3,500 μg/L of uranium. The pH was then adjusted to the desired value and the stock solution transferred to the bottles containing the soil mixture using a 100-mL glass pipet. The bottles were then capped, placed on a mixing wheel, and rotated about the short axis at 3 to 5 rpm (revolutions per minute). During the first several hours, pH was measured in the A bottles every 15 to 30 minutes, and the appropriate volume of acid or base was then titrated into the A, B, and C bottles. The D bottles were not pH adjusted and remained closed until each experiment was completed.

After the specified equilibration time, the bottles were removed from the mixing wheel, and centrifuged at 12,000 rpm for 20 minutes. After centrifuging, the solutions were filtered though a 47-mm-diameter, 0.1-µm pore size cellulose-nitrate filter placed in a polyethylene holder using a peristaltic pump as a pressure source. Before filtration, the system was flushed with 10 volumes of deionized water. After finishing, the sample solution was pumped with the filter holder inverted until the system was filled (approximately 25 mL) and the filter completely saturated. After 5 minutes, this filtered solution was discarded and the remaining sample was then filtered into polyethylene sample bottles.

Samples collected from the B and D bottles were submitted to the USGS national water-quality laboratory for analysis. Major cations and trace elements were analyzed by flameless atomic absorption and inductively coupled plasma (ICP). Anions and nitrogen species were analyzed by methods described in Fishman and Friedman (1989). A 40-mL subsample from these bottles was submitted to the USGS geochemistry laboratory for uranium analysis by ICP-MS. Samples from the C bottles were submitted for major cation and trace-element analysis only to check reproducibility of B-bottle results. A summary of the results of these experiments is listed in table 6, at the back of this report.

The remaining sample in the A bottle was split into two fractions. One fraction was acidified with ultrapure nitric acid for flameless atomic-absorption analysis performed as part of graduate-student research projects. The remaining fraction was archived in an environmental room at about 4 °C. Soil samples from the experiments were removed from the bottles with a Teflon spatula, placed in sealed polyethylene containers, and archived in a environmental room at 4 °C.

All new glassware was soaked in a 10-percent hydrochloric-acid solution for a minimum of 30 minutes followed by a triple rinse of tap water and a triple rinse of deionized water. Contaminated glassware, such as beakers, burets, flasks, pipets, and polyethylene centrifuge bottles, were cleaned by a three-step process. An initial scrubbing with laboratory detergent was followed by a detergent soaking for 30 minutes. This was followed by thorough washing in tap water before overnight soaking in a 10-percent hydrochloric-acid solution. Rinsing procedures described above were then used before air drying on storage racks.

Mineralogy and Geochemistry

The overburden units at the site are primarily composed of silt-size particles, with lesser quantities of clay-size and sand-size particles. The predominate mineral in the bulk (less than 2 mm) fraction is quartz; other minerals in the bulk fraction included albite, orthoclase, montmorillonite, kaolinite, calcite, and mica in varying proportions. Considerable variation among individual samples is likely (table 2). For example, a lower clay till sample from geotechnical drillhole GTS-1 is composed of 34 percent sand-size particles and is about 25 percent by weight calcite and other carbonate minerals. The percentage of clay minerals listed in table 2 is relative to the total abundance of clay minerals in the clay-size fraction. Montmorillonite is the predominant clay mineral, followed by kaolinite and illite. Although not listed in table 2, quartz is the predominate mineral in all units in the clay-size fraction. Concentrations of calcium in the bulk fraction range from 0.1 to 5 percent by weight. Concentrations of iron generally are larger than those for calcium ranging from 0.7 to 7 percent by weight with the Ferrelview Formation and clay till containing the largest quantities.

Average physical, mineralogic, and chemical characteristics of the five overburden units are listed in table 3. The loess is composed mainly of silt-size particles (77 percent) with lesser quantities of clay-size particles (16 percent) and sand-size particles (7 percent). It is enriched in orthoclase (13 percent) relative to the other units and contains moderate quantities of calcite (4 percent). The Ferrelview Formation is composed of slightly finer-grained material than the other units, in particular the upper Ferrelview, which is composed of, on average, 69 percent silt-size particles and 25 percent clay-size particles. The middle and lower parts of the Ferrelview contain larger quantities of quartz (84 to 85 percent) than other units and are virtually devoid of calcite and other carbonate minerals. The clay till contains less than average quantities of silt-size particles (46 to 54 percent) and more sand-size particles (19 to 27 percent) than do the Ferrelview Formation and the loess. Quantities of calcite in the clay till (3 to 8 percent) tend to increase with depth.

The distribution of clay minerals changes with depth, with the relative quantity of kaolinite increasing to a maximum in the basal till. Conversely, the quantity of montmorillonite decreases to a minimum in the basal till. This unit is similar to the clay till in most other aspects. The residuum contains the largest quantity of sand-size particles (52 percent) and calcite (20 percent), and contains lesser quantities of quartz (73 percent) relative to the other units.

Laboratory Sorption Experiments

The results of laboratory sorption experiments conducted at fixed values of pH for various constituents are listed in table 6. The values listed are concentrations in solution at the conclusion of each experiment. The first row of each group represents the concentrations in the initial stock solution before interaction with the overburden units. These samples have the suffix "- initial". The first two digits of the sample number indicate the overburden unit used in the experiment--FP denotes Ferrelview Formation and CP denotes the clay till. The third and fourth digits indicate the value of fixed pH--45 denotes pH 4.5; 70 denotes pH 7.0; and 90 denotes pH 9.0. The fifth and sixth digits indicate the bottle number and time period. The last six rows list constituent concentrations for the D bottles that were not pH adjusted during the experiments. In these samples, the third and fourth digits indicate only the pH of the initial leachate solution.

Concentrations of most contaminants in the simulated leachate solution decreased when in contact with the Ferrelview Formation and clay till in laboratory experiments. Concentrations of calcium in solution, however, generally increased with reaction time, especially at pH 4.5 in contact with the clay till. For example, concentrations of calcium in solution in contact with the clay till increased from 530 mg/L in the initial solution to 1,400 mg/L after 480 hours (20 days) at pH 4.5. Magnesium concentrations in solution generally decreased with time at all values of pH except for solutions in contact with the clay till at pH 4.5. Concentrations of sodium, sulfate, and nitrite plus nitrate as nitrogen generally remained unchanged with time at all values of pH for both the Ferrelview Formation and clay-till experiments. Less than 15 percent of sulfate, 19 percent of nitrite plus nitrate as nitrogen, and 30 percent of lithium were removed at fixed pH values of 4.5, 7.0, or 9.0. Aluminum concentrations in solution in contact with the Ferrelview Formation and clay till generally decreased with time at pH 7.0 and 9.0. At pH 4.5, however, aluminum concentrations generally increased with time, especially when solutions were in contact with the clay till--80 μg/L at time period 0 to 3,100 μg/L at time period 5 (480 hours). Concentrations of lead and vanadium decreased rapidly at all values of pH for both overburden units to less than the detection limits, with more than 95 percent of the lead and 86 percent of the vanadium removed. Concentrations of molybdenum that remained in solution were substantially affected by pH. At pH 4.5, molybdenum decreased from 4,400 μg/L and 4,000 μg/L in the Ferrelview Formation and clay-till experiments to less than the detection limit of 100 μg/L at the end of 480 hours. The decrease in molybdenum concentrations in the low pH experiment represent removal of more than 97 percent of the initial concentrations. Lesser quantities of molybdenum were removed at pH 7.0 (less than 41 percent) and no substantial removal was observed at pH 9.0 (less than 5 percent removed).

Concentrations of uranium in solution decreased at all pH values in the Ferrelview Formation and clay-till experiments. At pH 4.5, uranium decreased from 3,400 μg/L and 3,100 μg/L in the initial Ferrelview and initial clay-till solutions to 160 μg/L (95 percent removed) and 75 μg/L (98 percent removed) after 480 hours. More than 98 percent of the uranium was removed from the unadjusted solutions (initial pH values of 4.5 and 7.0) in contact with the Ferrelview Formation. Similar to most other contaminants, larger quantities of uranium remained in solution with increasing values of pH, except for the solution in contact with the clay till at pH 9.0. At this pH, 92 percent of the initial quantity of uranium was removed from the solution after 480 hours, whereas only 52 percent of the initial quantity of uranium was removed from the solution in contact with the clay till at pH 7.0.

RAFFINATE SLUDGE AND INTERSTITIAL WATER GEOCHEMISTRY

Any effort to characterize movement of contaminants from the raffinate pits requires an accurate assessment of the nature of contaminants within the pits. To determine the quality of the interstitial water within the raffinate-pit sludges, a pilot sampling was initiated in August 1989.

Methodology

Because of concerns with the removal of large quantities of radiologically contaminated materials from the site, an experimental in-situ technique using dialysis cells modified after Ronen and others (1986) was used. Passive interstitial geochemical samplers were constructed and placed at various depths within the sludge in raffinate pit 3. A schematic representation of a sampler is given in figure 5. In theory, the samplers, containing deionized-deoxygenated water, are in contact with the interstitial water across a 0.2-μm pore size membrane, allowing constituents to diffuse from the larger concentrations outside the sampler to the smaller concentrations inside.

The samplers were constructed from 6-in. lengths of 1 1/2-in.-diameter PVC (polyvinyl chloride) pipe to which a 1 1/2-in. to 1-in. threaded compression coupler was attached. The colored plastic gasket supplied with the couplers was replaced by a clear polyethylene gasket. A 2-in.-diameter pipe about 5-in. long to which a nylon rope had been attached through predrilled holes was used as a sleeve over the 1 1/2-in. tube, and a second coupler then was attached. To protect the membrane-covered openings of the samplers during installation, caps were made from 2-in. PVC well points. Between 20 and 25 1/4-in.-diameter holes were drilled along the sides of the well points. After assembly, the samplers and caps were scrubbed with detergent soap, rinsed, and soaked in 10-percent hydrochloric acid for 12 hours. They then were removed, triple rinsed with tap water, triple rinsed with deionized water, and stored under deionized water in a sealed plastic container. The deionized-deoxygenated water used to fill the samplers was prepared in the laboratory by boiling deionized water for 30 minutes. This water then was transferred to a 6-L carboy and purged with nitrogen overnight.

At the site, the samplers and caps were removed from the storage container and rinsed with deionized water before installation of the membranes. The membranes used were Gellman Versapore-200 47-mm-diameter polycarbonate coated nylon filters with a pore size of 0.2 μm. Fifteen samplers were preassembled in this fashion and placed in a covered plastic tray. A small, flat-bottom row boat was used to access the raffinate pit. Once the boat was positioned and anchored, each sampler was charged with the deionized-deoxygenated water, fitted with

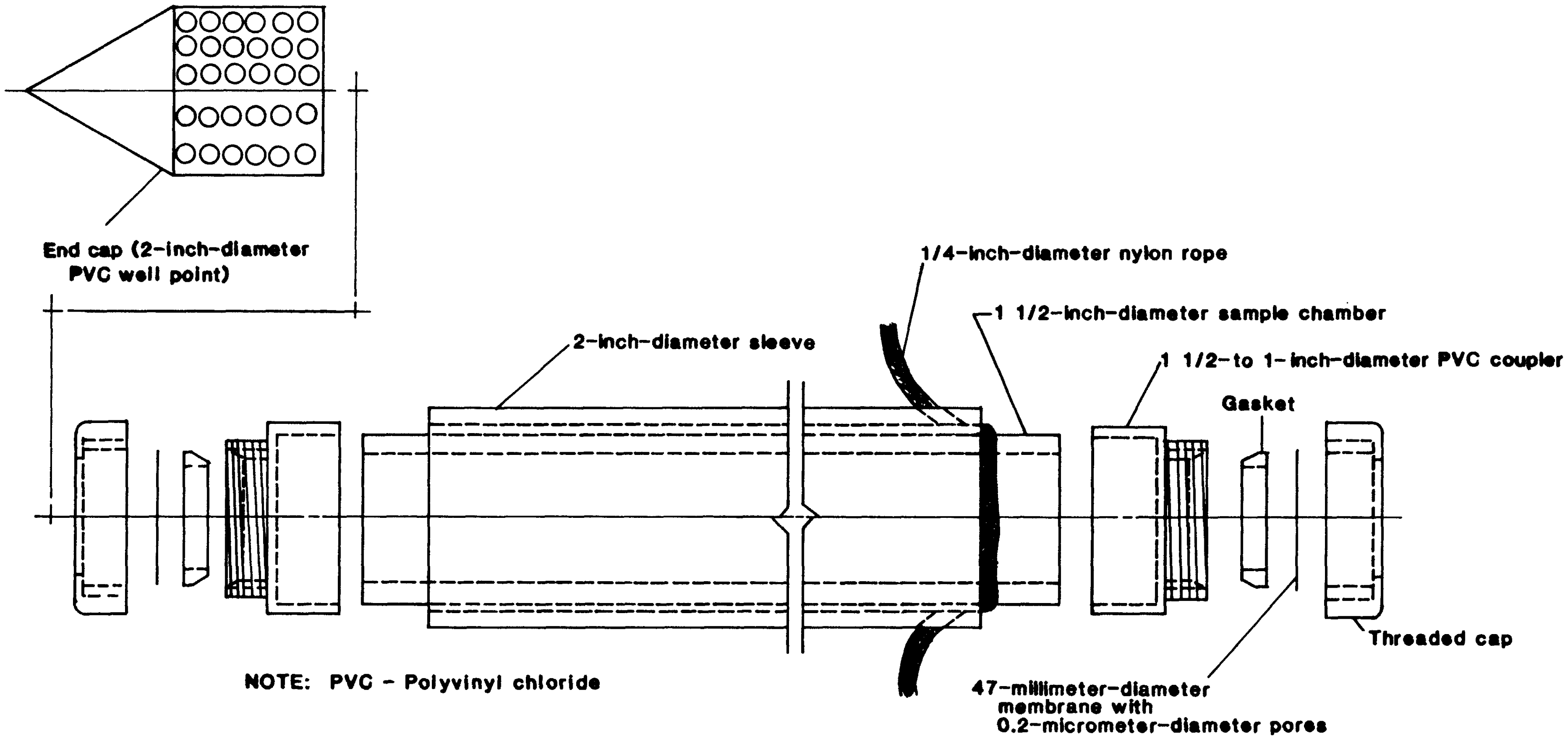

Figure 5.--Schematic representation of a passive interstitial geochemical sampler.

protective caps, and inserted to a specified depth below the water-sediment interface. This was accomplished by using a flexible rubber coupler to attach the end cap of the samplers to an 8-ft section of 2-in.-diameter PVC pipe. Once the sampler was pushed to the desired depth, a section of 1 1/2-in.-diameter PVC pipe was used as a plunger to detach the sampler from the larger pipe. Three samplers were placed at each of the following depths below the water-sediment interface; 1.5, 3, 4, and 4.5 ft. Each group of samplers was identified by securing the individual ropes to a single float. Depth of water in the raffinate pit during sampler installation ranged from 1.5 to 2.0 ft.

After an equilibration time of 51 days, the samplers were retrieved by boat. Because of the thixotropic nature of the sludge, only slight upward pressure on the ropes was required to remove the samplers. After being brought to the surface, the protective caps were removed and the samplers were washed with deionized water, using a small spray tank, before being placed in sealed nitrogen-filled plastic bags. A small quantity of sludge was scraped from several of the protective caps for mineralogic and scanning-electron-microscope (SEM) characterization. On shore, a 100-mL syringe with an 18-gauge stainless-steel needle was used to extract the fluid from the samplers. pH, temperature, and dissolved-oxygen determinations then were made using the water from at least one sampler from each depth. Dissolved oxygen was measured using the HACH Indigo Carmine method and a portable spectrophotometer. Water from samplers placed at equal depths was composited into a 500-mL polyethylene bottle. This was split into two 75-mL acidified aliquots for major-cation, trace-element, and uranium determinations, and two 75-mL aliquots for anion and nutrient determinations. The preservatives used were identical to those used for ground- and surface-water samples. All analytical determinations were made at the USGS national water-quality laboratory, except for uranium analyses, which were done at the USGS geochemistry laboratory.

Summary of Data

Elemental and mineralogic analyses of a composite sludge sample collected from a depth of 4.5 ft below the water-sediment interface during the removal of the samplers are listed in table 7, at the back of this report. The predominant mineral identified by X-ray diffraction was apatite, probably fluorapatite, comprising more than 99 percent of the sample with minor quantities of quartz, hornblende, amorphous iron oxides, and trace flakes of graphite. Detailed SEM analyses using energy-dispersive X-ray (EDS) identified scattered grains of carnotite. The majority of the uranium, however, is associated with the apatite phase. Concentrations of thorium and uranium in this sample were 1,200 and 1,600 mg/kg (milligrams per kilogram) after partial digestion using hydrochloric acid and hydrogen peroxide, and were 1,290 and 1,700 mg/kg after complete digestion using concentrated hydrochloric, hydrofluoric, nitric, and perchloric acids. Large quantities of calcium (20 weight percent), phosphorus (10 weight percent), and iron (8.5 to 8.9 weight percent) were detected. Small quantities of most other trace constituents were detected (table 7).

Values of most properties and concentrations of most constituents in the raffinate-sludge interstitial water increased with increasing depth below the water-sediment interface (table 8, at the back of this report). Specific conductance increased from 12,000 µS/cm in the surface water just above the water-sediment interface to 53,900 µS/cm at a depth of 4.5 ft. Values of pH decreased from 8.51 above the water-sediment interface to 7.31 at a depth of 4.5 ft. Concentrations of dissolved oxygen in the surface water were large, 10.4 mg/L, and concentrations remained greater than 1 mg/L within the sludge. Because dissolved-oxygen concentrations were not made immediately after the samples were retrieved, their values may be unreliable. Concentrations of selenium increased more than three orders of magnitude from less than 1 µg/L in the surface water to 3,700 µg/L at a depth of 4.5 ft below the water-sediment interface. Increases of more than two orders of magnitude were detected in the concentrations of nitrite, ammonia, and manganese with depth. Several other constituents, such as calcium, iron, and zinc had increases greater than one order of magnitude. Concentrations of chromium in the interstitial water were extremely variable, ranging from 2 µg/L above the water-sediment interface to 8,500 µg/L at a depth of 4.5 ft, with marked decreases detected in samples from depths of 3 to 4 ft. Concentrations of most other constituents, except bicarbonate, fluoride, lithium, molybdenum, and uranium, generally increased with increasing depth.

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List of abbreviations used in table 1

TD	Total depth of well, in feet
Q	Instantaneous discharge, in cubic feet per second
Cond	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius
pH	In standard units
Eh	Oxidation-reduction potential converted to standard hydrogen electrode, in millivolts
Temp	Water temperature, in degrees Celsius
DO	Dissolved oxygen, in milligrams per liter
Ca	Dissolved calcium, in milligrams per liter
Mg	Dissolved magnesium, in milligrams per liter
Na	Dissolved sodium, in milligrams per liter
K	Dissolved potassium, in milligrams per liter
HCO_3	Bicarbonate, in milligrams per liter
CO_3	Carbonate, in milligrams per liter
Alk	Alkalinity as $CaCO_3$, in milligrams per liter
SO_4	Dissolved sulfate, in milligrams per liter
Cl	Dissolved chloride, in milligrams per liter
F	Dissolved fluoride, in milligrams per liter
Br	Dissolved bromide, in milligrams per liter
SiO_2	Dissolved silica, in milligrams per liter
TOC	Total organic carbon, in milligrams per liter
DS	Dissolved solids, residue at 180 degrees Celsius, in milligrams per liter
$NO_2 + NO_3$	Dissolved nitrite plus nitrate as N, in milligrams per liter
NO_2	Dissolved nitrite as N, in milligrams per liter
NH_4	Dissolved ammonium as N, in milligrams per liter
P	Dissolved phosphorus as P, in milligrams per liter
Al	Dissolved aluminum, in micrograms per liter
As	Dissolved arsenic, in micrograms per liter
Ba	Dissolved barium, in micrograms per liter
Be	Dissolved beryllium, in micrograms per liter
B	Dissolved boron, in micrograms per liter
Cd	Dissolved cadmium, in micrograms per liter
Cr	Dissolved chromium, in micrograms per liter
Co	Dissolved cobalt, in micrograms per liter
Cu	Dissolved copper, in micrograms per liter
Fe	Dissolved iron, in micrograms per liter
Fe^{2+}	Dissolved ferrous iron, in micrograms per liter
Pb	Dissolved lead, in micrograms per liter
Li	Dissolved lithium, in micrograms per liter
Mn	Dissolved manganese, in micrograms per liter
Mo	Dissolved molybdenum, in micrograms per liter

List of abbreviations used in table 1--Continued

Ni	Dissolved nickel, in micrograms per liter
Se	Dissolved selenium, in micrograms per liter
Ag	Dissolved silver, in micrograms per liter
Sr	Dissolved strontium, in micrograms per liter
V	Dissolved vanadium, in micrograms per liter
Zn	Dissolved zinc, in micrograms per liter
Ra	Dissolved radium-228, in picocuries per liter
U	Dissolved uranium, in micrograms per liter
tU	Total uranium, in micrograms per liter
Trit	Total tritium, in picocuries per liter
$Sr^{87/86}$	Isotopic ratio of strontium-87 to strontium-86

Table 1.--*Water-quality data from ground- and surface-water sites*

[--, not determined; <, less than; trib., tributary; Is., Island]

Site (figs. 2 and 3)	Date	Time	TD	Q	Cond	pH	Eh	Temp	DO	Ca	Mg	Na	K
MW-2001	6-05-89	1500	58.3	--	778	7.17	443	13.5	7.0	84	40	9	1.6
MW-2002	8-02-89	1100	58.2	--	2,620	7.18	548	15.0	--	260	85	110	--
MW-2003	3-13-89	1445	58.3	--	4,500	6.80	362	13.5	--	470	150	220	11
	6-06-89	1045	58.3	--	5,460	6.24	577	14.5	6.0	560	190	240	12
MW-2004	8-02-89	1430	75.7	--	671	7.19	537	13.5	6.4	63	40	10	1.1
MW-2005	5-11-89	1030	75.6	--	889	7.29	504	14.5	--	81	45	17	2.3
	6-06-89	0900	75.6	--	815	6.94	499	14.2	--	86	45	17	1.8
MW-2006	3-14-89	1030	65.5	--	1,460	6.61	328	14.5	--	120	55	77	7.0
	6-06-89	1330	65.5	--	1,480	6.76	294	15.0	3.3	130	56	81	7.0
MW-2021	8-01-89	1400	111	--	747	6.70	469	16.5	2.7	63	51	10	1.2
MW-2022	8-03-89	1430	126	--	620	7.13	309	15.5	.7	57	47	6	1.1
MW-2029	8-03-89	0900	101.4	--	611	7.21	706	14.0	4.1	57	46	8	1.1
MW-3003	5-10-89	0900	89.2	--	3,850	6.77	517	14.0	--	320	140	230	10
MW-3006	5-10-89	1500	135	--	461	7.32	328	15.5	--	22	16	37	35
MW-3008	3-15-89	1200	101	--	5,700	6.70	337	13.0	--	640	180	220	2.3
	6-06-89	1500	101	--	8,100	6.25	508	15.0	11.0	900	240	260	2.6
MW-3009	3-15-89	1530	99.4	--	1,020	7.29	314	13.5	--	94	55	20	1.0
	6-08-89	0900	99.4	--	658	7.48	521	15.0	1.4	57	39	10	.5
LY 3601	8-03-89	1430	--	--	1,040	7.00	--	22.9	--	91	79	170	2.3
LY 3603	8-03-89	1155	--	--	2,920	6.90	--	22.1	--	290	76	250	1.1
Seep west levee pit 4	4-11-89	1030	--	0.07	785	7.20	--	7.0	--	110	39	12	1.0
	6-08-89	0815	--	--	713	7.63	499	20.6	6.6	97	36	9	.6
STP seep	3-15-89	1100	--	.00	1,070	7.72	367	9.0	--	140	25	51	2.7
Burgermeister spring	3-16-89	1100	--	--	372	6.54	364	8.5	--	43	10	13	2.4
	6-07-89	0945	--	--	663	6.79	431	11.0	--	73	18	29	2.8
	8-02-89	0815	--	--	749	6.33	510	10.5	8.2	75	20	33	3.0
MWGS-04	4-11-89	1045	310	--	476	8.05	--	14.5	--	46	34	6	3.5
O'Fallon/Gasconade	6-07-89	1245	--	--	619	6.84	437	17.0	<2	53	29	36	8.6
Ash pond outflow	3-14-89	1330	--	--	407	7.98	346	13.5	--	48	10	19	3.5
Frog pond	6-06-89	1530	--	--	1,090	8.89	--	30.0	--	40	9	160	3.8
Raffinate pit 3	3-14-89	1500	--	--	11,000	7.51	--	16.0	--	490	360	1,100	85
	6-08-89	1115	--	--	12,000	8.51	--	25.5	10.4	490	370	1,300	87
Raffinate pit 4	3-14-89	1600	--	--	1,120	8.92	325	11.0	--	11	37	190	13
Unnamed trib. Twin Is.	6-07-89	1125	--	--	312	7.56	--	21.7	--	42	9	13	2.4

Table 1.--*Water-quality data from ground- and surface-water sites*--Continued

Site (figs.. 2 and 3)	Date	Time	HCO_3	CO_3	Alk	SO_4	Cl	F	Br	SiO_2	TOC	DS	NO_2+NO_3
MW-2001	6-05-89	1500	420	0	346	7	7.5	0.1	0.04	8.7	0.9	419	12
MW-2002	8-02-89	1100	350	0	284	100	--	--	.09	15	.5	--	220
MW-2003	3-13-89	1445	340	0	276	210	15	.1	--	11	.8	3,720	560
	6-06-89	1045	300	0	248	220	21	.1	.03	11	1.6	4,400	680
MW-2004	8-02-89	1430	430	0	349	2	1.2	.2	.03	9.4	.4	340	.68
MW-2005	5-11-89	1030	360	0	292	9	1.9	.2	--	9.4	.1	456	26
	6-06-89	0900	360	0	294	7	2.5	.1	.03	9.7	.9	466	36
MW-2006	3-14-89	1030	390	0	320	32	200	.1	--	9.6	4.9	750	13
	6-06-89	1330	400	0	324	32	250	.1	.09	9.7	6.1	789	6.4
MW-2021	8-01-89	1400	450	0	366	13	1.1	.1	.02	8.6	.4	368	<.01
MW-2022	8-03-89	1430	420	0	346	14	.8	.1	.02	8.5	.3	343	.11
MW-2029	8-03-89	0900	420	0	343	18	1.6	.2	.02	10	.3	348	<.01
MW-3003	5-10-89	900	340	0	280	200	13	.2	--	10	--	3,030	440
MW-3006	5-10-89	1500	240	0	198	71	1.3	.3	--	.2	.3	304	.31
MW-3008	3-15-89	1200	330	0	274	41	13	.2	--	12	.5	4,270	680
	6-06-89	1500	300	0	245	43	20	.1	.10	12	1.4	6,470	1,100
MW-3009	3-15-89	1530	190	0	156	46	3.4	.2	--	8.8	.3	693	84
	6-08-89	0900	200	0	164	65	1.8	.2	<.01	8.4	1.2	387	24
LY 3601	8-03-89	1430	--	--	--	250	--	.7	--	73	--	--	--
LY 3603	8-03-89	1155	--	--	--	160	19	.3	<.01	78	--	--	--
Seep west levee pit 4	4-11-89	1030	190	0	154	270	1.9	.5	--	4.4	1.7	535	.48
	6-08-89	0815	150	0	124	250	3.1	.5	<.01	6.7	2.6	483	1.2
STP seep	3-15-89	1100	260	0	210	130	4.7	.6	--	6.5	5.9	747	59
Burgermeister spring	3-16-89	1100	110	0	94	34	10	.2	--	9.2	3.6	214	8.2
	6-07-89	0945	190	0	155	45	11	.2	.04	11	2.2	371	20
	8-02-89	0815	220	0	176	57	23	.2	.06	12	1.6	422	21
MWGS-04	4-11-89	1045	250	0	249	15	1.9	.6	--	3.3	.5	234	<.1
O'Fallon/Gasconade	6-07-89	1245	--	--	281	38	10	1.4	.04	8.5	.5	356	.32
Ash pond outflow	3-14-89	1330	130	0	109	40	5	.4	--	9.1	8.3	254	12
Frog pond	6-06-89	1530	68	17	82	46	260	.3	<.01	3.9	8.0	591	.25
Raffinate pit 3	3-14-89	1500	58	0	48	570	19	5.6	--	.4	3.1	8,820	1,400
	6-08-89	1115	30	12	44	630	23	6.9	<.01	1.1	5.4	9,550	1,500
Raffinate pit 4	3-14-89	1600	400	64	432	110	6.5	6.0	--	1.4	11.0	733	7.4
Unnamed trib. Twin Is.	6-07-89	1125	140	0	117	18	15	.3	.08	6.1	--	179	.69

Table 1.--*Water-quality data from ground- and surface-water sites*--Continued

Site (figs. 2 and 3)	Date	Time	NO_2	NH_4	P	Al	As	Ba	Be	B	Cd	Cr	Co
MW-2001	6-05-89	1500	0.03	0.02	0.030	10	<1	210	<1	<10	<1	2	<3
MW-2002	8-02-89	1100	<.01	.06	.040	<10	<1	300	10	10	<1	2	1
MW-2003	3-13-89	1445	.01	.07	.030	30	<1	300	<10	20	<1	3	1
	6-06-89	1045	<.01	.14	.020	<10	<1	300	<10	10	<1	<1	1
MW-2004	8-02-89	1430	<.01	<.01	.030	<10	<1	140	<1	<10	<1	<1	<3
MW-2005	5-11-89	1030	<.01	.02	.040	<10	<1	170	<1	10	<1	2	<3
	6-06-89	0900	<.01	.02	.041	<10	<1	170	<.5	20	<1	<1	<3
MW-2006	3-14-89	1030	.01	.01	.020	<10	<1	280	<1	10	<1	2	<3
	6-06-89	1330	<.01	.02	.020	<10	<1	280	<1	<10	<1	<1	<3
MW-2021	8-01-89	1400	<.01	.02	.050	<10	2	220	<1	20	<1	<1	<3
MW-2022	8-03-89	1430	<.01	.02	.030	<10	<1	180	<1	10	<1	<1	<3
MW-2029	8-03-89	0900	<.01	<.01	.040	<10	<1	120	<1	<10	1	<1	<3
MW-3003	5-10-89	0900	.19	.08	.030	<10	<1	300	<10	50	<1	2	1
MW-3006	5-10-89	1500	<.01	.03	.490	<10	1	2	1	20	<1	20	<3
MW-3008	3-15-89	1200	.01	.12	.010	<10	<1	500	<10	20	<1	3	<1
	6-06-89	1500	<.01	.39	<.010	<10	<1	500	<10	20	<1	3	2
MW-3009	3-15-89	1530	.02	.01	<.010	<10	2	1,300	<1	<10	<1	<1	<3
	6-08-89	0900	.02	.02	<.010	<10	3	450	<1	<10	<1	<1	4
LY 3601	8-03-89	1430	--	--	--	<170	5	140	<8	70	2	3	4
LY 3603	8-03-89	1155	--	--	--	<100	1	150	<5	30	1	4	5
Seep west levee pit 4	4-11-89	1030	<.01	--	--	20	<1	34	<1	40	1	<1	<3
	6-08-89	815	<.01	.02	<.010	<10	<1	21	<1	30	<1	<1	<3
STP seep	3-15-89	1100	.03	.03	.010	<10	<1	110	<1	30	<1	20	<3
Burgermeister spring	3-16-89	1100	<.01	.01	.020	<10	<1	77	<1	30	<1	<1	<3
	6-07-89	0945	<.01	.01	.020	<10	<1	120	<1	40	<1	<1	<3
	8-02-89	0815	<.01	.02	.040	<10	<1	120	<1	80	<1	1	<3
MWGS-04	4-11-89	1045	<.01	--	--	10	<1	33	<1	70	4	<1	<3
O'Fallon/Gasconade	6-07-89	1245	.04	.32	<.010	<10	<1	19	<1	800	<1	<1	<3
Ash pond outflow	3-14-89	1330	.25	.02	.010	10	<1	68	<1	110	<1	<1	<3
Frog pond	6-06-89	1530	<.01	.01	<.010	20	5	65	<1	70	<1	<1	<3
Raffinate pit 3	3-14-89	1500	.91	.55	<.010	20	3	100	<10	70	<1	2	<1
	6-08-89	1115	1.10	.32	<.010	20	3	100	<10	100	<1	2	<1
Raffinate pit 4	3-14-89	1600	<.01	<.01	.020	10	6	150	<1	40	<1	<1	<3
Unnamed trib. Twin Is.	6-07-89	1125	.04	.40	<.010	<10	1	160	<1	30	<1	<1	<3

Table 1.--*Water-quality data from ground- and surface-water sites*--Continued

Site (figs. 2 and 3)	Date	Time	Cu	Fe	Fe^{2+}	Pb	Li	Mn	Mo	Ni	Se	Ag	Sr
MW-2001	6-05-89	1500	<1	5	<10	3	7	<1	<10	<1	11	<1	99
MW-2002	8-02-89	1100	2	30	10	2	450	<10	3	3	8	1	360
MW-2003	3-13-89	1445	<1	60	<10	<5	910	20	<1	<1	15	<1	1,000
	6-06-89	1045	<1	40	<10	<1	1,000	20	<1	1	<1	1	1,100
MW-2004	8-02-89	1430	2	3	<10	1	9	<1	<10	1	<1	<1	150
MW-2005	5-11-89	1030	1	11	<10	4	39	2	<10	<1	1	<1	120
	6-06-89	0900	1	5	<10	1	39	<1	<10	1	<1	<1	120
MW-2006	3-14-89	1030	2	77	<10	5	14	49	<10	58	<1	<1	200
	6-06-89	1330	<1	90	<10	2	14	56	<10	78	<1	<1	210
MW-2021	8-01-89	1400	<1	5	<10	1	10	110	10	3	<1	<1	130
MW-2022	8-03-89	1430	<1	120	40	<1	9	55	<10	1	<1	<1	150
MW-2029	8-03-89	0900	2	3	<10	1	9	7	10	2	<1	<1	190
MW-3003	5-10-89	0900	1	20	<10	1	740	180	17	17	8	<1	830
MW-3006	5-10-89	1500	<1	6	90	<1	45	2	<10	<1	<1	<1	26
MW-3008	3-15-89	1200	<1	40	20	<5	150	10	<1	<1	16	1	2,000
	6-06-89	1500	<1	40	<10	<1	170	<20	<1	<1	<1	<1	2,900
MW-3009	3-15-89	1530	1	<3	--	<5	16	4	<10	21	2	<1	200
	6-08-89	0900	<1	<3	<10	<1	8	8	<10	35	<1	<1	110
LY 3601	8-03-89	1430	5	810	880	1	110	660	<170	47	<33	--	560
LY 3603	8-03-89	1155	2	80	20	4	52	600	<100	33	<3	--	630
Seep west levee pit 4	4-11-89	1030	<1	110	--	<5	8	590	50	20	11	<1	250
	6-08-89	0815	1	4	--	<1	8	4	80	22	<1	<1	190
STP seep	3-15-89	1100	1	5	--	<5	24	2	20	<1	5	1	330
Burgermeister spring	3-16-89	1100	10	8	<10	<5	10	1	<10	<1	<1	<1	110
	6-07-89	0945	1	4	<10	<1	28	2	<10	<1	<1	<1	160
	8-02-89	0815	1	3	<10	<1	35	<1	<10	<1	1	<1	170
MWGS-04	4-11-89	1045	<1	1,400	--	<5	9	480	<10	2	<1	<1	320
O'Fallon/Gasconade	6-07-89	1245	1	11	--	1	54	5	<10	<1	<1	<1	1,400
Ash pond outflow	3-14-89	1330	<1	19	--	<5	6	6	<10	<1	1	<1	140
Frog pond	6-06-89	1530	2	9	<10	<1	11	14	<10	2	<1	<1	200
Raffinate pit 3	3-14-89	1500	3	50	--	<5	3,000	10	4,700	<1	200	1	200
	6-08-89	1115	3	40	<10	<1	3,600	10	4,700	1	<1	<1	2,100
Raffinate pit 4	3-14-89	1600	2	3	--	<5	520	1	740	<1	7	2	140
Unnamed trib. Twin Is.	6-07-89	1125	<1	5	<10	<1	5	2,200	<10	1	<1	<1	120

Table 1.--*Water-quality data from ground- and surface-water sites*--Continued

Site (figs. 2 and 3)	Date	Time	V	Zn	Ra	U	tU	Trit	Sr $^{87/86}$
MW-2001	6-05-89	1500	<6	7	--	1	--	--	--
MW-2002	8-02-89	1100	1	<10	--	--	--	--	--
MW-2003	3-13-89	1445	<1	30	3.3	3	--	61.0	--
	6-06-89	1045	<1	10	--	3	--	76.0	--
MW-2004	8-02-89	1430	<6	9	--	--	--	--	--
MW-2005	5-11-89	1030	<6	11	--	1	--	--	--
	6-06-89	0900	<6	6	--	1	--	10.2	--
MW-2006	3-14-89	1030	<6	12	.1	2	--	45.0	--
	6-06-89	1330	<6	12	--	1	--	55.0	--
MW-2021	8-01-89	1400	<6	11	--	--	--	--	--
MW-2022	8-03-89	1430	<6	12	--	--	--	--	--
MW-2029	8-03-89	0900	<6	9	--	--	--	--	--
MW-3003	5-10-89	0900	<1	40	--	17	--	--	--
MW-3006	5-10-89	1500	<6	3	--	2	--	--	--
MW-3008	3-15-89	1200	<1	20	.1	4	--	22.0	--
	6-06-89	1500	<1	10	--	7	--	22.4	0.71107
MW-3009	3-15-89	1530	<6	8	.7	57	--	<5.7	--
	6-08-89	0900	<6	8	--	110	--	5.7	.71069
LY 3601	8-03-89	1430	14	--	--	46	--	--	--
LY 3603	8-03-89	1155	6	--	--	21	--	--	--
Seep west levee pit 4	4-11-89	1030	<6	53	.4	--	9.2	--	.71070
	6-08-89	0815	<6	12	--	13	--	--	.71020
STP seep	3-15-89	1100	<6	12	.1	1,900	--	--	--
Burgermeister spring	3-16-89	1100	<6	6	.1	180	--	38.0	--
	6-07-89	0945	6	11	--	150	--	--	--
	8-02-89	0815	<6	7	--	84	--	--	--
MWGS-04	4-11-89	1045	<6	93	1.9	--	<1	--	.71172
O'Fallon/Gasconade	6-07-89	1245	<6	49	--	<1	--	<5.7	--
Ash pond outflow	3-14-89	1330	<6	8	.1	1,300	--	--	--
Frog pond	6-06-89	1530	<6	4	--	200	--	--	--
Raffinate pit 3	3-14-89	1500	290	20	47.0	320	--	--	--
	6-08-89	1115	520	10	--	320	--	--	.70938
Raffinate pit 4	3-14-89	1600	70	<3	4.9	2,800	--	--	--
Unnamed trib. Twin Is.	6-07-89	1125	<6	4	--	19	--	--	--

List of abbreviations used in tables 2, 3, and 4

Sand	Particles with a diameter less than 2 millimeters but greater than 0.063 millimeter, in percentage by weight
Silt	Particles with a diameter less than 0.063 millimeter but greater than 0.002 millimeter, in percentage by weight
Clay	Particles with a diameter less than 0.002 millimeter, in percentage by weight
Qtz	Quartz, in percentage by weight
Alb	Albite, in percentage by weight
Orth	Orthoclase, in percentage by weight
Mont	Montmorillinite, in percentage by weight
Kaol	Kaolinite, in percentage by weight
Calc	Calcite, in percentage by weight
Mica	Mica, in percentage by weight
Ill	Illite, in percentage by weight
Ca	Total calcium, in percentage by weight, semiquantitative
Fe	Total iron, in percentage by weight, semiquantitative
Mg	Total magnesium, in percentage by weight, semiquantitative
Na	Total sodium, in percentage by weight, semiquantitative
Ti	Total titanium, in percentage by weight, semiquantitative
As	Total arsenic, in micrograms per gram, semiquantitative
Ba	Total barium, in micrograms per gram, semiquantitative
Be	Total beryllium, in micrograms per gram, semiquantitative
B	Total boron, in micrograms per gram, semiquantitative
Cd	Total cadmium, in micrograms per gram, semiquantitative
Cr	Total chromium, in micrograms per gram, semiquantitative
Co	Total cobalt, in micrograms per gram, semiquantitative
Cu	Total copper, in micrograms per gram, semiquantitative
Ga	Total gallium, in micrograms per gram, semiquantitative
Ge	Total germanium, in micrograms per gram, semiquantitative
La	Total lanthanum, in micrograms per gram, semiquantitative
Pb	Total lead, in micrograms per gram, semiquantitative
Mn	Total manganese, in micrograms per gram, semiquantitative
Mo	Total molybdenum, in micrograms per gram, semiquantitative
Ni	Total nickel, in micrograms per gram, semiquantitative
Se	Total selenium, in micrograms per gram, semiquantitative
Ag	Total silver, in micrograms per gram, semiquantitative
Sr	Total strontium, in micrograms per gram, semiquantitative
Th	Total thorium, in micrograms per gram, semiquantitative
Sn	Total tin, in micrograms per gram, semiquantitative
V	Total vanadium, in micrograms per gram, semiquantitative
Y	Total yttrium, in micrograms per gram, semiquantitative
Zn	Total zinc, in micrograms per gram, semiquantitative
Zr	Total zirconium, in micrograms per gram, semiquantitative

Table 2. -- *Mineralogical analyses of overburden units at the Weldon Spring chemical plant site*

[Percentages may not sum to 100 percent due to rounding error; t, detected in trace quantity, but less than limit of quantitation; --, not determined; NA, not applicable]

Geotechnical drillhole	Grain size (percentage by weight)			Bulk mineralogy (approximate percentage of total sample, by weight)							Clay mineralogy (percentage of clay fraction)			Emission spectrometry (percentage by weight, semiquantitative)				
(fig. 4)	Sand	Silt	Clay	Qtz	Alb	Orth	Mont	Kaol	Calc	Mica	Mont	Kaol	Ill	Ca	Fe	Mg	Na	Ti
Loess																		
GT-61	11	77	12	77	5	15	2	1	0	0	85	15	0	0.1	0.7	0.2	0.5	0.3
GT-58P	4	77	19	72	7	11	2	2	7	t	75	15	10	.2	2.0	.5	.7	.3
Upper Ferrelview Formation																		
GTS-1	7	74	19	72	8	9	4	4	2	t	65	15	20	.2	2.0	.5	.5	.2
GTS-5	6	74	20	80	5	12	2	1	0	0	60	20	20	.2	3.0	.5	1.0	.5
GTS-6	5	76	19	79	6	10	3	1	0	0	80	20	0	.2	7.0	1.0	1.0	1.0
GTS-7	4	66	30	82	5	8	3	2	0	0	85	15	0	.1	3.0	.5	.7	.5
GT-59	1	77	22	68	7	9	3	1	7	1	75	15	10	.3	3.0	.7	1.5	.5
GT-61	5	55	40	85	5	6	3	0	t	0	85	15	t	.1	1.5	.3	.5	.2
GT-60P	10	63	27	73	6	11	3	2	5	t	70	15	15	.5	2.0	.5	.5	.3
GT-63P	10	66	24	73	6	10	3	5	t	2	60	20	20	.1	2.0	.7	.7	.5
GT-67P	6	68	26	85	5	6	3	0	0	0	80	20	0	.1	2.0	.5	.5	.5
Middle Ferrelview Formation																		
GTS-5	6	68	26	89	4	5	2	0	0	0	75	25	0	.2	3.0	.5	.2	.3
GT-61	4	54	42	86	4	5	3	0	t	0	80	10	10	.1	1.5	.5	.5	.3
GT-60P	7	64	29	85	4	6	4	0	t	0	85	15	0	.1	1.5	.3	.5	.3
GT-64P	3	53	44	80	7	7	4	0	0	0	75	20	5	.1	2.0	.7	.7	.5
GT-66P	7	64	29	85	3	10	2	0	0	0	80	15	5	.1	1.0	.3	.5	.3
GT-67P	10	61	29	86	4	6	2	1	0	0	85	15	t	.1	2.0	.3	.3	.5
Lower Ferrelview Formation																		
GTS-1	6	56	38	81	6	7	2	2	0	0	75	20	5	.1	2.0	.3	.2	.3
GTS-5	12	54	34	85	3	7	3	2	0	0	75	25	0	.1	3.0	.5	.2	.3
GTS-6	20	46	34	84	4	7	2	2	0	0	90	10	0	.2	7.0	.7	.3	.7
GTS-7	5	71	24	86	5	7	2	0	0	t	95	5	0	.2	3.0	.7	.7	.3
GT-59	14	47	39	80	4	6	5	4	0	0	80	20	t	.2	2.0	.5	.7	.3
GT-61	12	49	39	86	4	5	2	2	0	0	85	15	0	.1	1.0	.3	.2	.2
GT-62	13	50	37	88	2	8	1	0	t	0	75	20	5	.1	2.0	.3	.5	.3
GT-58P	7	58	35	85	4	7	2	1	0	0	72	25	3	.1	1.0	.3	.2	.2
GT-60P	11	60	29	85	4	6	3	1	0	0	80	15	5	.1	1.5	.5	.5	.5
GT-63P	18	50	32	79	5	10	3	3	t	0	75	15	10	.2	2.0	.5	.7	.3
GT-67P	14	64	22	87	4	6	2	0	0	0	80	15	5	.1	1.0	.5	.5	.5

Table 2. -- *Mineralogical analyses of overburden units at the Weldon Spring chemical plant site*--Continued

Geotechnical drillhole	Grain size (percentage by weight)			Bulk mineralogy (approximate percentage of total sample, by weight)							Clay mineralogy (percentage of clay fraction)			Emission spectrometry (percentage by weight, semiquantitative)				
(fig. 4)	Sand	Silt	Clay	Qtz	Alb	Orth	Mont	Kaol	Calc	Mica	Mont	Kaol	Ill	Ca	Fe	Mg	Na	Ti
								Upper clay till										
GTS-1	15	58	27	80	3	9	4	2	0	0	75	24	1	0.2	2.0	0.5	0.2	0.3
GTS-5	34	43	23	68	5	11	2	6	8	t	70	15	15	.5	5.0	.7	.3	.5
GTS-6	32	46	22	77	4	8	4	5	0	0	70	30	t	.3	7.0	1.0	1.0	.7
GTS-7	33	54	13	80	5	9	2	3	0	0	80	20	0	.2	3.0	.5	.7	.3
GT-59	31	37	32	79	5	7	3	5	t	0	60	30	10	.2	3.0	.5	1.0	.3
GT-61	30	44	26	70	6	14	7	4	0	t	70	25	5	.2	2.0	.5	.5	.3
GT-62	28	35	37	78	6	7	4	3	0	0	60	30	10	.2	3.0	.5	.7	.3
GT-58P	24	54	22	80	4	10	3	3	0	0	70	30	0	.1	2.0	.3	.2	.2
GT-60P	29	46	25	68	4	20	3	3	0	0	80	20	t	.2	1.0	.3	.5	.2
GT-63P	17	65	18	76	4	9	9	1	0	0	60	35	5	1.0	1.5	.2	.5	.3
GT-64P	18	51	31	55	4	2	3	3	33	0	80	10	10	5.0	1.0	.3	.3	.3
GT-67P	22	48	30	87	2	5	3	2	0	0	80	20	t	.2	2.0	.2	.5	.3
								Middle clay till										
GTS-5	21	53	26	76	3	7	2	4	8	t	80	15	5	.5	2.0	.5	.5	.3
GTS-6	34	42	24	67	4	7	2	4	16	1	60	30	10	2.0	5.0	1.5	1.0	.5
GTS-7	36	50	14	64	8	6	3	4	14	1	70	25	5	2.0	3.0	1.0	.5	.3
GT-63P	32	43	25	82	3	7	3	5	0	t	70	20	10	.2	1.5	.2	.5	.3
GT-66P	11	44	45	88	2	5	3	2	0	0	80	15	5	.2	2.0	.2	.2	.2
GT-67P	28	44	28	78	6	8	4	3	0	0	75	25	0	.2	2.0	.3	.5	.2
								Lower clay till										
GTS-1	34	48	18	55	4	7	3	5	25	t	70	20	10	2.0	2.0	.7	.2	.3
GTS-5	13	50	37	90	2	4	2	3	t	0	90	10	0	.1	2.0	.5	.0	.3
GTS-6	19	62	19	87	3	7	t	2	0	0	50	35	15	.2	5.0	.5	.5	.7
GTS-7	11	63	26	66	3	9	1	3	18	0	70	25	5	2.0	2.0	.5	.5	.5
GT-59	7	56	37	87	4	3	3	2	0	0	75	15	10	.2	3.0	.5	.5	.3
GT-61	35	43	22	53	5	14	3	5	19	1	55	35	10	2.0	1.0	1.0	.5	.2
GT-62	2	47	51	86	3	4	4	2	t	0	65	30	5	.1	3.0	.7	.5	.3
GT-58P	29	49	22	64	5	10	3	3	14	t	50	35	15	.5	1.0	.3	.2	.2
GT-60P	29	53	18	65	5	12	3	4	11	0	60	30	10	1.5	1.0	.5	.5	.2
GT-63P	3	82	15	85	4	7	3	t	t	0	69	30	1	.2	.7	.2	.5	.3
GT-64P	22	37	41	94	3	0	2	1	t	0	90	10	t	.2	2.0	.5		.2

Table 2. -- *Mineralogical analyses of overburden units at the Weldon Spring chemical plant site*--Continued

Geotechnical drillhole	Grain size (percentage by weight)			Bulk mineralogy (approximate percentage of total sample, by weight)							Clay mineralogy (percentage of clay fraction)			Emission spectrometry (percentage by weight, semiquantitative)				
(fig. 4)	Sand	Silt	Clay	Qtz	Alb	Orth	Mont	Kaol	Calc	Mica	Mont	Kaol	Ill	Ca	Fe	Mg	Na	Ti
Basal till																		
GTS-1	3	78	19	88	3	7	1	0	0	0	75	25	0	0.1	1.5	0.3	0.3	0.5
GT-61	29	45	26	76	4	5	2	4	8	t	50	40	10	.5	1.0	.5	.3	.2
GT-61	31	45	24	63	5	10	3	5	13	t	60	30	10	1.0	1.5	.7	.5	.2
GT-62	7	55	38	86	4	6	2	1	t	0	75	20	5	.1	2.0	.5	.5	.5
Residuum																		
GT-59	72	10	18	96	2	0	2	0	0	0	85	15	t	.1	.7	.2	.0	.2
GT-62	61	22	17	98	0	0	2	0	0	0	90	10	t	.1	1.5	.2	.0	.2
GT-58P	45	36	19	50	0	2	5	1	42	0	85	15	0	1.0	1.5	.5	.0	.2
GT-63P	55	30	15	85	3	3	1	6	0	0	60	30	10	.1	3.0	.1	--	.2
GT-64P	29	32	39	36	t	0	4	0	60	0	90	10	0	5.0	1.0	.3	--	.2
Composite Ferrelview Formation																		
NA	8	65	27	84	5	8	2	0	t	0	80	15	5	.2	1.5	.3	.5	.5
Composite clay till																		
NA	23	49	28	74	5	9	3	3	5	0	70	20	10	.5	2.0	.5	.5	.5

Table 3. -- *Average mineralogical content of overburden units at the Weldon Spring chemical plant site*

[Percentages may not sum to 100 percent due to rounding error]

Geologic	Grain size (percentage by weight)			Bulk mineralogy (approximate percentage of total sample, by weight)							Clay mineralogy (percentage of clay fraction)			Emission spectrometry (percentage by weight, semiquantitative)				
unit	Sand	Silt	Clay	Qtz	Alb	Orth	Mont	Kaol	Calc	Mica	Mont	Kaol	Ill	Ca	Fe	Mg	Na	Ti
Loess	7	77	16	75	6	13	2	2	4	0.1	80	15	5	0.2	1.4	0.4	0.6	0.3
Ferrelview Formation																		
Upper	6	69	25	77	6	9	3	2	2	.4	73	17	9	.2	2.8	.6	.8	.5
Middle	6	61	33	85	4	7	3	0	0	.0	80	17	3	.1	1.8	.4	.5	.4
Lower	12	55	33	84	4	7	2	2	0	.0	80	17	3	.1	2.3	.5	.4	.4
Total	9	61	30	82	5	8	3	1	.7	.1	78	17	5	.2	2.4	.5	.6	.4
Clay till																		
Upper	26	48	26	75	4	9	4	3	3	.0	71	24	5	.7	2.7	.5	.5	.3
Middle	27	46	27	76	4	7	3	4	6	.4	72	22	6	.9	2.6	.6	.5	.3
Lower	19	54	28	76	4	7	2	3	8	.1	68	25	8	.8	2.1	.5	.4	.3
Total	23	50	27	75	4	8	3	3	6	.1	70	24	6	.8	2.4	.5	.5	.3
Basal till	18	56	27	78	4	7	2	3	5	.1	65	29	6	.4	1.5	.5	.4	.4
Residuum	52	26	22	73	1	1	3	1	20	.0	82	16	2	1.3	1.5	.3	.0	.2
Composite																		
Ferrelview	8	65	27	84	5	8	2	0	0	.0	80	15	5	.2	1.5	.3	.5	.5
Clay till	23	49	28	74	5	9	3	3	5	.0	70	20	10	.5	2.0	.5	.5	.5

Table 4.--*Semiquantitative emission spectrograph analyses of overburden units at the Weldon Spring chemical plant site*

[Coarse, less than 2 millimeters, but greater than 0.063 millimeter; fine, less than 0.063 millimeter; t, detected in trace quantity, but less than limit of quantitation; <, less than]

Geotechnical	Ca		Fe		Mg		Na		Ti		As		Ba	
drillhole (fig. 4)	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
							Loess							
GT-61	0.07	0.15	0.7	2	0.2	1	0.5	t	0.3	0.2	<200	<200	500	300
GT-58P	.2	.2	2	5	.5	1	.7	.3	.3	.3	<200	<200	500	300
							Upper Ferrelview Formation							
GTS-1	.15	.15	2	5	.5	1	.5	.2	.2	.2	--	--	700	500
GTS-5	.15	.15	3	3	.5	.7	1	t	.5	.2	<200	<200	700	300
GTS-6	.2	.2	7	10	1	2	1	.2	1	.5	<200	<200	700	300
GTS-7	.1	.2	3	5	.5	1.5	.7	.2	.5	.3	<200	<200	500	500
GT-59	.3	.2	3	5	.7	1.5	1.5	t	.5	.2	<200	<200	500	500
GT-61	.05	.1	1.5	1	.3	.5	.5	<.2	.2	.1	<200	<200	200	150
GT-60P	.5	.15	2	2	.5	.5	.5	t	.3	.2	<200	<200	500	300
GT-63P	.1	.1	2	3	.7	1	.7	t	.5	.2	<200	<200	300	300
GT-67P	.1	.07	2	2	.5	.5	.5	.2	.5	.15	<200	<200	1,000	300
							Middle Ferrelview Formation							
GTS-5	.15	.2	3	5	.5	1	.2	.2	.3	.2	<200	<200	300	200
GT-61	.1	.15	1.5	1	.5	.7	.5	<.2	.3	.15	<200	<200	1,500	300
GT-60P	.1	.07	1.5	1	.3	.2	.5	t	.3	.15	<200	<200	500	200
GT-64P	.1	.1	2	2	.7	.7	.7	t	.5	.2	<200	<200	300	200
GT-66P	.1	.1	1	2	.3	.7	.5	t	.3	.2	<200	<200	500	300
GT-67P	.1	.15	2	3	.3	1	.3	.2	.5	.3	<200	<200	300	300
							Lower Ferrelview Formation							
GTS-1	.07	.2	2	5	.3	.7	.2	t	.3	.2	<200	<200	500	300
GTS-5	.1	.2	3	3	.5	.7	.2	t	.3	.2	<200	<200	300	200
GTS-6	.2	.3	7	10	.7	2	.3	t	.7	.5	<200	<200	500	300
GTS-7	.15	.2	3	3	.7	1	.7	t	.3	.2	<200	<200	500	300
GT-59	.15	.2	2	5	.5	.7	.7	<.2	.3	.3	<200	<200	200	200
GT-61	.1	.1	1	1	.3	.5	.2	<.2	.2	.15	<200	<200	200	100
GT-62	.1	.2	2	5	.3	1	.5	.2	.3	.3	<200	<200	300	300
GT-58P	.1	.2	1	5	.3	1	.2	.2	.2	.3	<200	<200	200	300
GT-60P	.1	.1	1.5	1	.5	.3	.5	<.2	.5	.15	<200	<200	300	200
GT-63P	.15	.15	2	2	.5	1	.7	t	.3	.2	<200	<200	500	300
GT-67P	.1	.15	1	2	.5	.7	.5	<.2	.5	.2	<200	<200	300	300
							Upper clay till							
GTS-1	.2	.1	2	2	.5	.5	.2	<.2	.3	.15	<200	<200	300	100
GTS-5	.5	.3	5	5	.7	1	.3	.3	.5	.3	<200	<200	500	500
GTS-6	.3	.5	7	10	1	2	1	.2	.7	.5	<200	<200	700	500
GTS-7	.2	.2	3	5	.5	1	.7	t	.3	.3	<200	<200	700	300
GT-59	.2	.7	3	7	.5	1	1	.2	.3	.2	<200	<200	500	500
GT-61	.15	.15	2	3	.5	1	.5	<.2	.3	.2	<200	<200	300	200

Table 4.--*Semiquantitative emission spectrograph analyses of overburden units from the Weldon Spring chemical plant site*--Continued

Geotechnical	Ca		Fe		Mg		Na		Ti		As		Ba	
drillhole (fig. 4)	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Upper clay till --Continued														
GT-62	0.15	0.15	3	3	0.5	0.7	0.7	t	0.3	0.2	<200	<200	300	200
GT-58P	.1	.2	2	3	.3	.7	.2	t	.2	.2	<200	<200	500	300
GT-60P	.2	.2	1	3	.3	1	.5	t	.2	.2	<200	<200	300	200
GT-63P	1	.2	1.5	3	.2	1	.5	.2	.3	.2	<200	<200	500	500
GT-64P	5	.2	1	2	.3	.5	.3	t	.3	.15	<200	<200	200	200
GT-67P	.15	.2	2	3	.2	.7	.5	t	.3	.2	<200	<200	200	200
Middle clay till														
GTS-5	.5	.3	2	5	.5	1	.5	t	.3	.3	<200	<200	500	300
GTS-6	2	.7	5	10	1.5	2	1	t	.5	.5	<200	<200	500	300
GTS-7	2	.5	3	5	1	1.5	.5	t	.3	.3	<200	<200	500	300
GT-63P	.15	.2	1.5	2	.2	.7	.5	t	.3	.15	<200	<200	500	300
GT-66P	.2	.2	2	2	.2	.7	.2	t	.2	.15	<200	<200	200	200
GT-67P	.2	.3	2	3	.3	1	.5	t	.2	.2	<200	<200	300	300
Lower clay till														
GTS-1	2	.3	2	5	.7	.7	.2	t	.3	.2	<200	<200	500	500
GTS-5	.1	.2	2	5	.5	1	t	t	.3	.3	<200	<200	200	200
GTS-6	.15	.3	5	7	.5	1.5	.5	t	.7	.7	<200	<200	500	300
GTS-7	2	.5	2	3	.5	1	.5	t	.5	.3	<200	<200	500	300
GT-59	.15	.2	3	5	.5	1	.5	t	.3	.2	<200	<200	200	200
GT-61	2	1	1	2	1	1	.5	.2	.2	.2	<200	<200	500	300
GT-62	.1	.2	3	5	.7	1	.5	<.2	.3	.2	<200	<200	300	200
GT-58P	.5	.5	1	5	.3	.7	.2	.2	.15	.2	<200	<200	300	500
GT-60P	1.5	.5	1	2	.5	.7	.5	t	.2	.15	<200	<200	500	500
GT-63P	.15	.2	.7	2	.2	.7	.5	t	.3	.2	<200	<200	500	300
GT-64P	.2	.15	2	1.5	.5	.3	t	<.2	.2	.1	<200	<200	200	200
Basal till														
GTS-1	.1	.2	1.5	3	.3	1	.3	t	.5	.2	<200	<200	300	150
GT-61	.5	.3	1	2	.5	.7	.3	t	.2	.2	<200	<200	300	200
GT-61	1	.5	1.5	2	.7	.7	.5	t	.2	.15	<200	<200	300	200
GT-62	.1	.2	2	7	.5	1	.5	t	.5	.3	<200	<200	300	200
Residuum														
GT-59	.1	.2	.7	5	.2	1	t	t	.15	.2	<200	<200	200	200
GT-62	.1	.2	1.5	3	.15	.7	t	t	.15	.2	<200	<200	150	200
GT-58P	1	.2	1.5	5	.5	1	t	t	.2	.2	<200	<200	500	300
GT-63P	.1	.3	3	3	.1	.7	t	t	.2	.2	<200	<200	500	500
GT-64P	5	.5	1	2	.3	1	t	.2	.15	.2	<200	<200	200	300

Table 4.--*Semiquantitative emission spectrograph analyses of overburden units from the Weldon Spring chemical plant site*--Continued

Geotechnical	Be		B		Cd		Cr		Co		Cu		Ga	
drillhole (fig. 4)	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
							Loess							
GT-61	t	1	30	20	<20	<20	20	50	15	15	7	30	20	20
GT-58P	t	1	20	30	<20	<20	50	1	10	20	10	30	10	20
							Upper Ferrelview Formation							
GTS-1	t	1	30	20	<20	<20	30	50	15	15	10	20	20	20
GTS-5	t	t	20	20	<20	<20	50	30	10	10	15	15	10	10
GTS-6	t	1	30	30	<20	<20	50	70	15	15	15	20	20	50
GTS-7	t	t	20	20	<20	<20	50	70	15	15	10	20	15	20
GT-59	t	1.5	20	30	<20	<20	50	30	15	20	20	30	15	20
GT-61	t	1	20	15	<20	<20	50	20	t	<10	10	10	15	10
GT-60P	t	1	30	20	<20	<20	30	20	10	10	10	15	10	15
GT-63P	1	1	30	50	<20	<20	50	30	15	10	15	20	20	30
GT-67P	t	1	20	15	<20	<20	70	50	10	t	15	10	15	20
							Middle Ferrelview Formation							
GTS-5	t	t	20	20	<20	<20	50	70	t	t	15	15	10	20
GT-61	t	1	20	15	<20	<20	50	30	10	<10	20	10	20	15
GT-60P	1	1	30	10	<20	<20	30	10	20	10	10	7	10	10
GT-64P	t	1	30	20	<20	<20	50	50	10	t	15	15	20	20
GT-66P	t	1.5	30	15	<20	<20	30	50	10	30	7	15	10	30
GT-67P	1	1.5	20	20	<20	<20	50	100	10	15	15	20	15	30
							Lower Ferrelview Formation							
GTS-1	t	1	20	15	<20	<20	30	50	t	10	7	20	10	20
GTS-5	t	1	15	15	<20	<20	50	20	10	10	10	10	10	10
GTS-6	1	1	20	30	<20	<20	50	100	20	15	15	30	15	50
GTS-7	1	1	20	10	<20	<20	30	50	t	t	10	15	15	15
GT-59	t	1.5	20	15	<20	<20	30	50	10	10	10	30	15	20
GT-61	t	1	15	15	<20	<20	30	20	30	10	10	7	10	15
GT-62	t	1	15	15	<20	<20	50	70	15	10	10	30	10	50
GT-58P	t	1	20	15	<20	<20	30	70	t	10	5	20	7	20
GT-60P	1	2	20	15	<20	<20	50	20	15	t	10	10	20	15
GT-63P	1	1	30	20	<20	<20	50	50	10	10	15	20	15	30
GT-67P	t	1	20	15	<20	<20	30	15	t	t	10	10	15	20
							Upper clay till							
GTS-1	1	2	20	10	<20	<20	50	20	30	10	10	5	15	10
GTS-5	t	1	20	20	<20	<20	30	100	15	20	15	30	15	20
GTS-6	t	1.5	20	50	<20	<20	50	100	10	20	20	50	30	70
GTS-7	1	2	20	20	<20	<20	50	70	70	20	15	20	15	15
GT-59	t	1.5	15	30	<20	<20	50	70	20	20	20	30	10	20
GT-61	1	1	20	20	<20	<20	70	50	20	10	15	20	10	20

Table 4.--*Semiquantitative emission spectrograph analyses of overburden units from the Weldon Spring chemical plant site*--Continued

Geotechnical	Be		B		Cd		Cr		Co		Cu		Ga	
drillhole (fig. 4)	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Upper clay till--Continued														
GT-62	1	2	20	20	<20	<20	50	30	30	t	20	20	15	20
GT-58P	1	2	20	20	<20	<20	20	70	15	15	10	30	10	30
GT-60P	1	2	20	20	<20	<20	30	50	10	10	15	20	15	20
GT-63P	t	1	30	20	<20	<20	50	50	50	50	15	30	10	30
GT-64P	t	1	20	20	<20	<20	50	50	10	10	15	15	15	20
GT-67P	1	2	15	15	<20	<20	50	50	20	15	15	30	10	20
Middle clay till														
GTS-5	t	t	15	20	<20	<20	30	50	t	10	10	20	15	15
GTS-6	t	1	30	50	<20	<20	100	150	15	20	20	30	20	50
GTS-7	t	1.5	15	50	<20	<20	50	70	10	15	15	30	15	20
GT-63P	1	1	30	30	<20	<20	50	30	10	10	15	20	15	20
GT-66P	1	2	20	20	<20	<20	30	30	15	t	20	20	15	50
GT-67P	1	1.5	20	20	<20	<20	50	50	10	10	20	20	15	20
Lower clay till														
GTS-1	t	1	20	20	<20	<20	30	50	10	15	50	20	10	20
GTS-5	t	t	20	15	<20	<20	30	50	20	15	10	20	10	20
GTS-6	t	2	30	50	<20	<20	50	50	15	10	15	30	10	50
GTS-7	t	1	20	20	<20	<20	70	20	t	t	10	20	10	15
GT-59	1	1.5	20	15	<20	<20	50	50	t	t	15	20	10	20
GT-61	t	1	20	50	<20	<20	50	70	<10	10	10	20	15	20
GT-62	t	t	20	15	<20	<20	50	30	10	t	20	20	15	20
GT-58P	t	1	20	20	<20	<20	20	1	10	20	7	30	10	20
GT-60P	t	1.5	20	30	<20	<20	50	30	10	10	20	20	15	20
GT-63P	t	1	20	15	<20	<20	20	30	t	10	10	15	10	20
GT-64P	2	5	20	15	<20	<20	30	20	30	15	20	10	10	10
Basal till														
GTS-1	<1	1	30	15	<20	<20	50	70	t	10	7	15	15	20
GT-61	t	1	20	20	<20	<20	50	70	t	15	10	30	15	20
GT-61	t	1.5	20	30	<20	<20	50	50	20	20	15	20	15	30
GT-62	t	1	20	20	<20	<20	20	50	t	10	20	50	15	30
Residuum														
GT-59	t	2	20	15	<20	<20	20	70	<10	10	7	20	5	20
GT-62	t	2	20	20	<20	<20	30	50	t	10	10	20	5	20
GT-58P	1.5	1.5	20	20	<20	<20	30	50	15	10	10	20	10	15
GT-63P	1	1	20	15	<20	<20	20	30	20	30	15	20	7	50
GT-64P	1	1.5	15	30	<20	<20	20	70	t	10	7	20	10	50

Table 4.--*Semiquantitative emission spectrograph analyses of overburden units from the Weldon Spring chemical plant site*--Continued

Geotechnical	Ge		La		Pb		Mn		Mo		Ni		Se	
drillhole (fig. 4)	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
							Loess							
GT-61	<10	<10	t	50	20	50	1,000	1,000	<5	t	t	30	5	10
GT-58P	<10	<10	t	50	10	20	700	1,000	<5	<5	100	70	5	10
							Upper Ferrelview Formation							
GTS-1	<10	<10	50	50	20	20	1,000	700	<5	<5	20	30	5	10
GTS-5	<10	<10	t	t	20	15	1,000	500	<5	t	15	20	7	7
GTS-6	<10	<10	50	70	20	20	2,000	300	<5	<5	20	50	7	15
GTS-7	<10	<10	50	t	10	20	500	500	t	<5	15	50	7	15
GT-59	<10	<10	50	50	20	50	2,000	1,000	<5	<5	20	50	7	10
GT-61	<10	<10	t	<50	20	10	70	50	<5	<5	10	10	7	5
GT-60P	<10	<10	t	t	20	20	300	150	<5	<5	10	20	10	10
GT-63P	<10	<10	t	t	30	30	500	150	5	t	20	20	7	10
GT-67P	<10	<10	t	<50	20	20	100	50	<5	<5	20	20	10	10
							Middle Ferrelview Formation							
GTS-5	<10	<10	t	<50	10	30	150	100	<5	<5	10	30	7	10
GT-61	<10	<10	t	<50	20	15	70	50	5	<5	15	20	10	7
GT-60	<10	<10	50	<50	20	10	1,000	200	<5	<5	15	15	7	7
GT-64P	<10	<10	t	<50	20	20	100	70	<5	<5	20	20	10	10
GT-66P	<10	<10	t	t	15	30	200	500	<5	<5	10	30	7	10
GT-67P	<10	<10	t	50	15	50	150	100	<5	<5	10	30	10	20
							Lower Ferrelview Formation							
GTS-1	<10	<10	<50	t	10	20	70	100	<5	<5	15	30	5	10
GTS-5	<10	<10	<50	<50	10	10	150	70	<5	<5	15	30	7	10
GTS-6	<10	<10	t	50	20	30	1,500	500	<5	<5	50	70	10	15
GTS-7	<10	<10	t	<50	20	20	200	150	<5	<5	15	20	7	10
GT-59	<10	<10	<50	<50	15	30	100	150	<5	<5	10	30	5	10
GT-61	<10	<10	<50	<50	15	15	200	100	<5	<5	20	20	5	7
GT-62	<10	<10	<50	<50	10	50	150	100	<5	<5	20	30	7	10
GT-58P	<10	<10	<50	<50	t	20	200	200	<5	<5	20	30	5	10
GT-60P	<10	<10	t	<50	30	15	300	70	<5	<5	20	20	7	7
GT-63P	<10	<10	t	t	50	30	500	100	<5	<5	15	50	7	15
GT-67P	<10	<10	t	<50	20	20	100	70	<5	<5	10	20	7	10
							Upper clay till							
GTS-1	<10	<10	50	<50	15	t	700	150	<5	<5	30	15	7	5
GTS-5	<10	<10	t	50	15	50	1,000	700	t	5	20	70	7	10
GTS-6	<10	<10	50	100	20	50	1,500	700	t	t	50	100	7	15
GTS-7	<10	<10	t	50	20	15	1,500	1,000	<5	<5	50	50	7	10
GT-59	<10	<10	50	50	20	50	3,000	2,000	5	5	50	100	5	10
GT-61	<10	<10	100	150	15	20	200	200	t	t	70	70	7	20

Table 4.--*Semiquantitative emission spectrograph analyses of overburden units from the Weldon Spring chemical plant site*--Continued

Geotechnical	Ge		La		Pb		Mn		Mo		Ni		Se	
drillhole (fig. 4)	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Upper clay till--Continued														
GT-62	<10	<10	50	t	20	20	700	200	<5	<5	50	20	7	7
GT-58P	<10	<10	<50	50	10	20	700	500	<5	<5	20	50	5	10
GT-60P	<10	<10	70	150	20	20	500	150	<5	<5	20	50	7	15
GT-63P	<10	<10	50	t	30	50	2,000	1,500	<5	<5	10	15	7	10
GT-64P	<10	<10	50	t	20	20	200	50	<5	<5	20	20	7	10
GT-67P	<10	<10	50	70	15	30	100	100	<5	<5	20	50	10	10
Middle clay till														
GTS-5	<10	<10	t	50	15	20	300	300	<5	t	15	50	5	10
GTS-6	<10	<10	50	70	20	50	2,000	700	t	5	50	70	7	15
GTS-7	<10	<10	t	50	20	30	500	700	<5	5	20	50	7	15
GT-63P	<10	<10	50	50	20	20	70	100	<5	<5	20	20	10	10
GT-66P	<10	<10	100	100	15	30	100	100	<5	<5	20	30	10	20
GT-67P	<10	<10	70	70	20	30	200	200	<5	<5	30	50	7	15
Lower clay till														
GTS-1	<10	<10	t	50	10	20	1,000	1,000	t	5	30	50	5	7
GTS-5	<10	<10	<50	<50	15	50	300	200	<5	<5	20	30	7	10
GTS-6	<10	<10	50	70	15	50	500	500	<5	<5	20	50	5	15
GTS-7	<10	<10	50	t	15	20	200	300	<5	<5	10	50	7	7
GT-59	<10	<10	t	<50	15	50	150	100	<5	<5	30	30	5	7
GT-61	<10	<10	50	50	20	20	100	100	<5	<5	20	50	5	20
GT-62	<10	<10	50	<50	15	20	500	200	<5	<5	20	20	10	10
GT-58P	<10	<10	t	50	t	30	300	1,000	<5	t	30	70	t	10
GT-60P	<10	<10	50	50	20	30	700	700	<5	<5	15	20	7	10
GT-63P	<10	<10	t	50	20	20	100	150	<5	<5	7	15	7	10
GT-64P	<10	<10	100	50	30	30	150	70	<5	<5	50	50	10	10
Basal till														
GTS-1	<10	<10	<50	t	10	20	100	100	<5	<5	20	30	5	10
GT-61	<10	<10	<50	t	20	30	100	150	<5	t	7	30	5	20
GT-61	<10	<10	t	50	30	50	700	200	t	5	30	50	5	20
GT-62	<10	<10	t	<50	15	50	300	200	<5	<5	20	30	7	15
Residuum														
GT-59	<10	<10	100	200	<10	20	150	500	<5	<5	20	70	t	10
GT-62	<10	<10	<50	50	t	30	100	200	<5	<5	15	30	5	7
GT-58P	<10	<10	100	100	10	20	1,000	700	<5	<5	50	50	5	10
GT-63P	<10	<10	t	50	20	50	2,000	2,000	5	t	20	50	7	15
GT-64P	<10	<10	50	50	10	30	200	150	<5	<5	15	30	7	30

Table 4.--*Semiquantitative emission spectrograph analyses of overburden units from the Weldon Spring chemical plant site*--Continued

Geotechnical	Ag		Sr		Th		Sn		V		Y		Zn		Zr	
drillhole (fig. 4)	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Loess																
GT-61	<0.5	10	<100	<100	<100	<100	<10	<10	50	150	20	20	<200	<200	300	70
GT-58P	<.5	<.5	150	<100	<100	<100	<10	<10	50	100	15	30	<200	t	300	100
Upper Ferrelview Formation																
GTS-1	<.5	<.5	100	<100	<100	<100	<10	<10	50	100	20	20	<200	<200	200	70
GTS-5	t	<.5	t	<100	<100	<100	<10	<10	70	100	20	15	<200	<200	700	50
GTS-6	<.5	<.5	<100	<100	<100	<100	<10	<10	100	150	20	20	<200	<200	1,000	150
GTS-7	<.5	.5	t	<100	<100	<100	<10	<10	70	150	20	15	<200	<200	500	100
GT-59	<.5	.5	100	<100	<100	<100	<10	<10	50	150	20	20	<200	<200	500	100
GT-61	<.5	<.5	<100	<100	<100	<100	<10	<10	70	70	20	10	<200	<200	200	50
GT-60P	.7	1	t	t	<100	<100	<10	<10	50	100	20	20	<200	<200	300	70
GT-63P	<.5	<.5	100	t	<100	<100	<10	<10	70	100	20	15	<200	<200	200	50
GT-67P	<.5	5	<100	<100	<100	<100	<10	<10	70	70	15	10	<200	<200	200	30
Middle Ferrelview Formation																
GTS-5	<.5	<.5	t	<100	<100	<100	<10	t	100	100	15	15	<200	<200	300	70
GT-61	<.5	<.5	<100	<100	<100	<100	<10	<10	70	100	30	10	<200	<200	300	70
GT-60P	<.5	<.5	<100	<100	<100	<100	<10	<10	50	70	20	10	<200	<200	300	50
GT-64P	<.5	<.5	t	<100	<100	<100	<10	<10	70	100	20	15	<200	<200	200	50
GT-66P	t	<.5	<100	<100	<100	<100	<10	<10	50	100	20	15	<200	<200	200	50
GT-67P	<.5	5	<100	<100	<100	<100	<10	<10	50	100	20	20	<200	<200	500	50
Lower Ferrelview Formation																
GTS-1	<.5	<.5	<100	<100	<100	<100	<10	<10	50	100	15	20	<200	<200	300	70
GTS-5	<.5	<.5	<100	<100	<100	<100	<10	<10	70	100	15	10	<200	<200	300	50
GTS-6	<.5	<.5	t	<100	<100	<100	<10	<10	100	200	20	20	<200	<200	1,000	150
GTS-7	t	<.5	t	<100	<100	<100	<10	<10	70	100	20	15	<200	<200	500	70
GT-59	<.5	t	<100	<100	<100	<100	<10	<10	70	100	10	10	<200	<200	200	70
GT-61	<.5	<.5	<100	<100	<100	<100	<10	<10	50	70	15	t	<200	<200	200	70
GT-62	<.5	.5	<100	<100	<100	<100	<10	<10	50	100	15	15	<200	<200	300	100
GT-58P	<.5	<.5	<100	<100	<100	<100	<10	<10	50	100	15	15	<200	<200	200	100
GT-60P	t	<.5	t	<100	<100	<100	<10	<10	50	100	20	10	<200	<200	200	50
GT-63P	.5	<.5	100	t	<100	<100	<10	<10	70	150	20	10	<200	<200	300	70
GT-67P	<.5	<.5	t	t	<100	<100	<10	<10	50	100	15	15	<200	<200	200	50
Upper clay till																
GTS-1	<.5	<.5	t	<100	<100	<100	<10	<10	50	50	20	15	<200	<200	300	50
GTS-5	<.5	<.5	t	t	<100	<100	<10	t	70	150	20	20	<200	<200	300	100
GTS-6	<.5	<.5	t	t	<100	<100	<10	t	150	150	20	50	<200	t	1,000	300
GTS-7	<.5	<.5	t	<100	<100	<100	<10	<10	100	100	20	15	<200	<200	500	100
GT-59	<.5	<.5	100	<100	<100	<100	<10	<10	100	150	30	30	<200	<200	500	70
GT-61	<.5	.5	<100	<100	<100	<100	<10	<10	70	100	50	100	<200	<200	200	100

Table 4.--*Semiquantitative emission spectrograph analyses of overburden units from the Weldon Spring chemical plant site*--Continued

Geotechnical	Ag		Sr		Th		Sn		V		Y		Zn		Zr	
drillhole (fig. 4)	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine	Coarse	Fine
Upper clay till--Continued																
GT-62	<0.5	<0.5	t	<100	<100	<100	<10	<10	70	70	15	10	<200	<200	300	50
GT-58P	<.5	<.5	<100	t	<100	<100	<10	<10	50	100	20	15	<200	<200	300	70
GT-60P	t	<.5	100	t	<100	<100	<10	<10	70	100	30	100	<200	<200	200	100
GT-63P	<.5	<.5	100	<100	<100	<100	<10	t	70	100	30	20	<200	<200	500	100
GT-64P	t	<.5	100	<100	<100	<100	<10	<10	70	70	20	15	<200	<200	200	70
GT-67P	<.5	.5	t	<100	<100	<100	<10	<10	50	100	20	20	<200	<200	300	70
Middle clay till																
GTS-5	<.5	<.5	t	<100	<100	<100	<10	20	70	150	20	15	<200	<200		100
GTS-6	<.5	<.5	t	<100	<100	<100	<10	<10	100	150	--	20	<200	<200	700	200
GTS-7	<.5	<.5	100	t	<100	<100	<10	<10	70	150	20	20	<200	t	300	70
GT-63P	t	t	100	<100	<100	<100	<10	<10	50	100	30	20	<200	<200	200	70
GT-66P	<.5	1	t	<100	<100	<100	<10	<10	50	70	50	50	<200	<200	200	70
GT-67P	<.5	1.5	100	t	<100	<100	<10	<10	70	100	70	100	<200	<200	200	70
Lower clay till																
GTS-1	<.5	<.5	100	<100	<100	<100	<10	<10	70	100	15	20	<200	<200	200	70
GTS-5	<.5	<.5	<100	<100	<100	<100	<10	<10	70	100	15	15	<200	<200	300	70
GTS-6	<.5	<.5	<100	<100	<100	<100	<10	t	100	150	20	20	<200	<200	1,000	150
GTS-7	<.5	<.5	t	<100	<100	<100	<10	<10	70	100	20	15	<200	<200	500	100
GT-59	<.5	.5	<100	<100	<100	<100	<10	<10	70	100	20	20	<200	<200	500	70
GT-61	t	<.5	t	<100	<100	<100	<10	<10	50	100	20	15	<200	<200	150	70
GT-62	<.5	t	<100	<100	<100	<100	<10	<10	70	100	15	10	<200	<200	300	70
GT-58P	<.5	<.5	<100	t	<100	<100	<10	<10	50	150	15	15	<200	<200	150	70
GT-60P	<.5	<.5	150	<100	<100	<100	<10	<10	50	70	20	15	<200	<200	200	70
GT-63P	t	t	100	<100	<100	<100	<10	<10	50	70	20	20	<200	<200	500	100
GT-64P	<.5	<.5	<100	<100	<100	<100	<10	<10	70	70	50	30	<200	<200	150	50
Basal till																
GTS-1	<.5	<.5	<100	<100	<100	<100	<10	<10	50	70	20	15	<200	<200	500	100
GT-61	<.5	<.5	t	<100	<100	<100	<10	<10	50	100	15	20	<200	<200	200	70
GT-61	t	5	t	<100	<100	<100	<10	<10	70	100	20	20	<200	<200	150	70
GT-62	<.5	2	<100	<100	<100	<100	<10	<10	70	100	20	20	<200	<200	500	100
Residuum																
GT-59	<.5	.5	<100	<100	<100	<100	<10	<10	50	100	20	70	<200	<200	50	70
GT-62	<.5	.5	<100	<100	<100	<100	<10	<10	50	100	15	15	<200	<200	200	70
GT-58P	<.5	<.5	<100	<100	<100	<100	<10	<10	50	70	50	50	<200	<200	70	50
GT-63P	<.5	<.5	<100	<100	<100	<100	<10	<10	100	100	20	30	<200	<200	200	100
GT-64P	<.5	2	<100	<100	<100	<100	<10	t	50	70	20	50	<200	<200	70	70

Table 5.--*List of constituents analyzed in laboratory sorption experiments*

[Analysis of chemical constituents performed at the U.S. Geological Survey national water-quality laboratory except as noted]

	Fixed pH			Unadjusted pH
Constituent	A Bottles [1]	B Bottles [1]	C Bottles [1]	D Bottles [2]
pH [3]	■	■	■	■
Alkalinity [3]	■	■	■	■
Nitrate [3]	■	■	■	■
Chromium [3]	■			
Lead [3]	■			
Nickel [3]	■			
Vanadium [3]	■			
Calcium		■	■	■
Magnesium		■	■	■
Sodium		■	■	■
Potassium		■	■	■
Chloride		■		■
Sulfate		■		■
Fluoride		■		■
Silica		■		■
Bromide		■		■
Nitrite plus Nitrate		■		■
Nitrite		■		■
Ammonia		■		■
Aluminum		■	■	■
Arsenic		■	■	■
Barium		■	■	■
Beryllium		■	■	■
Boron		■	■	■
Cadmium		■	■	■
Chromium		■	■	■
Cobalt		■	■	■
Copper		■	■	■
Iron		■	■	■
Lead		■	■	■
Lithium		■	■	■
Manganese		■	■	■
Molybdenum		■	■	■
Nickel		■	■	■
Selenium		■	■	■
Strontium		■	■	■
Vanadium		■	■	■
Uranium [4]		■	■	■

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[1] The pH was adjusted in initial solution and maintained at fixed value throughout experiment.

[2] The pH was adjusted in initial solution, but not adjusted afterwards.

[3] Analysis performed at the University of Missouri-Rolla.

[4] Analysis performed by the U.S. Geological Survey, Denver, Colorado.

List of abbreviations used in table 6

Time	Reaction time, in hours
pH	In standard units
Ca	Dissolved calcium, in milligrams per liter
Mg	Dissolved magnesium, in milligrams per liter
Na	Dissolved sodium, in milligrams per liter
K	Dissolved potassium, in milligrams per liter
HCO_3	Bicarbonate, in milligrams per liter
CO_3	Carbonate, in milligrams per liter
Alk	Alkalinity as $CaCO_3$, in milligrams per liter
SO_4	Dissolved sulfate, in milligrams per liter
Cl	Dissolved chloride, in milligrams per liter
F	Dissolved fluoride, in milligrams per liter
SiO_2	Dissolved silica, in milligrams per liter
$NO_2 + NO_3$	Dissolved nitrite plus nitrate as N, in milligrams per liter
NO_2	Dissolved nitrite as N, in milligrams per liter
Al	Dissolved aluminum, in micrograms per liter
Cr	Dissolved chromium, in micrograms per liter
Fe	Dissolved iron, in micrograms per liter
Pb	Dissolved lead, in micrograms per liter
Li	Dissolved lithium, in micrograms per liter
Mn	Dissolved manganese, in micrograms per liter
Mo	Dissolved molybdenum, in micrograms per liter
Ni	Dissolved nickel, in micrograms per liter
Se	Dissolved selenium, in micrograms per liter
Sr	Dissolved strontium, in micrograms per liter
V	Dissolved vanadium, in micrograms per liter
Zn	Dissolved zinc, in micrograms per liter
U	Dissolved uranium, in micrograms per liter

Table 6.--*Results from laboratory sorption experiments with the Ferrelview Formation and clay till*

[Values are concentrations remaining in solution after reaction with overburden unit; Fv, Ferrelview Formation; CT, clay till; underline indicates value substituted from replicate experiment because of analytical difficulties; --, not determined; <, less than]

Sample	Time	Unit	pH	Ca	Mg	Na	K	HCO_3	CO_3	Alk	SO_4	Cl	F	SiO_2	NO_2+NO_3	NO_2
FP-45-Initial	0	Fv	4.50	540	380	1,200	110	--	--	--	610	70	7.0	1.0	1,300	5.1
FP-45B-1	24	Fv	4.60	570	340	1,200	--	--	--	--	580	110	1.7	36	1,300	5.0
FP-45B-2	48	Fv	4.59	580	350	1,200	--	--	--	--	580	120	1.3	36	1,300	5.0
FP-45B-3	120	Fv	4.64	600	350	1,300	--	--	--	--	580	130	1.5	47	1,300	4.8
FP-45B-4	240	Fv	4.64	600	350	1,300	--	--	--	--	580	140	1.5	50	1,400	4.7
FP-45B-5	480	Fv	4.61	640	360	1,300	69	--	--	--	630	150	1.7	53	1,400	4.5
FP-70-Initial	0	Fv	7.00	540	390	1,300	110	37	0	30	620	24	7.0	.9	1,300	5.4
FP-70B-1	24	Fv	6.88	560	330	1,200	--	31	0	25	600	24	1.8	13	1,300	5.4
FP-70B-2	48	Fv	6.92	560	350	1,300	--	29	0	24	600	24	1.8	10	1,300	5.5
FP-70B-3	120	Fv	6.93	570	340	1,300	--	29	0	24	600	23	1.8	11	1,300	5.2
FP-70B-4	240	Fv	6.94	550	330	1,200	--	30	0	25	600	23	1.7	11	1,300	5.4
FP-70B-5	480	Fv	6.90	610	340	1,400	66	28	0	23	650	23	2.1	12	1,600	5.4
FP-90-Initial	0	Fv	9.00	540	380	1,300	110	38	11	49	610	22	7.2	.9	1,600	5.5
FP-90B-1	24	Fv	8.88	550	310	1,300	--	33	12	46	600	22	6.8	4.3	1,300	5.4
FP-90B-2	48	Fv	8.74	550	310	1,300	--	32	9	42	600	22	6.4	6.7	1,300	5.4
FP-90B-3	120	Fv	8.83	540	310	1,400	--	31	13	48	610	23	6.9	4.6	1,300	5.5
FP-90B-4	240	Fv	8.74	590	300	1,400	61	41	11	51	650	22	6.4	5.0	--	5.4
FP-90B-5	480	Fv	8.93	570	280	1,600	58	37	13	53	630	67	6.4	5.0	--	5.4
CP-45-Initial	0	CT	4.50	530	370	1,400	110	--	--	--	660	47	7.0	1.0	1,400	5.3
CP-45B-1	24	CT	5.59	1,100	370	1,300	73	--	--	--	640	1,000	5.4	35	1,400	4.7
CP-45B-3	120	CT	5.62	1,300	420	1,300	73	--	--	--	630	1,600	1.4	35	1,400	4.9
CP-45B-4	240	CT	5.38	--	--	--	--	--	--	--	--	--	--	--	--	--
CP-45B-5	480	CT	4.44	1,400	440	1,300	71	--	--	--	570	1,900	2.8	96	1,500	1.9
CP-70-Initial	0	CT	7.00	540	370	1,400	110	40	0	32	650	22	7.0	1.0	1,400	5.8
CP-70B-1	24	CT	7.33	640	340	1,300	67	97	0	79	640	52	1.0	12	1,500	5.3
CP-70B-3	120	CT	7.03	700	360	1,300	66	119	0	98	650	120	3.2	15	1,400	5.4
CP-70B-4	240	CT	7.06	--	--	--	--	122	0	100	--	--	--	--	--	--
CP-70B-5	480	CT	6.98	700	360	1,300	63	109	0	90	590	130	2.6	21	1,500	5.8
CP-90-Initial	0	CT	9.00	530	370	1,400	110	48	10	55	650	22	7.0	1.0	1,400	5.6
CP-90B-1	24	CT	8.95	600	320	1,300	63	24	11	38	640	22	6.2	38	1,400	5.1
CP-90B-3	120	CT	8.85	600	320	1,400	63	22	5	27	650	22	5.8	5.0	1,300	5.3
CP-90B-4	240	CT	8.85	--	--	--	--	17	6	23	--	--	--	--	--	--
CP-90B-5	480	CT	8.60	590	320	1,400	62	21	5	25	600	25	4.7	7.0	1,500	5.8
FP-45D-5	480	Fv	6.28	620	350	1,300	66	13	0	10	--	--	--	--	--	--
FP-70D-5	480	Fv	6.60	590	340	1,300	65	31	0	26	--	--	--	--	--	--
FP-90D-5	480	Fv	6.87	610	350	1,300	64	39	0	32	--	--	--	--	--	--
CP-45D-3	120	CT	7.42	660	350	1,300	69	41	0	34	640	48	3.7	12	--	--
CP-70D-3	120	CT	7.43	640	350	1,300	67	54	0	44	640	22	3.8	12	--	--
CP-90D-3	120	CT	7.58	630	340	1,300	65	52	0	43	640	22	3.9	11	--	--

Table 6.--*Results from laboratory sorption experiments with the Ferrelview Formation and clay till*--Continued

Sample	Al	Cr	Fe	Pb	Li	Mn	Mo	Ni	Se	Sr	V	Zn	U
FP-45-Initial	330	[a]52	70	[a]105	3,900	20	4,400	45.0	260	2,000	[a]480	20	3,400
FP-45B-1	--	[a]28	39	20	3,200	1,400	160	80.0	--	2,300	[a]<12	45	240
FP-45B-2	--	[a]25	36	2	3,200	1,500	165	60.0	--	2,300	[a]<12	81	220
FP-45B-3	--	[a]20	36	--	3,200	2,300	110	74.3	--	2,300	[a]<12	81	220
FP-45B-4	--	[a]14	9	--	3,100	2,800	80	89.5	--	2,200	[a]<12	42	250
FP-45B-5	1,600	[a]11	130	--	3,600	4,300	<100	130	260	2,400	[a]<12	30	160
FP-70-Initial	130	[a]54	60	[a]115	4,000	10	4,400	43.0	260	2,000	[a]480	10	3,400
FP-70B-1	--	[a]49	8	[a]<5	3,100	490	3,100	--	--	2,200	[a]<12	27	160
FP-70B-2	--	[a]49	23	[a]<5	3,200	510	3,100	--	--	2,300	[a]<12	58	160
FP-70B-3	--	--	15	[a]<5	3,100	530	3,000	13.3	--	2,200	[a]<12	21	150
FP-70B-4	--	--	16	[a]<5	3,000	560	2,800	13.0	--	2,200	[a]<12	15	140
FP-70B-5	<10	--	350	[a]<5	3,400	520	2,600	16.0	260	2,400	[a]<12	10	100
FP-90-Initial	210	60	50	--	4,100	10	4,200	59.0	260	2,100	[a]480	10	3,400
FP-90B-1	--	40	24	<10	2,800	10	4,200	--	--	2,200	[a]<12	44	720
FP-90B-2	--	50	200	--	2,800	11	4,200	--	--	2,000	[a]<12	49	770
FP-90B-3	--	48	15	--	2,700	<5	4,300	<2.9	--	2,100	[a]<12	26	730
FP-90B-4	20	80	30	--	3,000	20	3,800	<2.9	260	1,900	[a]<12	<10	690
FP-90B-5	<10	--	310	--	2,900	20	4,000	<2.0	260	1,900	[a]<12	10	520
CP-45-Initial	80	60	220	[a]96	3,900	20	4,000	44.0	260	2,300	440	10	3,100
CP-45B-1	190	40	110	[a]<6	3,600	580	1,300	48.0	260	2,800	30	20	240
CP-45B-3	100	30	130	[a]<6	3,500	1,500	750	92.0	260	3,000	19	40	87
CP-45B-4	--	--	--	[a]<6	--	--	--	--	--	--	--	--	39
CP-45B-5	3,100	<10	85	[a]<1	3,300	11,000	<100	--	240	2,900	<60	--	75
CP-70-Initial	70	60	300	[a]96	3,800	20	4,000	44.0	260	2,000	460	10	3,100
CP-70B-1	20	40	190	[a]<6	3,600	20	3,300	12.0	260	2,500	52	10	1,200
CP-70B-3	50	20	40	[a]<6	3,600	20	3,000	8.0	260	2,500	44	10	1,500
CP-70B-4	--	--	--	[a]<6	--	--	--	--	--	--	--	--	1,500
CP-70B-5	<100	<10	<30	<1	3,300	16	3,100	--	220	2,200	<60	--	1,500
CP-90-Initial	70	50	150	[a]100	3,900	20	4,000	42.0	260	2,000	520	10	3,100
CP-90B-1	30	40	130	[a]<6	3,500	20	3,900	2.0	250	2,200	89	10	580
CP-90B-3	<10	60	30	[a]<6	3,400	20	3,900	4.0	240	2,100	53	<10	290
CP-90B-4	--	--	--	[a]<6	--	--	--	--	--	--	--	--	240
CP-90B-5	--	<10	94	<1	2,900	<10	4,400	--	200	2,100	<60	--	240
FP-45D-5	20	40	50	--	3,500	1,000	1,700	44.0	260	2,400	--	10	17
FP-70D-5	10	20	30	--	3,500	740	2,100	28.0	260	2,700	--	10	76
FP-90D-5	<10	30	30	--	3,500	620	2,200	22.0	260	3,000	--	10	167
CP-45D-3	40	70	250	[a]<6	3,600	20	3,300	10.0	250	2,100	[a]71	10	670
CP-70D-3	<10	50	280	[a]<6	3,600	20	3,300	4.0	240	1,400	[a]71	<10	860
CP-90D-3	<10	70	240	[a]<6	3,600	20	3,400	2.0	250	--	[a]73	10	730

[a] Trace-element analysis performed by flameless atomic absorption at the University of Missouri-Rolla.

Table 7.--*Mineralogical and elemental analyses of sludge material from 0 to 4.5 feet in depth below the water-sediment interface from raffinate pit 3 at the Weldon Spring chemical plant site*

[SEM, scanning electron microscope; mg/kg, milligrams per kilogram]

Mineralogic Analysis

X-ray diffraction--	Apatite, minor quartz, horneblende, and amorphous iron oxides, and trace flakes of graphite
SEM analysis--	Scattered grains of carnotite, $K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$

Elemental analyses by inductively coupled plasma

Element	Unit	Partial digestion [1]	Total digestion [2]
Calcium	weight percent	20	20
Phosphorus	weight percent	10	10
Iron	weight percent	8.5	8.9
Magnesium	weight percent	3.3	3.5
Aluminum	weight percent	1.5	1.5
Sodium	weight percent	.9	.9
Potassium	weight percent	.10	.11
Titanium	weight percent	.05	.05
Arsenic	mg/kg	330	360
Barium	mg/kg	220	230
Cadmium	mg/kg	2.3	2.5
Cesium	mg/kg	6.0	4.3
Chromium	mg/kg	100	104
Cobalt	mg/kg	12	11
Copper	mg/kg	820	850
Lead	mg/kg	193	205
Lithium	mg/kg	165	177
Manganese	mg/kg	516	520
Molybdenum	mg/kg	390	388
Nickel	mg/kg	101	120
Scandium	mg/kg	16	17
Silver	mg/kg	.5	1
Strontium	mg/kg	122	127
Thorium	mg/kg	1,200	1,290
Tin	mg/kg	70	166
Uranium	mg/kg	1,600	1,700
Vanadium	mg/kg	1,230	1,300
Yittrium	mg/kg	22	22
Zinc	mg/kg	120	127
Zirconium	mg/kg	115	530

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[1] 12 N hydrochloric acid plus 30-percent hydrogen peroxide.

[2] Concentrated hydrochloric, hydrofluoroic, nitric, and perchloric acids.

List of abbreviations used in table 8

Cond	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius
pH	In standard units
Temp	Water temperature, in degrees Celsius
DO	Dissolved oxygen, in milligrams per liter
Ca	Dissolved calcium, in milligrams per liter
Mg	Dissolved magnesium, in milligrams per liter
Na	Dissolved sodium, in milligrams per liter
K	Dissolved potassium, in milligrams per liter
HCO_3	Bicarbonate, in milligrams per liter
Alk	Alkalinity as $CaCO_3$, in milligrams per liter
SO_4	Dissolved sulfate, in milligrams per liter
Cl	Dissolved chloride, in milligrams per liter
F	Dissolved fluoride, in milligrams per liter
$NO_2 + NO_3$	Dissolved nitrite plus nitrate as N, in milligrams per liter
NO_2	Dissolved nitrite as N, in milligrams per liter
NH_4	Dissolved ammonium as N, in milligrams per liter
P	Dissolved phosphorus as P, in milligrams per liter
Al	Dissolved aluminum, in micrograms per liter
As	Dissolved arsenic, in micrograms per liter
Ba	Dissolved barium, in micrograms per liter
Be	Dissolved beryllium, in micrograms per liter
B	Dissolved boron, in micrograms per liter
Cd	Dissolved cadmium, in micrograms per liter
Cr	Dissolved chromium, in micrograms per liter
Co	Dissolved cobalt, in micrograms per liter
Cu	Dissolved copper, in micrograms per liter
Fe	Dissolved iron, in micrograms per liter
Fe^{2+}	Dissolved ferrous iron, in micrograms per liter
Pb	Dissolved lead, in micrograms per liter
Li	Dissolved lithium, in micrograms per liter
Mn	Dissolved manganese, in micrograms per liter
Mo	Dissolved molybdenum, in micrograms per liter
Ni	Dissolved nickel, in micrograms per liter
Se	Dissolved selenium, in micrograms per liter
Ag	Dissolved silver, in micrograms per liter
Sr	Dissolved strontium, in micrograms per liter
V	Dissolved vanadium, in micrograms per liter
Zn	Dissolved zinc, in micrograms per liter
U	Dissolved uranium, in micrograms per liter

Table 8.--*Chemical analyses of surface and interstitial water samples from raffinate pit 3 at the Weldon Spring chemical plant site*

[>, greater than; <, less than; --, not determined]

Sample source	Depth	Number of subsamples composited	Cond	pH	Temp	DO	Ca	Mg	Na	K	HCO_3	Alk	SO_4	Cl
Surface water	0	1	12,000	8.51	25.5	10.4	490	370	1,300	87	30	44	630	23
Sample 4	1.5	2	12,900	7.46	19.0	>1	1,100	590	1,900	100	98	81	1,100	27
Sample 6	3	2	43,300	7.89	22.0	>1	6,400	680	4,900	300	38	31	1,400	58
Sample 1	3	3	47,900	7.09	19.0	>1	6,900	1,100	4,600	300	47	39	1,400	63
Sample 2	4	4	31,100	7.21	19.0	>1	4,900	720	3,600	230	39	32	860	45
Sample 3	4	2	38,900	7.01	19.0	>1	7,900	830	5,800	300	61	50	1,300	65
Sample 5	4.5	1	53,900	7.31	20.0	>1	9,500	660	6,200	350	46	38	1,300	71

Sample source	F	NO_2+NO_3	NO_2	NH_4	P	Al	As	Ba	Be	B	Cd	Cr	Co	Cu
Surface water	6.9	1,500	1.1	0.32	<0.01	20	3	100	<10	100	<1	2	<1	3
Sample 4	9.2	2,300	42	3.5	.19	<100	13	<100	<10	220	<10	5,700	<10	500
Sample 6	5.0	7,100	170	65	.13	<100	21	400	<10	--	<10	2,400	<10	200
Sample 1	8.3	8,500	160	61	.30	<100	56	<1,000	<10	290	<10	200	<10	80
Sample 2	2.9	5,600	130	75	.56	<100	32	1,800	<10	190	<10	130	<10	100
Sample 3	2.9	9,700	200	110	.26	<100	33	1,800	<10	530	<10	260	<10	100
Sample 5	2.2	9,600	250	85	.10	<100	28	<100	<10	--	<10	8,500	<10	70

Sample source	Fe	[a]Fe^{2+}	Pb	Li	Mn	Mo	Ni	Se	Ag	Sr	V	Zn	U
Surface water	40	<10	<1	3,600	10	4,700	1	<1	<1	2,100	520	10	320
Sample 4	680	--	60	4,100	2,300	6,400	20	410	<10	3,300	1,100	200	270
Sample 6	2,500	--	20	2,000	42,000	3,000	10	2,400	<10	13,000	200	690	33
Sample 1	8,800	<10	20	4,200	34,000	5,800	20	2,200	<10	16,000	1,100	660	150
Sample 2	7,800	--	10	2,000	27,000	2,600	10	1,600	<10	11,000	440	590	100
Sample 3	2,700	--	10	790	25,000	3,300	10	3,300	<10	17,000	660	690	360
Sample 5	3,200	--	10	370	28,000	3,200	10	3,700	<10	19,000	560	680	140

[a] Analyses of dissolved ferrous iron by field spectrometer.