Data for Water Levels, Water Quality, Lithology, and Surface-Water Discharge in the Vicinity of Lincoln Park, Colorado, 1961 through 1996

By Edward R. Banta

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PLATE

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1. Map showing locations of data-collection sites in the vicinity of Lincoln Park, Colorado, 1961–96

FLOPPY DISK

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1. Data for water levels, water quality, and lithology in the vicinity of Lincoln Park

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
cubic foot per second	0.02832	cubic meter per second
foot (ft)	0.3048	meter
foot per mile (ft/mi)	0.1894	meter per kilometer
inch (in.)	2.54	centimeter
square mile (mi^2)	2.59	square kilometer

Degree Celsius (°C) may be converted to degree Fahrenheit (°F) by using the following equation:

$$°F = 9/5\ (°C) + 32.$$

The following abbreviations also are used in this report:

micrometer (µm)
milligram per liter (mg/L)
milligram per kilogram (mg/kg)

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

Data for Water Levels, Water Quality, Lithology, and Surface-Water Discharge in the Vicinity of Lincoln Park, Colorado, 1961 through 1996

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Abstract

From 1958 through 1979, uranium-mill wastes were placed in a series of unlined tailings ponds near Lincoln Park, Colorado. Seepage of water apparently originating from the tailings ponds resulted in contamination of shallow ground water. In 1994, the U.S. Geological Survey began a study to investigate migration of effluent from the tailings ponds in ground water. This report presents data-collection site descriptions, a site-location map, water-level data, water-quality data, lithologic descriptions of borehole cuttings and cores, solid-phase concentrations of uranium and molybdenum in boreholes, results of X-ray-diffraction analyses, grain-size analyses, clay-mineral analyses, cation-exchange capacities, and surface-water discharge measurements. Much of the data are in a series of digital files, which are included on a 3.5-inch floppy disk, organized as a data base.

INTRODUCTION

In 1958, a uranium-ore processing mill began operating at a site south of Cañon City, Colorado. From 1958 through 1979, mill wastes were discharged to a series of unlined tailings ponds adjacent to the mill. By 1968, ground water from some wells in Lincoln Park, a subdivision of Cañon City that is situated between the uranium mill and the Arkansas River, was recognized (W.A. Wahler & Associates, 1978) as having been affected by contaminants apparently originating from the tailings ponds.

In 1994, the U.S. Geological Survey (USGS), in cooperation with the Colorado Department of Public Health and Environment (CDPHE), began a study to evaluate the geohydrology and geochemistry of the Lincoln Park vicinity, including an assemblage of existing data. During the study, a consistent data base and an updated site-location map were needed. Much of the data came from the Cotter Corporation in digital form. Some of the lithologic data were obtained from the Colorado State Engineer's Office in Denver. Additional data were collected onsite by USGS personnel. Thorough checking of the data for correctness was done during the study; however, some undetected errors in the data may remain.

Purpose and Scope

This report presents data-collection site descriptions, a site-location map, water-level data, water-quality data, lithologic descriptions of borehole cuttings and cores, solid-phase concentrations of uranium and molybdenum in boreholes, results of X-ray-diffraction analyses, grain-size analyses, clay-mineral analyses, cation-exchange capacities, and surface-water discharge measurements at the project site. The collection dates for water-level and water-quality data range from 1961 to 1996. The discharge measurements were made in May or August 1995.

Data-File Format

The digital data files for this report are on the enclosed 3.5-in., 1.44-megabyte floppy disk (in pocket) in the executable file LPDATA.EXE, which is a self-extracting archive. When executed on an IBM-compatible microcomputer using the MS-DOS operating system, this file generates the data files listed in the following table in American Standard Code for Information Interchange (ASCII) format:

File name	Size, in bytes	Brief description of contents
SITES.RDB	75,635	Listing of sites and site-related information
WL.RDB	810,464	Water-level data
QW.RDB	820,191	Water-quality data
LITH.RDB	293,883	Lithologic data
SOLID.RDB	42,891	Solid-phase uranium and molybdenum data

The ordered structure of each of these files is:

1. Any number of comment lines, designated by a "#" character in the first column.
2. One line containing column names, one name per column. Column names are delimited by the ASCII tab character (<tab>).
3. One line containing column definitions, one definition per column. Column definitions are delimited by the <tab> character.
4. Any number of data lines, with data entries delimited by the <tab> character. A null datum entry is indicated by consecutive <tab> characters.

The column definitions used in the files in this report have the format: width; type, where width is an integer indicating the nominal width of the column in characters and type is "N" for numeric; "S" for string; or "D" for date. For example, "9S" would indicate a column that has a nominal width of nine characters containing entries consisting of strings of characters (other than the <tab> character), and "6N" would indicate a column of numeric values that has a nominal width of 6 characters. The actual number of characters making up a given value in a column may exceed the nominal width.

In the comment lines at the top of each file is a brief description of the contents. Each description is an abbreviated version of the description of the data-file contents in the following sections.

Acknowledgments

The author extends thanks to the Cotter Corporation for supplying data and particularly to Cotter Corporation employees Preston Niesen, Philip Krauth, Paul Blanchette, and Richard Wooten for responding professionally and promptly to numerous requests for data. Thanks also are extended to Mark Currey of the Cotter Corporation for assistance to USGS personnel during ground-water-sampling operations and to Jennifer Cox of the Environmental Careers Organization for assisting in water-sample collection and data collation. The DeWeese Dye Ditch and Reservoir Company graciously allowed access to the ditch and irrigation ponds for data collection. Thanks are extended to all well owners who allowed their wells to be used for water sampling and water-level measurement.

DESCRIPTION OF STUDY AREA

The uranium mill is located in a small structural basin bounded by a hogback-shaped ridge immediately to the south and a lower ridge situated between the mill and Lincoln Park (pl. 1). Between the hogback and the ridge, the land surface is moderately rolling and slopes generally northeastward at about 100 ft/mi.

Lincoln Park is on relatively flat land that forms a terrace between the ridge and an escarpment on the south side of the Arkansas River. Land surface in Lincoln Park slopes northeastward at about 80 ft/mi.

The study area is shown by the extent of the map on plate 1. The area of greatest interest is a 6.2 mi^2 area extending from the hogback on the south to the escarpment between Lincoln Park and the Arkansas River on the north and approximately from Oak Creek Grade Road on the west to the unnamed ephemeral stream on which the Willow Lakes are located on the east.

The investigation focuses on permeable earth materials possibly affected by effluent from the mill and underlying, relatively impermeable strata. Stratigraphic units of interest in the study area are listed in table 1; descriptions are modified from Scott (1977).

DATA-COLLECTION SITES

Sites for which data are tabulated in this report are listed in data file SITES.RDB. All site identifiers listed in SITES.RDB, except those identifiers for quality-assurance water samples, are shown on plate 1, and all sites shown on plate 1 have corresponding entries in SITES.RDB. Because of the ongoing remediation effort at Lincoln Park, a need for a comprehensive source of information related to past or potential data-collection sites exists. Plate 1 and data file SITES.RDB are intended to fulfill this need. Accordingly, plate 1 shows locations of sites that are listed in no other tables or files than SITES.RDB.

Table 1. Stratigraphic units of interest in the study area

System	Series	Geologic unit and thickness, in feet	Formation symbol	Lithologic characteristics
Quaternary	Holocene	Alluvium, 0–10	Qa	Sand and gravel, locally very coarse.
	Holocene and Pleistocene	Terrace alluvium, 0–60	Qta	Gravel, sand, silt, and clay.
	Pleistocene	Terrace deposits, 0–20	Qtd	Alluvial and colluvial gravel, with some sand, silt, and clay. In places, contains pebbles, cobbles, and boulders.
Tertiary	Paleocene	Poison Canyon Formation, 0–1,000	Tpc	Claystone, siltstone, and medium-grained to pebbly sandstone; some conglomerate in lower part.
Tertiary and Cretaceous	Paleocene and Upper Cretaceous	Raton Formation, 0–500	TKr	Hard, medium- to coarse-grained sandstone.
Cretaceous	Upper Cretaceous	Vermejo Formation, 0–1,100	Kv	Shaley, fine- to medium-grained sandstone interlayered with sandy to clayey shale and coal. In some areas, removal of coal layers by mining has resulted in water-filled voids. Some of the coal beds are fractured.
		Trinidad Sandstone, 0–90	Kt	Fine- to medium-grained sandstone interlayered with carbonaceous shale.
		Pierre Shale, 3,900	Kp	Clayey, silty, and sandy shale with bentonite beds.

SITES.RDB contains information that is fixed for each site. Each column in the data file and a description of its contents are listed in table 2.

WATER-LEVEL DATA

Depth to water in wells and boreholes measured from either land surface or measuring point are listed in data file WL.RDB. Measurement dates range from 1961 to 1996. Each column in the data file and a description of its contents are listed in table 2.

Pressure transducers and data loggers were used to record water levels at 1-hour intervals in wells 121 and LP85-3 to determine the effect of leakage from DeWeese Dye Ditch and irrigation pond 9 on water levels in these wells (figs. 1 and 2). Water began flowing in the ditch and into irrigation pond 9 on May 13. Filling of irrigation pond 9 was completed on May 14. The ditch was shut down on May 15 because of a failure of the ditch bank downstream from well 121. Operation of the ditch resumed about June 4. The ditch was shut down for the season sometime during the last week of September (Honey Moschetti, DeWeese Dye Ditch and Reservoir Company, oral commun., 1995). Numerous short-duration downward spikes are apparent in the record of pressure-transducer measurements for well 121 (fig. 1). This well was observed to be pumping during the manual measurement made on June 21, 1995, which coincides with one of the spikes. The well also was pumping during the July 14 manual measurement. Small daily fluctuations in the hydrograph for well LP85-3, of an amplitude generally less than 0.5 ft (fig. 2), likely are an artifact caused by variations in temperature of part of the pressure-transducer hardware, which was subjected to large diurnal temperature variations in the surface casing of the well. A similar problem occurred with a pressure-transducer installed in well LP85-1S, except that the amplitude of the daily fluctuations was as much as about 1 ft. Daily pressure-transducer measurements made at 8:00 a.m. correspond well with manual measurements for this well (fig. 3), and only the 8:00-a.m. pressure-transducer measurements and the manual measurements are listed for this well in data file WL.RDB.

WATER-QUALITY DATA

Data file QW.RDB contains aqueous concentrations and other water-quality constituents and properties selected as being of interest in geochemical

Table 2. Contents of five digital-data files

Column name	Description of contents
	Data File SITES.RDB
wellidp	Numeric or alpha-numeric site identifier. To facilitate sorting, numeric identifiers are left-filled with zeros to four places; leading zeros have no other significance.
stationid	Station identifier for the U.S. Geological Survey (USGS) National Water Information System (NWIS) data base.
permno	State Engineer's permit number.
permsuf	Suffix to State Engineer's permit number.
otherid	Alternate or former site identifier.
st	Site type. Possible types are: w, well; b, borehole; qa, quality-assurance sample not associated with a particular location; t, trench; sp, spring; sw, surface-water site; ms, mine shaft.
easting	Colorado State plane easting coordinate, in feet.
northing	Colorado State plane northing coordinate, in feet.
hloc	Code indicating method of horizontal location. Possible codes are: addr, located by street address; dbsa, from Daniel B. Stephens & Associates, Inc. (1993), plate 1; ftg, located by distance from section lines as indicated in well permit from State Engineer's Office; ll, converted from latitude and longitude in NWIS; none, location not unique (as for municipal water); off, offset from another site; qqq, estimated from township, range, section, quarter-quarter-quarter section; surv, surveyed; vipl, visited, plotted on 1:24,000-scale topographic map.
lsd	Land-surface datum, in feet above sea level.
slsd	Source of lsd; "surv" if land-surface datum was surveyed; where estimated from map data, null.
mp_alt	Measuring point altitude for water-level measurements, in feet above sea level.
vmp	Method of determining mp_alt; "surv" if measuring-point altitude was surveyed; where estimated from map data, null.
con_date	Construction date, in format: yyyymmdd.
depth	Hole depth, in feet.
g_top	Depth of top of gravel pack in well or piezometer, in feet.
g_bot	Depth of bottom of gravel pack in well or piezometer, in feet.
s_top	Depth of top of screened interval in well or piezometer, in feet.
s_bot	Depth of bottom of screened interval in well or piezometer, in feet.
h_diam	Hole diameter, in inches.
c_diam	Casing inside or nominal diameter, in inches.
c_mat	Casing material.
desc	Description of site.
remark	Remark.
gh1	Primary geohydrologic unit of completion zone. Possible unit designations are: af, artificial fill; Qa, alluvium of Quaternary age; Qta, terrace alluvium of Quaternary age; Qtd, terrace deposits of Quaternary age; Tpc, Poison Canyon Formation of Tertiary age; TKr, Raton Formation of Tertiary and Cretaceous age; Kv, Vermejo Formation of Cretaceous age; Kt, Trinidad Sandstone of Cretaceous age; and Kp, Pierre Shale of Cretaceous age.
gh2	Secondary geohydrologic unit of completion zone. Possible unit designations are the same as for column gh1.
	Data File WL.RDB
wellidp	Numeric or alpha-numeric site identifier, as in data file SITES.RDB.
datetime	Date and time, using 24-hour notation, of water-level measurement, in format: yyyy.mm.dd hh:mm. In many cases, the time of measurement is not available; for these measurements, a time of 12:00 is assumed. For cases where date in month is unknown, date is assumed to be 15 and time is assumed to be 00:00
dbmp	Depth to water below measuring point, in feet.
dbls	Depth to water below land surface, in feet.
method	Measurement-method code. Possible codes are: et, electric water-level sounder; pt, pressure transducer and data logger; st, steel tape.
status	Status code. Possible codes are: D, dry; X, affected by surface-water feature; pump, pumping water level; test, water level measured during aquifer test or other test; unk, unknown—may have been measured after purging.
remark	Remark.

Table 2. Contents of five digital-data files—Continued

Column name	Description of contents
	Data File QW.RDB
wellidp	Numeric or alpha-numeric site identifier, as in data file SITES.RDB.
sampdate	Date sample was collected, in format: yyyy.mm.dd.
samptime	Time sample was collected, using 24-hour notation, in format: hhmm.
sampler	Organization that collected sample; possible entries are: Cotter, Cotter Corporation; USGS, U.S. Geological Survey.
remark	Remark.
Al	Aluminum concentration, in milligrams per liter.
Alk	Alkalinity concentration, in milligrams per liter as $CaCO_3$.
Ca	Calcium concentration, in milligrams per liter.
Cl	Chloride concentration, in milligrams per liter.
CO3	Carbonate concentration, in milligrams per liter.
FCond	Field specific conductance, in microsiemens per centimeter at 25 degrees Celsius.
DO	Dissolved-oxygen concentration, in milligrams per liter.
Fe	Iron concentration, in milligrams per liter.
HCO3	Bicarbonate concentration, in milligrams per liter.
K	Potassium concentration, in milligrams per liter.
Mg	Magnesium concentration, in milligrams per liter.
Mn	Manganese concentration, in milligrams per liter.
Mo	Molybdenum concentration, in milligrams per liter.
Na	Sodium concentration, in milligrams per liter.
NH4	Ammonium concentration, in milligrams per liter as nitrogen.
NO3	Nitrate concentration, in milligrams per liter as nitrogen.
FpH	Field pH, in standard units.
pH	pH, standard units.
Se	Selenium concentration, in milligrams per liter.
SO4	Sulfate concentration, in milligrams per liter.
TDS	Dissolved-solids concentration, in milligrams per liter. For 1995–96 data from the USGS, this constituent is USGS-laboratory-reported residue on evaporation at 180 degrees Celsius.
Temp	Water temperature, in degrees Celsius.
U	Uranium concentration, in milligrams per liter.
	Data File LITH.RDB
wellidp	Numeric or alpha-numeric site identifier, as in data file SITES.RDB.
int_top	Depth to interval top below land surface, in feet.
int_bot	Depth to interval bottom below land surface, in feet.
ghu	Geologic unit; formation symbols are listed in table 1.
lith_desc	Lithologic description. Some descriptions include comments on drilling conditions.
	Data File SOLID.RDB
wellidp	Numeric or alpha-numeric site identifier, as in data file SITES.RDB.
int_top	Depth to interval top below land surface, in feet.
int_bot	Depth to interval bottom below land surface, in feet.
Mosolid	Solid-phase concentration of molybdenum, in milligrams per kilogram.
Usolid	Solid-phase concentration of uranium, in milligrams per kilogram.

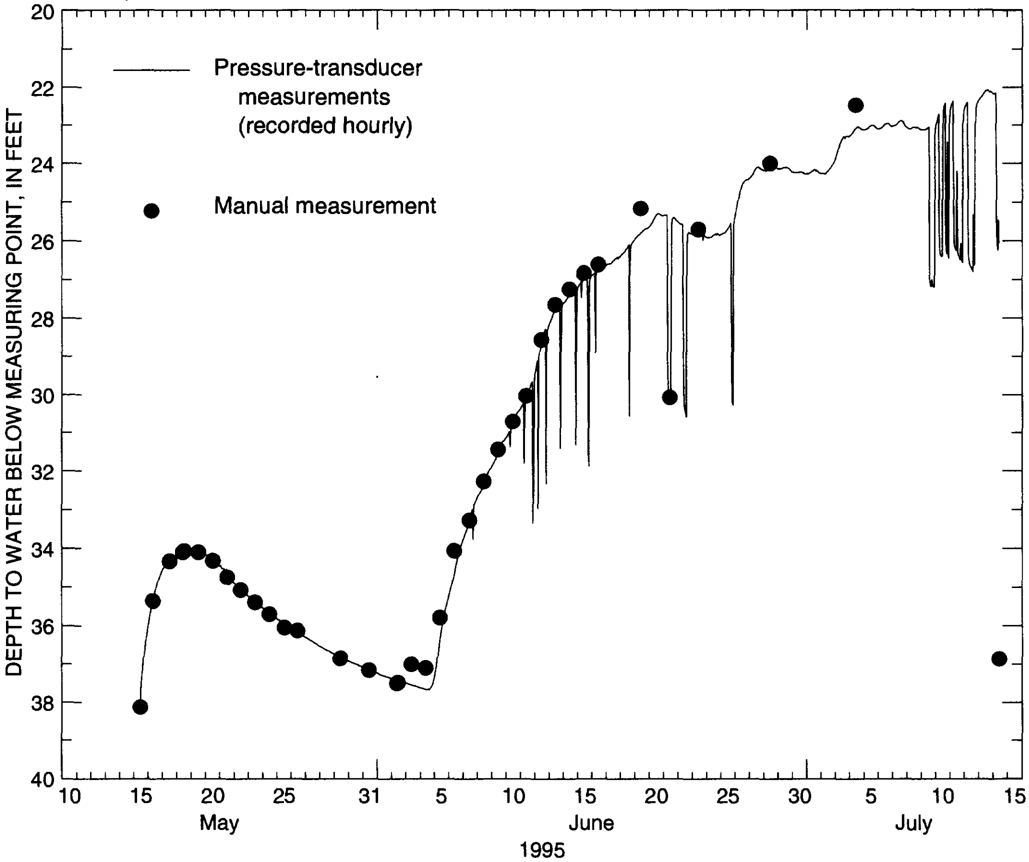

Figure 1. Hourly water-level hydrograph for well 121, May 15 to July 14, 1995.

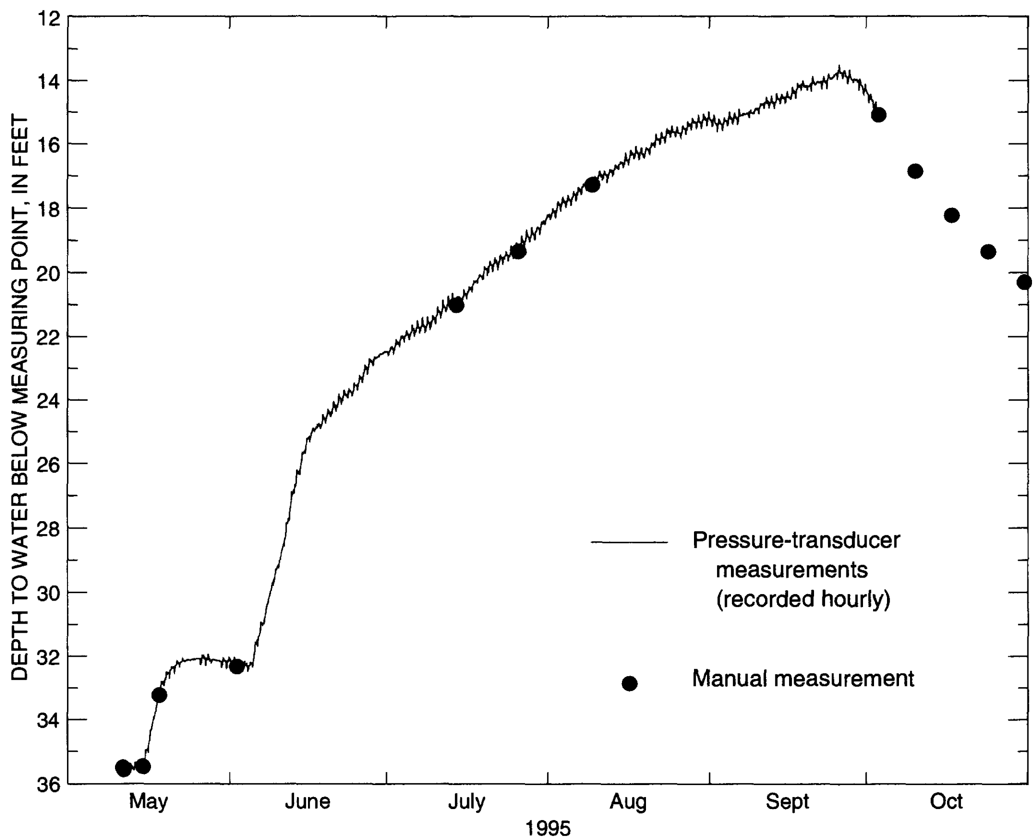

Figure 2. Hourly water-level hydrograph for well LP85-3, May 11 to October 31, 1995.

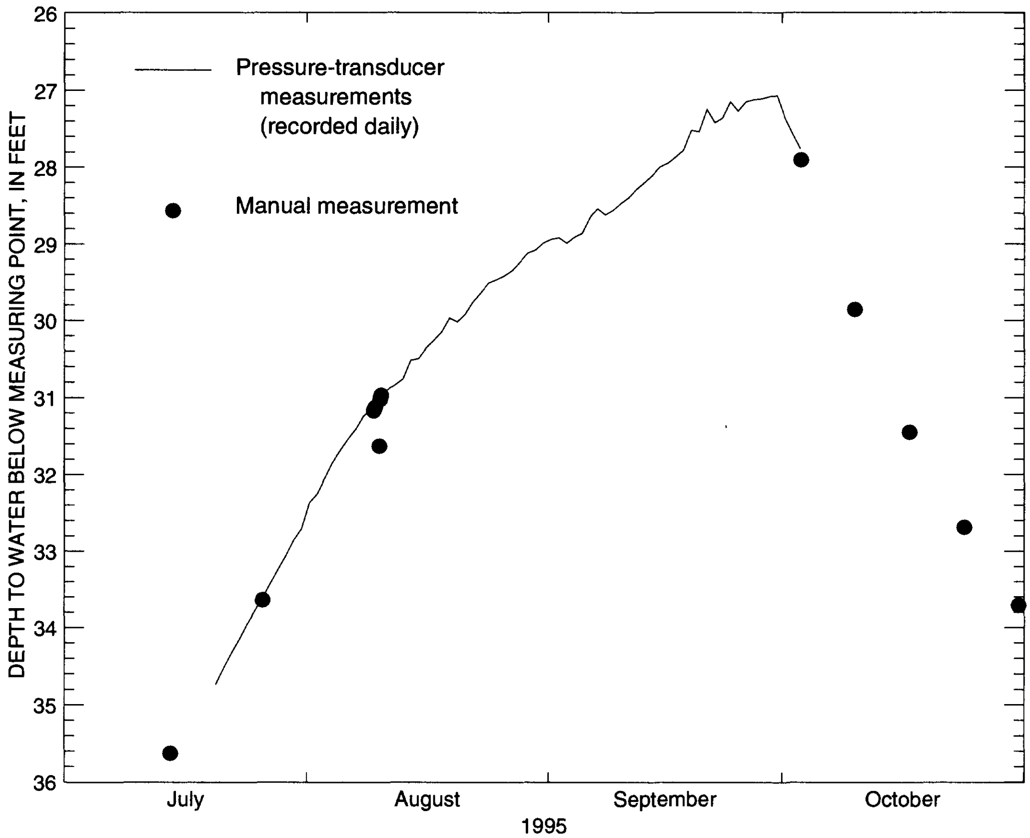

Figure 3. Daily water-level hydrograph for well LP85-1S, July 14 to October 31, 1995.

modeling. Analyses are listed for water samples collected between 1961 and 1996. In the columns containing concentrations, negative concentrations are used for designating analyses for which the constituent was not detected. The detection limit can be obtained by multiplying the listed concentration by –1. Each column in the data file and a description of its contents are listed in table 2.

LITHOLOGIC DATA FROM DRILL CUTTINGS AND CORES

Lithologic descriptions of drill cuttings and cores in borehole intervals are listed in data file LITH.RDB. This data file also gives the geologic unit for each interval described, which corresponds to the units in table 1. Each column in the data file and a description of its contents are listed in table 2.

Solid-phase concentrations of uranium and molybdenum from cuttings collected during drilling of selected boreholes and wells are listed in data file SOLID.RDB. In the columns containing solid-phase concentrations, negative concentrations are used for designating analyses in which the constituent was not detected. The detection limit can be obtained by multiplying the listed concentration by –1. Each column in the data file and a description of its contents are listed in table 2.

Twenty-eight samples from drill cuttings and cores were selected for analysis to determine mineral composition using a variety of methods; lithologic descriptions, in addition to descriptions for solid-phase concentrations of uranium and molybdenum, are listed in table 3. Each of these samples was analyzed by X-ray diffraction for abundance of selected minerals; results are listed in table 4. Thirteen of the samples were analyzed for abundance of selected size fractions (table 5). Fourteen samples were analyzed for abundance of clay minerals in the size fraction less than 2 μm (table 6). Cation-exchange capacity for the size fraction less than 2 μm was determined for thirteen samples (table 7). Analytical results listed in tables 3 through 7 were provided by George Breit (U.S. Geological Survey, written commun., 1996).

Table 3. Lithologic description of selected drill cuttings and cores

[See pl. 1 for site locations; depth is in feet below land surface; see table 1 for explanation of formation symbols; >, greater than; µm, micrometer; XRD, X-ray diffraction; mm, millimeter; <, less than; ?, rock type or mineral identification uncertain; descriptions from George Breit (U.S. Geological Survey, written commun., 1996)]

Site and depth	Formation symbol	Type of sample	Sample description	Description of >62-µm fraction
A1 20–25	Tpc	Reverse circulation, composite	Light brown, ground sample (bulk sample not available)	(Ground sample) fine to very fine sand; rock fragments of incompletely disaggregated gneiss (?); minerals include quartz, pink microcline, black opaques (many magnetic) with traces of muscovite and biotite; many grains have a thin coating of yellow-orange (iron oxides)
D5 5–10	Tpc	Reverse circulation, composite	Unconsolidated light brown, very fine sand	Pebbles to fine sand; rock fragments include plutonic (granitic) and metamorphic rocks (gneiss), white metaquartzite (gneiss fragment?); minerals include quartz, pink microcline, plagioclase, biotite, black opaques (many magnetic), and trace of epidote; many grains stained with yellow-orange coating (iron oxides)
F1 45–50	Tpc	Reverse circulation, composite	Unconsolidated, medium-gray clay and fine sand, few granule-sized rock fragments	Not separated
H6 5–10	Tpc	Reverse circulation, composite	Unconsolidated, buff, very fine sand and clay with a few fragments of consolidated mudstone	Grains are mainly incompletely disaggregated, green-brown siltstone and mudstone fragments, one fragment of granitic rock; minerals include quartz and muscovite; several grains have an orange to brown coating, a few grains have a black iridescent coating (iron oxides?)
J7 15–20	Tpc	Reverse circulation, composite	Unconsolidated brown mudstone; minor rock fragments	Fine to very fine sand grains; most grains are rock fragments of incompletely disaggregated silt and clay; crystals of gypsum (XRD confirmed) are abundant; visible grains of muscovite, biotite, and opaques (some are magnetic); yellow-brown coatings (iron oxides?) on quartz grains
K7 10–15	Tpc	Reverse circulation, composite	Tan, ground sample (bulk sample not available)	Not separated
K14 10–15	Tpc	Reverse circulation, composite	Unconsolidated, light brown sand with clay; granule-sized fragments of igneous and metamorphic rocks	Not separated
L10 15–20	Tpc	Reverse circulation, composite	Unconsolidated, brown, clay-rich sand with fragments of weathered metamorphic rocks and mudstone	Not separated

Table 3. Lithologic description of selected drill cuttings and cores—Continued

[See pl. 1 for site locations; depth is in feet below land surface; see table 1 for explanation of formation symbols; >, greater than; µm, micrometer; XRD, X-ray diffraction; mm, millimeter; <, less than; ?, rock type or mineral identification uncertain; descriptions from George Breit (U.S. Geological Survey, written commun., 1996)]

Site and depth	Formation symbol	Type of sample	Sample description	Description of >62-µm fraction
M3 25–30	Tpc	Reverse circulation, composite	Unconsolidated, buff, fine sand, silt, and clay with a few metamorphic rock fragments	Poorly disaggregated siltstone fragments with a few granules of plutonic and metamorphic rock; siltstone fragments are micaceous, some have an orange-brown to black coating (iron oxides?); abundant gypsum crystals (XRD confirmed); minerals include quartz, muscovite, biotite, black opaques (magnetic), and a few feldspar grains. Surfaces of rock fragments are chalky and pitted
M9 0–5	Tpc	Reverse circulation, composite	Unconsolidated sand, clay- to pebble-sized fragments of igneous and metamorphic rock; a few modern root fragments	Mainly granules to fine sand; rock fragments are volcanic, metamorphic, and plutonic; minerals include pink feldspar, plagioclase, biotite, muscovite, quartz, black opaques (many magnetic); also contains light-blue fragments (XRD amorphous); green, glassy grains (XRD amorphous); fragments of botryoidal, dark-gray grains of slag (?); gray, metallic spheres, 2 mm in diameter (XRD identified as powellite, $CaMoO_4$). These materials indicate that the site accumulated trash
6 35–40	Kv	Reverse circulation, composite	Fine sand and silt	Fine to very fine sand; minerals include quartz, biotite, muscovite, weathered feldspars, a few black opaques (most are magnetic); few grains coated or bound by yellow-orange cement (iron oxides); some discrete grains of orange-brown iron oxide (goethite per XRD)
6 40–43	Kv	Reverse circulation, composite	Unconsolidated, fine sand, silt, and clay with a few mudstone fragments	Not separated
6 45–50	Kv	Reverse circulation, composite	Unconsolidated gray, fine sand and clay with mudstone fragments and a few coalified plant fragments	Fine sand; most rock fragments are incompletely disaggregated fragments of original lithologies, including light gray-green, fine-grained sandstone and gray mudstone; minerals include quartz, biotite, microcline, plagioclase, also coal fragments and a few gray metallic fragments; a few rock fragments have a yellow-brown cement (iron oxides)

Table 3. Lithologic description of selected drill cuttings and cores—Continued

[See pl. 1 for site locations; depth is in feet below land surface; see table 1 for explanation of formation symbols; >, greater than; μm, micrometer; XRD, X-ray diffraction; mm, millimeter; <, less than; ?, rock type or mineral identification uncertain; descriptions from George Breit (U.S. Geological Survey, written commun., 1996)]

Site and depth	Formation symbol	Type of sample	Sample description	Description of >62-μm fraction
18 18	Tpc	Core	Medium-grained, brown, well-cemented sandstone with iron oxide grain coatings and gypsum crystals on partings. Thin-section description: moderately sorted, medium- to fine-grained sandstone with volcanic rock fragments and laminae of heavy minerals along bedding planes; most grains have a dark-brown rim of iron oxides as much as 0.1 mm thick on at least two sides; porosity approximately 10 percent, mainly as small pores intermixed with clay; biotite altering to chlorite	Not separated
18 22.25– 22.5	Tpc	Core	Medium-grained, brown, well-cemented sandstone with iron oxide grain coatings and gypsum crystals on partings. Thin-section description: poorly sorted, argillaceous sandstone with approximately 30 percent volcanic rock fragments; porosity approximately 5 percent; rim of orange-brown iron oxides on most grains; micritic calcite is a common cement	Not separated
18 27.25	Tpc	Core	Coarse- to medium-grained, brown sandstone with iron oxides and scattered, carbonized wood fragments	Not separated
18 30	Tpc	Core	Gray-black mudstone with yellow-brown iron oxides on partings	Incompletely disaggregated rock fragments of siltstone and mudstone and coal fragments; minerals include quartz, biotite, muscovite, and black opaques (many are magnetic); rock fragments are mainly gray, but a few have brown cement (iron oxides)
18 120	Tpc	Core	White, medium-grained sandstone overlying a 40-mm-thick coal layer	Not separated
21 19–20	Tpc	Core	Gray to black conglomerate and coarse sandstone with some fragments cemented by calcium carbonate	Gray pebble to very fine sand; rock fragments are volcanic, plutonic (granite), metamorphic (gneiss), and possibly sedimentary (white sandstone with white, chalky cement); minerals include quartz, plagioclase, microcline, and biotite

Table 3. Lithologic description of selected drill cuttings and cores—Continued

[See pl. 1 for site locations; depth is in feet below land surface; see table 1 for explanation of formation symbols; >, greater than; µm, micrometer; XRD, X-ray diffraction; mm, millimeter; <, less than; ?, rock type or mineral identification uncertain; descriptions from George Breit (U.S. Geological Survey, written commun., 1996)]

Site and depth	Formation symbol	Type of sample	Sample description	Description of >62-µm fraction
21 20.25	Tpc	Core	Gray-green, well-cemented, argillaceous sandstone. Thin-section description: poorly sorted, argillaceous sandstone with abundant grains of quartz, muscovite, plagioclase, and biotite and abundant fragments of metamorphic and volcanic rock; porosity <3 percent; iron oxide grain coatings are absent and framboidal pyrite and subhedral pyrite are locally abundant (a few percent of the sample)	Not separated
21 26–27	Tpc	Core	Large, gray, igneous and metamorphic clasts in gray mudstone matrix	Gray pebbles to very fine sand; rock fragments are plutonic (?), volcanic, and metamorphic with some vein quartz; minerals include quartz, biotite, and minor microcline; rock fragments have chloritized biotite and argillized feldspar
21 27.5–38.5	Tpc	Core	Conglomerate and coarse gray-green sandstone with a silty clay matrix and well-cemented volcanic rock fragments	Not separated
817 15	Qta	Hollow-stem auger	Tan sandstone with minor pebbles and granules	Pebbles to very fine sand with plutonic (granitic) and metamorphic rock fragments; minerals include quartz, pink microcline, plagioclase, biotite, black opaques (many are magnetic), epidote, goethite (XRD confirmed), and massive hematite (XRD confirmed); a few grains have yellow-brown cement (iron oxides)
817 27.5–28	Kv	Hollow-stem auger	Very fine sandstone with coalified plant fragments and tan sandstone with minor pebbles and granules	Not separated
821 9.3–19	Qta	Core	Sandy gravel; apparently cemented with calcium carbonate (caliche layer?) near top; pebble-sized material was separated prior to further analysis	Pebbles to fine sand; plutonic (mainly granitic), metamorphic (gneiss), and sedimentary (?; white, sugary quartzite) rock fragments, many coated with calcium carbonate; minerals include pink microcline, biotite, quartz, and black opaques (many magnetic); a few rock fragments are cemented by yellow-brown iron oxides
821 9.3–9.5	Qta	Core	Subsample of the previous sample; contains abundant calcite cement	Not separated

Table 3. Lithologic description of selected drill cuttings and cores—Continued

[See pl. 1 for site locations; depth is in feet below land surface; see table 1 for explanation of formation symbols; >, greater than; µm, micrometer; XRD, X-ray diffraction; mm, millimeter; <, less than; ?, rock type or mineral identification uncertain; descriptions from George Breit (U.S. Geological Survey, written commun., 1996)]

Site and depth	Formation symbol	Type of sample	Sample description	Description of >62-µm fraction
821 20–24	Qta	Core	Light-brown, fine sand, silt, and clay. Thin-section description of 21-ft depth: poorly sorted, argillaceous sandstone with rock fragments of intraclasts and volcanic material; porosity varies irregularly across thin section from 5 to 20 percent, some possibly caused by shrinkage of smectite during drying; most pores are lined with clay minerals	Not separated
821 24–30	Qta	Core	Conglomerate; fine sand to cobble	Mostly fine to very fine sand grains with a few well-rounded granules and plutonic (granitic), metamorphic (gneiss), and sedimentary (?; gray quartzite) rock fragments; mineral grains include quartz, pink microcline, plagioclase, black opaques (many magnetic), biotite, and a few grains of epidote

Table 4. Results of whole-rock X-ray-diffraction analysis for selected minerals in selected drill cuttings and cores

[See pl. 1 for site locations; sample depths are in feet below land surface; listed minerals were detected in two or more samples; values are peak heights, which are useful for comparison among samples, in arbitrary units; interference from other minerals limited use of calcite peak heights, which are not reported; nd, not detected; ?, identification tentative; <, less than; >, more than; analyses from George Breit (U.S. Geological Survey, written commun., 1996]

Site	Sample depth	Mineral peak height or relative abundance							
		Quartz	Potassium feldspar	Plagioclase	Illite/mica	Kaolinite/ chlorite	Calcite	Gypsum	Clinoptilolite
A1	20–25	30	10	10	4	2	nd	nd	7
D5	5–10	40	80	80	9	nd	nd	nd	15
F1	45–50	45	10	10	11	5	nd	nd	nd
H6	5–10	40	10	19	10	2	nd	nd	nd
J7	15–20	40	10	10	10	3	Minor?	nd	nd
K7	10–15	45	60	60	5	2	nd	4	nd
K14	10–15	90	90	70	6	9	Minor	nd	nd
L10	15–20	55	35	25	8	5	nd	nd	nd
M3	25–30	40	10	15	7?	1	nd	nd	3?
M9	0–5	63	90	90	5	1	Minor	nd	nd
6	35–40	50	45	90	5	15	Minor?	nd	nd
6	40–43	50	50	90	5	10	nd	nd	nd
6	45–50	60	>90	90	5	18	nd	nd	nd
18	18	90	90	90	4	2	nd	6	nd
18	22.25–22.5	20	50	80	18	2	nd	nd	nd
18	27.25	50	80	90	10	4	nd	6	nd
18	30	40	8	10	5	6	nd	nd	nd
18	120	90	90	50	<3	16	Minor	nd	nd
21	19–20	65	>90	>90	5	15	nd	nd	nd
21	20.25	30	90	55	4	15	Major	nd	nd
21	26–27	85	90	80	10	19	nd	nd	nd
21	27.5–38.5	80	>90	>90	2	5	nd	nd	nd
817	15	60	90	90	25	3	Major	nd	nd
817	27.5–28	50	28	15	3	10	Minor	nd	nd
821	9.3–19	60	90	90	<3	1	Minor	nd	2?
821	9.3–9.5	50	90	90	3	1	Major	nd	nd
821	20–24	34	90	90	5	2	Minor	nd	nd
821	24–30	55	80	90	10	3	nd	nd	nd

Table 5. Relative abundance of size fractions for selected drill cuttings and cores

[See pl. 1 for site locations; sample depths are in feet below land surface; greater-than 62-micrometer fraction does not include fragments greater than 1 centimeter, which are reported in the sample description in table 3; some sample percentages do not add up to 100 percent because of rounding; >, greater than; µm, micrometer; <, less than; analyses from George Breit (U.S. Geological Survey, written commun., 1996)]

Site	Sample depth	Percent of size fraction		
		>62 µm	2 to 62 µm	<2 µm
D5	5–10	73	24	3.5
H6	5–10	22	64	14
J7	15–20	6.0	68	26
M3	25–30	60	33	7.5
M9	0–5	76	22	1.8
6	35–40	80	19	1.0
6	45–50	79	20	0.9
18	30	0.4	95	4.6
21	19–20	77	20	3.0
21	26–27	72	27	1.4
817	15	78	21	1.3
821	9.3–19	93	6.1	0.3
821	24–30	77	22	1.0

SURFACE-WATER DISCHARGE DATA

Surface-water discharge measurements were made at selected locations on DeWeese Dye Ditch and on the diversion from DeWeese Dye Ditch that leads to irrigation pond 9 for two gain-loss investigations on the DeWeese Dye Ditch in May and August 1995. Additional discharge measurements were made near the mouth of Sand Creek. Locations of discharge-measurement sites are shown on plate 1 and are listed in the data file SITES.RDB. The discharge-measurement sites are described in the following table.

Site identifier	Description
SW1	Sand Creek, at mouth
SW2	DeWeese Dye Ditch, at flume about 290 feet upstream (west) from Sand Creek channel
SW3	DeWeese Dye Ditch, immediately downstream from diversion for irrigation pond 9
SW4	Irrigation pond 9 inlet ditch
SW5	DeWeese Dye Ditch, about 470 feet down stream from diversion for irrigation pond 9
SW6	DeWeese Dye Ditch, immediately downstream from diversion for irrigation pond 3
SW7	DeWeese Dye Ditch, about 750 feet downstream from diversion to irrigation pond 3

Table 6. Abundance of clay minerals in the less-than 2-micrometer size fraction for selected drill cuttings and cores

[See pl. 1 for site locations; sample depths are in feet below land surface; relative abundances are based on peak heights from X-ray-diffraction analysis; nd; not detected; --, no other minerals detected; analyses from George Breit (U.S. Geological Survey, written commun., 1996)]

Site	Sample depth	Relative abundance of clays			Other minerals detected
		Smectite	Kaolinite	Illite	
A1	20–25	Major	Minor	Very minor	--
D5	5–10	Major	Minor	nd	Minor clinoptilolite
H6	5–10	Major	Very minor	Minor	Very minor quartz
J7	15–20	Major	Minor	Minor	Minor quartz
M3	25–30	Major	Minor	nd	--
M9	0–5	Major	Minor	Very minor	Minor calcite
6	35–40	Major	Minor	nd	Very minor plagioclase
6	45–50	Major	Minor	Very minor	Chlorite
18	30	Major	Minor	Very minor	--
21	19–20	Major	Major	Very minor	--
21	26–27	Major	Minor	Very minor	Very minor quartz
817	15	Major	Minor	nd	--
821	9.3–19	Major	Minor	Very minor	Minor calcite
821	24–30	Major	Minor	Minor	Minor calcite

Table 7. Cation-exchange capacities of the less-than 2-micrometer size fraction for selected drill cuttings and cores

[µm, micrometer; see pl. 1 for site locations; sample depths are in feet below land surface; some samples required correction of calcium exchange because of calcite dissolution; this correction was done by subtracting an equivalent amount of inorganic carbon analyzed in split samples; meq/100 g, milliequivalents per 100 grams; sample from site A1 was analyzed from ground sample, assuming grinding did not appreciably affect the less-than 2-micrometer size fraction; some percentages of cation-exchange capacity do not add up to 100 percent because of rounding; analyses from George Breit (U.S. Geological Survey, written commun., 1996)]

Site	Sample depth	Cation-exchange capacity (meq/100 g)					Cation-exchange capacity (percent)			
		Ca	Mg	N	K	Total	Ca	Mg	Na	K
A1	20–25	75	16	16	2.4	110	69	14	15	2
D5	5–10	51	1.7	28	0.6	82	63	2	34	1
H6	5–10	58	11	14	0.7	84	69	14	16	1
J7	15–20	24	14	16	0.6	55	44	26	30	1
M3	25–30	31	16	12	0.6	59	52	26	21	1
6	35–40	46	14	13	1.3	74	62	18	18	2
6	45–50	50	10	1.3	3.2	65	77	16	2	5
18	30	36	11	4.8	1.4	53	68	20	9	3
21	19–20	26	4.1	0.3	0.9	31	83	13	1	3
21	26–27	88	11	1.0	2.7	100	86	11	1	3
817	15	97	10	0.0	1.7	109	89	9	0.0	2
821	24–30	30	16	0.5	1.2	48	63	33	1	3
821	9.3–19	36	14	0.0	1.1	51	70	28	0.0	2

Discharge measurements for these sites are listed in table 8. On May 15, 1995, during the gain-loss investigation, a bank of DeWeese Dye Ditch failed at a location downstream from the discharge-measurement sites. Because of this failure, the DeWeese Dye Ditch and Reservoir Company shut off the flow of water into the ditch at a location outside the study area (Honey Moschetti, DeWeese Dye Ditch and Reservoir Company, oral commun., 1995). During the shutdown procedure, the stage (height) of water at the flume at site SW2 varied substantially. Because of this variation, comparison of discharge measurements at sites along DeWeese Dye Ditch generally is of questionable value. However, during the time interval including the discharge measurements at SW6 and SW7 on May 15, 1995, the stage remained within a 0.01-ft range at SW6, where water depth in the cross section generally was between 1.3 and 1.4 ft. Flow in this reach can be expected to have been approximately steady during these two measurements.

Table 8. Surface-water discharge measurements, 1995

[Entries are in chronological order]

Site (see pl. 1)	Measurement date and time interval	Discharge (cubic feet per second)	Estimated maximum error (percent)
SW1	05–11–1995 1450 – 1518	2.41	8
SW4	05–14–1995 1325 – 1357	6.24	Not estimated
SW4	05–15–1995 0825 – 0840	0.06	More than 8
SW2	05–15–1995 0905 – 1000	7.36	8
SW3	05–15–1995 1024 – 1059	8.71	8
SW5	05–15–1995 1125 – 1155	8.49	8
SW6	05–15–1995 1211 – 1238	9.35	5
SW7	05–15–1995 1257 – 1321	7.26	8
SW2	08–09–1995 1030 – 1100	17.8	More than 8
SW5	08–09–1995 1215 – 1240	15.1	More than 8
SW6	08–09–1995 1250 – 1310	15.5	More than 8
SW7	08–09–1995 1335 – 1400	14.4	More than 8
SW1	08–10–1995 0935 – 1000	4.43	More than 8
SW2	08–10–1995 1100 – 1128	7.05	Not estimated

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