



Prepared in cooperation with the  
**METRO WASTEWATER RECLAMATION DISTRICT**

# **BIOSOLIDS, SOIL, CROP, GROUND-WATER, AND STREAMBED-SEDIMENT DATA FOR A BIOSOLIDS-APPLICATION AREA NEAR DEER TRAIL, COLORADO, 2001**

**Open-File Report 2004–1388**



**U.S. Department of the Interior  
U.S. Geological Survey**

# **Biosolids, Soil, Crop, Ground-Water, and Streambed-Sediment Data for a Biosolids-Application Area Near Deer Trail, Colorado, 2001**

By Tracy J.B. Yager, David B. Smith, and James G. Crock

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**U.S. Department of the Interior**  
**U.S. Geological Survey**

**U.S. Department of the Interior**  
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# Contents

Abstract .....	1
Introduction .....	1
Purpose and Scope .....	2
Acknowledgments .....	2
Biosolids .....	2
Objectives of Monitoring Biosolids .....	3
Approach for Monitoring Biosolids.....	3
Sampling Methods for Biosolids .....	3
Analytical Methods for Biosolids.....	3
Quality Assurance for Biosolids .....	3
Biosolids Data .....	3
Discussion of Biosolids Data .....	4
Soils .....	4
Objectives of Monitoring Soils.....	4
Approach for Monitoring Soils .....	4
Site Selection for Monitoring Soils .....	4
Sampling Methods for Soils.....	4
Analytical Methods for Soils .....	4
Quality Assurance for Soils .....	5
Soil Data .....	5
Discussion of Soil Data .....	5
Crops .....	5
Objectives of Monitoring Crops .....	5
Crop Data.....	5
Ground Water .....	5
Objectives of Monitoring Ground Water .....	6
Approach for Monitoring Ground Water .....	6
Site Selection for Monitoring Ground Water .....	6
Sampling Methods for Ground Water .....	7
Analytical Methods for Ground Water.....	7
Quality Assurance for Ground Water .....	7
Ground-Water Data .....	7
Meteorologic Data .....	8
Hydrologic Data .....	8
Water-Quality Data .....	8
Discussion of Ground-Water Data .....	8
Regulatory Standards .....	9
Trends .....	9
Streambed Sediment .....	10
Objectives of Monitoring Streambed Sediment .....	10
Approach for Monitoring Streambed Sediment .....	10
Site Selection for Monitoring Streambed Sediment .....	10
Sampling Methods for Streambed Sediment .....	11

Analytical Methods for Streambed Sediment .....	11
Quality Assurance for Streambed Sediment .....	11
Streambed-Sediment Data .....	12
Discussion of Streambed-Sediment Data .....	12
References Cited .....	12
Data Section .....	15

## Figures

### 1-4. Maps showing:

1. Location of study area and U.S. Geological Survey monitoring sites near Deer Trail, Colorado, 2001 .....	17
2. Metro Wastewater Reclamation District biosolids-application areas (METROGRO Farm) near Deer Trail, Colorado, 2001 .....	18
3. Arapahoe County, Colorado, soil-monitoring site: T. 4 S., R. 58 W., sec. 22 .....	19
4. Elbert County, Colorado, soil-monitoring site: T. 6 S., R. 57 W., sec. 8 .....	20

### 5-8. Graphs showing:

5. Continuous water-level, water-temperature, precipitation, and air-temperature data for well D25 near Deer Trail, Colorado, 2001 .....	21
6. Continuous water-level, water-temperature, precipitation, and air-temperature data for well DTX2 near Deer Trail, Colorado, 2001 .....	22
7. Continuous water-level, water-temperature, precipitation, and air-temperature data for well DTX5 near Deer Trail, Colorado, 2001 .....	23
8. Continuous water-level data for wells DTX9, DTX10A, and DTX11, and precipitation data for the EDL recharge-evaluation site near Deer Trail, Colorado, 2001 .....	24
9. Diagrams showing water levels for the recharge-evaluation site containing wells DTX7 and DTX8 near Deer Trail, Colorado, for (a) July, (b) August, and (c) September 2001 .....	25

### 10-12. Graphs showing:

10. Data for the recharge-evaluation site containing wells DTX9, DTX10, and DTX11 near Deer Trail, Colorado, 2001 .....	28
11. Distribution of ground-water data collected near Deer Trail, Colorado, compared to regulatory standards for selected constituents, 2001 .....	29
12. Ground-water concentrations near Deer Trail, Colorado, for selected constituents and selected wells, 1999-2001 .....	32

## Tables

1. Biosolids applications by Metro Wastewater Reclamation District to the study area near Deer Trail, Colorado, 2001 .....	34
2. Methods used to analyze biosolids and soil samples collected near Deer Trail, Colorado, 2001 .....	35
3. Chemical data for biosolids samples collected at the Metro Wastewater Reclamation District during 2001 .....	36

4. U.S. Geological Survey soil data for samples collected June 11, 2001, at the Arapahoe County site and November 29–December 1, 2000, at the Elbert County site .....	37
5. Methods used to analyze ground-water samples collected near Deer Trail, Colorado, 2001 .....	38
6. Information for U.S. Geological Survey monitoring wells near Deer Trail, Colorado, 2001 .....	40
7. Monthly water-level data for U.S. Geological Survey monitoring wells near Deer Trail, Colorado, 2001 .....	41
8. Water-quality data for monitoring wells near Deer Trail, Colorado, 2001 .....	42
9. Quality-control data for blank samples associated with ground-water samples collected near Deer Trail, Colorado, 2001 .....	52
10. Comparison of water-quality data for ground-water and replicate samples collected near Deer Trail, Colorado, 2001 .....	54
11. Statistical comparison of concentrations for selected chemical constituents in ground-water samples collected near Deer Trail, Colorado, 1999-2001, and lowest applicable water-quality standard .....	60
12. Statistical evaluation of monotonic time-series trend using the Kendall's tau correlation coefficient for selected constituents in ground-water samples collected near Deer Trail, Colorado, 1999-2001 .....	64
13. Methods used to analyze streambed-sediment samples collected near Deer Trail, Colorado, 2001 .....	65
14. Chemical data for streambed-sediment samples collected near Deer Trail, Colorado, 2001 .....	66
15. Radioactivity data for streambed-sediment samples collected near Deer Trail, Colorado, 2001 .....	66
16. Comparison of chemical data for streambed-sediment and replicate samples collected near Deer Trail, Colorado, 2001 .....	67

## Conversion Factors

Multiply	by	To obtain
acre	0.4047	hectare (ha)
centimeter (cm)	0.3937	inch
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
gram (g)	0.035	ounce
inch	2.54	centimeter
liter (L)	0.2642	gallon (gal)
micrometer ( $\mu\text{m}$ )	0.00003937	inch
mile (mi)	1.609	kilometer
milliliter (mL)	0.0610	cubic inch
millimeter (mm)	0.03937	inch
square mile ( $\text{mi}^2$ )	2.590	square kilometer

Temperature in degrees Celsius ( $^{\circ}\text{C}$ ) can be converted to degrees Fahrenheit ( $^{\circ}\text{F}$ ) using the formula  

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32.$$

Temperature in degrees Fahrenheit ( $^{\circ}\text{F}$ ) may be converted to degrees Celsius ( $^{\circ}\text{C}$ ) using the formula  

$$^{\circ}\text{C} = (^{\circ}\text{F} - 32) / 1.8$$

Vertical coordinate information is referenced to National Geodetic Vertical Datum of 1929 (NGVD 29); horizontal coordinate information is referenced to North American Datum of 1927 (NAD 27) except as noted.

### ADDITIONAL ABBREVIATIONS

gal/min	gallons per minute
mg	milligrams
mg/g	milligrams per gram
$\mu\text{g/L}$	micrograms per liter
$\mu\text{S/cm}$	microsiemens per centimeter at 25 degrees Celsius
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
$\rho\text{Ci/L}$	picocuries per liter
$\rho\text{Ci/g}$	picocuries per gram
ROE	residue on evaporation

# Biosolids, Soil, Crop, Ground-Water, and Streambed-Sediment Data for a Biosolids-Application Area Near Deer Trail, Colorado, 2001

By Tracy J.B. Yager, David B. Smith, and James G. Crock

## Abstract

In January 1999, the U.S. Geological Survey (USGS) began an expanded monitoring program near Deer Trail, Colorado, in cooperation with the Metro Wastewater Reclamation District and the North Kiowa Bijou Groundwater Management District. Monitoring components were biosolids, soils, crops, ground water, and streambed sediment. The monitoring program addresses concerns from the public about chemical effects from applications of biosolids to farmland in the Deer Trail, Colorado, area. Constituents of primary concern to the public are arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, plutonium, and gross alpha and beta activity, and they are included for all monitoring components. This report presents chemical data from the third year of the monitoring program, January–December 2001, for biosolids, soils, alluvial and bedrock ground water, and streambed sediment. The ground-water section also includes climate data, water levels, and results of statistical testing of selected data for trends and for exceedance of Colorado regulatory standards. The chemical data include the constituents of highest concern to the public in addition to many other constituents.

## Introduction

Since 1993, the Metro Wastewater Reclamation District (MWRD) has been applying biosolids resulting from municipal sewage treatment in Denver, Colo., to their property near Deer Trail, Colo. The biosolids are trucked about 75 mi east from Denver to the MWRD property and are applied to nonirrigated farmland. From 1993 to 1999, the U.S. Geological Survey (USGS), in cooperation with the MWRD, monitored the quality of shallow ground-water on the MWRD central property (fig. 1 in the Data Section at the back of the report), which encompassed about 15 mi<sup>2</sup> and was the first property the MWRD purchased near Deer Trail. In 1995, the MWRD traded some of the property and acquired additional property in the same area. The new property consisted of about 14.5 mi<sup>2</sup> known as the north property and about 50 mi<sup>2</sup> known as the south property. In 1999, the three MWRD properties together, known as the METROGRO Farm, encompassed almost 70 mi<sup>2</sup> of farmland, including land in Arapahoe and Elbert Counties. The three MWRD properties and surrounding private property are hereinafter referred to as the “study area” (fig. 1).

The study area is located on the eastern plains of Colorado about 10 mi east of Deer Trail. The study area is on the eastern margin of the Denver Basin, a bowl-shaped sequence of sedimentary rocks that was formed in an ocean or near-ocean environment. The geology of the study area consists of interbedded shale, siltstone, and sandstone, which may be overlain by clay, windblown silt and sand, or alluvial sand and gravel (Sharps, 1980; Major and others, 1983; Robson and Banta, 1995). The primary water-supply aquifer is the Laramie-Fox Hills aquifer, which is a bedrock aquifer that ranges from 0 to about 200 ft thick in the study area and is the bottom aquifer in the Denver Basin aquifer sequence (Robson and others, 1981; Robson and Banta, 1995). Multiple alluvial aquifers are present in the study area. These aquifers are associated with the surficial drainage network and contain water of variable quality, are of limited extent, and generally yield little water (Stevens and others, 2003; Yager and Arnold, 2003). The study area is within the South Platte River drainage basin; all streams in this area drain northward to the South Platte River (U.S. Geological Survey, 1974; Seaber and others, 1987; Yager and Arnold, 2003). Short segments of some of the streams are intermittent, but in general, the streams are ephemeral and flow only after storms. No surface water flows off the MWRD properties except after storms. Most ponds in the area have been created by detention structures. Soils in the area generally are sandy or loamy on flood plains and stream terraces, clayey to loamy on gently sloping to rolling uplands, and sandy and shaley on steeper uplands (Larsen and others, 1966; Larsen and Brown, 1971).

Land use in the study area was historically rangeland or cropland and pasture (U.S. Geological Survey, 1980). Some petroleum exploration was done in the area (Drew and others, 1979), but no oil or gas production took place within the study area during 2001. Land use in the study area during 2001 was rangeland or cropland. Cattle and sheep are the primary domesticated animals grazing the area, and wheat is the primary crop. Farmland is not irrigated. Land use on the MWRD properties during 2001 was primarily cropland (with biosolids applied as a fertilizer) and some rangeland.

Public concern about applications of biosolids to farmland increased after the MWRD agreed to accept treated ground water from the Lowry Landfill Superfund site in Denver. The concern was that water from the Lowry Superfund site might contain radionuclides that would then contaminate the MWRD biosolids. In January 1999, the USGS began a new monitoring program in cooperation with the MWRD and the North Kiowa Bijou Groundwater Management District. The USGS refers to the new



## 2 Data for a Biosolids-Application Area Near Deer Trail, Colorado, 2001

monitoring program (1999–2004) as the “expanded monitoring program.”

The expanded monitoring program near Deer Trail is distinct from, but builds on, the previous monitoring program in which the USGS monitored the quality of shallow ground water on the MWRD central property (1993–99). Relative to the previous program, the expanded program includes a larger study area (fig. 1) (all three MWRD properties and private-property locations), more monitoring components (biosolids, soils, crops, and streambed sediment in addition to ground water), a more comprehensive list of chemical constituents, expanded statistical analyses of data, and an extended monitoring period (1999–2003). Both programs use USGS and MWRD funds. Both programs are designed, accomplished, and interpreted independently by the USGS, and quality-assured USGS data and reports are released to the public and the MWRD at the same time.

Biosolids are applied by the MWRD to their properties near Deer Trail according to agronomic loading rates. Land-applied biosolids must meet Colorado regulations for metals and radioactivity; otherwise, agronomic loading rates could be exceeded and soils could become overloaded. Soil quality either can be improved by biosolids applications through increased nutrients and organic matter or degraded through accumulation of excessive nutrients or metals. Pesticides, herbicides, and other fertilizers also may have been applied to the MWRD properties, but little information is available about these applications.

Animal waste related to grazing domestic livestock and applications of pesticides, herbicides, and fertilizers (including biosolids) can affect soil quality, crops, water quality in alluvial and bedrock aquifers, and streambed-sediment chemistry. Water quality can be affected directly by contaminated recharge water or by infiltration of water through contaminated soils or sediment (remobilization). Water quality can be affected indirectly by tilling that mobilizes or mixes subsurface chemical constituents or by contributions to natural processes such as nitrification. Contaminated ground water or surface water could contaminate other aquifers (such as bedrock water-supply aquifers or alluvial aquifers), other surface-water bodies (ponds or streams), or streambed sediment.

The expanded monitoring program near Deer Trail addresses these concerns about biosolids applications and other farming-related effects on the environment and should increase scientific insight about Denver Basin hydrology. The objectives of this USGS program are to (1) evaluate the combined effects of biosolids applications, land use, and natural processes on soils, crops, the bedrock aquifer, alluvial aquifers, and streambed sediment by comparing chemical data to (a) regulatory standards, (b) data from a site where biosolids are not applied (a control site), or (c) earlier data from the same site (trends), (2) monitor biosolids for trace elements and radioactivity and compare trace-element concentrations and radioactivity with regulatory standards and (3) characterize the hydrology of the study area. The monitoring of each component (such as soils or ground water) is a stand-alone study that includes radioactivity analyses because of public concerns about effects from the Lowry Landfill Superfund site. More detailed information about the monitoring of each component is included later in this report.

## Purpose and Scope

The purpose of this report is to present information from the expanded monitoring program near Deer Trail for 2001 (January through December). This report presents data for all monitoring components of the program except crops. The report includes information about biosolids, soils, crops (although no crop data were collected in 2001), ground water (alluvial and bedrock), and streambed sediment. The ground-water section includes meteorologic data, hydrologic data (depth to ground water), water-quality data (chemistry and field measurements), and results of statistical testing of selected data for exceedance of regulatory standards and trends. This report does not include the hydrogeologic structure maps that were done as part of the bedrock ground-water monitoring component of the program. The structure maps were used to select bedrock-aquifer monitoring locations for the expanded monitoring program. The structure maps, along with a more detailed discussion of the hydrogeology of the region, are included in Yager and Arnold, 2003.

This report is organized by monitoring component because each component (such as soils or ground water) is monitored as a separate study. For each monitoring component, the specific objectives, scope, approach, analytical results, quality-assurance information, and a discussion are included. Data in this report were collected by the USGS after the water transfer from the Lowry Landfill Superfund site to the MWRD plant. The water transfer from the Lowry Landfill Superfund site to the MWRD began in July 2000.

## Acknowledgments

The USGS thanks all private landowners for allowing access to their properties for data collection. The USGS especially thanks the Price and Weisensee families and the MWRD for allowing USGS instrument or well installations on their property and the Kalcevic family for timely sediment information after storms and for allowing streambed-sediment sampling on their property.

## Biosolids

Biosolids are solid organic matter recovered from a sewage-treatment process that meet State and Federal regulatory criteria for beneficial use, such as for fertilizer. Land-applied biosolids must meet or exceed Grade II, Class B criteria (Colorado Department of Public Health and Environment, 1998). Grade I exceeds Grade II. The MWRD applies Grade I, Class B biosolids to their properties near Deer Trail. The biosolids-application areas, dates of application, and application rates provided by the MWRD for their properties near Deer Trail are listed in table 1 (located in the Data Section at the back of the report); application areas (called “Destination Codes”) are shown in figure 2 (in the Data Section at the back of the report).

## Objectives of Monitoring Biosolids

The biosolids must meet regulatory standards for trace elements and radioactivity. Exceeding these standards could adversely affect the quality of soil on which the biosolids are applied and could alter MWRD plans for the application of biosolids in Arapahoe and Elbert Counties. The composition of the biosolids was monitored to provide an independently determined data set against which the MWRD chemical analyses and the regulatory standards for biosolids can be compared. The data also will constitute a chemical baseline against which any future change in the concentration of constituents analyzed for in this study may be recognized, measured, and compared.

## Approach for Monitoring Biosolids

In 2001, the USGS continued the protocol established in 1999 for monitoring MWRD biosolids for concentrations of arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, plutonium, and gross alpha and beta activity. Radioactivity analyses were included in response to public concerns that biosolids radioactivity could increase from the transfer of water from the Lowry Landfill Superfund site.

Biosolids samples were collected directly from the MWRD facility in Denver rather than from individual trucks or fields near Deer Trail to enable the USGS to obtain a more representative sample. Normal annual sampling protocol calls for one biosolids sample to be collected each quarter. The January 2001 sample was the last in a series of monthly sampling begun in August 2000. This monthly sampling was initiated shortly after MWRD began receiving treated water from the Lowry Landfill Superfund site. Additional samples were collected in April, July, and October 2001. The samples were prepared and analyzed at the chemical laboratories of the USGS Mineral Resources Program in Denver. The concentrations in the samples were compared to applicable Colorado standards for biosolids (Colorado Department of Public Health and Environment, 1998).

## Sampling Methods for Biosolids

Each biosolids sample is a 24-hour composite of 12 subsamples collected about every 2 hours by MWRD personnel at the MWRD facility. The subsamples were collected from the conveyor belt that transfers the biosolids into the transport trucks. Each sample was delivered to the USGS in two acid-washed, rinsed, 1-gallon plastic bottles.

## Analytical Methods for Biosolids

The biosolids material was air dried and then ground to less than 150  $\mu\text{m}$  prior to chemical analysis. The biosolids samples were processed and analyzed for trace elements at the laboratories of the USGS Mineral Resources Program in Denver and analyzed for radioactivity at a commercial laboratory, Acculabs, in Denver. The methods used to analyze the biosolids for each

constituent are listed in table 2 (located in the Data Section at the back of the report).

## Quality Assurance for Biosolids

The purpose of the quality-assurance program developed for the biosolids monitoring component was to ensure the analytical results were within acceptable limits of both precision (the reproducibility of results) and accuracy (the degree of conformity of results for a sample having known concentrations). The precision was determined by analyzing the same biosolids sample multiple times, and accuracy was determined by analyzing National Institute of Standards and Technology (NIST) standard reference material SRM 2781, a domestic sludge. This SRM was prepared by NIST from material collected at the MWRD treatment plant in Denver. SRM 2781 has been analyzed extensively by many laboratories throughout the world, and the NIST has certified an acceptable range of values for various constituents in the SRM. The constituents include those of interest in this study. Each biosolids sample was submitted to the laboratories with a sample of the SRM. If the analytical results for the constituent of interest in the SRM were within the acceptable range, the results for the biosolids samples were accepted. Plans are to publish complete quality-assurance data for biosolids samples in a separate report.

In 2002, the USGS became concerned about the gross alpha data for the biosolids samples. The samples were analyzed by Acculabs, a commercial laboratory in Denver, Colo. For the March 1999 through June 2000 samples, the gross alpha data from Acculabs for the NIST standard reference material 2781 (domestic sludge) ranged from 27-37 pCi/g. For the August 2000 through August 2001 samples, the gross alpha data ranged from 37-60 pCi/g. This shift to higher values for the same standard-reference material indicates possible increasing analytical bias that could be present in the gross alpha data for the biosolids samples collected from the MWRD. Additional information about these analyses is not available because Acculabs went out of business in early 2002. Therefore, the USGS submitted split samples from a subset of the biosolids samples and NIST standard reference material to a different laboratory, Severn Trent Laboratory (STL) in Washington, in an attempt to reconcile this issue. A split of the April and October 2001 biosolids samples and three splits of the NIST standard reference material 2781 were analyzed for radioactivity in 2002 by STL, under a contract with the USGS National Water Quality Laboratory (NWQL). No analytical bias in the Acculabs analyses for the 2001 biosolids samples was indicated by the STL analyses, so only the Acculabs data are included in this report.

## Biosolids Data

Summaries of all the chemical analyses for trace-element concentrations and radioactivity data (gross alpha activity, gross beta activity, and plutonium concentration) for the biosolids samples collected in 2001 are listed in table 3 (in the Data Section at the back of the report). The table also lists Colorado standards (maximum allowable concentrations) for Grade I biosolids.

## Discussion of Biosolids Data

All trace-element concentrations were less than the maximum allowable concentrations established for Grade I biosolids. Gross alpha activity was less than the maximum allowable for Grade I biosolids in the January and April samples but above the Colorado standard (maximum allowable value) in the July and October samples. The reanalysis data from STL for the April and October samples compare with the Acculabs data from 2001. No significant analytical bias or variability likely is present in the 2001 biosolids data from Acculabs.

The radioactivity data are reported in the uncensored form as received from the laboratory rather than censored by either the contract or calculated minimum detectable concentration (MDC). Relative to the censored form (data reported as less than the MDC), the uncensored form provides more information about the uncertainty, the very small concentrations of plutonium, and the gross alpha and gross beta activity. The negative activity concentration reported for the radiochemical samples means the sample count was less than the laboratory background count for that day. Radioactivity data are produced from instruments that detect radioactive decay (disintegrations) in a sample as counts per minute. The background count was subtracted from the sample count, and the resulting value was converted to activity-concentration units of picocuries per gram.

## Soils

Biosolids can contain elevated concentrations of certain trace constituents. Therefore, the application of biosolids to farmland has caused public concern regarding the potential short-term and long-term effects on soil quality.

## Objectives of Monitoring Soils

Soils were monitored for trace elements and plutonium and gross alpha and gross beta activity to establish independent geochemical data sets for the composition of soil before and after the application of biosolids. The data will enable the USGS to recognize and quantify significant changes in soil composition caused by the application of biosolids to agricultural soils or by other natural or human-induced processes.

## Approach for Monitoring Soils

In August 1999, the USGS began monitoring soils at two sites, one site on MWRD property in Arapahoe County and one site on MWRD property in Elbert County (fig. 1). The sites were monitored for arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, plutonium, and gross alpha and gross beta activity. Radioactivity analyses were included in response to public concerns that biosolids radioactivity could increase because of the transfer of water from the Lowry Landfill Superfund site to the MWRD. Soil samples were collected once before

the application of biosolids to monitoring sites, and the data were reported in progress reports and in the annual data report for 1999 (Stevens and others, 2003). Soil monitoring will continue through two cycles of biosolids application and crop harvest. In 2000, the Elbert County monitoring site was sampled during November 29 to December 1 after the wheat harvest. The Arapahoe County site was not sampled until June 11, 2001.

Fields that receive biosolids applications were monitored along with fields that receive no biosolids, which represented reference conditions for comparison. Each of the two soil-monitoring sites consisted of three 20-acre (933 ft by 933 ft) fields separated by 100-ft buffer zones (figs. 3 and 4 in the Data Section in the back of the report). Biosolids were applied on the center 20-acre field at each site after the initial soil sampling. The other two 20-acre fields at each site will not have biosolids applied and will be used as "control" fields to determine the natural variability of soil composition for the duration of the study. All three 20-acre fields at each site are farmed in a similar way as the rest of the MWRD property and have crops planted and harvested. Soils from each of the six fields were sampled in 1999 before biosolids were applied to the two center fields and will be sampled again after each harvest. Data will be compared after each sampling and at the conclusion of the study to determine how the elements of interest vary with time.

## Site Selection for Monitoring Soils

Sites were selected on MWRD properties where biosolids have never been applied. One site was selected on the MWRD's north property in Arapahoe County, and one site was selected on the MWRD's south property in Elbert County. The Arapahoe County site is located in T. 4 S., R. 58 W., sec. 22 and lies about 0.25 mi west of Badger Creek (fig. 3). The Elbert County site is located in T. 6 S., R. 57 W., sec. 8 and lies immediately west of Beaver Creek (fig. 4).

## Sampling Methods for Soils

The sampling protocol was designed to answer the following question: What is the average composition of the top 12 inches of soil in each of the six 20-acre fields? To address this question, soil samples were collected with a standard soil auger to a depth of 12 inches according to a systematic grid pattern. For each of the two fields to which biosolids will be applied, 36 subsamples are collected on approximately 133-ft centers. A similar grid is used to collect 36 subsamples from the southern "control" field on the Arapahoe County site. For the remaining three "control" fields, 30 subsamples are collected on approximately 150-ft centers.

## Analytical Methods for Soils

All soil subsamples are air dried at ambient temperature in the laboratories of the USGS Mineral Resources Program in Denver. Each of the dried subsamples is disaggregated and sieved to less than 2 mm. This minus-2-mm material then is ground to less

than 150  $\mu\text{m}$ . Splits of each subsample are taken for archival storage, and the subsamples for each field are composited into one sample for chemical analysis. The composite soil samples, each representing one 20-acre field, were analyzed for trace elements at the laboratories of the USGS Mineral Resources Program in Denver and analyzed for radioactivity at a commercial laboratory, Acculabs, in Denver. Analytical methods for the soil samples are listed in table 2 (in the Data Section in the back of the report).

## Quality Assurance for Soils

The accuracy of the soil analysis was evaluated by the analysis of NIST SRM 2709, an agricultural soil. Separate splits of this SRM were randomly placed among the soil samples and submitted to the laboratories. If the analytical results for the constituent of interest in the SRM are within an acceptable range, analytical results for the soil samples are accepted. Separate splits of each composited soil sample are analyzed independently and the results averaged to determine the concentration reported for a given constituent. Plans are to publish quality-assurance data for soil samples in a separate report.

## Soil Data

In 2000, the Elbert County monitoring site was sampled during three days (November 29-December 1, 2000) after the wheat had been harvested in July. In 2001, the Elbert County site was not sampled. The Arapahoe County site was sampled June 11, 2001. These samples from both sites were submitted to the laboratories for analysis in September 2001. Data for both these sites are listed in table 4 (in the Data Section at the back of the report).

## Discussion of Soil Data

The Elbert County samples for both control and biosolids-applied fields had higher trace-element concentrations than the Arapahoe County samples. This relation also was noted in the 1999 data report (Stevens and others, 2003) for the samples taken before biosolids were applied. These higher concentrations probably are related to the higher clay content, which is caused by a higher component of shale as parent material, in the Elbert County soils. Shales usually contain more trace elements than sandstones (Drever, 1988), which make up the other parent material for soils in Arapahoe and Elbert Counties (Sharps, 1980; Yager and Arnold, 2003).

The radioactivity data are reported in the uncensored form as received from the laboratory rather than censored by either the contract or calculated MDC. Relative to the censored form (data reported as less than the MDC), the uncensored form provides more information about the uncertainty, the very small concentrations of plutonium, and the gross alpha and gross beta activity. The negative activity concentration reported for the radiochemical samples means the sample count was less than the laboratory background count for that day. Radioactivity data are produced from instruments that detect radioactive decay (disintegrations) in a sample as counts per minute. The background count was

subtracted from the sample count, and the resulting value was converted to activity-concentration units of picocuries per gram.

## Crops

As previously mentioned, biosolids can contain elevated concentrations of certain trace elements. The application of biosolids to farmland on which grains are grown that will eventually be consumed by animals or humans has led to public concern about the composition of the crops grown on the fields receiving biosolids.

## Objectives of Monitoring Crops

Crops are monitored for trace elements (and selected samples are monitored for plutonium and gross alpha and gross beta activity) to establish independent chemical data sets for the composition of the crops before and after the application of biosolids. The data will enable the USGS to recognize and quantify significant changes in crop composition caused by the application of biosolids to agricultural soils or by other natural or human-induced processes.

## Crop Data

No crop data are included in this report. During 2001, no crops were grown on either the Arapahoe or Elbert County soil-monitoring sites. Wheat is scheduled to be planted and harvested at both sites in 2002, and data will be reported in the 2002-2003 data report.

## Ground Water

Applications of pesticides, herbicides, or fertilizers (including biosolids) to the land surface can affect the quality of shallow ground water directly by contaminated recharge or by infiltration through contaminated soils or sediment (remobilization). These applications also can affect the quality of shallow ground water indirectly by tilling (which could mobilize subsurface constituents) or by contributions to natural processes such as nitrification. Further, discharge from contaminated alluvial ground water could contaminate surface water (ponds or streams) or bedrock water-supply aquifers. For this report, alluvial ground water is defined as the water contained in subsurface, unconsolidated (uncemented), wind- or water-transported sediment in current or historical stream channels or flood plains. Bedrock ground water is defined as the water contained in the fractures or pore spaces of the rock (consolidated sediments) that underlies soil or other uncemented materials; the primary bedrock aquifer in the study area is the Laramie-Fox Hills aquifer (Robson and Banta, 1995; Yager and Arnold, 2003). Alluvial and bedrock ground water are separate components in the monitoring program but are combined

in this report because the data were collected in the same way and the types of data included are the same.

## **Objectives of Monitoring Ground Water**

Ground water was monitored to characterize the hydrology and water quality of the aquifers; to determine if concentrations of nitrate, arsenic, cadmium, copper, chromium, lead, mercury, molybdenum, nickel, selenium, zinc, and plutonium and gross alpha and gross beta activity in the ground water are significantly greater than regulatory standards; and to determine if concentrations of these constituents are increasing with time in ground water at or near the MWRD properties.

## **Approach for Monitoring Ground Water**

Structure maps of the top and base of the Laramie-Fox Hills aquifer were compiled for the study area by using available information such as geophysical logs from oil and gas exploration and other data. The structure maps are included in an interpretive USGS report by Yager and Arnold (2003). The structure maps were used to determine locations for well pairs: two bedrock-aquifer wells and two alluvial-aquifer wells that constitute the recharge-evaluation sites. Multiple wells in the same location enable different zones of ground water to be monitored without having to consider spatial variability and can enable inferences about vertical directions of ground-water flow between zones. Each of the two bedrock-aquifer wells are nested, which means each borehole has two separate piezometers screened at two separate zones. Therefore, three different aquifer zones are monitored at each of the two recharge-evaluation sites in Muddy Creek downgradient from the MWRD properties (fig. 1). Lithologic and well-completion information for these wells is included in the 1999 data report (Stevens and others, 2003). A fourth aquifer zone (well DTX11) is monitored at the DTX9 recharge site to provide information about a deeper coarse-grained part of the Muddy Creek alluvial aquifer than is monitored by well DTX9. Lithologic and well-completion information for this well is included in the 2000 data report (Yager and others, 2004). In 2000, electronic data-logger (EDL) equipment was installed to continuously monitor precipitation and water levels in wells DTX9, DTX10, and DTX11, and to provide more detailed information about ground-water recharge at that location. The 2001 EDL data are included in this report, but are not available on the Internet.

Monitoring wells for the expanded monitoring program include selected wells installed as part of the previous monitoring program and new wells. Of the 33 USGS ground-water monitoring wells from the previous study on the MWRD central property, 7 are included in this study (all 7 wells were monitored for water levels, and water-quality samples were collected from 6 of these wells). "D"-numbered wells were drilled before 1999 as part of the previous monitoring program, and "DTX"-numbered wells were drilled in 1999 or 2000 (fig. 1). Lithologic and well-completion information for these well locations are provided by Stevens and others (2003) and Yager and others (2004).

Water levels in the monitoring wells were measured monthly. Data-collection platforms (DCP's) with various sensors were installed during summer and fall of 1999 at three alluvial-aquifer wells (D25, DTX2, and DTX5) to continuously monitor ground-water levels, water temperature, precipitation, and air temperature. The data were transmitted to Denver by satellite and were available on the Internet. The data provided information about the hydrology in the study area and the response of ground water to climate variables.

Water samples were collected from alluvial-aquifer wells on the MWRD properties (fig. 1), and water samples were collected from the shallowest zones of the bedrock aquifer at three locations that are important to alluvial/bedrock ground-water interactions. The remaining USGS monitoring wells were used to provide hydrologic information only. Water samples were collected and analyzed quarterly for physical properties, dissolved major ions and trace elements, and dissolved and total nutrients. Analyses were done by the USGS National Water-Quality Laboratory (NWQL) and included nitrate, arsenic, cadmium, copper, chromium, lead, mercury, molybdenum, nickel, selenium, and zinc. Samples also were collected and analyzed annually for total plutonium, although the annual sample for 2001 was actually taken during the last quarter of 2000 because of financial issues. Gross alpha and gross beta activity analyses were included in the 1999 monitoring but were discontinued thereafter because of matrix-interference problems caused by the high concentrations of dissolved solids in the ground-water samples. The plutonium and gross alpha and gross beta activity analyses were included in the monitoring program in response to public concerns that radioactivity in biosolids could increase from the transfer of water from the Lowry Landfill Superfund site to the MWRD. Water levels and field measurements such as pH and specific conductance were recorded with the collection of each ground-water sample. Blank and replicate samples were analyzed to evaluate bias and variability of the ground-water data.

All data are maintained in the USGS National Water Information System (NWIS) data base. Selected data were published in the "USGS Expanded Monitoring Program Near Deer Trail" quarterly and progress reports. All ground-water data collected for this program during 1999 were published in Stevens and others (2003). All ground-water data collected for this program during 2000 were published in Yager and others (2004). Selected water-quality data will be statistically analyzed each year of the program and after about 5 years to determine (1) if concentrations in the ground water are significantly greater than regulatory standards and (2) if the concentrations are increasing significantly with time. For these statistical analyses, water-quality values reported by the laboratory as less than the minimum reporting level (MRL) are set equal to one-half the MRL value.

## **Site Selection for Monitoring Ground Water**

Shallow aquifers can be recharged by runoff and streamflow or can contribute water to streamflow and ponds. Therefore, the sites for alluvial-aquifer wells were selected by the USGS according to the following criteria: (1) locations in proximity to a stream channel that could carry runoff from MWRD biosolids-applied

fields, (2) locations at the most downstream point of the drainage basin, (3) locations at MWRD property boundaries to represent the condition of ground water leaving the properties and to consider only those effects from activities on MWRD properties and not from other landowners, (4) locations where most of the upstream basin is on MWRD property, (5) locations that represent the larger drainage basins, (6) locations where USGS monitoring wells already existed and where data already had been collected, and (7) locations accessible year round for drilling and sampling wells. Alluvial-aquifer wells were not installed upgradient from MWRD property boundaries because the constituents of concern generally are not conservative along the ground-water flow path; that is, subtracting upgradient concentrations from downgradient concentrations may not represent the effects of biosolids on the ground water for these constituents. Monitoring alluvial ground water near Rattlesnake Creek was a low priority because most of the basin is upstream from the MWRD properties, and that part of the basin that receives biosolids is relatively small. Therefore, the USGS installed two alluvial-aquifer wells on the MWRD north property and four on the MWRD south property (fig. 1); all wells on the MWRD central property used for this study (fig. 1) were installed before 1999 as part of the previous monitoring program.

Bedrock aquifers can be recharged by alluvial ground water or can be a source of water to alluvial aquifers. Therefore, the sites for bedrock-aquifer wells were selected by the USGS according to the following criteria: (1) locations where a particular sandstone sequence within the Laramie-Fox Hills aquifer is present at substantial areal extent and thickness, (2) locations on MWRD property where the bedrock aquifer is present without an alluvial aquifer, (3) locations where the bedrock aquifer is present beneath an alluvial aquifer that could be affected by the application of biosolids, (4) locations where USGS monitoring wells already existed and where data already had been collected, and (5) locations accessible year round for drilling and sampling wells. Locations where the particular sandstone sequence within the bedrock aquifer is present in this area were determined by the USGS on the basis of the USGS structure maps (completed in 1999) of the top and base of the Laramie-Fox Hills aquifer in this area (Yager and Arnold, 2003). For the expanded monitoring program, the USGS installed two new bedrock-aquifer wells (DTX8 and DTX10) in 1999, along with corresponding alluvial-aquifer wells (DTX7 and DTX9) (fig. 1), at locations where the bedrock aquifer is present beneath the Muddy Creek alluvial aquifer; the Muddy Creek alluvial aquifer could be affected by the application of biosolids. One previously installed USGS ground-water monitoring well, D29 (fig. 1), was included in this monitoring program because the well is on MWRD property where the bedrock aquifer is present without an alluvial aquifer, and prior sampling data are available.

DCP sites provided information about the variability in space and time of climate and hydrology in the study area as well as about the hydrologic responses to climate. This monitoring program includes three DCP sites, one on each of the MWRD north, south, and central properties (wells DTX2, DTX5, and D25, respectively). The locations of these DCP sites were selected according to the following criteria: (1) locations where alluvial-aquifer wells are sampled, (2) locations near possible

streambed-sediment sampling areas (to indicate likely runoff conditions), (3) locations near other wells so the information may apply to more than one well, (4) locations far enough apart from each other to indicate spatial variability in hydrology, (5) locations needing additional hydrologic information to explain chemical variability (well D25), and (6) locations accessible year round.

## Sampling Methods for Ground Water

All data-collections methods used in 2001 were the same as the 1999 methods, which are detailed in the 1999 data report (Stevens and others, 2003). Monthly water-level measurements were made using a vinyl-coated electric tape. DCP and EDL data were automatically recorded hourly. Water-quality samples were collected quarterly using standard USGS methods (Horowitz and others, 1994; Wilde and others, 1998-1999). All sampling equipment was used exclusively by the USGS and was used only in the study area to prevent cross contamination from other sites in other study areas. All samples and sampling equipment were kept at all times in the custody of the USGS in locked, guarded facilities.

## Analytical Methods for Ground Water

Ground-water samples were submitted to the USGS NWQL in Denver. Plutonium analyses were done by Severn Trent Laboratory in Richland, Wash., under a contract with the USGS NWQL. All other analyses were done by the NWQL. The methods used to analyze the 2001 ground-water samples are listed in table 5 (in the Data Section in the back of the report) along with laboratory MRL's for the elements of interest.

## Quality Assurance for Ground Water

Quality-assurance procedures were implemented during the course of the monitoring program to ensure the quality of the data. Procedures were implemented for water-level measurements, DCP-data and core-data collection, ground-water-sampling preparation, field-parameter measurements, ground-water sampling, and laboratory analysis. Quality-assurance procedures are detailed in the 1999 data report (Stevens and others, 2003). The analytical quality-assurance practices and procedures of the NWQL are described in Friedman and Erdmann (1982).

## Ground-Water Data

Monitoring at ground-water sites during 2001 produced meteorologic, hydrologic, and water-quality data. Meteorologic data include precipitation at four sites and air temperature at three sites. Hydrologic data include monthly water levels at all wells, hourly water levels and water temperature at three DCP sites, and hourly water levels at three EDL wells. Water-quality data include analytical results from quarterly sampling. Information

## 8 Data for a Biosolids-Application Area Near Deer Trail, Colorado, 2001

about the ground-water monitoring sites is listed in table 6 (in the Data Section in the back of the report).

### Meteorologic Data

Precipitation and air temperature were recorded hourly during 2001 at wells D25, DTX2, and DTX5 (figs. 5 through 7 in the Data Section in the back of the report). Precipitation was recorded hourly during 2001 at the EDL site, the well cluster including well DTX11 (fig. 8 in the Data Section in the back of the report). Rain occurred during thunderstorms and frontal storms, usually during April–October. The precipitation data recorded during January through March and October through December could represent melted snow. The data indicate air temperatures can fluctuate more than 20°C during the day but were similar for all monitored sites.

### Hydrologic Data

Monthly water-level data and continuous water-level and water-temperature data can be useful for describing the hydrology of the aquifers in the area near Deer Trail. The monthly water-level data for the USGS monitoring wells used in this study are listed in table 7 (in the Data Section in the back of the report), and the continuous water-level and water-temperature data for the three DCP sites (D25, DTX2, and DTX5; fig. 1) are shown in figures 5–7 (in the Data Section in the back of the report). Continuous water-level data for the EDL site (wells DTX9, DTX10, and DTX11; fig. 1) and precipitation data are shown in figure 8 (in the Data Section in the back of the report). Monthly water-level data are listed as depth to water below measuring point at a specific time. Continuous water-level data are shown as daily maximum depth to water below land surface. Water-level data can indicate seasonal effects and can aid in the interpretation of chemical data.

Water-level data also can indicate ground-water recharge information. Robson and others (1981) showed that recharge of the Laramie-Fox Hills aquifer along the margin of the Denver Basin (such as in the Deer Trail area) can be from deeper parts of the Denver Basin, from alluvial aquifers and surficial features, or from infiltration of precipitation on or near outcrop areas. Recharge of the alluvial aquifers in the Deer Trail area can be from the Laramie-Fox Hills aquifer, from surface-water features, or from infiltration of precipitation (Robson and others, 1981). Hydrologic interactions between alluvial and bedrock aquifers can be inferred using water-level data for the same point in time for wells drilled into the aquifers at the same site. The direction of the vertical movement of ground water, or the recharge direction, may be indicated by noting that water moves from areas of high hydraulic head (high water-level elevation) to areas of low hydraulic head (low water-level elevation). For the expanded monitoring program, such interactions were monitored at two recharge-evaluation sites, each of which included one alluvial-aquifer well and one bedrock-aquifer well. The interactions in the bedrock aquifer were monitored in two different zones (designated by “A” [shallow] or “B” [deep] after the well name).

Therefore, three aquifer zones (one alluvial, one shallow bedrock, and one deep bedrock) were monitored at the north recharge-evaluation site (wells DTX7 and DTX8), and four aquifer zones (two alluvial, one shallow bedrock, and one deep bedrock) were monitored at the south recharge-evaluation site (wells DTX9, DTX10, and DTX11). Water levels for the paired alluvial-aquifer and bedrock-aquifer wells at the two recharge-evaluation sites are shown in figure 9 (in the Data Section in the back of the report) for the north recharge-evaluation site at discrete time periods, and in figure 10 (in the Data Section in the back of the report) for the south recharge-evaluation site continuously for the year. The July water levels shown in figure 9 represent hot, dry summer conditions; the August and September water levels shown in figure 9 represent summer-recharge (rainy) conditions.

### Water-Quality Data

Water-quality data for samples collected quarterly from 11 alluvial-aquifer and 3 bedrock-aquifer wells (fig. 1) in 2001 are listed in table 8 (in the Data Section in the back of the report). Data are given for field parameters, physical properties, major ions, nutrients, and trace elements. No radioactivity data are included for 2001 because the radioactivity samples were collected in October 2000 (included in Yager and others, 2004) and January 2002 (will be included in the 2002-2003 data report). Quality-control water-quality data for the blank samples are listed in table 9 (in the Data Section in the back of the report), and comparison data for replicate samples are listed in table 10 (in the Data Section in the back of the report).

### Discussion of Ground-Water Data

Concentrations for the blank samples (table 9) generally indicate little or no contamination bias. The blank samples collected January 10, 2001, were from the submersible pump, and these data indicate a slight high bias in some trace-element concentrations; this pump is used only at wells DTX8A, DTX10A, and D29, so only samples from these wells may be affected. Concentrations for the blank samples were much less than those for the ground-water samples. Data for rerun samples (not included in this report) indicate occasional slight contamination bias in laboratory analyses of aluminum, arsenic, copper, nickel, and zinc. Therefore, the sample data that indicate small concentrations of aluminum, arsenic, copper, nickel, and zinc could be affected by a slight high bias.

The relative percent differences (RPD) between the ground-water samples and the replicate samples were computed to summarize sample variability (table 10). Many of the larger RPD's are due to values or concentrations near the MRL where precision is expected to be poor. In these cases, concentrations may vary little but result in large RPD's. For example, a ground-water sample concentration of 0.01 mg/L and a replicate-sample concentration of 0.02 mg/L would result in an RPD of 67 percent, but the difference might be considered to be within the precision of the method at that concentration. Data values for individual replicate pairs also are listed in table 10 to help the reader

determine if large RPD's are the result of substantial differences between replicate-sample concentrations or just small differences between small concentrations. The replicate-sample data indicate generally reproducible analytical results.

In general, the expanded monitoring program is too new for sufficient data to have been collected for meaningful interpretation of the ground-water data. However, the data included in this report indicate alluvial- and bedrock-aquifer hydrology and chemistry are variable in space (from site to site) and in time (from one data-collection time to the next at the same site) in the study area.

The USGS was asked to evaluate the water-quality data for biosolids effects each year of the monitoring program. Therefore, the results for selected constituents were tested to determine if statistical evidence indicated exceedance of regulatory standards and a trend in concentration with time.

## Regulatory Standards

Regulatory standards that might be used as guidelines to evaluate the ground-water quality in the study area are the human health standards and agricultural standards enforced by the State of Colorado (Colorado Department of Public Health and Environment, 1993). For this report, a one-tailed Sign Test (Helsel and Hirsch, 1992) was used to indicate the level of statistical evidence that selected median constituent concentrations were significantly greater than regulatory standards. The hypotheses tested were as follows:

$H_o$  = median concentration less than or equal to the regulatory standard and

$H_a$  = median concentration greater than the regulatory standard.

A small p-value result from the Sign Test indicates  $H_o$ , the null hypothesis, should be rejected. The confidence level in rejecting  $H_o$  and, therefore, accepting  $H_a$  can be determined by subtracting the p-value from 1 and multiplying by 100. The confidence level also can be thought of as the probability (in percent) that the regulatory standard has been exceeded by the median concentration (table 11 at the back of the report). For example, if the Sign Test for a constituent results in a p-value of 0.100, there is a 90-percent confidence level or probability that the median concentration for that constituent is greater than the regulatory standard. The results of the statistical testing of the data for the 11 alluvial-aquifer wells and 3 bedrock-aquifer wells for exceedance of regulatory standards for 11 constituents identified as important by the public are listed in table 11 (in the Data Section in the back of the report). Nitrate concentrations at well D6 were the only data that had a statistically significant probability that the median concentration exceeded the regulatory standard.

Because quarterly samples have been collected for only 3 years to date, the power of the statistical test (level of statistical evidence) is low. As sampling continues, the power of the test will increase. Radioactivity data were not statistically tested because few radiochemical samples, an insufficient number of samples for statistical testing, were collected at each well since

1999. The distribution of concentrations at each well for selected constituents during 2001, and the regulatory standards used to test the ground-water data are shown in figure 11 (in the Data Section in the back of the report). Time-series graphs (concentration plotted with time) of selected constituents for selected wells are included as figure 12 (in the Data Section in the back of the report).

## Trends

Upward trends in concentration mean that concentration for a parameter increases over time, although not necessarily in a straight line. These upward trends could indicate biosolids, other farm practices, grazing, or even natural processes such as geochemical dissolution are affecting ground water. For this report, the Kendall's tau statistic (Helsel and Hirsch, 1992) was used as a nonparametric measure of correlation between concentration and time. Kendall's tau is a number between negative one and positive one where values approaching negative or positive one indicate increasing strength of the correlation and a number approaching zero indicates decreasing strength of correlation. Positive values of Kendall's tau indicate upward trends, and negative values indicate downward trends. The results of the statistical testing of the data for trends in 11 constituents identified as important by the public are listed in table 12 (in the Data Section in the back of the report). A p-value is listed to indicate the level of significance of the coefficient, the tau value. The p-value must be less than or equal to 0.05 for tau to be significant with at least 95-percent confidence. Values in table 12 indicating statistically significant trends are shown in bold. Radioactivity data were not statistically tested because only three radiochemical samples, which are an insufficient number of samples for statistical testing, have been collected at each well since the program began in 1999.

If all data for a constituent were less than the MRL, no trend could be identified (such as for mercury at most of the wells). If at least one concentration value for a constituent at a well was greater than the MRL, the data were analyzed for trend. Many of the reported concentrations included in the trend analysis were less than the MRL, and the MRL varied for most of the constituents. Therefore, the trends evaluated by the statistical analyses may be artificial; that is, the difference in MRL, not differences in concentration, may result in an apparent trend. All the apparently statistically significant trends for cadmium, lead, and nickel (table 12) were caused by changes in the MRL, so these values are not shown in bold in table 12.

The results of trend analysis on the 1999 through 2001 combined data set (table 12) indicate a number of statistically significant upward trends in the ground-water data. Ground-water samples from well D6 had the greatest number of significant upward trends; nitrate, copper, selenium, and zinc data for this site all had significant upward trends. The constituent tested that had the most upward trends was copper (table 12). The results of trend analysis on the 1999 through 2001 combined data set (table 12) commonly were different than the results of trend analysis on only the 1999 data set (Stevens and others, 2003) or the 1999 through 2000 combined data set (Yager and others, 2004). Some



of the trend directions changed from upward to downward trends or from downward to upward trends when the 1999 and 2000 data were retested with the 2001 data, and significance of the trend result increased. Some of these changes may be caused by the low power of the test when few data are used in the test (as in 1999), by changes in the MRL as mentioned previously, or because seasonal effects have not been considered (too few data). Because quarterly samples have been collected for only 3 years to date, the power of the trend test is still low, and too few data are available to consider seasonal effects. As sampling continues, the power of the test will increase and the amount of data available will enable seasonal effects to be removed. Time-series graphs (concentration plotted with time) of selected constituents for selected wells are included as figure 12.

## Streambed Sediment

Animal waste related to grazing livestock and applications of pesticides, herbicides, or fertilizers (including biosolids) to the land surface could affect surface-water quality directly by contaminated inflow or by runoff over contaminated soils or sediment (remobilization). These applications also can affect surface-water quality indirectly by tilling that mobilizes or changes surface constituents or surface characteristics; by inflow, base flow, or recharge to surface water from contaminated ground water; or by contributions to natural processes such as nitrification. Contaminated surface water could contaminate downstream, previously uncontaminated ponds, streams, streambed sediment, alluvial aquifers, or bedrock water-supply aquifers in aquifer-recharge zones.

Surface-water contamination from biosolids applications is a public concern. However, because streams flow off the MWRD properties only after intense thunderstorms, surface-water sampling is impractical, and monitoring extreme surface-water events is difficult. Monitoring streambed-sediment chemistry is more practical and cost effective and offers greater opportunity to establish comparison or baseline sites than monitoring surface-water chemistry. For the expanded monitoring program, streambed sediment is defined as the fine-grained alluvium freshly deposited in the drainage bottoms by surface-water flow after rainstorms.

Sediment affected by the applications of biosolids could be transported off MWRD property into streambeds when precipitation is intense enough to cause overland flow. Therefore, streambed-sediment chemistry is used as an indirect indicator of surface-water quality because of the close contact between surface flows and sediment during transport. Contaminants in the streambed sediment could cause contamination in ground water or surface water if the contaminants are resuspended in water or leached from the streambed sediment. Furthermore, concentrations of trace elements and plutonium and gross alpha and gross beta activity may be higher in the streambed sediment than in the surface water.

## Objectives of Monitoring Streambed Sediment

Streambed sediment was monitored to determine if concentrations of nitrate, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, organic carbon, gross alpha and beta radioactivity, and plutonium in sediment derived from (or transported through) biosolids-application areas are significantly higher than in streambed sediment derived from nearby farmland that did not receive biosolids applications.

## Approach for Monitoring Streambed Sediment

Two small drainage basins were selected for comparison of streambed-sediment chemistry (fig. 1). The basins have similar physical characteristics, but one basin (known as the biosolids-applied basin) receives biosolids applications and is part of the MWRD farming program, and the other basin (known as the control basin) receives no biosolids applications and is farmed privately.

A DCP site (with a rain gage) is near the biosolids-applied basin. The DCP data were transmitted remotely to enable the USGS to determine when rainfall of sufficient intensity and duration had occurred near the basins. For sampling to take place, sufficient rainfall was needed to cause the fine-grained materials and dissolved constituents to wash off the hillsides of the drainage basins into downgradient streambeds. Paired streambed-sediment samples were collected when freshly deposited streambed sediment was available from both the biosolids-applied basin and the control basin at the same time (after the same storm). The USGS determined that at least a 0.50 inch of rain in a single hour had to be received by the tipping-bucket rain gage at DTX2 before runoff in the biosolids-applied basin was enough for a streambed-sediment sample to be collected. This rainfall scenario occurred only three times in 2001, and the USGS was able to collect three paired samples during 2001. When sufficient storms occur, three to four paired samples per year are planned.

Streambed-sediment samples were analyzed for nitrate, phosphorus, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, zinc, carbon, gross alpha and beta radioactivity, and plutonium. The radioactivity analyses were included in response to public concerns that biosolids radioactivity concentrations could increase from the transfer of water from the Lowry Landfill Superfund site to the MWRD. When enough paired samples are collected, data will be statistically tested to determine if streambed-sediment chemistry is significantly different between the two basins.

## Site Selection for Monitoring Streambed Sediment

Several pairs of similar small basins (one on MWRD property and one on nearby private property) were considered by the USGS for monitoring. Only small (less than 5-mi<sup>2</sup>) basins were considered because (1) the large biosolids basins did not have a nearby corresponding control basin that had similar characteristics, (2) the thunderstorms likely to cause runoff were usually localized and were not likely to affect two large basins with

the same duration and intensity, (3) sampling is more efficient in small basins because each streambed-sediment sample is a composite of sediment collected throughout the basin, and (4) the large basins in the study area are more variable with respect to geology, soil type, and land use. Sediment collected from the large basins is more likely to be affected by this variability and, therefore, may not indicate effects from biosolids. The criteria used to pair basins included distance between basins; proximity to a USGS ground-water-monitoring well that included DCP instrumentation; land use (farmed); likely accessibility even after severe thunderstorms; and similar bedrock geology, soil type, aspect, stream order, channel length, channel slope, relief, and ponding. From the three basin pairs identified as candidates for streambed-sediment monitoring (Stevens and others, 2003), the pair on Badger Creek tributaries (on and near the MWRD's north property) was selected. The selected basins are shown as streambed-sediment sampling areas in figure 1.

## Sampling Methods for Streambed Sediment

Before sampling, equipment was washed with phosphate-free detergent, rinsed three times with deionized (DI) water and wrapped in clean, plastic bags for transport to the sampling site. Trace-element sampling equipment received an additional rinse with 5-percent trace-element-grade nitric-acid solution and three more rinses with DI water. Clean 63- $\mu\text{m}$  sieve cloth was used for each site. The trace-element equipment was allowed to air dry and was stored in plastic bags until use. Stainless-steel equipment (which was not used to prepare trace-element samples) was allowed to air dry and was wrapped in aluminum foil and stored in sealed plastic containers.

DCP data transmitted by satellite to the USGS were monitored daily throughout the year to determine the occurrence, intensity, and duration of rainfall in the study area. If sufficient rainfall in the area of the paired basins was indicated by the data, the sampling crew visited the sites to determine if the rainfall had produced sediment transport from the hillsides to the alluvial channel in both basins. If transport occurred in both basins, a streambed-sediment sample was collected from the newly transported sediment in the mainstream channel of the basin.

Freshly deposited streambed sediment from the basins (fig. 1) was sampled after rainfall runoff by using dedicated equipment for each basin in accordance with the procedures of Radtke (1997). Streambed sediment was collected from various locations in the alluvial channel in each of the selected basins by using Teflon spoons. The upper 2 cm of fine-grained, wet sediment that collects in depositional areas was removed, composited in a clean sealable plastic bag, and transported in a cooler containing ice to the USGS District laboratory in Denver for processing. Processing consisted of homogenizing, sieving, and bottling each sample. For the trace-element sample, the sediment was washed into an acid-rinsed polypropylene sample jar through a nylon, 63- $\mu\text{m}$  sieve using DI water. The sediment in the jar was allowed to settle, and then any clear water was removed from the top of the sample by using a plastic syringe. This procedure was repeated until sufficient sediment (about 35 g total) was sieved for the sample. The procedure was repeated using a 2-mm stain-

less-steel sieve to fill sample containers for analyses of inorganic and organic carbon (500 g in a 1-liter, baked glass jar), nutrients (20 g in a polypropylene jar), gross alpha (1 g in a polypropylene jar), and plutonium (150 g in a polypropylene jar). The samples were labeled and transported to the USGS NWQL for analyses. Laboratory analyses consisted of nutrients (total nitrogen and total phosphorus), carbon, trace elements (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc), and plutonium and gross alpha and gross beta activity.

## Analytical Methods for Streambed Sediment

Nitrogen analyses were done by Severn Trent Laboratory in Arvada, Colo., under a contract with the USGS. Gross alpha, gross beta, and plutonium analyses were done by Severn Trent Laboratory in Richland, Wash., under a contract with the USGS NWQL. All other analyses were done by the USGS NWQL. The analytical methods used to analyze the streambed-sediment samples and the laboratory MRL's or MDC's are listed in table 13 (in the Data Section in the back of the report).

## Quality Assurance for Streambed Sediment

Quality-assurance procedures were implemented during the course of the monitoring program to ensure the quality of the data. Laboratory and field cleaning procedures were rigorous and designed to prevent contamination of samples. Prior to sample collection, all sampling equipment and materials were cleaned according to standard procedures given in Horowitz and others (1994), Radtke (1997), and Wilde and others (1998-99).

If results for a particular constituent were questionable, the sample was reanalyzed by the laboratory. If results from the second analysis were more consistent with known characteristics of the site or the particular sample, the new results were used instead of the previous results; otherwise, the initial result was retained. The analytical quality-assurance practices and procedures of the NWQL are described in Friedman and Erdmann (1982).

Sufficient streambed sediment was available for replicate samples, so a replicate July 27 sample of the biosolids-applied site and a replicate August 17 sample of the control site also were analyzed. These data provide information about variability in the sediment itself or contributed by field conditions, sampling equipment, or the laboratory. Other quality-control data for 2001 not included in this report are lab replicates, lab method blanks, and lab spikes analyzed only for plutonium and gross alpha and gross beta activity. The lab replicate was used to assess analytical precision. Lab blanks were used to assess contamination bias. The lab spike was prepared by the laboratory using known concentrations of a constituent to assess recovery and analytical precision. The quality-control samples provided information about the bias and variability contributed by the laboratory but not the bias and variability contributed by field conditions or sampling equipment or about the variability of the sediment.

## Streambed-Sediment Data

The USGS collected three paired samples during 2001: July 27, August 17, and September 1. Chemical data for these samples are listed in table 14, and radioactivity data for these samples are listed in table 15 (in the Data Section in the back of the report). The associated replicate data, a calculation of the difference in sample data between the two sites, and a calculation of the difference in sample data between the environmental sample and the replicate are included in table 16 (in the Data Section in the back of the report).

## Discussion of Streambed-Sediment Data

A comparison of the sample data with the replicate data (table 16) indicate variability within the sample may be about the same as variability between the basins. No statistical evaluations are possible with the limited data collected.

The radioactivity data are reported in the uncensored form as received from the laboratory rather than censored by either the contract or calculated MDC. Relative to the censored form (data reported as less than the MDC), the uncensored form provides more information about the uncertainty, the very small concentrations of plutonium, and the gross alpha and gross beta activity. The negative activity concentration reported for the radiochemical samples means the sample count was less than the laboratory background count for that day. Radioactivity data are produced from instruments that detect radioactive decay (disintegrations) in a sample as counts per minute. The background count was subtracted from the sample count, and the resulting value was converted to activity-concentration units of picocuries per gram.

The streambed-sediment data in this report were all collected after the Lowry Landfill Superfund site water transfer to the MWRD and can provide information about contamination associated with biosolids applications and that water transfer. The beginning of the water transfer from the Lowry site to the MWRD was July 25, 2000.

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## 14 Data for a Biosolids-Application Area Near Deer Trail, Colorado, 2001

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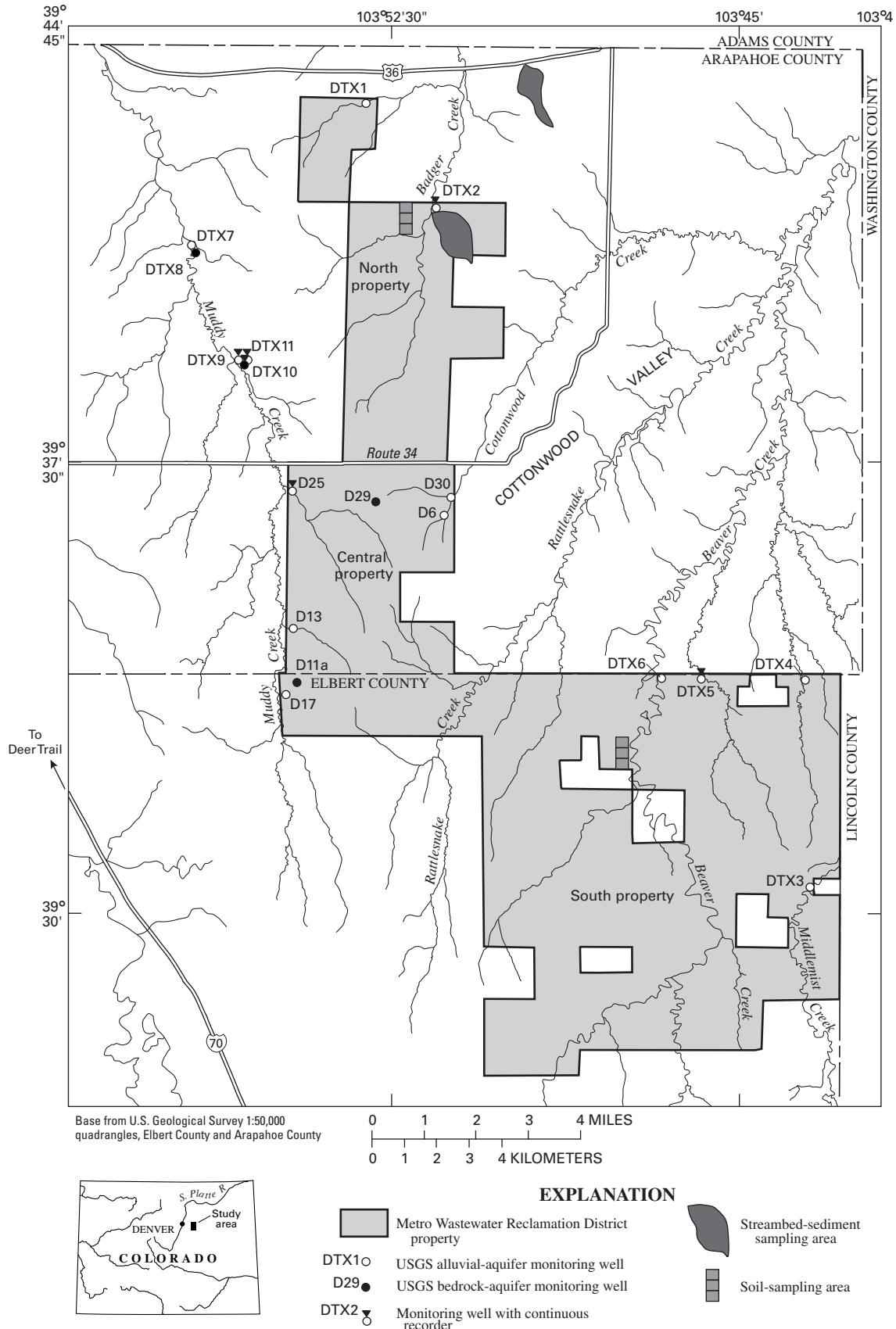
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## **Data Section**

## TERMS AND ABBREVIATIONS

The following terms and abbreviations are used in this section:

bls	below land surface
bmp	below the measuring point of the well casing
mi	mile
ft or '	feet
hhmm	24-hour time
mm/dd/yy	numerical date format for two-digit month/two-digit day/and the last two digits of the year
C	Celsius
cm	centimeters
°	degree
in. or ”	inch
µS/cm	microsiemens per centimeter at 25°C
pH units	are the negative base-10 log of the hydrogen-ion activity in moles per liter
mg/L	milligrams per liter
µg/L	micrograms per liter
dissolved	refers to that fraction of material in a water sample that passes through a 0.45-µm membrane filter
>	greater than
<	less than
WH	whole water (unfiltered) sample
g/kg	gram per kilogram
mg/kg	milligrams per kilogram
pCi/g	picocuries per gram
µg/g	micrograms per gram



**Figure 1.** Location of study area and U.S. Geological Survey monitoring sites near Deer Trail, Colorado, 2001. Metro Wastewater Reclamation District property boundaries shown are from 1999.



18 Data for a Biosolids-Application Area Near Deer Trail, Colorado, 2001

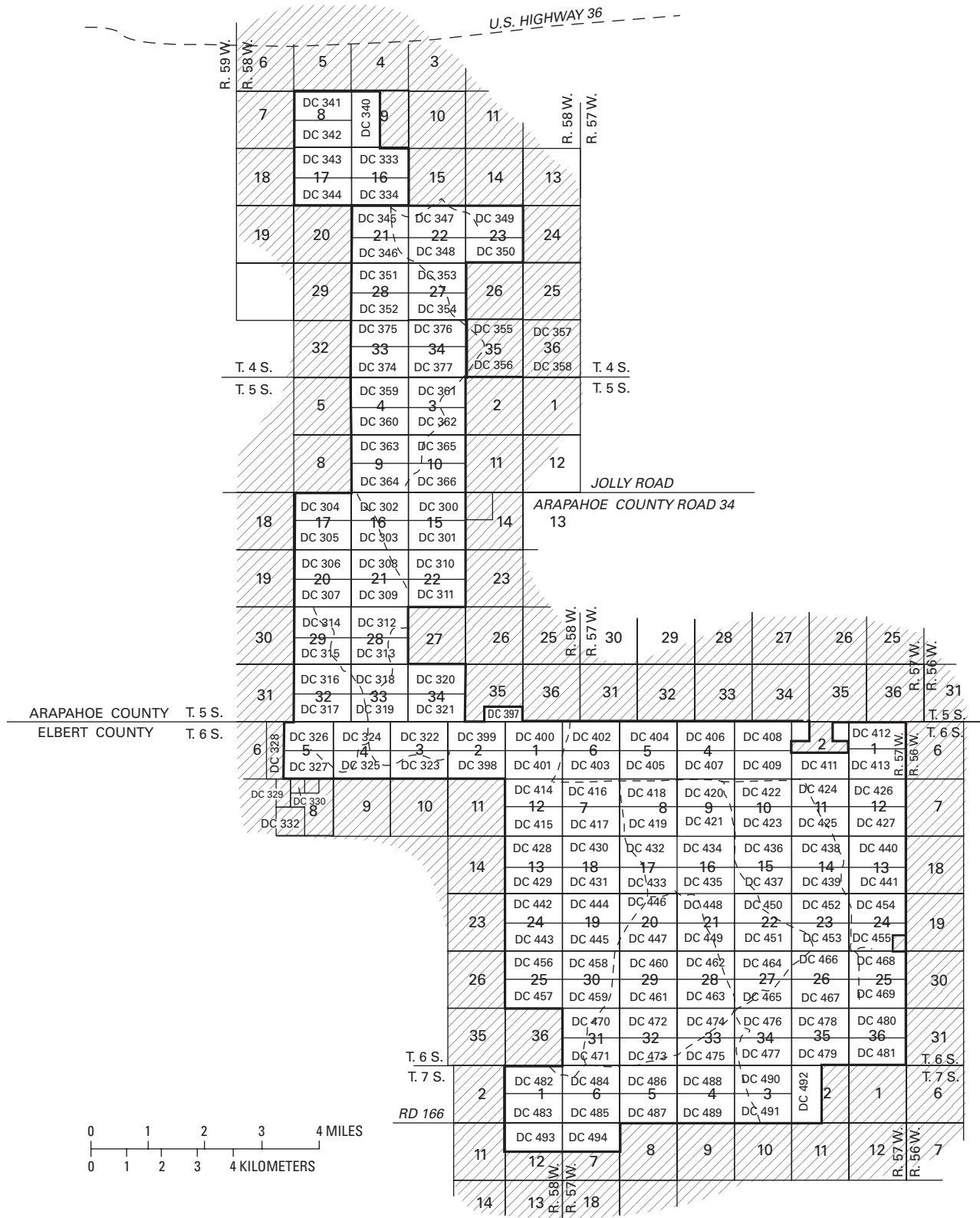
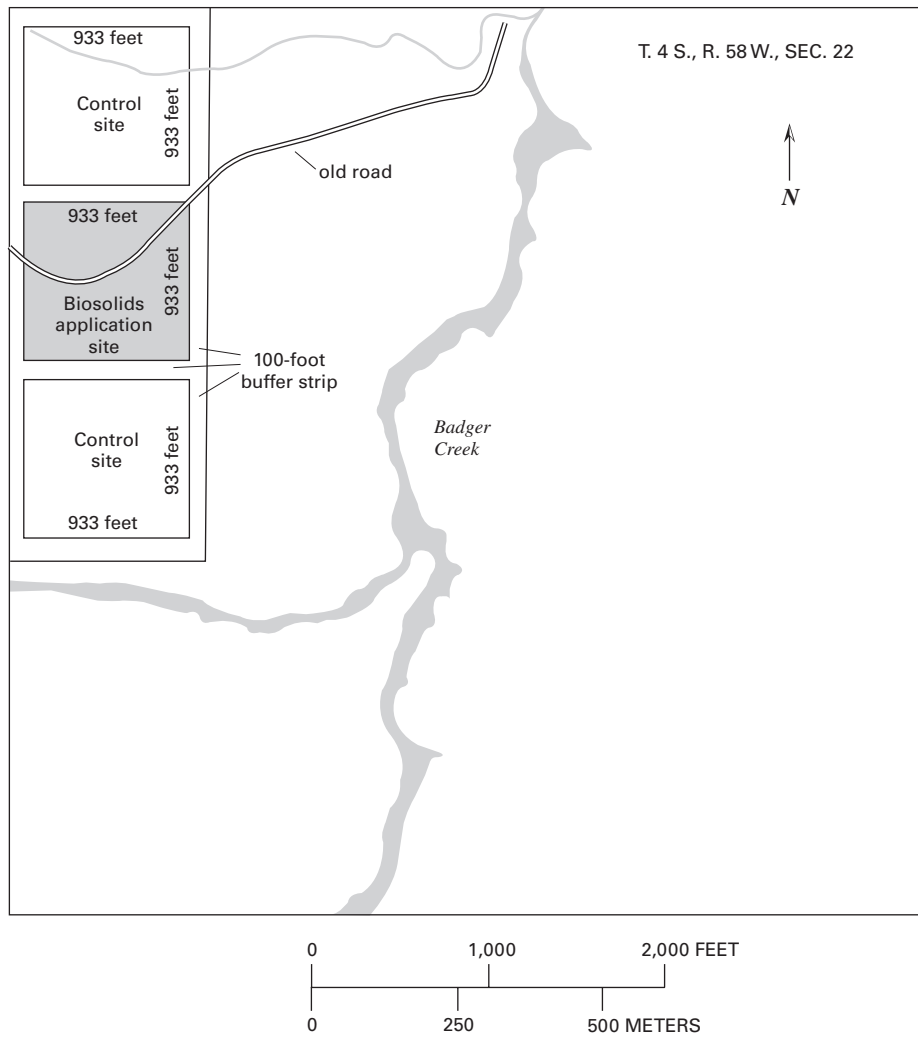
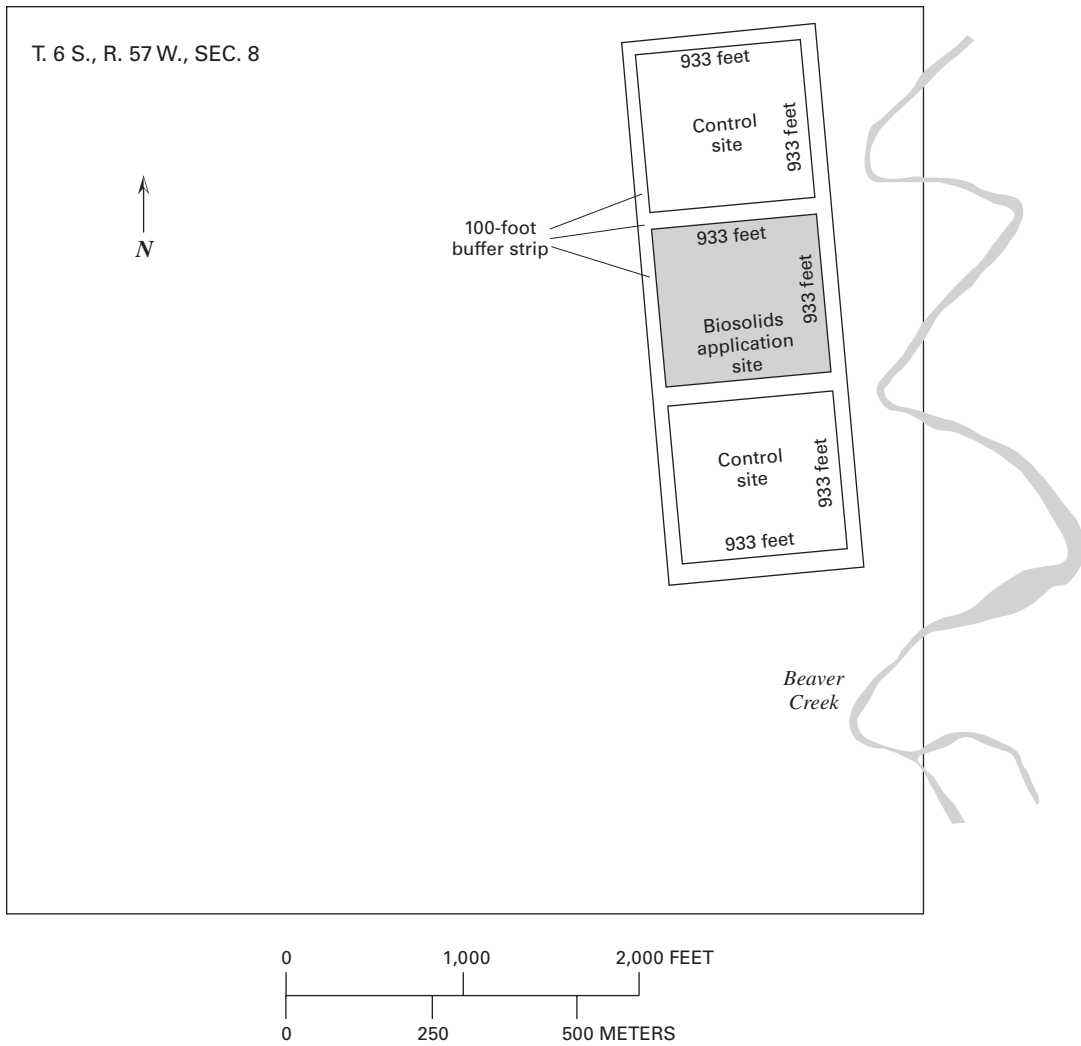


Figure 2. Metro Wastewater Reclamation District biosolids-application areas (METROGRO Farm) near Deer Trail, Colorado, 2001. Map provided by Metro Wastewater Reclamation District. (DC, Destination Code.)



**Figure 3.** Arapahoe County, Colorado, soil-monitoring site: T. 4 S., R. 58 W., sec. 22 (from Metro Wastewater Reclamation District).



**Figure 4.** Elbert County, Colorado, soil-monitoring site: T. 6 S., R. 57 W., sec. 8 (from Metro Wastewater Reclamation District).

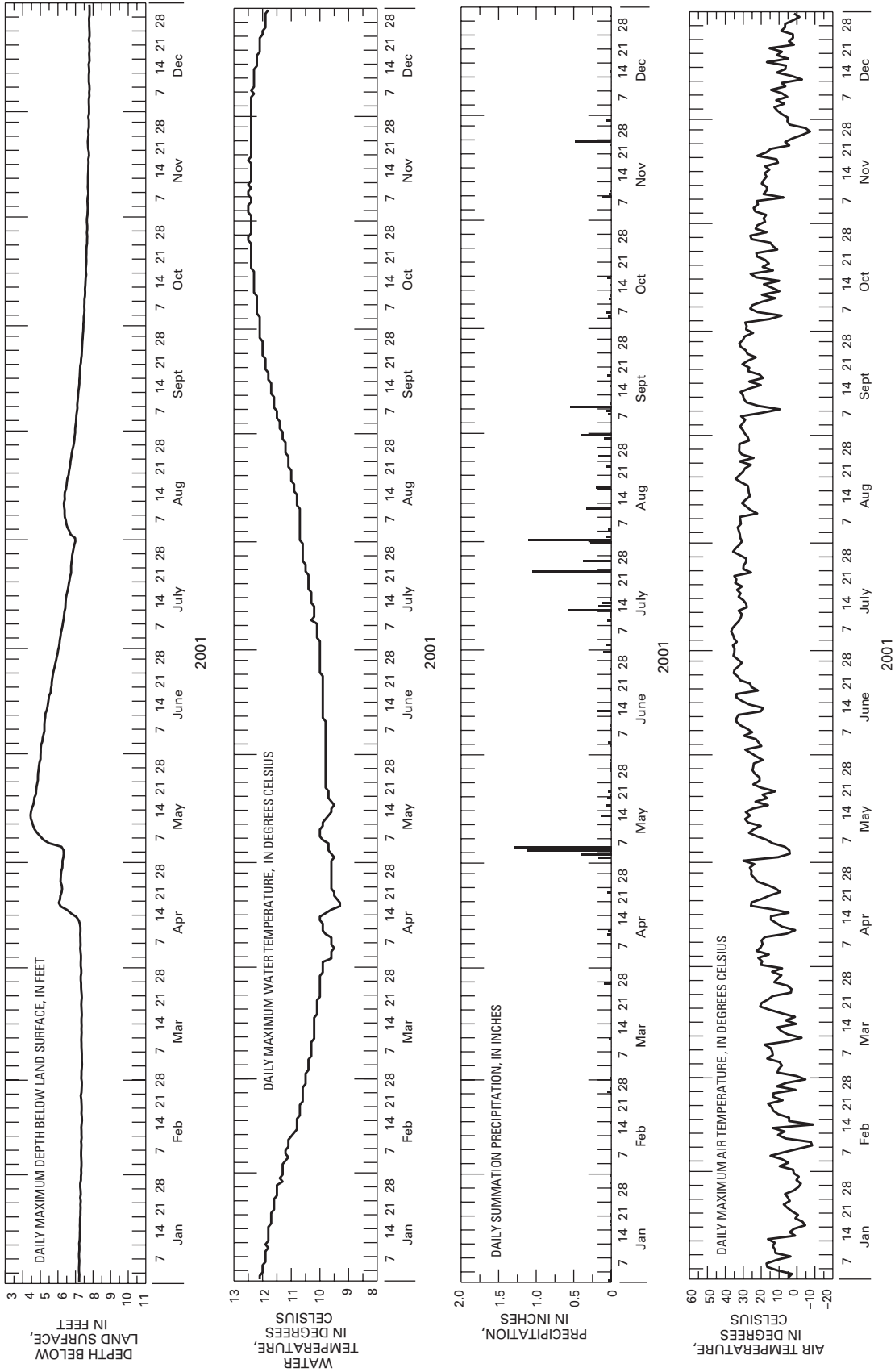


Figure 5. Continuous water-level, water-temperature, precipitation, and air-temperature data for well D25 near Deer Trail, Colorado, 2001.

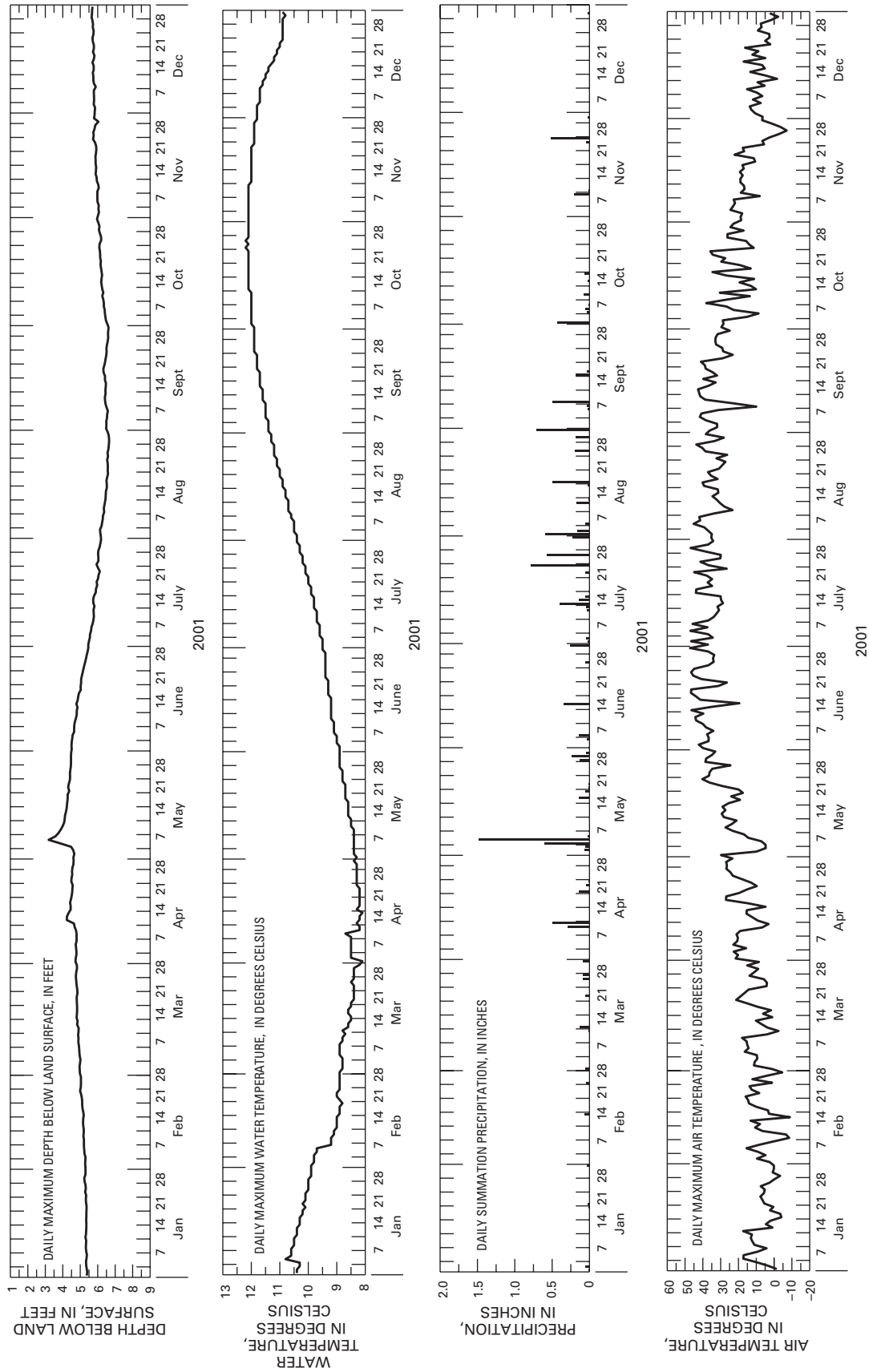


Figure 6. Continuous water-level, water-temperature, precipitation, and air-temperature data for well DTX2 near Deer Trail, Colorado, 2001.

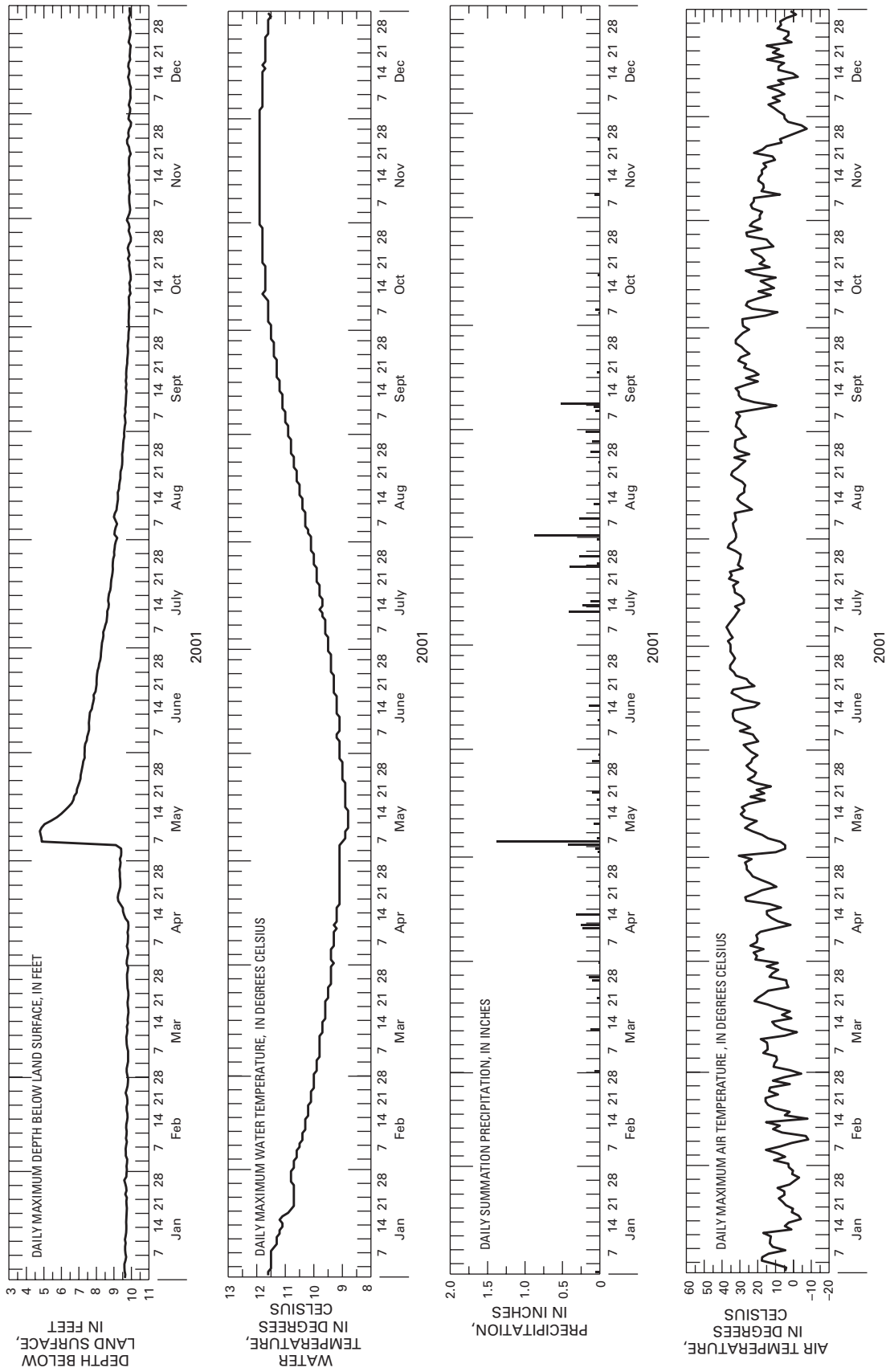


Figure 7. Continuous water-level, water-temperature, precipitation, and air-temperature data for well DTX5 near Deer Trail, Colorado, 2001.

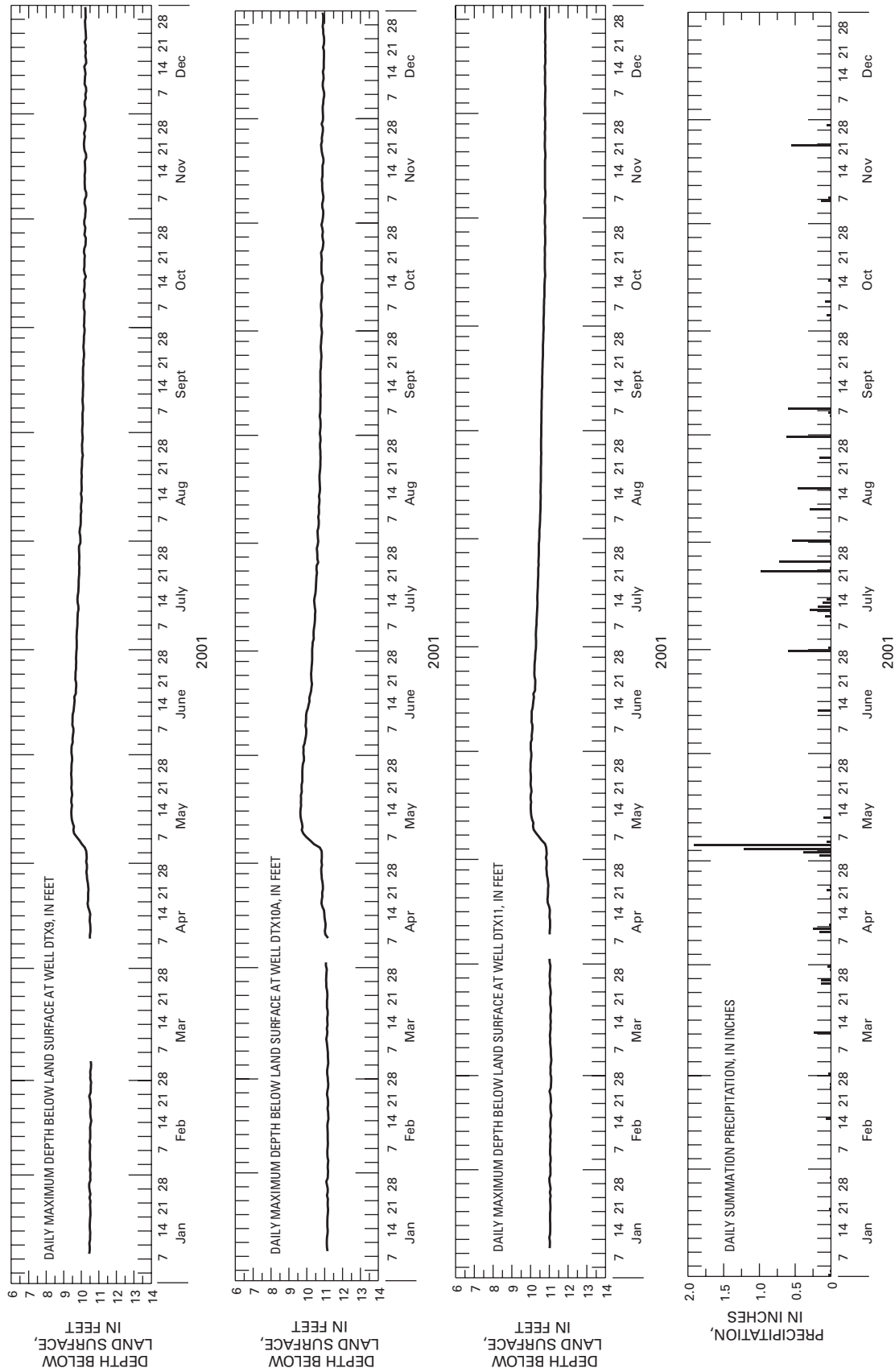
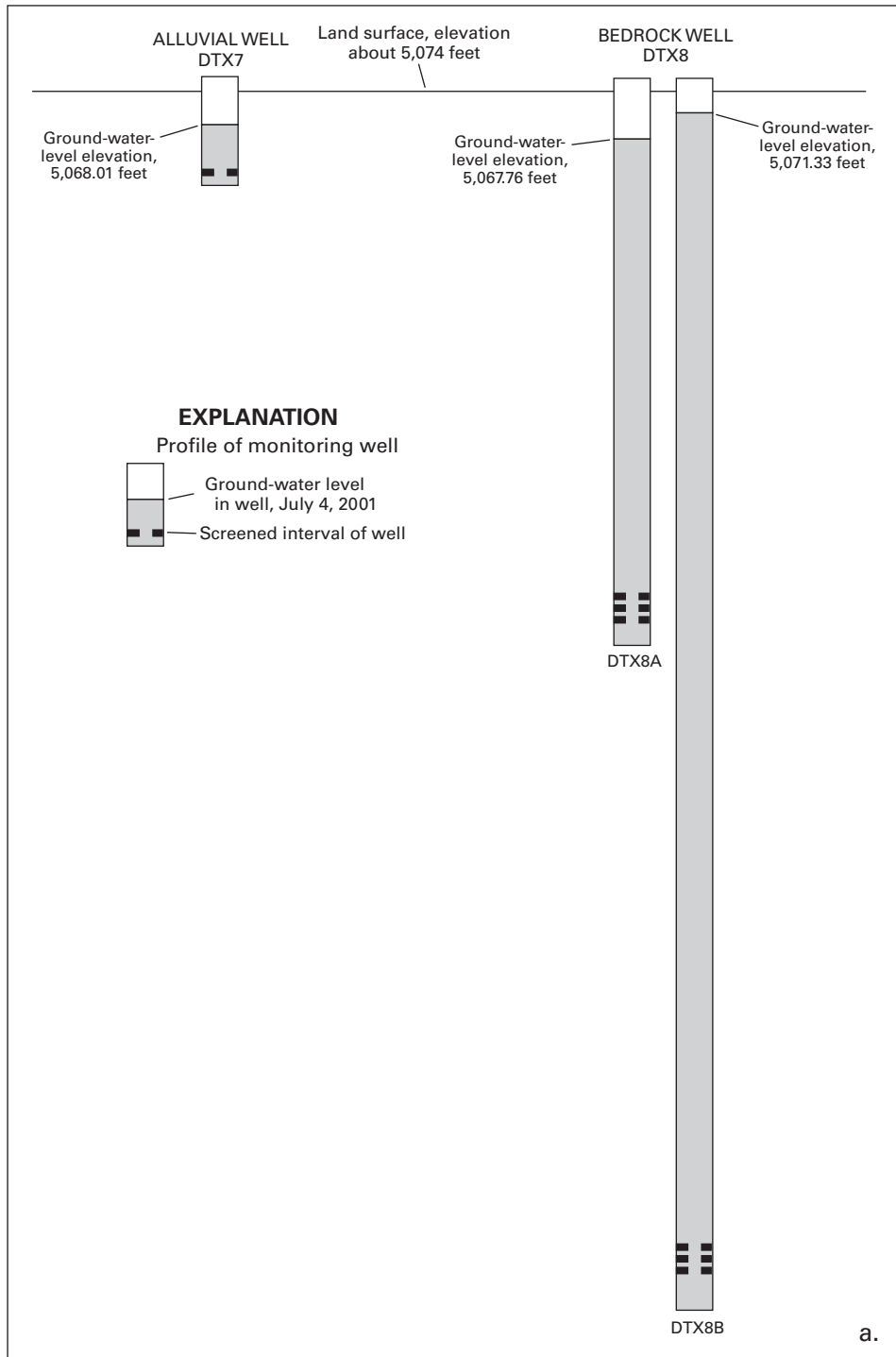
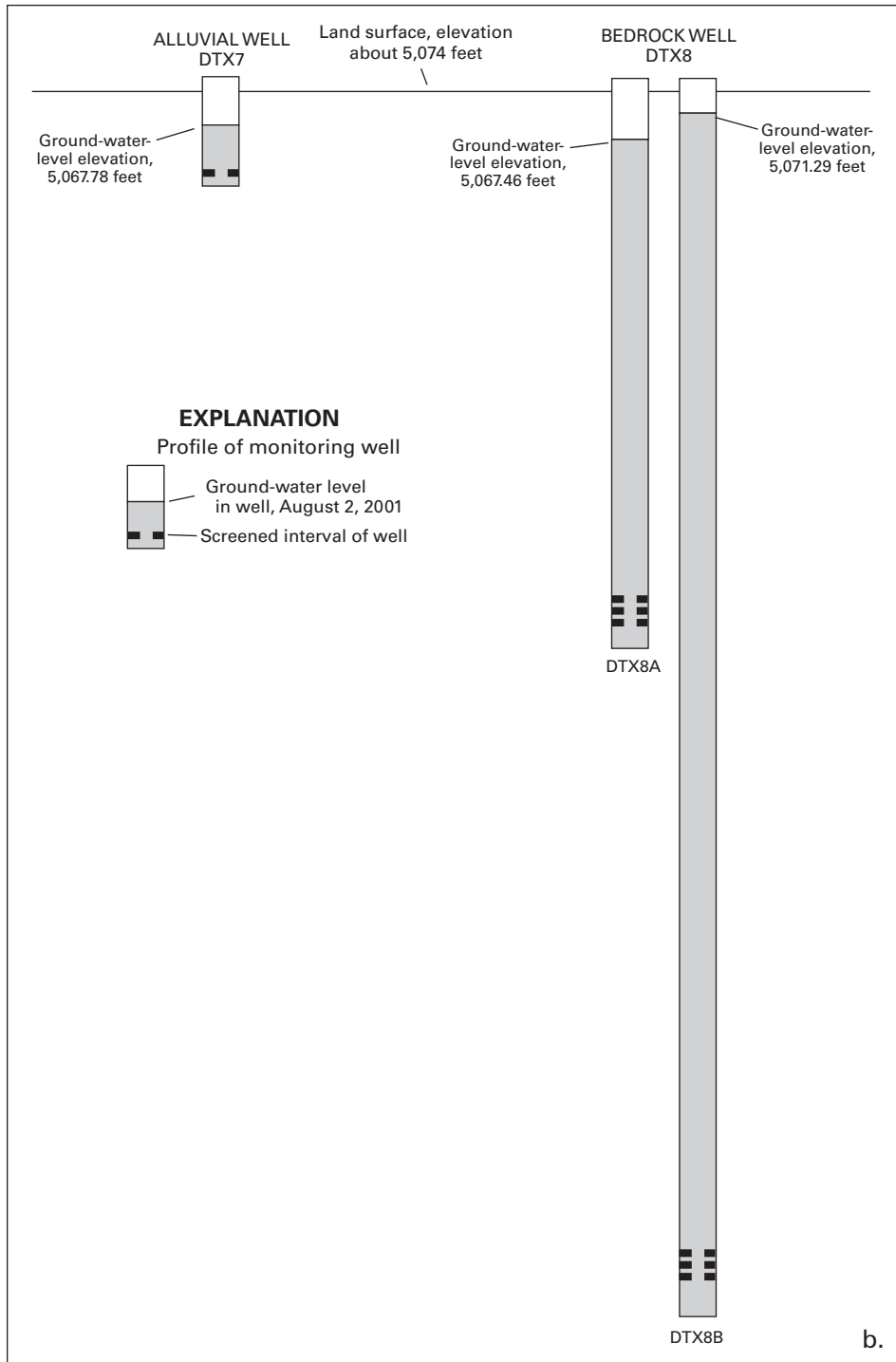


Figure 8. Continuous water-level data for wells DTX9, DTX10A, and DTX11, and precipitation data for the EDL recharge-evaluation site near Deer Trail, Colorado, 2001. (EDL, electronic data logger)

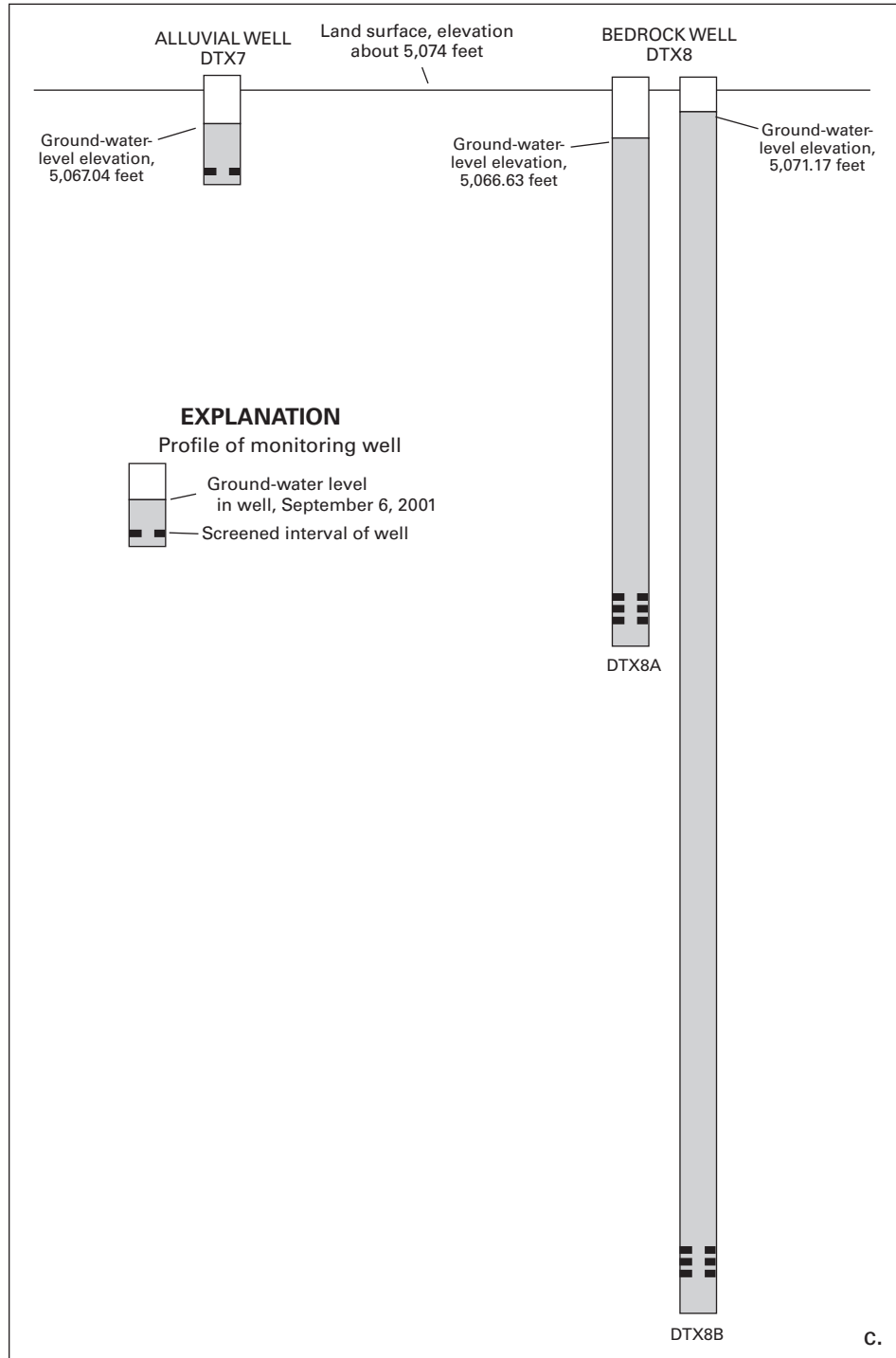


**Figure 9.** Water levels for the recharge-evaluation site containing wells DTX7 and DTX8 near Deer Trail, Colorado, for (a) July, (b) August, and (c) September 2001. (Elevation is in feet above NAVD 88.)





**Figure 9.** Water levels for the recharge-evaluation site containing wells DTX7 and DTX8 near Deer Trail, Colorado, for (a) July, (b) August, and (c) September 2001. (Elevation is in feet above NAVD 88.)—Continued



**Figure 9.** Water levels for the recharge-evaluation site containing wells DTX7 and DTX8 near Deer Trail, Colorado, for (a) July, (b) August, and (c) September 2001. (Elevation is in feet above NAVD 88.)—Continued

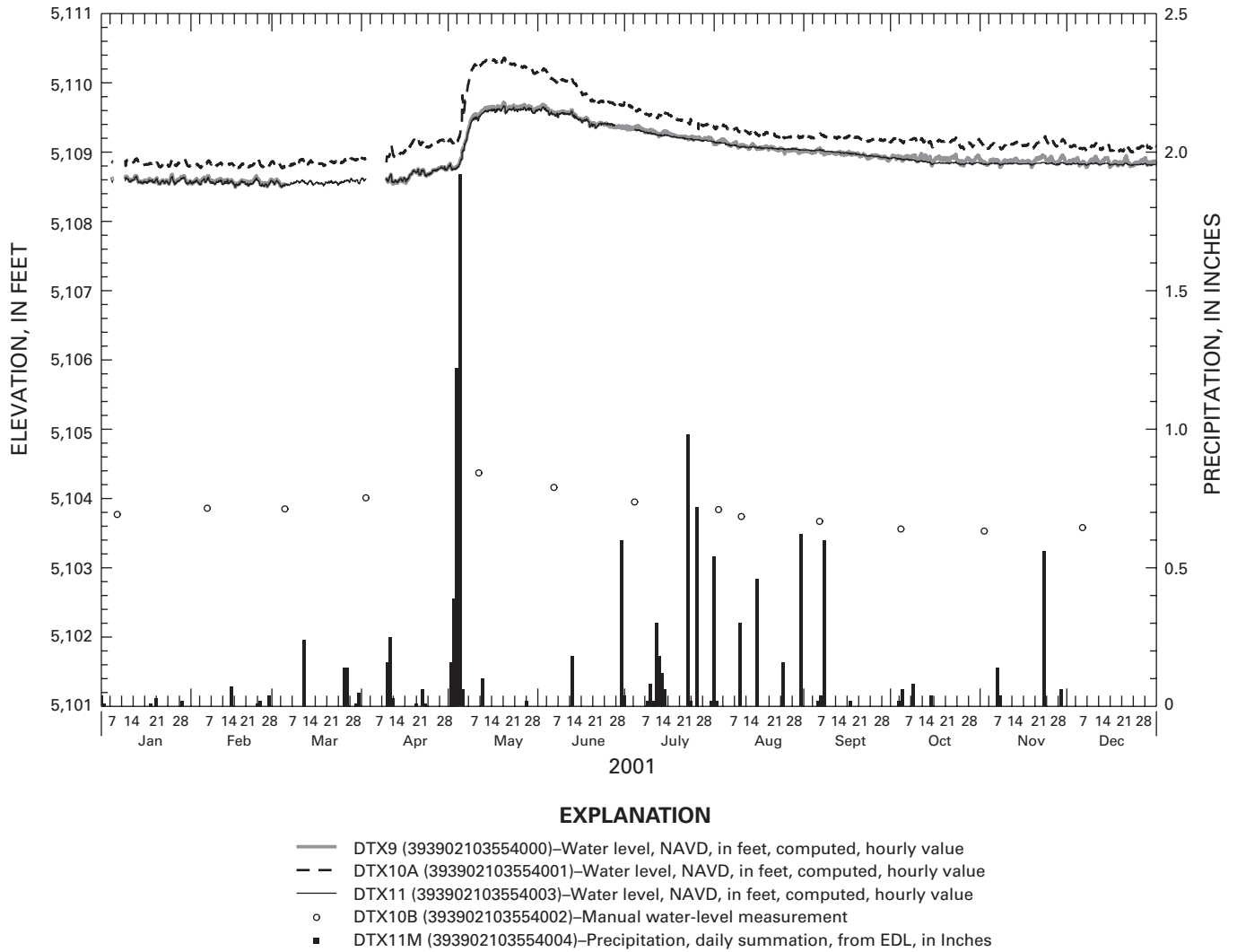


Figure 10. Data for the recharge-evaluation site containing wells DTX9, DTX10, and DTX11 near Deer Trail, Colorado, 2001.

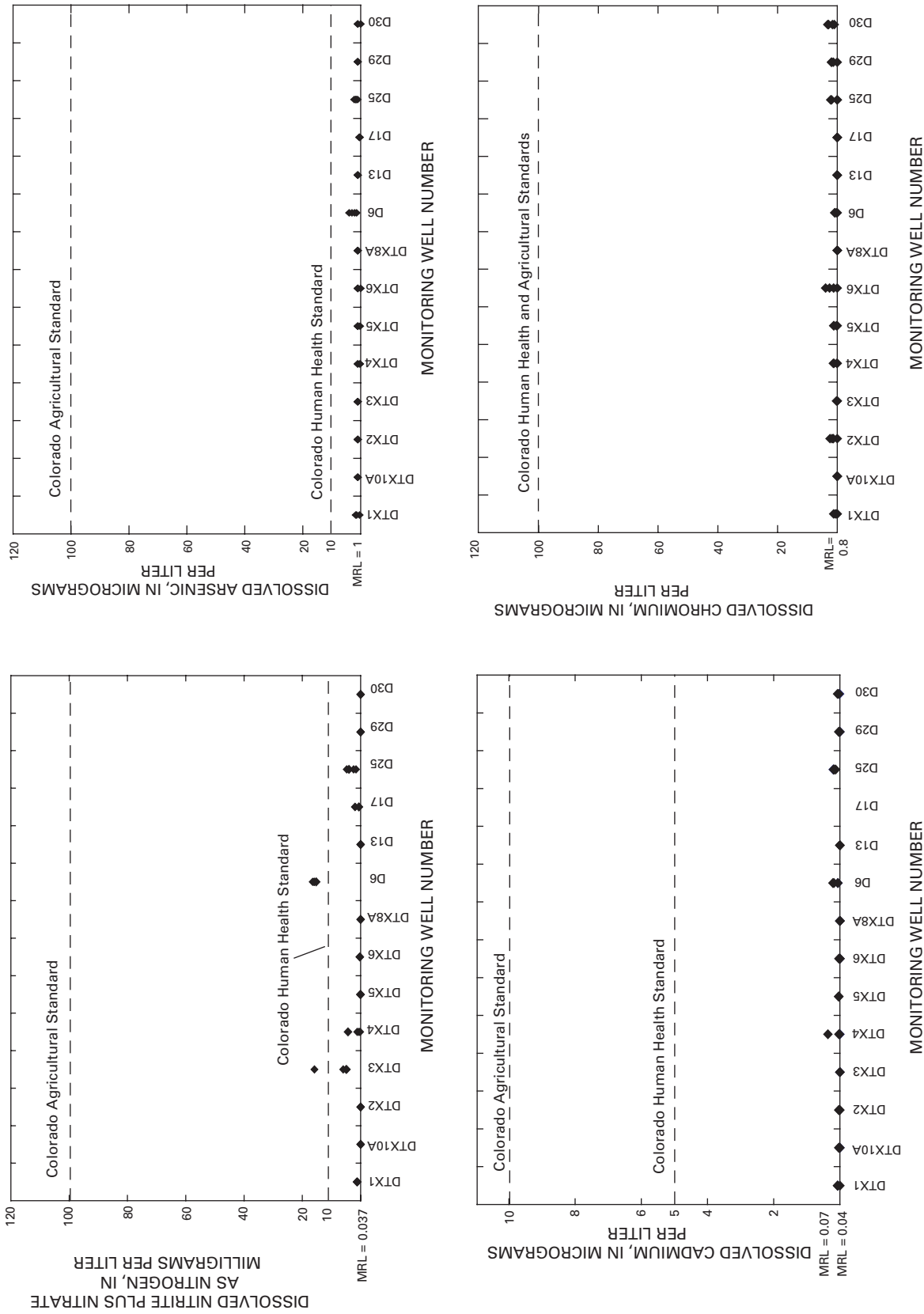


Figure 11. Distribution of ground-water data collected near Deer Trail, Colorado, compared to regulatory standards for selected constituents, 2001.

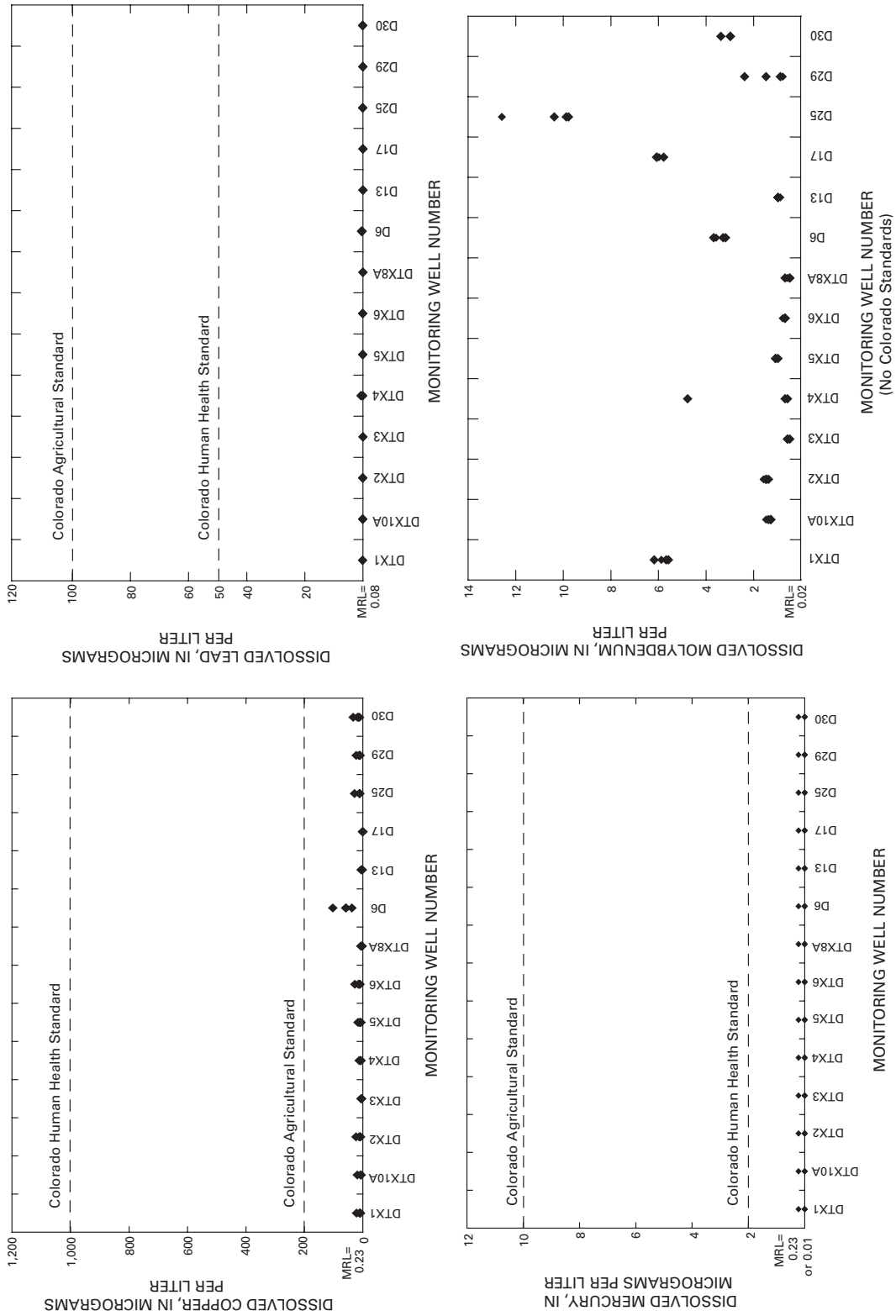


Figure 11. Distribution of ground-water data collected near Deer Trail, Colorado, compared to regulatory standards for selected constituents, 2001.—Continued

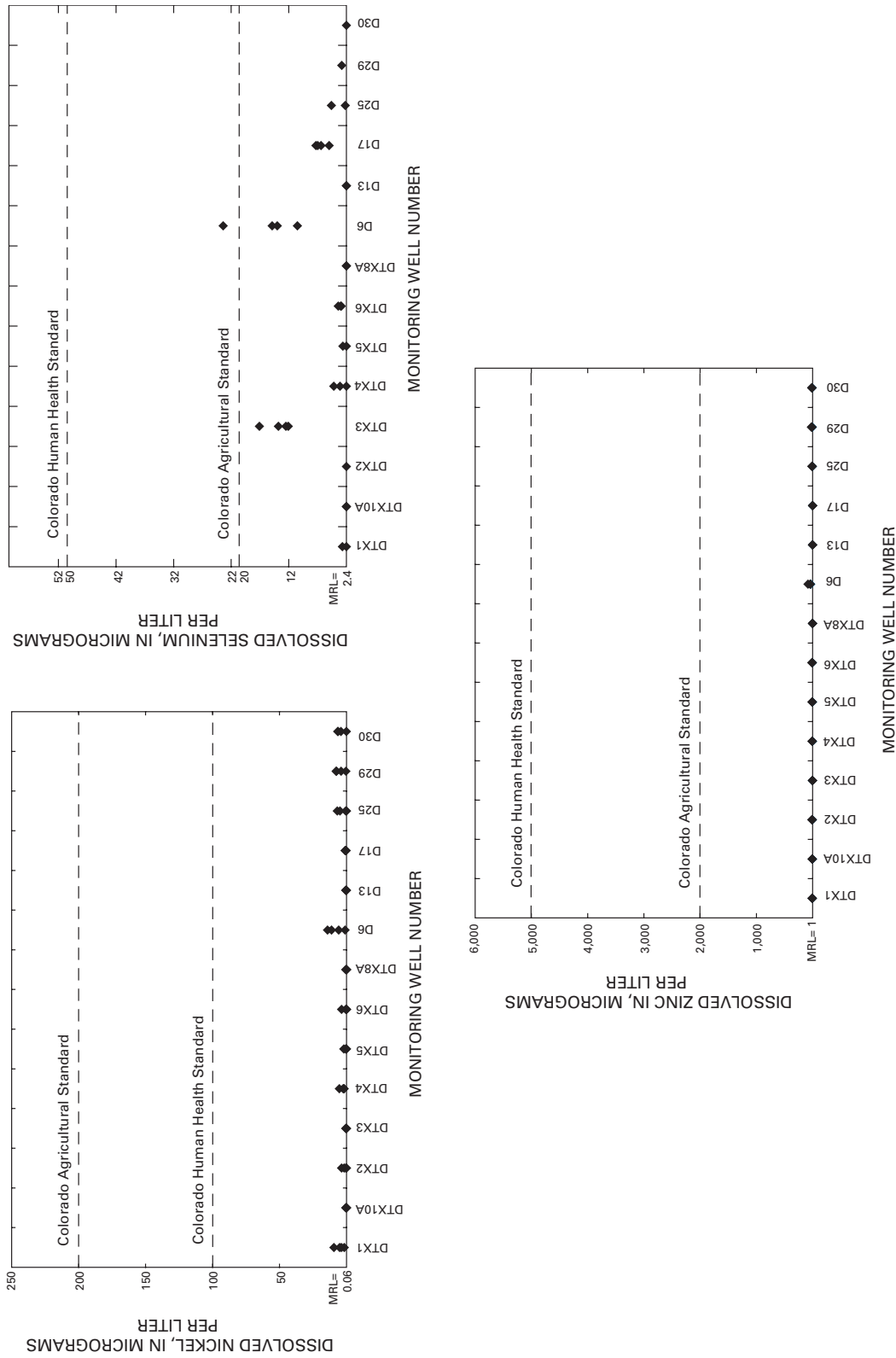


Figure 11. Distribution of ground-water data collected near Deer Trail, Colorado, compared to regulatory standards for selected constituents, 2001.—Continued

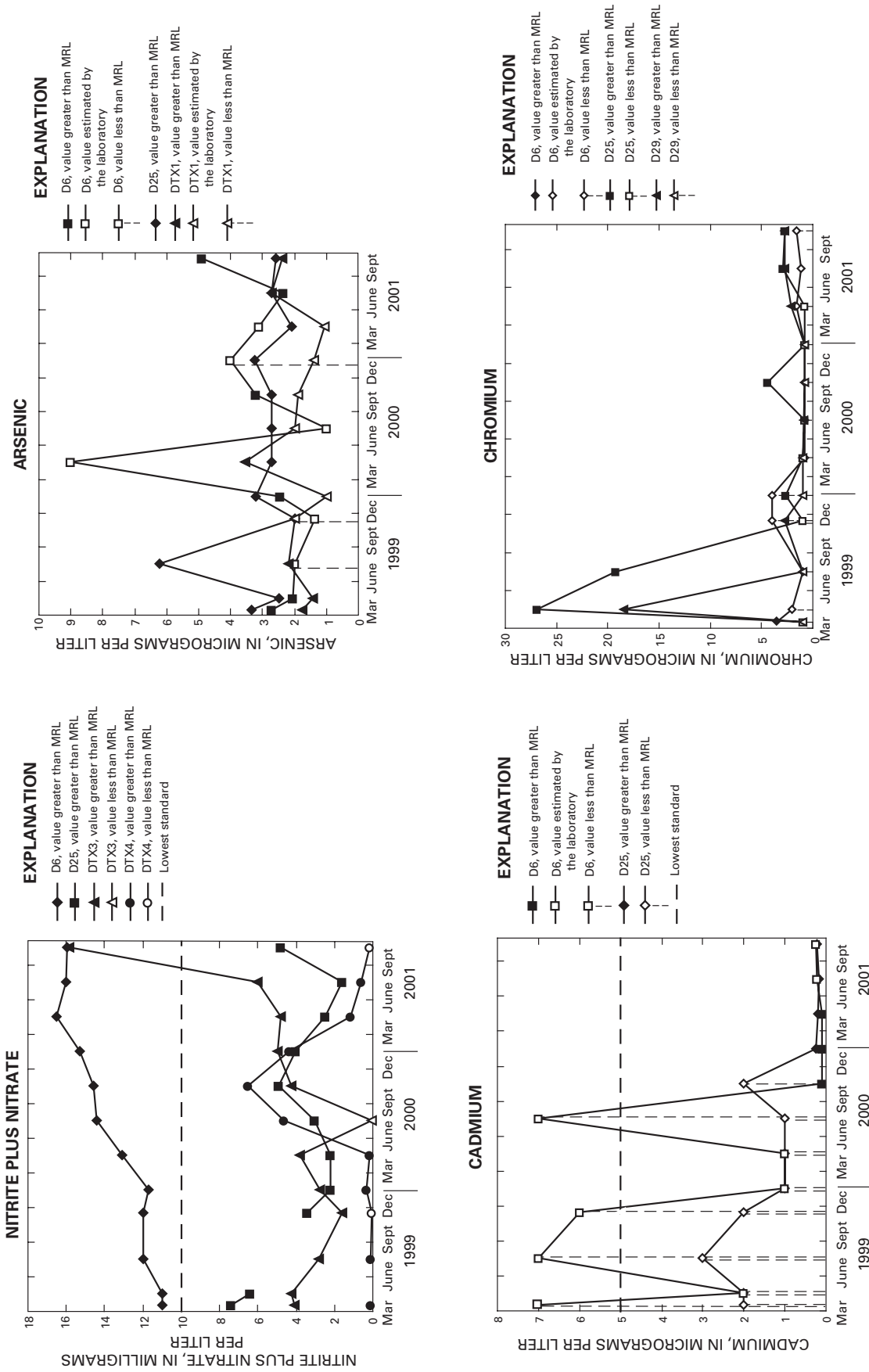


Figure 12. Ground-water concentrations near Deer Trail, Colorado, for selected constituents and selected wells, 1999-2001. (MRL, minimum reporting limit.)

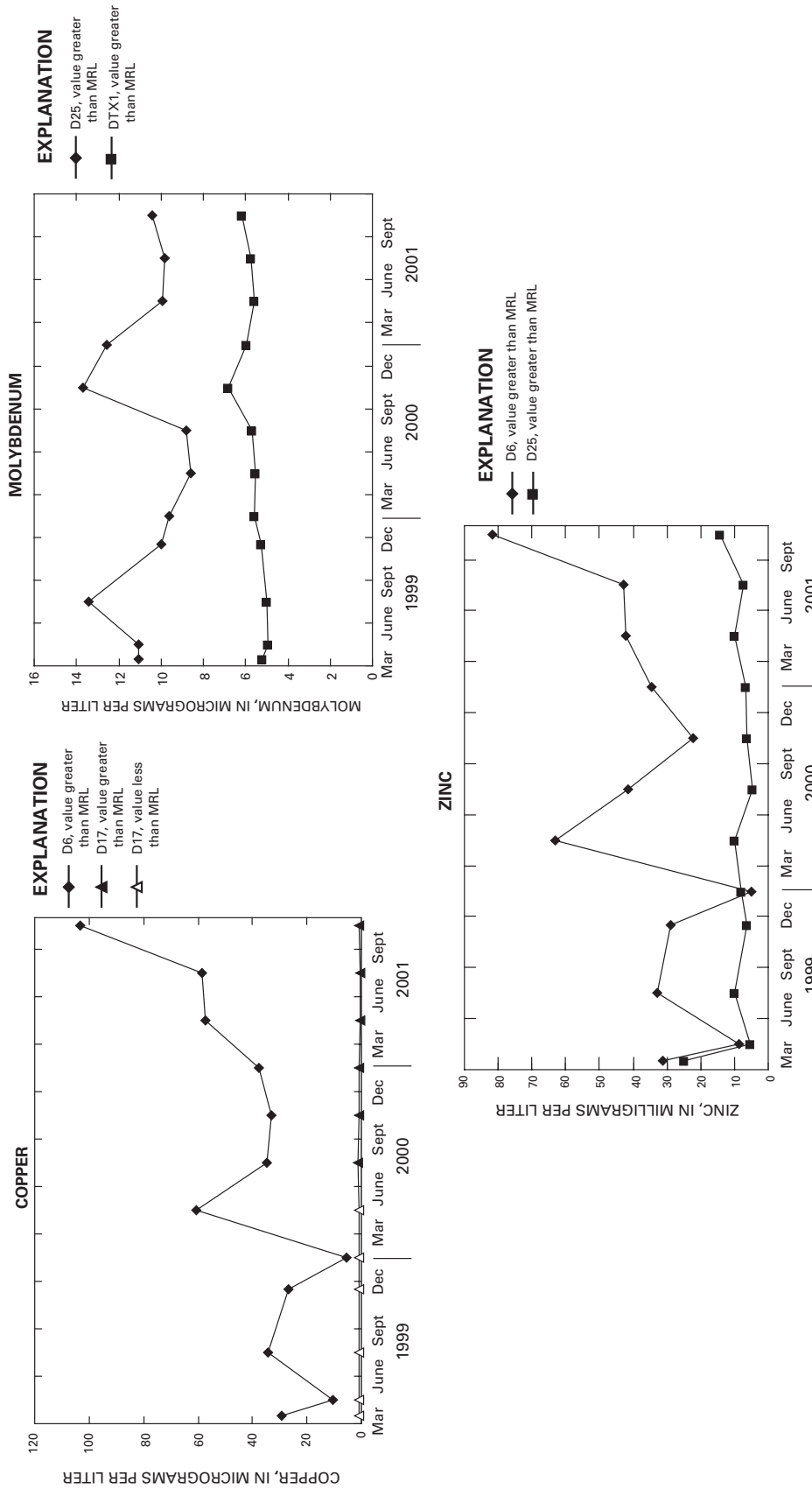


Figure 12. Ground-water concentrations near Deer Trail, Colorado, for selected constituents and selected wells, 1999-2001. (MRL, minimum reporting limit.)—Continued



**Table 1. Biosolids applications by Metro Wastewater Reclamation District to the study area near Deer Trail, Colorado, 2001.**

[All information provided by Metro Wastewater Reclamation District; DC, destination code (shown in fig. 2); Legal description is of the form quarter-section township range CAKE, Grade I Class B biosolids; MAC, biosolids amended with wood fiber; lbs/Ac, pounds per acre; Y, yes; N, no; O/GR, oats and grass]

DC Code	Legal Description	Area Applied To, Acres	METROGRO Product	Start Date	Stop Date	Total Loads	Total Wet Tons	Total Dry Tons	Loading Rate, Dry Tons per Acre		Nitrogen Loading Rate lbs/Ac	Crop	Reclamation Project
									Cake	MAC			
306	N 1/2 SEC 20 T5S R58W	106.6	CAKE/MAC	02/15/01	04/23/01	58	1283.11	266.5	1.93	0.57	62	WHEAT	N
306	N 1/2 SEC 20 T5S R58W	117	CAKE/MAC	08/13/01	09/08/01	41	879.19	173.24	1.18	0.30	32	PASTURE	N
306	N 1/2 SEC 20 T5S R58W	106	CAKE/MAC	11/26/01	12/17/01	67	1362.16	230.65	2.03	0.14	62	WHEAT	N
307	S 1/2 SEC 20 T5S R58W	92.1	CAKE	03/14/01	03/31/01	52	1167.31	208.52	2.27	0.00	63	WHEAT	N
307	S 1/2 SEC 20 T5S R58W	139	CAKE/MAC	08/13/01	09/11/01	49	1063.52	212.68	1.27	0.25	36	PASTURE	N
310	N 1/2 SEC 22 T5S R58W	235.5	CAKE	11/29/01	12/02/01	86	1878.23	299.15	1.27	0.00	38	WHEAT	N
311	S 1/2 SEC 22 T5S R58W	233.2	CAKE/MAC	12/02/01	12/12/01	85	1895.72	317.3	1.30	0.06	39	WHEAT	N
313	S 1/2 SEC 28 T5S R58W	96	CAKE	09/19/01	09/22/01	40	873.47	151.74	1.58	0.00	43	WHEAT	N
314	N 1/2 SEC 29 T5S R58W	48.8	CAKE/MAC	02/19/01	03/13/01	38	867.9	165.82	3.07	0.31	89	WHEAT	N
318	N 1/2 SEC 33 T5S R58W	78.7	CAKE	09/19/01	09/21/01	33	721.26	125.02	1.59	0.00	43	WHEAT	N
323	S 1/2 SEC 3 T6S R58W	230.6	CAKE/MAC	12/26/00	01/04/01	184	4144	683	2.83	0.13	82	WHEAT	N
333	N 1/2 SEC 16 T4S R58W	310	CAKE/MAC	12/17/01	12/30/01	209	4729.81	837.57	2.45	0.25	70	WHEAT	N
340	W 1/2 SEC 9 T4S R58W	258.4	CAKE/MAC	10/06/00	06/20/01	99	2207.24	487.04	1.21	0.67	41	WHEAT	N
341	N 1/2 SEC 8 T4S R58W	120.2	CAKE/MAC	11/07/01	12/18/01	26	581.72	123.34	0.74	0.28	24	WHEAT	N
347	N 1/2 SEC 22 T4S R58W	160	CAKE/MAC	09/21/01	12/15/01	35	763.18	139.86	0.77	0.10	22	WHEAT	N
348	N 1/2 SEC 22 T4S R58W	160	CAKE/MAC	12/11/01	12/14/01	36	767.8	137.21	0.76	0.10	22	WHEAT	N
353	S 1/2 SEC 27 T4S R58W	280	CAKE	09/22/01	10/04/01	141	3043.57	517.5	1.85	0.00	51	WHEAT	N
354	S 1/2 SEC 27 T4S R58W	280	CAKE	10/01/01	10/12/01	193	4339.38	734.16	2.62	0.00	67	WHEAT	N
359	N 1/2 SEC 4 T5S R58W	290	CAKE/MAC	01/03/01	01/20/01	231	5262.24	871.01	2.84	0.16	78	WHEAT	N
360	S 1/2 SEC 4 T5S R58W	145	CAKE/MAC	12/30/00	01/19/01	116	2564.07	443.56	2.75	0.30	77	WHEAT	N
361	N 1/2 SEC 3 T5S R58W	25.8	CAKE/MAC	01/24/01	01/30/01	23	511.53	121.81	2.98	1.74	108	WHEAT	N
361	N 1/2 SEC 3 T5S R58W	220.3	CAKE	10/12/01	10/17/01	111	2454.08	427.99	1.94	0.00	52	WHEAT	N
362	S 1/2 SEC 3 T5S R58W	100.3	CAKE/MAC	01/27/01	02/02/01	75	1649.34	304.97	2.73	0.31	88	WHEAT	N
362	S 1/2 SEC 3 T5S R58W	179	CAKE	10/18/01	10/24/01	115	2561.56	436.17	2.44	0.00	66	WHEAT	N
363	N 1/2 SEC 9 T5S R58W	81.3	CAKE/MAC	01/20/01	01/24/01	67	1526.49	263.42	3.05	0.18	80	WHEAT	N
364	S 1/2 SEC 9 T5S R58W	145.9	CAKE/MAC	01/21/01	01/26/01	62	1405.33	247.73	1.60	0.10	48	WHEAT	N
365	N 1/2 SEC 10 T5S R58W	139.8	CAKE/MAC	01/25/01	02/09/01	109	2400.57	455.29	2.70	0.55	89	WHEAT	N
366	S 1/2 SEC 10 T5S R58W	127.5	CAKE/MAC	02/02/01	02/10/01	105	2299.27	421.04	2.83	0.47	93	WHEAT	N
411	S 1/2 SEC 2 T6S R57W	350	CAKE/MAC	02/10/01	05/09/01	263	5866.74	1103.28	2.75	0.40	81	WHEAT	N
414	N 1/2 SEC 12 T6S R58W	105	CAKE	07/23/01	07/27/01	72	1627.17	278.67	2.66	0.00	70	WHEAT	N
415	S 1/2 SEC 12 T6S R58W	92	CAKE	07/14/01	07/17/01	65	1469.63	262.66	2.86	0.00	75	WHEAT	N
416	N 1/2 SEC 7 T6S R57W	188.79	CAKE	07/18/01	07/23/01	121	2694.39	480.48	2.54	0.00	68	WHEAT	N
417	S 1/2 SEC 7 T6S R57W	205	CAKE	07/12/01	07/18/01	45	994.14	176.38	0.86	0.00	22	WHEAT	N
418	N 1/2 SEC 8 T6S R57W	242	CAKE/MAC	03/21/01	09/05/01	98	2227.92	474.55	1.52	0.44	44	WHEAT	N
419	S 1/2 SEC 8 T6S R57W	255	CAKE	06/29/01	07/08/01	175	3966.4	686.68	2.69	0.00	70	WHEAT	N
420	N 1/2 SEC 9 T6S R57W	290	CAKE/MAC	10/31/01	12/11/01	196	4414.75	774.27	2.44	0.22	72	WHEAT	N
421	S 1/2 SEC 9 T6S R57W	240.6	CAKE	09/07/01	09/19/01	155	3495.13	605.42	2.51	0.00	66	WHEAT	N
430	N 1/2 SEC 18 T6S R57W	139	CAKE	07/10/01	07/12/01	51	1168.51	209.03	1.50	0.00	39	WHEAT	N
431	S 1/2 SEC 18 T6S R57W	221.33	CAKE	07/31/01	08/07/01	152	3366.84	577.47	2.61	0.00	66	WHEAT	N
432	N 1/2 SEC 17 T6S R57W	157	CAKE	07/08/01	07/10/01	36	821.22	144.87	0.92	0.00	40	WHEAT	N
433	S 1/2 SEC 17 T6S R57W	207	CAKE	08/07/01	08/20/01	142	3217.99	564.93	2.73	0.00	71	WHEAT	N
434	N 1/2 SEC 16 T6S R57W	190	CAKE/MAC	10/26/01	11/02/01	130	2919.71	489.84	2.48	0.09	71	WHEAT	N
435	S 1/2 SEC 16 T6S R57W	47.7	CAKE	10/24/01	10/26/01	33	733.32	122.52	2.58	0.00	73	WHEAT	N
458	N 1/2 SEC 30 T6S R57W	106.2	CAKE/MAC	01/04/99	09/07/01	350	7781.53	1534.92	11.80	2.66	329	O/GR	Y
459	S 1/2 SEC 30 T6S R57W	112.5	CAKE/MAC	01/04/99	08/28/01	389	8644.99	1500.39	13.12	0.21	319	O/GR	Y
460	N 1/2 SEC 29 T6S R57W	20	CAKE	01/11/99	08/29/01	28	611.98	103.09	5.15	0.00	139	O/GR	Y
461	S 1/2 SEC 29 T6S R57W	23.9	CAKE/MAC	01/09/99	08/24/01	76	1696.32	294.27	11.72	0.59	300	O/GR	Y

**Table 2.** Methods used to analyze biosolids and soil samples collected near Deer Trail, Colorado, 2001.

Element or property	Medium	Analytical method	Reference
Arsenic	Soils and Biosolids	HG-AAS <sup>1</sup>	Hageman and Welsch (1996)
Cadmium	Biosolids	ICP-MS <sup>2</sup>	Briggs and Meier (1999)
Cadmium	Soils	ICP-AES <sup>3</sup>	Motooka (1996)
Copper	Biosolids	ICP-MS <sup>2</sup>	Briggs and Meier (1999)
Copper	Soils	ICP-AES <sup>3</sup>	Briggs (1996)
Lead	Biosolids	CP-MS <sup>2</sup>	Briggs and Meier (1999)
Lead	Soils	ICP-AES <sup>3</sup>	Briggs (1996)
Mercury	Soils and Biosolids	V-AAS <sup>4</sup>	O'Leary and others (1996)
Molybdenum	Biosolids	CP-MS <sup>2</sup>	Briggs and Meier (1999)
Molybdenum	Soils	ICP-AES <sup>3</sup>	Motooka (1996)
Nickel	Biosolids	CP-MS <sup>2</sup>	Briggs and Meier (1999)
Nickel	Soils	ICP-AES <sup>3</sup>	Briggs (1996)
Selenium	Soils and Biosolids	HG-AAS <sup>1</sup>	Hageman and Welsch (1996)
Zinc	Biosolids	CP-MS <sup>2</sup>	Briggs and Meier (1999)
Zinc	Soils	ICP-AES <sup>3</sup>	Briggs (1996)
Gross Alpha, Total	Soils and Biosolids	Radiological method	Greenberg (1992)
Gross Beta, Total	Soils and Biosolids	Radiological method	Greenberg (1992)
Plutonium-238, Total	Soils and Biosolids	Radiological method	Whittaker and Grothaus (1979); Lyon (1980)
Plutonium-239+240, Total	Soils and Biosolids	Radiological method	Whittaker and Grothaus (1979); Lyon (1980)

<sup>1</sup>Hydride Generation-Atomic Absorption Spectrometry.<sup>2</sup>Inductively Coupled Plasma-Mass Spectrometry.<sup>3</sup>Inductively Coupled Plasma-Atomic Emission Spectrometry.<sup>4</sup>Continuous Flow-Cold Vapor-Atomic Absorption Spectrometry.

**Table 3.** Chemical data for biosolids samples collected at the Metro Wastewater Reclamation District during 2001.

[ppm, parts per million; pCi/g, picocuries per gram; ±, plus or minus the analytical uncertainty; \*, these data are in review because of quality-assurance issues; Maximum allowable values from Colorado Department of Public Health and Environment (1998)]

Element or property	Maximum allowable	January	April	July	October
Arsenic, ppm	41	1.5	2.1	2.1	1.7
Cadmium, ppm	39	3.2	2.6	2.6	2.7
Copper, ppm	1,500	570	610	610	630
Lead, ppm	300	59	62	63	61
Mercury, ppm	17	1.4	1.4	2.0	1.7
Molybdenum, ppm	No standard set for Grade I, 75 for Grade II	21	30	28	33
Nickel, ppm	420	24	30	25	24
Selenium, ppm	100	8.8	7.0	12	12
Zinc, ppm	2,800	640	670	680	700
Gross alpha, pCi/g	40	* 30 ± 10	* 34 ± 12	* 54 ± 12	* 49 ± 11
Gross beta, pCi/g	No standard set for Grade I	24 ± 5	22 ± 5	31 ± 7	28 ± 6
Plutonium 238, pCi/g	No standard set for Grade I	-0.01 ± 0.01	0.00 ± 0.01	-0.004 ± 0.019	-0.004 ± 0.120
Plutonium 239+240, pCi/g	No standard set for Grade I	0.01 ± 0.02	0.00 ± 0.01	0.009 ± 0.012	0.000 ± 0.012

**Table 4.** U.S. Geological Survey soil data for samples collected June 11, 2001, at the Arapahoe County site and November 29–December 1, 2000, at the Elbert County site.

[Data are preliminary and subject to revision. mg/kg, milligrams per kilogram; <, less than; pCi/g, picocuries per gram; ±, plus or minus the analytical uncertainty]

Constituent or Property	Units	Arapahoe County, North (control) field	Arapahoe County, Middle (biosolids application) field	Arapahoe County, South (control) field	Elbert County, North (control) field	Elbert County, Middle (biosolids application) field	Elbert County, South (control) field
Arsenic	mg/kg	8.0	8.1	7.7	12.5	16.6	17.2
Cadmium	mg/kg	0.2	0.3	0.2	0.2	0.2	0.2
Copper	mg/kg	14.3	17.0	15.0	24.5	25.8	19.3
Lead	mg/kg	18	19	18	25.5	28	25
Mercury	mg/kg	0.03	0.03	0.03	0.04	0.04	0.04
Molybdenum	mg/kg	0.7	0.8	0.7	1.2	1.7	1.4
Nickel	mg/kg	15	16	15	24	22	17
Selenium	mg/kg	0.4	0.4	0.4	1.0	1.2	1.0
Zinc	mg/kg	55	58	54	91	87	73
Gross alpha	pCi/g	25 ± 7	30 ± 8	19 ± 6	22 ± 7	23 ± 7	24 ± 7
Gross beta	pCi/g	25 ± 5	20 ± 5	25 ± 5	26 ± 5	26 ± 5	26 ± 5
Plutonium 238	pCi/g	-0.01 ± 0.02	0.006 ± 0.015	-0.009 ± 0.018	-0.002 ± 0.016	0.004 ± 0.011	0.000 ± 0.014
Plutonium 239+240	pCi/g	0.005 ± 0.015	0.002 ± 0.013	0.002 ± 0.013	0.018 ± 0.020	0.018 ± 0.019	0.000 ± 0.011

**Table 5.** Methods used to analyze ground-water samples collected near Deer Trail, Colorado, 2001.

[MRL, minimum reporting level, and dilutions for samples having high specific conductance may result in higher MRL's for some samples; ICP, inductively coupled plasma; AA, atomic absorption spectrometry; MS, mass spectroscopy; ASF, automated segmented-flow spectrophotometry; IC, ion chromatography; CVAA, cold vapor atomic absorption spectrometry; CVAF, cold vapor atomic fluorescence spectrometry;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $\text{mg}/\text{L}$ , milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter]

Property or constituent	Units	Analytical method	MRL	Method Reference
Major ions and mineral characteristics				
Specific conductance, lab	$\mu\text{S}/\text{cm}$	Wheatstone bridge	2.6	Fishman and Friedman (1989)
pH, lab	units	Electrometric electrode	0.1	Fishman and Friedman (1989)
Calcium, dissolved	$\text{mg}/\text{L}$	ICP	0.02	Fishman (1993)
Magnesium, dissolved	$\text{mg}/\text{L}$	ICP	0.014	Fishman (1993)
Sodium, dissolved	$\text{mg}/\text{L}$	ICP	0.09	Fishman (1993)
Potassium, dissolved	$\text{mg}/\text{L}$	AA	0.24	Fishman and Friedman (1989)
Acid-neutralizing capacity, lab as $\text{CaCO}_3$	$\text{mg}/\text{L}$	Electrometric titration	1	Fishman and Friedman (1989)
Sulfate, dissolved	$\text{mg}/\text{L}$	IC	0.31	Fishman and Friedman (1989)
Chloride, dissolved	$\text{mg}/\text{L}$	IC	0.29	Fishman and Friedman (1989)
Fluoride, dissolved	$\text{mg}/\text{L}$	Colorimetry, ASF, ion-selective electrode	0.1	Fishman and Friedman (1989)
Bromide, dissolved	$\text{mg}/\text{L}$	Colorimetry, ASF, fluorescein	0.01	Fishman and Friedman (1989)
Silica, dissolved	$\text{mg}/\text{L}$	ICP	0.09	Fishman (1993)
Dissolved solids, residue at $180^\circ\text{C}$	$\text{mg}/\text{L}$	Gravimetric	10	Fishman and Friedman (1989)
Nutrients				
Nitrite plus nitrate, dissolved as N	$\text{mg}/\text{L}$	Colorimetry, ASF, cadmium reduction, diazotization	0.037	Fishman (1993)
Nitrogen, ammonia, dissolved as N	$\text{mg}/\text{L}$	Colorimetry, ASF, salicylate-hypochlorite	0.029	Fishman (1993)
Nitrogen, ammonia plus organic, total as N	$\text{mg}/\text{L}$	Colorimetry, ASF, microkjeldahl digestion	0.1	Patton and Truitt (2000)
Nitrogen, ammonia plus organic, dissolved as N	$\text{mg}/\text{L}$	Colorimetry, ASF, microkjeldahl digestion	0.1	Patton and Truitt (2000)
Phosphorus, total as P	$\text{mg}/\text{L}$	Colorimetry, ASF, microkjeldahl digestion	0.05	Patton and Truitt (1992)
Phosphorus, dissolved as P	$\text{mg}/\text{L}$	Colorimetry, ASF, microkjeldahl digestion	0.05	Patton and Truitt (1992)
Trace elements				
Aluminum, dissolved as Al	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Antimony, dissolved as Sb	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Arsenic, dissolved as As	$\mu\text{g}/\text{L}$	Hydride generation	2	Jones and Garbarino (1999)
Barium, dissolved as Ba	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Beryllium, dissolved as Be	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Boron, dissolved as B	$\mu\text{g}/\text{L}$	ICP-MS	16	Struzeski, DeGiacomo, and Zayhowski (1996)
Cadmium, dissolved as Cd	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Chromium, dissolved as Cr	$\mu\text{g}/\text{L}$	GF AA	0.8	McClain (1993)
Cobalt, dissolved as Co	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Copper, dissolved as Cu	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Iron, dissolved as Fe	$\mu\text{g}/\text{L}$	ICP	3	Fishman (1993)
Lead, dissolved as Pb	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)

**Table 5.** Methods used to analyze ground-water samples collected near Deer Trail, Colorado, 2001.—Continued

[MRL, minimum reporting level, and dilutions for samples having high specific conductance may result in higher MRL's for some samples; IC P, inductively coupled plasma; AA, atomic absorption spectrometry; MS, mass spectroscopy; ASF, automated segmented-flow spectrophotometry; IC, ion chromatography; CVAA, cold vapor atomic absorption spectrometry; CVAF, cold vapor atomic fluorescence spectrometry;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $\text{mg}/\text{L}$ , milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter]

Property or constituent	Units	Analytical method	MRL	Method Reference
Manganese, dissolved as Mn	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Mercury, dissolved as Hg	$\mu\text{g}/\text{L}$	CVAF <sup>1</sup>	0.02	Garbarino and Damrau (2001)
Molybdenum, dissolved as Mo	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Nickel, dissolved as Ni	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Selenium, dissolved as Se	$\mu\text{g}/\text{L}$	Hydride generation	2.4	Jones and Garbarino (1999)
Silver, dissolved as Ag	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Strontium, dissolved as Sr	$\mu\text{g}/\text{L}$	ICP	1	Fishman (1993)
Zinc, dissolved as Zn	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Radioactivity				
Uranium, natural, dissolved	$\mu\text{g}/\text{L}$	ICP-MS	1	Faires (1993)
Plutonium-238, dissolved	pCi/L	Alpha spectrometry	20.1	Not available
Plutonium-239+240, dissolved	pCi/L	Alpha spectrometry	20.1	Not available

<sup>1</sup> Method was hydride generation for January 2001 samples; method reference is Fishman and Friedman (1989).

<sup>2</sup> Contractual MDC; reported value may be lower depending upon the sample.

**Table 6.** Information for U.S. Geological Survey monitoring wells near Deer Trail, Colorado, 2001.

[Latitude and longitude are in the format degrees minutes seconds referenced to NAD83; bmp, below measuring point (stickup); Wells shown in bold are sampled for water quality; Elev., elevation in feet above NAVD88; Metro, Metro Wastewater Reclamation District]

Well	Latitude	Longitude	County	Date drilled	Stickup (feet)	Total depth (feet bmp)	Screened interval		Screen length (feet)	Screen opening (inches)	Sump length (feet)	Elev. of measuring point (feet)	Property owner	Well diameter (inches)
							Top (feet bmp)	Bottom (feet bmp)						
<b>DTX1</b>	394333	1035251	ARAPAHOE	02/16/99	2.56	25.50	20.59	22.19	1.60	0.010	3.31	4,909	Metro	2
<b>DTX2*</b>	394149	1035138	ARAPAHOE	02/16/99	3.23	20.50	15.59	17.19	1.60	0.010	3.31	4,903	Metro	2
<b>DTX3</b>	393024	1034328	ELBERT	02/12/99	3.11	18.71	13.80	15.40	1.60	0.010	3.31	5,195	Metro	2
<b>DTX4</b>	393358	1034342	ELBERT	02/10/99	2.70	16.72	11.81	13.41	1.60	0.010	3.31	4,957	Metro	2
<b>DTX5*</b>	393358	1034548	ELBERT	02/10/99	2.30	20.90	16.09	17.69	1.60	0.010	3.21	4,975	Metro	2
<b>DTX6</b>	393358	1034648	ELBERT	02/9/99	2.43	39.21	34.30	35.90	1.60	0.010	3.31	4,970	Metro	2
DTX7	394054	1035646	ARAPAHOE	02/18/99	2.77	16.10	11.19	12.79	1.60	0.010	3.31	5,075	Price	2
<b>DTX8A</b>	394054	1035645	ARAPAHOE	03/2/99	2.46	77.52	67.56	71.83	4.27	0.010	5.69	5,076	Price	2
DTX8B	394054	1035645	ARAPAHOE	03/2/99	2.49	177.48	167.52	171.79	4.27	0.010	5.69	5,076	Price	2
DTX9*	393902	1035540	ARAPAHOE	02/17/99	2.46	30.15	22.72	24.32	1.60	0.010	5.83	5,121	Weisensee	2
<b>DTX10A*</b>	393902	1035540	ARAPAHOE	03/4/99	2.03	61.97	52.01	56.28	4.27	0.010	5.69	5,122	Weisensee	2
DTX10B	393902	1035540	ARAPAHOE	03/4/99	2.11	121.73	111.77	116.04	4.27	0.010	5.69	5,122	Weisensee	2
DTX11*	393902	1035540	ARAPAHOE	01/19/00	2.24	32	28	30	1.85	0.020	2.35	5,122	Weisensee	2
<b>D6</b>	393633	1035122	ARAPAHOE	09/12/93	2.65	25	15	25	10	0.010	0.3	5,128.78	Metro	2
D11a	393345	1035423	ELBERT	10/23/97	2.46	143.03	112.65	122.65	10	0.010	20.38	5,377	Metro	2
<b>D13</b>	393442	1035438	ARAPAHOE	04/4/94	1.81	16	6	16	10	0.010	0.3	5,235.33	Metro	2
<b>D17</b>	393334	1035436	ELBERT	04/5/94	0.90	21	11	21	10	0.010	0.3	5,277.73	Metro	2
<b>D25*</b>	393702	1035442	ARAPAHOE	05/1/95	2.23	23	13	23	10	0.010	0.3	5,167.13	Metro	2
<b>D29</b>	393641	1035248	ARAPAHOE	11/4/97	2.38	183.19	147.81	157.81	10	0.010	25.38	5,371	Metro	2
<b>D30</b>	393655	1035122	ARAPAHOE	05/5/95	1.98	19	9	19	10	0.010	0.3	5,096.43	Metro	2

\*Wells having continuous-recorder equipment.

**Table 7. Monthly water-level data for U.S. Geological Survey monitoring wells near Deer Trail, Colorado, 2001.**

[Et1, Solinst electric tape; Et2, Slope Indicator electric tape; Et3, Keck electric tape; ST, steel tape; \*, Data Collection Platform or Electronic Data Logger continuous-recorder site; W.L. bmp, water level below measuring point, in feet]

Well	January (01/06/01)		February (02/06/01)		March (03/05/01)		April (04/02/01)		May (05/11/01)		June (06/06/01)		July (07/04/01)		August (08/02/02 - 08/10/01)		September (09/06/01)		October (10/04/01)		November (11/02/01)		December (12/06/01)	
	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et1	W.L. bmp, Et2, ST	W.L. bmp, Et3, Et2	W.L. bmp, Et3	W.L. bmp, Et3	W.L. bmp, Et3	W.L. bmp, Et3	W.L. bmp, Et3	W.L. bmp, Et3
DTX1	9.60	9.60	9.60	9.60	9.60	9.60	9.44	9.44	6.80	7.71	8.25	8.25	8.25	8.25	8.25	8.25	8.26	8.49	8.58	8.58	8.58	8.58	8.58	8.58
DTX2*	8.33	8.19	7.95	7.95	7.95	7.95	7.69	7.69	7.04	7.62	8.43	8.43	9.24	9.24	9.24	9.24	9.44	9.35	9.07	9.07	9.07	9.07	9.07	8.78
DTX3	10.54	10.72	10.89	10.89	11.02	10.20	11.02	11.02	9.93	10.20	10.53	10.53	10.04	10.04	10.04	10.04	10.53	10.78	10.92	10.92	10.92	10.92	10.92	11.07
DTX4	12.82	12.92	13.01	13.01	13.06	8.56	13.06	13.06	6.13	8.56	10.54	10.54	11.73	11.73	11.73	11.73	11.69	13.18	13.43	13.43	13.43	13.43	13.43	13.47
DTX5*	12.00	12.07	12.22	12.22	12.12	9.89	12.12	12.12	7.36	9.89	10.81	10.81	11.54	11.54	11.54	11.54	11.98	12.23	12.27	12.27	12.27	12.27	12.27	12.24
DTX6	22.69	22.75	22.80	22.80	22.63	21.02	22.63	22.63	21.05	21.02	21.47	21.47	21.58	21.58	21.58	21.58	21.73	21.98	22.18	22.18	22.18	22.18	22.18	22.33
DTX7	8.13	7.98	7.94	7.94	7.75	6.84	7.75	7.75	6.12	6.84	7.51	7.51	7.74	7.74	7.74	7.74	8.48	8.63	8.35	8.35	8.35	8.35	8.10	
DTX8A	8.50	8.32	8.28	8.28	8.04	7.16	8.04	8.04	5.97	7.16	8.24	8.24	8.54	8.54	8.54	8.54	9.37	9.54	9.27	9.27	9.27	9.27	8.58	
DTX8B	4.77	4.74	4.79	4.79	4.66	4.62	4.66	4.66	4.50	4.62	4.72	4.72	4.76	4.76	4.76	4.76	4.88	4.89	4.93	4.93	4.93	4.93	4.80	
DTX9*	12.89	12.88	12.99	12.99	12.90	11.94	12.90	12.90	12.00	11.94	12.18	12.18	12.43	12.43	12.43	12.43	12.48	12.59	12.68	12.68	12.68	12.68	12.69	
DTX10A*	13.11	13.14	13.21	13.21	13.09	11.96	13.09	13.09	11.78	11.96	12.42	12.42	12.70	12.70	12.70	12.70	12.74	12.83	12.91	12.91	12.91	12.91	12.95	
DTX10B	18.32	18.23	18.24	18.24	18.08	17.93	18.08	18.08	17.72	17.93	18.14	18.14	18.35	18.35	18.35	18.35	18.42	18.53	18.56	18.56	18.56	18.56	18.51	
DTX11*	13.22	13.22	13.31	13.31	13.22	12.29	13.22	13.22	12.35	12.29	12.52	12.52	12.76	12.76	12.76	12.81	12.81	12.93	13.01	13.01	13.01	13.01	13.02	
D6	9.23	9.42	9.40	9.40	9.16	6.31	9.16	9.16	7.36	6.31	7.21	7.21	8.03	8.03	8.03	8.45	7.98	7.98	9.36	9.36	9.36	9.36	9.45	
D9	57.75	57.78	57.84	57.84	57.75	57.85	57.75	57.75	57.88	57.85	57.80	57.80	57.74	57.74	57.74	57.53	57.53	57.57	57.57	57.57	57.57	57.57	57.50	
D11a	112.92	112.91	113.15	113.15	112.92	113.13	112.92	112.92	113.31	113.13	113.04	113.04	113.00	113.00	113.00	112.53	112.85	112.85	112.92	112.92	112.92	112.92	112.84	
D13	7.42	7.25	7.08	7.08	6.55	6.04	6.55	6.55	4.55	6.04	7.13	7.13	7.32	7.32	7.32	7.47	7.72	7.72	7.50	7.50	7.50	7.50	7.06	
D17	12.34	12.27	12.18	12.18	12.10	10.76	12.10	12.10	11.06	10.76	10.87	10.87	11.08	11.08	11.08	11.12	11.27	11.27	11.37	11.37	11.37	11.37	11.45	
D19	20.94	21.02	21.11	21.11	21.16	21.18	21.16	21.16	21.21	21.18	21.22	21.22	21.24	21.24	21.24	21.13	21.17	21.17	21.18	21.18	21.18	21.18	21.19	
D25*	9.41	9.51	9.57	9.57	9.49	7.38	9.49	9.49	6.81	7.38	8.35	8.35	8.56	8.56	8.56	9.28	9.71	9.71	9.92	9.92	9.92	9.92	10.00	
D29	154.14	154.18	154.54	154.54	154.03	154.36	154.03	154.03	154.63	154.36	154.46	154.46	154.44	154.44	154.44	154.45	154.45	154.10	154.24	154.24	154.24	154.24	154.12	
D30	4.33	4.31	4.31	4.31	4.23	4.31	4.23	4.23	3.57	4.31	4.73	4.73	4.59	4.59	4.59	4.85	4.97	4.97	4.79	4.79	4.79	4.79	4.32	



**Table 8.** Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.

[ $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $\text{mg}/\text{L}$ , milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter; <, less than;  $^{\circ}\text{C}$ , degrees Celsius; ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; --, no sample submitted; analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Specific conductance, field ( $\mu\text{S}/\text{cm}$ )	pH, field (standard units)	Water temperature ( $^{\circ}\text{C}$ )	Water level before			Oxygen, dissolved (mg/L)	Air temperature ( $^{\circ}\text{C}$ )	Specific conductance, lab ( $\mu\text{S}/\text{cm}$ )	pH, WH, laboratory (standard units)	Hardness, total (mg/L as $\text{CaCO}_3$ )
						measuring point (feet)	depth below	sampling, depth below					
DTX1	01/05/01	1000	4,000	7.2	12.0	9.60		0.6	9	4,160	7.3	2,000	
DTX1	04/09/01	0945	4,200	7.0	10.0	9.45		.6	11	4,100	7.3	2,100	
DTX1	07/11/01	1635	4,300	7.1	11.0	8.38		.7	28	3,990	7.3	2,000	
DTX1	10/12/01	0950	4,000	7.0	11.0	8.52		1.4	6	4,060	7.3	2,000	
DTX2	01/05/01	1215	4,200	7.0	12.0	5.31		.8	18	4,380	7.1	2,100	
DTX2	04/09/01	1120	4,500	6.8	10.0	7.78		.8	15	4,330	7.1	2,100	
DTX2	07/13/01	1150	4,400	6.8	12.0	8.70		1.2	31	4,180	7.1	2,100	
DTX2	10/12/01	1130	4,200	6.8	11.0	9.23		2.1	7	4,270	7.1	2,100	
DTX3	01/04/01	1005	2,100	6.9	11.0	10.50		4.6	10	2,160	7.3	1,100	
DTX3	04/05/01	1020	2,100	6.8	9.0	11.03		6.0	17	2,140	7.2	1,100	
DTX3	07/10/01	1430	2,200	6.9	13.0	10.60		5.6	33	2,070	7.3	1,000	
DTX3	10/10/01	1340	1,800	6.8	9.0	10.81		ND	14	1,700	7.3	760	
DTX4	01/04/01	1210	3,100	6.8	12.0	12.75		3.4	17	3,200	7.0	1,800	
DTX4	04/05/01	1200	3,100	6.8	12.0	13.07		7.4	19	3,130	7.1	1,900	
DTX4	07/11/01	1430	2,900	6.8	12.0	10.87		1.2	36	2,680	7.1	1,400	
DTX4	10/11/01	1530	3,100	6.9	16.0	13.26		ND	14	--	--	1,800	
DTX5	01/04/01	1430	3,000	6.9	11.0	11.94		1.0	18	3,050	7.2	1,600	
DTX5	04/05/01	1335	3,200	6.8	10.0	12.15		1.6	26	3,140	7.2	1,700	
DTX5	07/12/01	1240	2,900	6.8	12.0	11.02		.8	32	2,770	7.2	1,600	
DTX5	10/11/01	1430	2,900	6.8	13.0	12.19		.8	21	2,840	7.1	1,600	
DTX6	01/08/01	1040	4,100	7.2	12.0	22.69		1.4	3	4,310	7.2	2,400	
DTX6	04/06/01	1020	4,300	6.9	13.0	22.60		1.5	18	4,330	7.2	2,300	
DTX6	07/12/01	1420	4,600	6.9	14.0	21.57		2.3		4,270	7.2	2,300	
DTX6	10/11/01	1300	4,300	6.9	13.0	22.02		1.3	23	4,260	7.1	2,300	
DTX8A	01/05/01	1445	1,840	7.5	15.0	8.49		3.4	19	1,920	7.5	470	
DTX8A	04/06/01	1420	1,900	7.3	15.0	8.02		5.4	24	1,910	7.6	500	
DTX8A	07/11/01	1230	2,000	7.4	15.0	8.43		1.4	31	1,900	7.6	510	
DTX8A	10/12/01	1400	1,900	7.4	13.0	9.46		.4	15	1,900	7.5	490	

**Table 8.** Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued

[ $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $\text{mg}/\text{L}$ , milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter; < less than;  $^{\circ}\text{C}$ , degrees Celsius; ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; —, no sample submitted; analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Specific conductance, field ( $\mu\text{S}/\text{cm}$ )	pH, field (standard units)	Water temperature ( $^{\circ}\text{C}$ )	Water level before		Oxygen, dissolved (mg/L)	Air temperature ( $^{\circ}\text{C}$ )	Specific conductance, lab ( $\mu\text{S}/\text{cm}$ )	pH, WH, laboratory (standard units)	Hardness, total (mg/L as $\text{CaCO}_3$ )
						depth	measuring point (feet)					
DTX10A	01/09/01	1310	2,900	7.3	13.0	13.11	1.0	16	3,180	7.2	1,800	
DTX10A	04/09/01	1315	3,200	7.0	16.0	13.15	4.5		3,130	7.2	1,800	
DTX10A	07/12/01	1020	3,300	6.8	17.0	12.50	1.3	28	3,110	7.2	1,800	
DTX10A	10/15/01	1345	3,000	7.0	14.0	13.01	3.8	8	3,100	7.1	1,800	
D6	01/08/01	1250	15,000	7.2	12.0	9.23	.6		16,300	7.1	9,900	
D6	04/04/01	1435	16,000	6.8	11.0	9.16	.3	12	16,700	7.0	9,900	
D6	07/10/01	1015	18,000	6.9	12.0	7.31	1.1	22	16,600	7.1	11,000	
D6	10/10/01	1545	14,000	7.1	7.0	9.00	ND	12	16,300	7.1	10,000	
D13	01/09/01	1025	1,400	7.2	8.0	7.41	1.0	12	1,520	7.4	740	
D13	04/10/01	0945	1,400	7.1	6.0	6.56	.8	5	1,450	7.4	710	
D13	07/13/01	0955	1,800	6.9	13.0	7.31	.8	26	1,710	7.3	870	
D13	10/15/01	1010	1,600	7.0	13.0	7.64	.8	7	1,570	7.2	790	
D17	01/03/01	1340	500	7.5	12.0	12.34	.7	11	480	7.7	230	
D17	04/06/01	1225	500	7.3	11.0	12.08	.8	19	484	7.7	220	
D17	07/09/01	1315	500	7.4	13.0	10.91	.7	32	501	7.8	220	
D17	10/16/01	1210	500	7.5	14.0	11.33	.9	22	497	7.4	220	
D25	01/03/01	1530	4,900	7.1	12.0	7.22	.3	11	4,920	7.3	2,800	
D25	04/10/01	1120	4,600	7.1	9.0	9.48	.9	6	4,850	7.3	2,700	
D25	07/09/01	1500	5,000	6.9	13.0	8.52	.6	35	4,720	7.3	2,600	
D25	10/15/01	1150	4,400	7.0	12.0	9.82	.8	7	4,620	7.2	3,100	
D29	01/03/01	1055	3,900	6.7	20.0	154.63	5.6	11	4,000	6.9	2,700	
D29	04/04/01	1135	4,000	6.5	17.0	154.30	3.6	10	4,090	6.8	2,700	
D29	07/09/01	1115	4,200	6.6	22.0	154.45	5.0	26	4,040	6.8	2,700	
D29	10/10/01	1040	4,200	6.5	9.0	154.21	ND	15	4,030	6.8	2,600	
D30	01/08/01	1510	4,700	7.2	10.0	4.33	.7	17	4,930	7.1	2,800	
D30	04/04/01	1630	5,000	6.8	9.0	4.25	.8	17	5,040	7.1	2,800	
D30	07/10/01	1240	5,300	6.8	12.0	4.77	.5	26	5,050	7.2	2,900	
D30	10/16/01	1000	4,800	6.8	13.0	4.83	.6	15	5,020	7.6	2,900	

**Table 8.** Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued

[ $\mu$ S/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter;  $\mu$ g/L, micrograms per liter; <, less than; °C, degrees Celsius; ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; —, no sample submitted; analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Sodium adsorption ratio	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Acid neutralizing capacity, titration to pH 4.5, lab (mg/L as CaCO <sub>3</sub> )	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO <sub>2</sub> )
DTX1	01/05/01	1000	479	204	3.54	3	340	27	312	44.3	0.8	32.4
DTX1	04/09/01	0945	483	206	3.16	3	339	26	312	45.9	.8	31.1
DTX1	07/11/01	1635	461	207	2.89	3	351	28	306	45.3	.7	32.2
DTX1	10/12/01	0950	456	205	3.24	3	342	27	310	47.5	.7	33.8
DTX2	01/05/01	1215	515	206	8.35	4	397	29	416	45.2	.5	17.1
DTX2	04/09/01	1120	499	194	8.59	4	414	30	425	47.9	.5	15.3
DTX2	07/13/01	1150	473	214	6.76	4	395	29	412	36.4	.5	16.4
DTX2	10/12/01	1130	481	210	7.83	4	383	29	414	44.7	.5	17.2
DTX3	01/04/01	1005	251	103	7.88	1	106	18	320	31.6	.4	16.6
DTX3	04/05/01	1020	274	104	6.78	1	112	18	304	27.4	.3	16.1
DTX3	07/10/01	1430	247	98.5	7.22	2	113	19	284	27.1	.4	16.6
DTX3	10/10/01	1340	185	72.1	6.30	1	92.5	21	299	15.9	.4	16.3
DTX4	01/04/01	1210	543	94.7	8.11	2	172	18	360	18.0	.2	10.8
DTX4	04/05/01	1200	586	93.6	7.91	2	158	16	376	15.6	.2	10.6
DTX4	07/11/01	1430	443	74.3	7.05	2	160	20	287	13.7	.2	9.9
DTX4	10/11/01	1530	550	90.9	8.80	2	158	16	—	13.7	.2	12.1
DTX5	01/04/01	1430	502	79.6	4.79	2	182	20	282	11.7	.3	11.2
DTX5	04/05/01	1335	535	82.5	5.12	2	196	20	286	10.4	.3	10.8
DTX5	07/12/01	1240	499	77.3	4.43	2	152	17	280	8.8	.3	11.6
DTX5	10/11/01	1430	492	77.0	5.11	2	160	18	280	9.9	.3	11.9
DTX6	01/08/01	1040	515	266	12.2	3	339	24	272	21.5	.5	11.6
DTX6	04/06/01	1020	479	257	13.8	3	333	24	272	19.8	.5	11.0
DTX6	07/12/01	1420	483	267	13.6	3	332	24	261	21.4	.5	11.5
DTX6	10/11/01	1300	481	267	12.6	3	331	24	266	21.9	.4	11.6
DTX8A	01/05/01	1445	138	30.9	6.32	5	238	52	224	29.2	.4	12.7
DTX8A	04/06/01	1420	146	31.1	6.84	5	240	51	227	26.2	.4	12.8
DTX8A	07/11/01	1230	149	32.6	6.17	5	242	51	222	27.4	.3	13.4
DTX8A	10/12/01	1400	142	31.7	6.18	5	234	51	225	27.2	.3	13.3

**Table 8. Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued**

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Sodium adsorption ratio	Sodium, dissolved (mg/L as Na)	Sodium (percent)	Acid neutralizing capacity, titration to pH 4.5, lab (mg/L as CaCO <sub>3</sub> )	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO <sub>2</sub> )
DTX10A	01/09/01	1310	429	165	9.83	2	156	16	223	17.6	0.9	16.1
DTX10A	04/09/01	1315	462	166	8.32	1	147	15	224	16.8	.9	16.7
DTX10A	07/12/01	1020	450	169	8.38	2	152	15	220	17.9	.9	17.1
DTX10A	10/15/01	1345	452	165	6.51	2	157	16	222	18.7	1.0	17.2
D6	01/08/01	1250	441	2,130	11.9	9	2,040	31	640	363	.8	21.8
D6	04/04/01	1435	432	2,140	13.0	9	1,990	30	647	394	.8	21.3
D6	07/10/01	1015	429	2,330	11.4	9	2,080	30	636	390	.7	21.6
D6	10/10/01	1545	425	2,210	12.6	9	1,970	30	641	423	.8	20.3
D13	01/09/01	1025	202	58.0	2.25	1	65.9	16	248	3.7	1.3	11.9
D13	04/10/01	0945	197	53.5	2.05	1.0	59.3	15	255	3.0	1.4	11.4
D13	07/13/01	0955	235	68.1	2.74	1	81.8	17	263	9.1	1.4	13.9
D13	10/15/01	1010	217	59.7	2.73	1	75.1	17	271	4.5	1.4	14.7
D17	01/03/01	1340	61.3	18.0	1.62	0.5	16.5	14	203	2.6	1.5	18.3
D17	04/06/01	1225	59.0	18.0	1.68	0.5	15.9	13	204	2.4	1.4	17.4
D17	07/09/01	1315	56.3	18.4	1.74	0.5	16.4	14	205	2.7	1.5	17.5
D17	10/16/01	1210	58.1	18.4	1.60	0.5	15.8	13	208	3.0	1.5	19.0
D25	01/03/01	1530	679	256	7.84	3	347	22	593	85.5	1.0	29.3
D25	04/10/01	1120	690	233	5.67	3	308	20	563	98.4	1.0	26.2
D25	07/09/01	1500	633	248	6.45	3	312	21	458	115	.9	27.9
D25	10/15/01	1150	838	237	6.35	3	320	18	524	95.2	1.0	32.3
D29	01/03/01	1055	563	325	10.6	1	136	10	292	13.1	.6	20.6
D29	04/04/01	1135	545	322	10.2	1	137	10	291	11.4	.5	20.3
D29	07/09/01	1115	534	331	10.7	1	143	10	289	12.8	.5	20.8
D29	10/10/01	1040	542	313	10.8	1	135	10	292	13.1	.6	20.4
D30	01/08/01	1510	447	409	.79	3	375	23	366	50.8	.8	21.4
D30	04/04/01	1630	450	404	4.22	3	354	22	370	53.7	.8	19.9
D30	07/10/01	1240	452	427	4.00	3	384	22	365	60.0	.7	21.6
D30	10/16/01	1000	463	422	3.89	3	386	22	372	60.7	.9	23.0

[μS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; μg/L, micrograms per liter; <, less than; °C, degrees Celsius  
 ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; —, no sample submitted;  
 analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Table 8. Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Sulfate, dissolved (mg/L as SO <sub>4</sub> )	Nitrogen			Nitrogen plus ammonia, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Solids, residue on evaporation at 180 °C, dissolved (mg/L)			Aluminum, dissolved (µg/L as Al)
				ammonia plus organic, dissolved (mg/L as N)	Nitrogen ammonia, dissolved (mg/L as N)	Nitrogen plus nitrate, dissolved (mg/L as N)				Dissolved solids, sum of constituents (mg/L)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	
DTX1	01/05/01	1000	2,400	0.19	0.18	1.20	0.090	0.086	4,180	3,700	1		
DTX1	04/09/01	0945	2,380	.21	< .049	1.19	.089	.111	3,980	3,690	< 1		
DTX1	07/11/01	1635	2,340	.17	< .050	1.25	.068	.080	4,100	3,640	< 2		
DTX1	10/12/01	0950	2,350	.19	E .040	1.42	.071	E .058	4,010	3,640	< 2		
DTX2	01/05/01	1215	2,450	.94	1.2	.618	< .037	< .060	4,340	3,890	< 1		
DTX2	04/09/01	1120	2,460	.91	.636	< .037	< .050	< .060	4,240	3,910	< 1		
DTX2	07/13/01	1150	2,410	.86	.540	< .037	< .050	E .036	4,280	3,810	< 2		
DTX2	10/12/01	1130	2,430	.92	.703	.046	< .050	< .060	4,250	3,830	< 2		
DTX3	01/04/01	1005	914	.22	.28	< .049	< .050	< .060	1,820	1,650	< 1		
DTX3	04/05/01	1020	944	.26	< .049	4.79	< .050	< .060	1,810	1,690	< 1		
DTX3	07/10/01	1430	873	.22	< .050	6.02	< .050	< .060	1,770	1,580	< 1		
DTX3	10/10/01	1340	623	.23	< .050	15.9	< .050	< .060	1,320	1,260	< 1		
DTX4	01/04/01	1210	1,740	.29	.42	4.37	< .050	< .060	3,080	2,830	< 1		
DTX4	04/05/01	1200	1,650	.24	E .030	1.18	< .050	< .060	3,020	2,760	1		
DTX4	07/11/01	1430	1,400	.19	< .050	.592	< .050	< .060	2,440	2,290	< 2		
DTX4	10/11/01	1530	1,670	.58	.32	< .190	< .050	< .060	2,920	2,720	< 10		
DTX5	01/04/01	1430	1,720	.13	.14	.053	< .050	< .060	2,950	2,680	1		
DTX5	04/05/01	1335	1,730	.14	.18	E .048	< .050	< .060	3,000	2,750	1		
DTX5	07/12/01	1240	1,510	.15	.16	< .050	< .050	< .060	2,640	2,440	< 2		
DTX5	10/11/01	1430	1,570	.15	.12	E .034	< .050	< .060	2,620	2,500	< 2		
DTX6	01/08/01	1040	2,690	E .07	.28	< .049	< .050	< .060	4,400	4,030	2		
DTX6	04/06/01	1020	2,650	.11	.19	< .049	< .050	< .060	4,310	3,940	1		
DTX6	07/12/01	1420	2,660	.11	.14	< .050	< .050	< .060	4,440	3,950	< 2		
DTX6	10/11/01	1300	2,690	.15	.11	E .041	< .050	< .060	4,410	3,980	< 2		
DTX8A	01/05/01	1445	765	1.6	1.5	1.38	< .037	< .060	1,420	1,360	2		
DTX8A	04/06/01	1420	764	1.5	1.6	1.39	< .037	< .060	1,440	1,370	2		
DTX8A	07/11/01	1230	748	1.4	1.6	1.36	< .037	< .060	1,420	1,360	2		
DTX8A	10/12/01	1400	766	1.5	1.4	1.44	< .040	< .060	1,440	1,360	2		

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; °C, degrees Celsius  
 ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; --, no sample submitted;  
 analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

**Table 8. Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued**

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; °C, degrees Celsius; ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; --, no sample submitted; analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Sulfate, dissolved (mg/L as SO <sub>4</sub> )	Nitrogen ammonia plus organic, dissolved (mg/L as N)	Nitrogen ammonia plus organic, total (mg/L as N)	Nitrogen ammonia, dissolved (mg/L as N)	Nitrogen plus nitrate, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Solids, residue on evaporation at 180° C, dissolved (mg/L)	Dissolved solids, sum of constituents (mg/L)	Aluminum, dissolved (µg/L as Al)
DTX10A	01/09/01	1310	1,850	1.5	1.3	1.25	< .037	< .050	< .060	3,010	2,790	< 1
DTX10A	04/09/01	1315	1,880	1.4	1.4	1.25	< .037	< .050	< .060	3,060	2,840	< 1
DTX10A	07/12/01	1020	1,870	1.2	1.3	1.25	< .037	< .050	< .060	3,000	2,830	< 2
DTX10A	10/15/01	1345	1,890	1.2	1.3	1.39	.058	< .050	E .032	3,020	2,860	< 2
D6	01/08/01	1250	13,000	1.6	1.5	.056	15.3	E .033	< .060	21,000	18,500	2
D6	04/04/01	1435	13,000	.68	.98	.051	16.5	E .034	< .060	21,100	18,400	1
D6	07/10/01	1015	13,500	.36	.56	.060	16.0	< .050	< .060	22,300	19,200	< 7
D6	10/10/01	1545	13,300	1.3	1.6	.052	15.9	< .050	E .034	20,800	18,900	< 7
D13	01/09/01	1025	636	.13	.15	E .026	E .019	< .050	< .060	1,200	1,130	< 1
D13	04/10/01	0945	580	.15	.14	< .049	< .037	< .050	< .060	1,140	1,060	< 1
D13	07/13/01	0955	752	.24	.21	< .050	< .037	< .050	< .060	1,440	1,320	< 1
D13	10/15/01	1010	666	.21	.21	.058	.042	< .050	E .047	1,260	1,210	< 1
D17	01/03/01	1340	49.9	.11	E .05	< .049	.648	.094	.064	293	295	< 1
D17	04/06/01	1225	51.6	E .08	E .07	< .049	.603	.096	.091	297	293	< 1
D17	07/09/01	1315	46.0	E .07	.10	< .050	2.03	.065	.083	305	293	< 1
D17	10/16/01	1210	48.2	E .10	E .09	< .050	1.90	.078	.083	302	300	< 1
D25	01/03/01	1530	2,870	.91	.89	E .036	4.05	.178	.163	5,230	4,660	< 1
D25	04/10/01	1120	2,710	.72	.68	E .029	2.47	.137	.128	4,860	4,430	< 1
D25	07/09/01	1500	2,640	.53	.63	E .038	1.62	.100	.146	4,550	4,280	< 2
D25	10/15/01	1150	2,750	.70	.67	.054	4.80	.129	.140	4,790	4,630	< 2
D29	01/03/01	1055	2,680	.43	.46	.441	< .037	< .050	.066	4,280	3,940	< 1
D29	04/04/01	1135	2,610	.47	.45	.407	< .037	< .050	.272	4,300	3,840	2
D29	07/09/01	1115	2,690	.37	.45	.397	< .037	< .050	< .060	4,310	3,930	< 2
D29	10/10/01	1040	2,650	.43	.45	.410	.053	< .050	.123	4,260	3,870	< 2
D30	01/08/01	1510	3,100	.26	.29	.059	< .037	E .034	E .039	5,230	4,630	3
D30	04/04/01	1630	3,130	.28	.29	.056	E .025	E .034	E .038	5,170	4,640	< 1
D30	07/10/01	1240	3,290	.31	.27	.084	< .037	E .030	E .031	5,370	4,870	< 3
D30	10/16/01	1000	3,150	.27	.36	.114	.041	E .030	E .049	5,360	4,740	< 3

**Table 8. Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued**

[ $\mu\text{S/cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $\text{mg/L}$ , milligrams per liter;  $\mu\text{g/L}$ , micrograms per liter;  $^{\circ}\text{C}$ , degrees Celsius; ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; —, no sample submitted; analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Antimony, dissolved ( $\mu\text{g/L as Sb}$ )	Arsenic, dissolved ( $\mu\text{g/L as As}$ )	Barium, dissolved ( $\mu\text{g/L as Ba}$ )	Beryllium, dissolved ( $\mu\text{g/L as Be}$ )	Boron, dissolved ( $\mu\text{g/L as B}$ )	Bromide, dissolved ( $\text{mg/L as Br}$ )	Cadmium, dissolved ( $\mu\text{g/L as Cd}$ )	Chromium, dissolved ( $\mu\text{g/L as Cr}$ )	Cobalt, dissolved ( $\mu\text{g/L as Co}$ )	Copper, dissolved ( $\mu\text{g/L as Cu}$ )	Iron, dissolved ( $\mu\text{g/L as Fe}$ )
DTX1	01/05/01	1000	0.18	E 1.4	8.4	<0.06	565	0.71	0.10	2.0	0.89	8.8	<30
DTX1	04/09/01	0945	.32	E 1.1	7.8	<.06	521	.82	.11	<.8	.70	8.9	<50
DTX1	07/11/01	1635	E .08	2.7	7.2	<.10	572	.70	E .04	.9	.92	11.7	<30
DTX1	10/12/01	0950	<.10	2.4	8.2	<.10	609	.72	.11	1.4	.53	21.7	<30
DTX2	01/05/01	1215	.30	<2.0	14.5	<.06	322	.61	E .03	2.5	5.01	8.0	460
DTX2	04/09/01	1120	.14	<2.0	13.6	<.06	289	.67	<.04	<.8	4.82	9.4	460
DTX2	07/13/01	1150	E .08	<2.0	12.4	<.10	378	.50	<.07	3.2	4.52	12.6	490
DTX2	10/12/01	1130	<.10	<2.0	15.1	<.10	351	.65	<.07	2.1	4.57	23.5	560
DTX3	01/04/01	1005	E .05	<2.0	19.4	<.06	210	.27	<.04	<.8	.57	4.1	<30
DTX3	04/05/01	1020	.05	<2.0	16.4	<.06	243	.25	<.04	<.8	.57	6.1	<30
DTX3	07/10/01	1430	E .04	<2.0	15.5	<.06	227	.28	E .04	1.1	.39	5.9	<30
DTX3	10/10/01	1340	<.05	<2.0	14.9	<.06	234	.19	E .02	E .6	.25	5.5	<10
DTX4	01/04/01	1210	.05	<2.0	13.7	<.06	268	.32	.04	<.8	1.30	7.7	<30
DTX4	04/05/01	1200	.08	<2.0	12.6	<.06	264	.31	.05	1.9	1.56	12.5	<30
DTX4	07/11/01	1430	E .06	E 1.3	10.3	<.10	227	.14	<.07	.9	.94	8.9	<30
DTX4	10/11/01	1530	2.75	E 1.2	14.5	<.60	406	.23	<.40	2.1	1.98	6.7	180
DTX5	01/04/01	1430	.23	<2.0	14.3	<.06	423	.24	E .02	<.8	1.55	6.4	130
DTX5	04/05/01	1335	.39	<2.0	12.9	E .03	418	.28	E .03	2.0	1.41	11.2	40
DTX5	07/12/01	1240	.76	<2.0	12.9	<.10	379	.22	<.07	1.1	1.31	8.5	<30
DTX5	10/11/01	1430	<.10	E 1.2	12.6	<.10	412	.25	.08	1.9	1.05	16.6	40
DTX6	01/08/01	1040	.07	<2.0	8.8	<.06	372	.18	<.04	3.4	.93	9.9	<50
DTX6	04/06/01	1020	.05	<2.0	8.5	<.06	370	.18	<.07	<.8	.92	15.6	<30
DTX6	07/12/01	1420	<.10	<2.0	8.0	<.10	338	.15	<.07	4.7	.70	11.4	<30
DTX6	10/11/01	1300	<.10	E 1.0	8.2	<.10	354	.15	E .04	2.0	.62	27.5	<30
DTX8A	01/05/01	1445	.07	<2.0	16.5	<.06	245	.26	<.04	<.8	.88	2.6	250
DTX8A	04/06/01	1420	.07	<2.0	16.5	<.06	255	.31	<.04	<.8	.89	5.3	290
DTX8A	07/11/01	1230	<.05	<2.0	15.1	<.06	269	.31	<.04	<.8	.94	3.4	340
DTX8A	10/12/01	1400	<.05	<2.0	15.5	<.06	260	.34	<.04	<.8	.69	7.2	420

**Table 8. Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued**

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; °C, degrees Celsius  
 ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; --, no sample submitted;  
 analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Boron, dissolved (µg/L as B)	Bromide, dissolved (mg/L as Br)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)	Iron, dissolved (µg/L as Fe)
DTX10A	01/09/01	1310	0.06	<2.0	12.5	E 0.04	226	0.25	<0.04	<0.8	1.02	6.3	4,020
DTX10A	04/09/01	1315	.20	<2.0	12.6	<.06	247	.29	<.04	<.8	.67	6.6	4,230
DTX10A	07/12/01	1020	<.10	<2.0	12.8	<.10	239	.27	<.07	<.8	.80	7.8	4,140
DTX10A	10/15/01	1345	<.10	E 1.1	12.1	<.10	233	.33	<.07	E .8	.59	19.1	4,260
D6	01/08/01	1250	.24	<4.0	5.7	<.06	855	4.21	.10	<.8	7.23	37.8	<150
D6	04/04/01	1435	.15	E 3.1	5.2	<.06	967	4.48	.10	<1.6	7.31	57.5	<150
D6	07/10/01	1015	<.30	2.4	<7.0	<.40	872	4.35	E .22	E 1.1	7.11	58.7	<100
D6	10/10/01	1545	<.30	18.3	<7.0	<.40	670	4.69	E .25	<1.6	6.63	103	<300
D13	01/09/01	1025	.08	<2.0	20.4	<.06	80	.18	E .02	<.8	.51	2.6	<10
D13	04/10/01	0945	.10	<2.0	18.3	<.06	71	.16	<.04	<.8	.44	2.6	M
D13	07/13/01	0955	.06	<2.0	22.2	<.06	109	.20	<.04	.9	.63	5.0	10
D13	10/15/01	1010	<.05	<2.0	22.5	<.06	116	.17	<.04	<.8	.46	5.7	20
D17	01/03/01	1340	.06	E 1.4	59.8	<.06	65	.08	E .02	<.8	.22	.7	<10
D17	04/06/01	1225	.10	E 1.3	59.4	<.06	61	.06	E .02	<.8	.21	.6	<10
D17	07/09/01	1315	.06	E 1.5	59.1	<.06	58	.06	E .02	<.8	.20	.5	<10
D17	10/16/01	1210	.07	E 1.2	55.7	<.06	64	.07	E .02	<.8	.21	.8	<10
D25	01/03/01	1530	.15	3.2	19.6	<.06	542	1.44	.24	<.8	3.39	11.1	<10
D25	04/10/01	1120	.34	2.1	18.2	<.06	370	1.66	.21	<.8	2.78	11.2	<50
D25	07/09/01	1500	.19	2.7	17.3	<.10	422	1.56	.17	3.0	3.04	12.0	<30
D25	10/15/01	1150	<.10	2.6	20.1	<.10	459	1.70	.23	2.7	3.17	28.5	<30
D29	01/03/01	1055	<.05	<2.0	8.9	<.06	191	.20	<.04	<.8	1.49	9.1	7,150
D29	04/04/01	1135	E .04	<2.0	9.0	E .03	200	.17	.04	2.1	1.48	13.9	5,660
D29	07/09/01	1115	E .05	<2.0	9.2	<.10	210	.17	<.07	2.7	1.25	12.4	6,860
D29	10/10/01	1040	<.10	E .9	8.7	<.10	180	.23	E .07	2.7	1.21	23.0	3,830
D30	01/08/01	1510	.12	<2.0	11.0	<.06	443	.71	.05	3.7	2.44	11.4	E 30
D30	04/04/01	1630	.07	<2.0	10.0	<.06	416	.74	E .03	1.8	2.45	18.4	E 30
D30	07/10/01	1240	<.10	E 1.0	10.1	<.20	451	.72	E .07	2.4	1.96	15.6	130
D30	10/16/01	1000	<.14	<2.0	9.6	<.18	514	.75	<.11	<4.0	2.28	33.3	140



**Table 8. Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued**

[ $\mu\text{S/cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $\text{mg/L}$ , milligrams per liter;  $\mu\text{g/L}$ , micrograms per liter;  $<$ , less than;  $^{\circ}\text{C}$ , degrees Celsius; ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; —, no sample submitted; analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Lead, dissolved ( $\mu\text{g/L as Pb}$ )	Manganese, dissolved ( $\mu\text{g/L as Mn}$ )	Mercury, dissolved ( $\mu\text{g/L as Hg}$ )	Molybdenum, dissolved ( $\mu\text{g/L as Mo}$ )	Nickel, dissolved ( $\mu\text{g/L as Ni}$ )	Selenium, dissolved ( $\mu\text{g/L as Se}$ )	Silver, dissolved ( $\mu\text{g/L as Ag}$ )	Strontium, dissolved ( $\mu\text{g/L as Sr}$ )	Zinc, dissolved ( $\mu\text{g/L as Zn}$ )	Uranium, natural, dissolved ( $\mu\text{g/L as U}$ )
DTX1	01/05/01	1000	E 0.04	98.6	< 0.23	5.9	5.15	< 2.4	< 1.0	5,390	6	50.0
DTX1	04/09/01	0945	E .05	97.6	< .01	5.6	3.92	E 1.2	< 1.0	5,480	8	54.7
DTX1	07/11/01	1635	< .20	144	< .01	5.7	9.46	3.1	< 2.0	5,540	8	48.5
DTX1	10/12/01	0950	< .20	163	< .01	6.2	1.67	E 1.9	< 2.0	5,630	11	50.3
DTX2	01/05/01	1215	E .05	4,370	< .23	1.6	1.81	E 1.9	< 1.0	5,260	6	34.4
DTX2	04/09/01	1120	< .08	4,920	< .01	1.5	< .06	< 2.4	< 1.0	5,000	10	35.4
DTX2	07/13/01	1150	< .20	3,950	< .01	1.5	3.81	< 2.0	< 2.0	5,320	8	37.4
DTX2	10/12/01	1130	< .20	3,960	< .01	1.4	< .60	< 2.0	< 2.0	5,450	14	36.7
DTX3	01/04/01	1005	< .08	E 0.1	< .23	.5	< .06	17.5	< 1.0	3,020	3	30.2
DTX3	04/05/01	1020	< .08	.2	< .01	.6	.14	12.9	< 1.0	3,060	4	29.2
DTX3	07/10/01	1430	E .05	E 1.1	< .01	.5	< .30	14.2	< 1.0	2,980	4	27.1
DTX3	10/10/01	1340	< .08	< .1	< .01	.6	< .60	12.5	< 1.0	2,240	3	21.2
DTX4	01/04/01	1210	E .05	49.2	< .23	.6	1.86	4.6	< 1.0	4,290	5	31.6
DTX4	04/05/01	1200	.13	47.4	< .01	.7	5.42	< 2.4	< 1.0	4,370	9	32.8
DTX4	07/11/01	1430	< .20	9.4	< .01	.6	2.58	3.5	< 2.0	3,530	6	23.6
DTX4	10/11/01	1530	< .80	171	< .01	4.8	2.14	E 1.1	< 10.0	4,390	< 10	30.2
DTX5	01/04/01	1430	< .08	121	< .23	1.0	< .06	3.0	< 1.0	4,560	5	35.5
DTX5	04/05/01	1335	.08	95.0	< .01	1.1	2.12	< 2.4	< 1.0	4,690	7	41.5
DTX5	07/12/01	1240	< .20	133	< .01	1.1	.28	E 2.3	< 2.0	4,650	6	39.7
DTX5	10/11/01	1430	< .20	112	< .01	1.0	< .60	E 1.3	< 2.0	4,530	13	32.5
DTX6	01/08/01	1040	< .08	.9	< .23	.8	3.72	3.3	< 1.0	5,620	8	42.8
DTX6	04/06/01	1020	< .08	.4	< .01	.7	< .04	E 1.9	< 1.0	5,480	9	37.1
DTX6	07/12/01	1420	< .20	.4	< .01	.7	< .10	3.8	< 2.0	5,790	8	35.9
DTX6	10/11/01	1300	< .20	.3	< .01	.7	< .60	3.4	< 2.0	5,680	15	34.4
DTX8A	01/05/01	1445	< .08	180	< .23	.6	< .06	< 2.4	< 1.0	2,380	2	.41
DTX8A	04/06/01	1420	< .08	177	< .01	.7	< .06	< 2.4	< 1.0	2,420	3	.23
DTX8A	07/11/01	1230	< .08	167	< .01	.5	< .06	< 2.0	< 1.0	2,520	2	.18
DTX8A	10/12/01	1400	< .08	153	< .01	.5	< .60	< 2.0	< 1.0	2,480	4	.26

**Table 8. Water-quality data for monitoring wells near Deer Trail, Colorado, 2001.—Continued**

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; °C, degrees Celsius  
 ND, no data available; E, value estimated by laboratory; M, presence of material verified but not quantified; —, no sample submitted;  
 analytical uncertainty is the 2-sigma precision estimate calculated by the laboratory as a combined standard analytical uncertainty]

Site number	Sample date (mm/dd/yy)	Sample time (hhmm)	Lead, dissolved (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Strontium, dissolved (µg/L as Sr)	Zinc, dissolved (µg/L as Zn)	Uranium, natural, dissolved (µg/L as U)
DTX10A	01/09/01	1310	< 0.08	300	< 0.23	1.5	0.16	< 2.4	< 1.0	5,300	5	0.17
DTX10A	04/09/01	1315	< .08	287	< .01	1.3	< .06	< 2.4	< 1.0	5,250	8	.17
DTX10A	07/12/01	1020	< .20	309	< .01	1.4	< .10	E 1.7	< 2.0	5,530	6	.17
DTX10A	10/15/01	1345	< .20	285	< .01	1.3	< .60	E 1.3	< 2.0	5,360	10	.19
D6	01/08/01	1250	.25	4,270	< .23	3.6	14.2	10.9	< 1.0	16,200	34	191
D6	04/04/01	1435	.46	4,060	< .01	3.7	11.3	15.3	< 1.0	16,700	42	176
D6	07/10/01	1015	.62	4,180	< .01	3.3	5.90	14.4	< 7.0	17,000	43	173
D6	10/10/01	1545	E .32	4,190	< .01	3.2	1.13	23.8	< 7.0	16,300	82	168
D13	01/09/01	1025	< .08	54.7	< .23	.9	< .06	< 2.4	< 1.0	1,070	2	8.50
D13	04/10/01	0945	< .08	67.4	< .01	1.0	.56	< 2.4	< 1.0	981	2	8.10
D13	07/13/01	0955	< .08	110	< .01	1.0	.29	< 2.0	< 1.0	1,270	2	9.42
D13	10/15/01	1010	< .08	97.1	< .01	1.0	< .60	< 2.0	< 1.0	1,160	3	7.99
D17	01/03/01	1340	< .08	275	< .23	6.0	.73	7.4	< 1.0	291	< 1	3.99
D17	04/06/01	1225	< .08	285	< .01	5.8	.32	5.4	< 1.0	294	< 1	4.22
D17	07/09/01	1315	< .08	335	< .01	6.1	.90	6.8	< 1.0	300	< 1	4.47
D17	10/16/01	1210	< .08	362	< .01	6.1	1.12	7.7	< 1.0	307	< 1	4.19
D25	01/03/01	1530	E .06	3,260	< .23	12.6	4.96	5.0	< 1.0	3,380	7	52.9
D25	04/10/01	1120	E .07	2,930	< .01	9.9	< .06	E 1.4	< 1.0	3,370	10	48.8
D25	07/09/01	1500	< .20	2,700	< .01	9.8	7.00	E 1.8	< 2.0	3,390	7	43.3
D25	10/15/01	1150	< .20	3,390	< .01	10.4	< .60	2.6	< 2.0	3,710	14	49.7
D29	01/03/01	1055	< .08	952	< .23	.8	4.08	3.2	< 1.0	5,670	6	.03
D29	04/04/01	1135	< .08	919	< .01	1.5	7.82	< 2.0	< 1.0	5,800	13	.07
D29	07/09/01	1115	E .08	917	< .01	.9	7.60	E 1.8	< 2.0	5,880	11	.06
D29	10/10/01	1040	< .20	859	< .01	2.4	.50	E 1.4	< 2.0	5,620	25	.07
D30	01/08/01	1510	E .06	352	< .23	3.0	6.37	< 2.4	< 1.0	5,980	10	43.8
D30	04/04/01	1630	E .07	359	< .01	3.0	4.28	< 2.0	< 1.0	5,920	13	41.9
D30	07/10/01	1240	< .20	330	< .01	3.0	< .20	E 1.3	< 3.0	6,290	11	40.0
D30	10/16/01	1000	< .24	360	< .01	3.4	6.57	< 2.0	< 3.0	6,280	19	36.0

**Table 9.** Quality-control data for blank samples associated with ground-water samples collected near Deer Trail, Colorado, 2001.

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; <, less than; E, value estimated by laboratory; M, presence of material verified but not quantified; --, no sample submitted; ND, no data available; \*, low-level trace-element blank; °C, degrees Celsius; site number refers to site where sample was processed or, for DTX10A blank, site where equipment was last used]

Blank type	Sample date (mm/dd/yy)	Sample time (hhmm)	Site Number	Specific conductance, lab (µS/cm)	pH, WH, laboratory (standard units)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Potassium, dissolved (mg/L as K)	Sodium, dissolved (mg/L as Na)	Acid-neutralizing capacity, titration to pH 4.5, lab (mg/L as CaCO <sub>3</sub> )	Chloride, dissolved (mg/L as Cl)
F	01/03/01	1325	D17	11	8.1	<0.01	<0.008	<0.20	<0.1	2	<0.1
F	01/04/01	1405	DTX5	5	8.0	<.01	<.008	<.24	<.1	2	<.1
Q	01/10/01	1500	DTX10A	E.2	7.5	.03	E.004	<.24	<.1	2	<.1
Q*	01/10/01	1501	DTX10A*	--	--	.04	.007	--	<.025	--	--
F	04/06/01	0945	DTX6	<3	7.9	<.01	<.008	<.09	<.1	2	<.1
F	04/10/01	0920	D13	5	7.7	<.01	<.008	<.09	E.1	2	<.1
F	07/12/01	1205	DTX5	<3	7.9	<.01	<.008	<.09	<.1	2	<.1
F	07/13/01	0920	D13	5	8.0	E.01	<.008	<.09	<.1	2	<.1
F	10/11/01	1200	DTX6	<3	8.6	<.01	<.008	<.10	<.1	2	<.3

Blank type	Sample date (mm/dd/yy)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO <sub>2</sub> )	Sulfate, dissolved (mg/L as SO <sub>4</sub> )	Nitrogen, ammonia plus organic, dissolved (mg/L as N)		Nitrogen, ammonia, dissolved (mg/L as N)	Nitrite plus nitrate, dissolved (mg/L as N)	Phosphorus, dissolved (mg/L as P)	Phosphorus, total (mg/L as P)	Solids, residue on evaporation at 180 °C, dissolved (mg/L)
					Nitrogen, ammonia plus organic, dissolved (mg/L as N)	Nitrogen, ammonia, total (mg/L as N)					
F	01/03/01	<0.2	<0.1	0.1	<0.10	<0.08	<0.050	<0.037	<0.050	<0.060	<10
F	01/04/01	<.2	<.1	<.1	<.10	<.08	<.049	<.037	<.050	<.060	<10
Q	01/10/01	<.2	<.1	<.1	<.10	<.08	<.049	<.037	<.050	<.060	<10
Q*	01/10/01	--	<.02	--	--	--	--	--	--	--	--
F	04/06/01	<.2	<.1	<.1	<.10	E.05	<.050	<.037	<.050	<.060	<10
F	04/10/01	<.2	<.1	E.1	<.10	<.08	<.049	<.037	<.050	<.060	<10
F	07/12/01	<.2	<.1	<.1	<.10	<.08	<.050	<.037	<.050	<.060	11
F	07/13/01	<.2	<.1	<.1	ND	ND	ND	ND	ND	ND	<10
F	10/11/01	E.1	<.1	<.1	<.10	<.10	<.050	.045	<.050	<.060	<10

**Table 9.** Quality-control data for blank samples associated with ground-water samples collected near Deer Trail, Colorado, 2001.—Continued

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; <, less than; E, value estimated by laboratory; M, presence of material verified but not quantified; --, no sample submitted; ND, no data available; \*, low-level trace-element blank; °C, degrees Celsius; site number refers to site where sample was processed or, for DTX10A blank, site where equipment was last used]

Blank type	Sample date (mm/dd/yy)	Aluminum, dissolved (µg/L as Al)	Antimony, dissolved (µg/L as Sb)	Arsenic, dissolved (µg/L as As)	Barium, dissolved (µg/L as Ba)	Beryllium, dissolved (µg/L as Be)	Boron, dissolved (µg/L as B)	Bromide, dissolved (µg/L as Br)	Cadmium, dissolved (µg/L as Cd)	Chromium, dissolved (µg/L as Cr)	Cobalt, dissolved (µg/L as Co)	Copper, dissolved (µg/L as Cu)
F	01/03/01	< 1	< 0.05	< 2.0	< 1.0	< 0.06	< 13	0.02	< 0.04	< 0.8	< 0.02	E 0.1
F	01/04/01	< 1	< .05	< 2.0	< 1.0	< .06	< 13	< .01	< .04	< .8	< .01	.2
Q	01/10/01	< 1	< .05	< 2.0	< 1.0	< .06	< 13	< .01	< .04	< .8	.06	3.5
Q*	01/10/01	< .3	< .20	--	.3	< .20	< 2	--	< .30	< .2	< .20	2.1
F	04/06/01	< 1	E .04	< 2.0	< 1.0	< .06	E 7	< .01	< .04	< .8	< .02	.3
F	04/10/01	< 1	E .04	< 2.0	< 1.0	< .06	< 13	< .01	< .04	< .8	< .01	< .2
F	07/12/01	< 1	< .05	< 2.0	< 1.0	< .06	< 13	< .01	< .04	< .8	< .02	.3
F	07/13/01	< 1	< .05	< 2.0	< 1.0	< .06	< 13	< .01	< .04	< .8	< .02	< .2
F	10/11/01	< 1	< .05	< 2.0	< 1.0	< .06	< 13	< .03	< .04	< .8	< .02	.7

Blank type	Sample date (mm/dd/yy)	Iron, dissolved (µg/L as Fe)	Lead, dissolved (µg/L as Pb)	Manganese, dissolved (µg/L as Mn)	Mercury, dissolved (µg/L as Hg)	Molybdenum, dissolved (µg/L as Mo)	Nickel, dissolved (µg/L as Ni)	Selenium, dissolved (µg/L as Se)	Silver, dissolved (µg/L as Ag)	Strontium, dissolved (µg/L as Sr)	Zinc, dissolved (µg/L as Zn)	Uranium, natural, dissolved (µg/L as U)
F	01/03/01	< 10	< 0.08	E 0.1	< 0.20	< 0.2	< 0.06	< 2.0	< 1.0	< 0.80	< 1	< 0.02
F	01/04/01	< 10	< .08	< .1	< .23	< .2	< .06	< 2.4	< 1.0	< .80	< 1	< .02
Q	01/10/01	20	< .08	.3	< .23	< .2	.42	< 2.4	< 1.0	< .80	1	< .02
Q*	01/10/01	M	< .30	.2	--	< .2	< .50	--	< .2	.37	2	< .20
F	04/06/01	< 10	< .08	< .1	< .01	< .2	E .06	< 2.0	< 1.0	< .80	< 1	< .02
F	04/10/01	< 10	< .08	< .1	< .01	< .2	< .06	< 2.4	< 1.0	< .80	< 1	< .02
F	07/12/01	< 10	< .08	< .1	< .01	< .2	< .06	< 2.0	< 1.0	< .80	< 1	< .02
F	07/13/01	< 10	E .07	< .1	< .01	< .2	< .06	< 2.0	< 1.0	< .80	< 1	< .02
F	10/11/01	< 10	< .08	< .1	< .01	< .2	< .06	< 2.0	< 1.0	< .60	< 1	< .02

**Table 10. Comparison of water-quality data for ground-water and replicate samples collected near Deer Trail, Colorado, 2001.**

[RPD, relative percent difference, which is defined as [(sample value - replicate value)/(sample value + replicate value)/2]] x 100; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; <, less than; E, value estimated by laboratory; --, not analyzed; ND, not determined because data were less than the minimum reporting limit; M, presence of material verified but not quantified]

Property or constituents	D25			D6			D6		
	01/03/01			01/08/01			04/04/01		
	Sample	Replicate	RPD	Sample	Replicate	RPD	Sample	Replicate	RPD
Specific conductance, lab (µS/cm at 25°C)	4,920	4,950	-1	16,300	16,400	-1	16,700	16,800	-1
pH, laboratory (standard units)	7.3	7.3	0	7.1	7.2	-1	7.0	7.2	-3
Hardness total (mg/L as CaCO <sub>3</sub> )	2,800	2,800	0	9,900	9,900	0	9,900	10,000	-1
Calcium, dissolved (mg/L as Ca)	679	678	0	441	469	-6	432	437	-1
Magnesium, dissolved (mg/L as Mg)	256	257	0	2,130	2,100	1	2,140	2,150	0
Sodium, dissolved (mg/L as Na)	347	341	2	2,040	2,000	2	1,990	2,010	-1
Potassium, dissolved (mg/L as K)	7.84	7.51	4	11.9	12.8	-7	13.0	12.2	6
Acid neutralizing capacity, titration to pH 4.5, lab (mg/L as CaCO <sub>3</sub> )	593	610	-3	640	640	0	647	648	0
Sulfate, dissolved (mg/L as SO <sub>4</sub> )	2,870	2,860	0	13,000	13,100	-1	13,000	13,000	0
Chloride, dissolved (mg/L as Cl)	85.5	83.9	2	363	374	-3	394	386	2
Fluoride, dissolved (mg/L as F)	1.0	1.1	-10	.8	.8	0	.8	.8	0
Bromide, dissolved (mg/L as Br)	1.44	1.47	-2	4.21	4.22	0	4.48	4.45	1
Silica, dissolved (mg/L as SiO <sub>2</sub> )	29.3	32.0	-9	21.8	22.1	-1	21.3	21.1	1
Solids, residue on evaporation at 180°C, dissolved (mg/L)	5,230	5,210	0	21,000	21,300	-1	21,100	21,000	0
Dissolved solids, sum of constituents (mg/L)	4,660	4,650	0	18,500	18,600	-1	18,400	18,500	-1
Nitrite plus nitrate, dissolved (mg/L as N)	4.05	4.10	-1	15.3	15.4	-1	16.5	15.9	4
Nitrogen ammonia, dissolved (mg/L as N)	E .036	E .033	ND	.056	.058	-4	.051	.062	-19
Nitrogen ammonia plus organic, total (mg/L as N)	.91	.88	3	1.5	1.5	0	.98	.90	9
Nitrogen ammonia plus organic, dissolved (mg/L as N)	.89	.88	1	1.6	1.6	0	.68	.80	-16
Phosphorus, total (mg/L as P)	.163	.155	5	< .060	E .030	ND	< .060	< .060	ND
Phosphorus, dissolved (mg/L as P)	.178	.153	15	E .033	E .034	ND	E .034	< .050	ND

**Table 10. Comparison of water-quality data for ground-water and replicate samples collected near Deer Trail, Colorado, 2001.—Continued**

[RPD, relative percent difference, which is defined as [(sample value - replicate value)/(sample value + replicate value)/2]] x 100; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; < less than; E, value estimated by laboratory; -, not analyzed; ND, not determined because data were less than the minimum reporting limit; M, presence of material verified but not quantified]

Property or constituents	D25			D6			D6		
	01/03/01			01/08/01			04/04/01		
	Sample	Replicate	RPD	Sample	Replicate	RPD	Sample	Replicate	RPD
Aluminum, dissolved (µg/L as Al)	<1	<1	ND	2	2	0	1	2	-67
Antimony, dissolved (µg/L as Sb)	.15	.16	-6	.24	.20	18	.15	.17	-13
Arsenic, dissolved (µg/L as As)	3.2	3.2	0	<4.0	<4.0	ND	E 3.1	E 3.1	ND
Barium, dissolved (µg/L as Ba)	19.6	19.7	-1	5.7	5.6	2	5.2	5.5	-6
Beryllium, dissolved (µg/L as Be)	<.06	<.06	ND	<.06	<.06	ND	<.06	<.06	ND
Boron, dissolved (µg/L as B)	542	558	-3	855	789	8	967	897	8
Cadmium, dissolved (µg/L as Cd)	.24	.25	-4	.10	.12	-18	.10	.12	-18
Chromium, dissolved (µg/L as Cr)	<.8	<.8	ND	<.8	2.1	ND	<1.6	<1.6	ND
Cobalt, dissolved (µg/L as Co)	3.39	3.51	-3	7.23	7.50	-4	7.31	7.45	-2
Copper, dissolved (µg/L as Cu)	11.1	11.3	-2	37.8	39.2	-4	57.5	58.1	-1
Iron, dissolved (µg/L as Fe)	<10	<10	ND	<150	<150	ND	<150	<150	ND
Lead, dissolved (µg/L as Pb)	E.06	E.07	ND	.25	.23	8	.46	.51	-10
Manganese, dissolved (µg/L as Mn)	3,260	3,290	-1	4,270	4,450	-4	4,060	4,190	-3
Mercury, dissolved (µg/L as Hg)	<.23	<.23	ND	<.23	<.23	ND	<.01	<.01	ND
Molybdenum, dissolved (µg/L as Mo)	12.6	13.1	-4	3.6	3.6	0	3.7	3.9	-5
Nickel, dissolved (µg/L as Ni)	4.96	5.55	-11	14.2	16.5	-15	11.3	10.4	8
Selenium, dissolved (µg/L as Se)	5.0	3.7	30	10.9	12.7	-15	15.3	14.8	3
Silver, dissolved (µg/L as Ag)	<1.0	<1.0	ND	<1.0	<1.0	ND	<1.0	<1.0	ND
Strontium, dissolved (µg/L as Sr)	3,380	3,380	0	16,200	16,200	0	16,700	16,700	0
Zinc, dissolved (µg/L as Zn)	7	7	0	34	35	-3	42	43	-2
Uranium, natural, dissolved (µg/L as U)	52.9	53.9	-2	191	188	2	176	177	-1

Table 10. Comparison of water-quality data for ground-water and replicate samples collected near Deer Trail, Colorado, 2001.—Continued

[RPD, relative percent difference, which is defined as [(sample value - replicate value)/(sample value + replicate value)/2]] x 100;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter; pCi/L, picocuries per liter; <, less than; E, value estimated by laboratory; -, not analyzed; ND, not determined because data were less than the minimum reporting limit; M, presence of material verified but not quantified]

Property or constituents	D25			D25			D6		
	04/10/01			07/09/01			07/10/01		
	Sample	Replicate	RPD	Sample	Replicate	RPD	Sample	Replicate	RPD
Specific conductance, lab ( $\mu\text{S}/\text{cm}$ at 25°C)	4,850	4,830	0	4,720	4,640	2	16,600	16,300	2
pH, laboratory (standard units)	7.3	7.3	0	7.3	7.3	0	7.1	7.1	0
Hardness total (mg/L as $\text{CaCO}_3$ )	2,700	2,700	0	2,600	2,600	0	11,000	11,000	0
Calcium, dissolved (mg/L as Ca)	690	693	0	633	640	-1	429	424	1
Magnesium, dissolved (mg/L as Mg)	233	238	-2	248	249	0	2,330	2,340	0
Sodium, dissolved (mg/L as Na)	308	321	-4	312	314	-1	2,080	2,070	0
Potassium, dissolved (mg/L as K)	5.67	6.53	-14	6.45	6.32	2	11.4	11.0	4
Acid neutralizing capacity, titration to pH 4.5, lab (mg/L as $\text{CaCO}_3$ )	563	555	1	458	465	-2	636	638	0
Sulfate, dissolved (mg/L as $\text{SO}_4$ )	2,710	2,730	-1	2,640	2,620	1	13,500	13,500	0
Chloride, dissolved (mg/L as Cl)	98.4	96.4	2	115	117	-2	390	400	-3
Fluoride, dissolved (mg/L as F)	1.0	.9	11	.9	.9	0	.7	.8	-13
Bromide, dissolved (mg/L as Br)	1.66	1.66	0	1.56	1.67	-7	4.35	4.23	3
Silica, dissolved (mg/L as $\text{SiO}_2$ )	26.2	26.8	-2	27.9	28.2	-1	21.6	21.0	3
Solids, residue on evaporation at 180°C, dissolved (mg/L)	4,860	4,900	-1	4,550	4,820	-6	22,300	21,200	5
Dissolved solids, sum of constituents (mg/L)	4,430	4,460	-1	4,280	4,270	0	19,200	19,300	-1
Nitrite plus nitrate, dissolved (mg/L as N)	2.47	2.56	-4	1.62	1.66	-2	16.0	16.2	-1
Nitrogen ammonia, dissolved (mg/L as N)	E .029	E .034	ND	E .038	E .032	ND	.060	.052	14
Nitrogen ammonia plus organic, total (mg/L as N)	.72	.83	-14	.63	.65	-3	.56	.54	4
Nitrogen ammonia plus organic, dissolved (mg/L as N)	.68	.74	-8	.53	.49	8	.36	.34	6
Phosphorus, total (mg/L as P)	.128	.145	-12	.146	.143	2	<.060	<.060	ND
Phosphorus, dissolved (mg/L as P)	.137	.156	-13	.100	.100	0	<.050	<.050	ND

**Table 10. Comparison of water-quality data for ground-water and replicate samples collected near Deer Trail, Colorado, 2001.—Continued**

[RPD, relative percent difference, which is defined as [(sample value - replicate value)/(sample value + replicate value)/2]] x 100; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; <, less than; E, value estimated by laboratory; -, not analyzed; ND, not determined because data were less than the minimum reporting limit; M, presence of material verified but not quantified]

Property or constituents	D25			D6					
	04/10/01		07/09/01		07/10/01				
	Sample	Replicate	RPD	Sample	Replicate	RPD			
Aluminum, dissolved (µg/L as Al)	< 1	< 1	ND	< 2	< 2	ND	< 7	< 7	ND
Antimony, dissolved (µg/L as Sb)	.34	.34	0	.19	.18	5	< .30	.30	ND
Arsenic, dissolved (µg/L as As)	2.1	E 1.9	ND	2.7	2.9	-7	2.4	2.9	-19
Barium, dissolved (µg/L as Ba)	18.2	18.0	1	17.3	17.3	0	< 7.0	< 7.0	ND
Beryllium, dissolved (µg/L as Be)	< .06	< .06	ND	< .10	< .10	ND	< .40	< .40	ND
Boron, dissolved (µg/L as B)	370	434	-16	422	453	-7	872	872	0
Cadmium, dissolved (µg/L as Cd)	.21	.21	0	.17	.09	62	E .22	E .23	ND
Chromium, dissolved (µg/L as Cr)	< .8	< .8	ND	3.0	3.2	-6	E 1.1	E 1.3	ND
Cobalt, dissolved (µg/L as Co)	2.78	2.68	4	3.04	3.12	-3	7.11	7.02	1
Copper, dissolved (µg/L as Cu)	11.2	11.1	1	12.0	15.6	-26	58.7	60.5	-3
Iron, dissolved (µg/L as Fe)	< 50	< 50	ND	< 30	< 30	ND	< 100	< 100	ND
Lead, dissolved (µg/L Pb)	E .07	E .08	ND	< .20	< .20	ND	.62	.67	-8
Manganese, dissolved (µg/L Mn)	2,930	3,530	-19	2,700	2,790	-3	4,180	4,090	2
Mercury, dissolved (µg/L as Hg)	< .01	< .01	ND	< .01	< .01	ND	< .01	< .01	ND
Molybdenum, dissolved (µg/L Mo)	9.9	10.0	-1	9.8	9.5	3	3.3	3.1	6
Nickel, dissolved (µg/L Ni)	< .06	2.42	ND	7.00	< .10	ND	5.90	7.40	-23
Selenium, dissolved (µg/L Se)	E 1.4	1.2	ND	E 1.8	E 1.9	ND	14.4	15.1	-5
Silver, dissolved (µg/L Ag)	< 1.0	< 1.0	ND	< 2.0	< 2.0	ND	< 7.0	< 7.0	ND
Strontium, dissolved (µg/L Sr)	3,370	3,420	-1	3,390	3,390	0	17,000	16,900	1
Zinc, dissolved (µg/L Zn)	10	10	0	7	11	-44	43	44	-2
Uranium, natural, dissolved (µg/L as U)	48.8	52.1	-7	43.3	46.1	-6	173	173	0



**Table 10.** Comparison of water-quality data for ground-water and replicate samples collected near Deer Trail, Colorado, 2001.—Continued

[RPD, relative percent difference, which is defined as [(sample value - replicate value)/((sample value + replicate value)/2)] x 100;  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius;  $\text{mg}/\text{L}$ , milligrams per liter;  $\mu\text{g}/\text{L}$ , micrograms per liter;  $\text{pCi}/\text{L}$ , picocuries per liter; <, less than; E, value estimated by laboratory; -, not analyzed; ND, not determined because data were less than the minimum reporting limit; M, presence of material verified but not quantified]

Property or constituents	D6 10/10/01			D25 10/15/01		
	Sample	Replicate	RPD	Sample	Replicate	RPD
Specific conductance, lab ( $\mu\text{S}/\text{Cm}$ at 25 °C)	16,300	16,300	0	4,620	4,640	0
pH, laboratory (standard units)	7.1	7.1	0	7.2	7.2	0
Hardness total ( $\text{mg}/\text{L}$ as $\text{CaCO}_3$ )	10,000	9,800	2	3,100	2,900	7
Calcium, dissolved ( $\text{mg}/\text{L}$ as Ca)	425	417	2	838	767	9
Magnesium, dissolved ( $\text{mg}/\text{L}$ as Mg)	2,210	2,130	4	237	230	3
Sodium, dissolved ( $\text{mg}/\text{L}$ as Na)	1,970	1,910	3	320	313	2
Potassium, dissolved ( $\text{mg}/\text{L}$ as K)	12.6	12.2	3	6.35	8.17	-25
Acid neutralizing capacity, titration to pH 4.5, lab ( $\text{mg}/\text{L}$ as $\text{CaCO}_3$ )	641	642	0	524	530	-1
Sulfate, dissolved ( $\text{mg}/\text{L}$ as $\text{SO}_4$ )	13,300	13,300	0	2,750	2,710	1
Chloride, dissolved ( $\text{mg}/\text{L}$ as Cl)	423	412	3	95.2	96.5	-1
Fluoride, dissolved ( $\text{mg}/\text{L}$ as F)	.8	.9	-12	1.0	1.0	0
Bromide, dissolved ( $\text{mg}/\text{L}$ as Br)	4.69	4.63	1	1.70	1.72	-1
Silica, dissolved ( $\text{mg}/\text{L}$ as $\text{SiO}_2$ )	20.3	18.8	8	32.3	30.4	6
Solids, residue on evaporation at 180°C, dissolved ( $\text{mg}/\text{L}$ )	20,800	20,800	0	4,790	4,820	-1
Dissolved solids, sum of constituents ( $\text{mg}/\text{L}$ )	18,900	18,700	1	4,630	4,500	3
Nitrite plus nitrate, dissolved ( $\text{mg}/\text{L}$ as N)	15.9	16.0	-1	4.80	4.65	3
Nitrogen ammonia, dissolved ( $\text{mg}/\text{L}$ as N)	.052	.050	4	.054	E .037	ND
Nitrogen ammonia plus organic, total ( $\text{mg}/\text{L}$ as N)	1.6	1.5	6	.67	.70	-4
Nitrogen ammonia plus organic, dissolved ( $\text{mg}/\text{L}$ as N)	1.3	.80	48	.70	.69	1
Phosphorus, total ( $\text{mg}/\text{L}$ as P)	E .034	< .060	ND	.140	.134	4
Phosphorus, dissolved ( $\text{mg}/\text{L}$ as P)	< .050	< .050	ND	.129	.127	2

**Table 10.** Comparison of water-quality data for ground-water and replicate samples collected near Deer Trail, Colorado, 2001.—Continued

[RPD, relative percent difference, which is defined as [(sample value - replicate value)/(sample value + replicate value)/2]] x 100; µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; pCi/L, picocuries per liter; <, less than; E, value estimated by laboratory; -, not analyzed; ND, not determined because data were less than the minimum reporting limit; M, presence of material verified but not quantified]

Property or constituents	D6			D25		
	Sample	Replicate	RPD	Sample	Replicate	RPD
Aluminum, dissolved (µg/L as Al)	< 7	< 7	ND	< 2	< 2	ND
Antimony, dissolved (µg/L as Sb)	< .30	< .30	ND	< .10	< .10	ND
Arsenic, dissolved (µg/L as As)	5.0	3.8	27	2.6	2.7	-4
Barium, dissolved (µg/L as Ba)	< 7.0	< 7.0	ND	20.1	20.1	0
Beryllium, dissolved (µg/L as Be)	< .40	< .40	ND	< .10	< .10	ND
Boron, dissolved (µg/L as B)	670	733	-9	459	425	8
Cadmium, dissolved (µg/L as Cd)	E .25	E .21	ND	.23	.22	4
Chromium, dissolved (µg/L as Cr)	< 1.6	< 1.6	ND	2.7	2.6	4
Cobalt, dissolved (µg/L as Co)	6.63	6.84	-3	3.17	2.82	12
Copper, dissolved (µg/L as Cu)	103	112	-8	28.5	24.1	17
Iron, dissolved (µg/L as Fe)	< 300	< 300	ND	< 30	< 30	ND
Lead, dissolved (µg/L as Pb)	E .32	E .49	ND	< .20	< .20	ND
Manganese, dissolved (µg/L as Mn)	4,190	4,260	-2	3,390	3,170	7
Mercury, dissolved (µg/L as Hg)	< .01	< .01	ND	< .01	< .01	ND
Molybdenum, dissolved (µg/L as Mo)	3.2	3.2	0	10.4	10.3	1
Nickel, dissolved (µg/L as Ni)	1.13	1.88	-50	< .60	E .54	ND
Selenium, dissolved (µg/L as Se)	23.8	18.0	28	2.6	2.7	-4
Silver, dissolved (µg/L as Ag)	< 7.0	< 7.0	ND	< 2.0	< 2.0	ND
Strontium, dissolved (µg/L as Sr)	16,300	15,800	3	3,710	3,640	2
Zinc, dissolved (µg/L as Zn)	82	86	-5	14	13	7
Uranium, natural, dissolved (µg/L as U)	168	171	-2	49.7	49.1	1

**Table 11.** Statistical comparison of concentrations for selected chemical constituents in ground-water samples collected near Deer Trail, Colorado, 1999–2001, and lowest applicable water-quality standard.

[–, not computed or missing; standard is from Colorado Department of Public Health and Environment (1993); H, health-based standard; A, agricultural standard; >, greater than]

Well	Sample size for statistical comparison	Minimum concentration for statistical comparison <sup>1</sup>	Maximum concentration for statistical comparison <sup>1</sup>	Median concentration for statistical comparison <sup>1</sup>	Colorado standard	Type of standard	<sup>2</sup> p value
Nitrate <sup>3</sup>							
D6	12	11	16.5	14	10	H	0.0002
D13	11	.018	.049	.019	10	H	>0.6
D17	12	.68	5.68	2.0	10	H	>0.6
D25	11	1.6	7.4	3.4	10	H	>0.6
D29	11	.018	.053	.018	10	H	>0.6
D30	11	.018	.06	.018	10	H	>0.6
DTX1	11	1.1	2.8	1.2	10	H	>0.6
DTX10A	12	.018	.058	.018	10	H	>0.6
DTX2	12	.018	.05	.018	10	H	>0.6
DTX3	12	.018	15.8	4.2	10	H	>0.6
DTX4	11	.018	6.52	.33	10	H	>0.6
DTX5	12	.018	.25	.018	10	H	>0.6
DTX6	11	.22	.34	.28	10	H	>0.6
DTX8A	12	.018	.099	.018	10	H	>0.6
Arsenic							
D6	12	1	9	2.4	10	H	>0.6
D13	12	.5	1	1	10	H	>0.6
D17	12	1	2	1.4	10	H	>0.6
D25	12	2	6	2.7	10	H	>0.6
D29	12	.5	2	1	10	H	>0.6
D30	12	.5	2.7	1	10	H	>0.6
DTX1	12	1	3.5	2.0	10	H	>0.6
DTX10A	12	.5	1.1	1	10	H	>0.6
DTX2	12	.5	2	1	10	H	>0.6
DTX3	12	.5	1	1	10	H	>0.6
DTX4	12	.5	2	1	10	H	>0.6
DTX5	12	.5	1.2	1	10	H	>0.6
DTX6	12	.5	2.2	1	10	H	>0.6
DTX8A	12	.5	1	1	10	H	>0.6
Cadmium <sup>4</sup>							
D6	12	.1	3.5	.5	5	H	>0.6
D13	12	.02	.5	.5	5	H	>0.6
D17	12	.02	.5	.5	5	H	>0.6
D25	12	.17	1.5	.5	5	H	>0.6
D29	12	.02	1	.5	5	H	>0.6
D30	12	.03	1	.5	5	H	>0.6
DTX1	12	.04	1	.75	5	H	>0.6
DTX10A	12	.02	1	.5	5	H	>0.6
DTX2	12	.02	1	.75	5	H	>0.6
DTX3	12	.02	.5	.5	5	H	>0.6
DTX4	12	.04	1	.75	5	H	>0.6
DTX5	12	0.02	1	0.5	5	H	>0.6
DTX6	12	.02	1	.5	5	H	>0.6
DTX8A	12	.02	.5	.5	5	H	>0.6

**Table 11.** Statistical comparison of concentrations for selected chemical constituents in ground-water samples collected near Deer Trail, Colorado, 1999–2001, and lowest applicable water-quality standard.—Continued

[–, not computed or missing; standard is from Colorado Department of Public Health and Environment (1993); H, health-based standard; A, agricultural standard; >, greater than]

Well	Sample size for statistical comparison	Minimum ground-water value used for statistical comparison <sup>1</sup>	Maximum ground-water value used for statistical comparison <sup>1</sup>	Median ground-water value used for statistical comparison <sup>1</sup>	Colorado standard	Type of regulatory standard	<sup>2</sup> p-value
Chromium							
D6	12	0.4	18	0.8	100	H, A	>0.6
D13	12	.4	2	.4	100	H, A	>0.6
D17	12	.4	.5	.4	100	H, A	>0.6
D25	12	.4	27	1.6	100	H, A	>0.6
D29	12	.4	18	.7	100	H, A	>0.6
D30	12	.4	9.5	1	100	H, A	>0.6
DTX1	12	.4	14	.71	100	H, A	>0.6
DTX10A	12	.4	5.7	.5	100	H, A	>0.6
DTX2	12	.4	11	1	100	H, A	>0.6
DTX3	12	.4	13	.5	100	H, A	>0.6
DTX4	12	.4	11	.94	100	H, A	>0.6
DTX5	12	.4	8.2	1.0	100	H, A	>0.6
DTX6	12	.4	11	1.4	100	H, A	>0.6
DTX8A	12	.4	.8	.4	100	H, A	>0.6
Copper							
D6	12	5	103	34	200	A	>0.6
D13	12	2	6	3	200	A	>0.6
D17	12	.5	1	.50	200	A	>0.6
D25	12	7	28	10	200	A	>0.6
D29	12	6	23	8	200	A	>0.6
D30	12	5	33	10	200	A	>0.6
DTX1	12	6	22	9	200	A	>0.6
DTX10A	12	3	19	6	200	A	>0.6
DTX2	12	5	24	8	200	A	>0.6
DTX3	12	2	6	3.5	200	A	>0.6
DTX4	12	4	12	6.5	200	A	>0.6
DTX5	12	4	16	7	200	A	>0.6
DTX6	12	6	27	9.5	200	A	>0.6
DTX8A	12	2	7	2.5	200	A	>0.6
Lead <sup>5</sup>							
D6	12	.04	3.5	.56	50	H	>0.6
D13	12	.04	.5	.5	50	H	>0.6
D17	12	.04	.5	.5	50	H	>0.6
D25	12	.06	1.5	.5	50	H	>0.6
D29	12	.04	1	.5	50	H	>0.6
D30	12	.04	1	.5	50	H	>0.6
DTX1	12	.04	1	.75	50	H	>0.6
DTX10A	12	.04	1	.5	50	H	>0.6
DTX2	12	.04	1	0.75	50	H	>0.6
DTX3	12	.04	.5	.5	50	H	>0.6
DTX4	12	.05	1	.5	50	H	>0.6
DTX5	12	.04	1	.5	50	H	>0.6
DTX6	12	.04	1	.5	50	H	>0.6
DTX8A	12	.04	.5	.5	50	H	>0.6

**Table 11.** Statistical comparison of concentrations for selected chemical constituents in ground-water samples collected near Deer Trail, Colorado, 1999–2001, and lowest applicable water-quality standard.—Continued

[–, not computed or missing; standard is from Colorado Department of Public Health and Environment (1993); H, health-based standard; A, agricultural standard; >, greater than]

Well	Sample size for statistical comparison	Minimum ground-water value used for statistical comparison <sup>1</sup>	Maximum ground-water value used for statistical comparison <sup>1</sup>	Median ground-water value used for statistical comparison <sup>1</sup>	Colorado standard	Type of regulatory standard	<sup>2</sup> p-value
Mercury							
D6	12	0.005	0.16	0.1	2	H	>0.6
D13	12	.005	.1	.1	2	H	>0.6
D17	12	.005	.1	.1	2	H	>0.6
D25	12	.005	.1	.1	2	H	>0.6
D29	12	.005	.1	.1	2	H	>0.6
D30	12	.005	.1	.1	2	H	>0.6
DTX1	12	.005	.1	.1	2	H	>0.6
DTX10A	12	.005	.1	.1	2	H	>0.6
DTX2	12	.005	.1	.1	2	H	>0.6
DTX3	12	.005	.1	.1	2	H	>0.6
DTX4	12	.005	.1	.1	2	H	>0.6
DTX5	12	.005	.1	.1	2	H	>0.6
DTX6	12	.005	.1	.1	2	H	>0.6
DTX8A	12	.005	.1	.1	2	H	>0.6
Molybdenum <sup>6</sup>							
D6	12	.5	4	3.2	-- <sup>6</sup>	--	--
D13	12	.5	1	1	-- <sup>6</sup>	--	--
D17	12	6	7	6	-- <sup>6</sup>	--	--
D25	12	9	14	10	-- <sup>6</sup>	--	--
D29	12	.5	2	1	-- <sup>6</sup>	--	--
D30	12	1	4	3	-- <sup>6</sup>	--	--
DTX1	12	5	7	6	-- <sup>6</sup>	--	--
DTX10A	12	.5	3	1	-- <sup>6</sup>	--	--
DTX2	12	1	1.6	1.2	-- <sup>6</sup>	--	--
DTX3	12	.5	.6	.5	-- <sup>6</sup>	--	--
DTX4	12	1	5	1	-- <sup>6</sup>	--	--
DTX5	12	.5	1	1	-- <sup>6</sup>	--	--
DTX6	12	.5	1	1	-- <sup>6</sup>	--	--
DTX8A	12	.5	2	.75	-- <sup>6</sup>	--	--
Nickel							
D6	12	1	23	10	100	H	>0.6
D13	12	.03	10	3	100	H	>0.6
D17	12	.32	2	1	100	H	>0.6
D25	12	.03	38	15	100	H	>0.6
D29	12	.5	24	8	100	H	>0.6
D30	12	0.1	15	7.5	100	H	>0.6
DTX1	12	2	31	13	100	H	>0.6
DTX10A	12	.03	21	3	100	H	>0.6
DTX2	12	.03	26	11	100	H	>0.6
DTX3	12	.03	9	2	100	H	>0.6
DTX4	12	.5	20	9	100	H	>0.6
DTX5	12	.03	46	8.5	100	H	>0.6
DTX6	12	.02	40	3.5	100	H	>0.6
DTX8A	12	.03	6	1.5	100	H	>0.6

**Table 11.** Statistical comparison of concentrations for selected chemical constituents in ground-water samples collected near Deer Trail, Colorado, 1999–2001, and lowest applicable water-quality standard.—Continued

[–, not computed or missing; standard is from Colorado Department of Public Health and Environment (1993); H, health-based standard; A, agricultural standard; >, greater than]

Well	Sample size for statistical comparison	Minimum ground-water value used for statistical comparison <sup>1</sup>	Maximum ground-water value used for statistical comparison <sup>1</sup>	Median ground-water value used for statistical comparison <sup>1</sup>	Colorado standard	Type of regulatory standard	<sup>2</sup> <i>p</i> -value
Selenium							
D6	12	6	24	11	20	A	>0.6
D13	12	.5	1.7	1.2	20	A	>0.6
D17	12	5	9	8	20	A	>0.6
D25	12	1.2	6	2.6	20	A	>0.6
D29	12	.5	3.3	1.4	20	A	>0.6
D30	12	.5	4.9	1.2	20	A	>0.6
DTX1	12	1.2	6	2.0	20	A	>0.6
DTX10A	12	.5	2	1.2	20	A	>0.6
DTX2	12	.5	4.3	1.2	20	A	>0.6
DTX3	12	4	17	14	20	A	>0.6
DTX4	12	1	12	2	20	A	>0.6
DTX5	12	.5	3.3	1.2	20	A	>0.6
DTX6	12	.5	6.1	3.4	20	A	>0.6
DTX8A	12	.5	1.2	1.2	20	A	>0.6
Zinc							
D6	12	5	82	34	2,000	A	>0.6
D13	12	.5	3	2	2,000	A	>0.6
D17	12	.5	.5	.5	2,000	A	>0.6
D25	12	5	25	7.7	2,000	A	>0.6
D29	12	6.5	25	12	2,000	A	>0.6
D30	12	4	19	8.9	2,000	A	>0.6
DTX1	12	4	11	6	2,000	A	>0.6
DTX10A	12	2	10	4.8	2,000	A	>0.6
DTX2	12	4	14	6.6	2,000	A	>0.6
DTX3	12	1	3.6	2	2,000	A	>0.6
DTX4	12	3	9.1	5.0	2,000	A	>0.6
DTX5	12	3	13	5	2,000	A	>0.6
DTX6	12	5	15	6.5	2,000	A	>0.6
DTX8A	12	1.8	3.8	2	2,000	A	>0.6

<sup>1</sup> Many of the values used in the statistical comparison were derived from concentrations that are less than the minimum reporting limit and therefore were set equal to one-half the minimum reporting limit.

<sup>2</sup> Value is the *p*-value resulting from a one-tailed Sign Test (Helsel and Hirsch, 1992), which is used to indicate the level of statistical evidence that selected constituent concentrations are significantly greater than regulatory standards. A value close to 0 indicates more evidence that the concentrations exceeded the standard, whereas a value close to 1 indicates little evidence that the concentrations exceeded the standard.

<sup>3</sup> Data compared to standard are for nitrite plus nitrate. Results indicate nitrite is a minor component.

<sup>4</sup> All data were less than laboratory minimum reporting limit. Minimum reporting limits were sometimes greater than the water-quality standard.

<sup>5</sup> All data were less than laboratory minimum reporting limit. Laboratory minimum reporting limit is less than the water-quality standard.

<sup>6</sup> No regulatory standard for this constituent.

**Table 12.** Statistical evaluation of monotonic time-series trend using the Kendall's tau correlation coefficient for selected constituents in ground-water samples collected near Deer Trail, Colorado, 1999–2001.

[Only values in bold type indicate statistically significant trends. For this report, the Kendall's tau statistic (Helsel and Hirsch, 1992) is used as a nonparametric measure of correlation between concentration and time. By this method, positive values of Kendall's tau indicate upward trends and negative values indicate downward trends. Kendall's tau is a number between -1 and 1 that indicates increasing strength of the correlation. A p-value is listed to indicate the level of significance of the correlation; -, not computed]

Well	Nitrate		Arsenic		Cadmium		Chromium		Copper		Lead	
	Tau	p-value	Tau	p-value	Tau	p-value	Tau	p-value	Tau	p-value	Tau	p-value
D6	<b>0.818</b>	<b>0.0003</b>	0.258	0.272	-0.500	0.028	-0.242	0.304	<b>0.576</b>	<b>0.011</b>	-0.454	0.047
D13	.036	.938	.303	.193	-.591	.009	-.273	.244	<b>.454</b>	<b>.047</b>	- <sup>1</sup>	- <sup>1</sup>
D17	-.182	.451	-.272	.244	-.530	.020	- <sup>1</sup>	- <sup>1</sup>	.424	.064	- <sup>1</sup>	- <sup>1</sup>
D25	-.309	.213	-.121	.631	-.591	.009	-.212	.373	<b>.606</b>	<b>.007</b>	-.545	.016
D29	-.127	.640	-.152	.537	-.576	.011	.061	.837	<b>.500</b>	<b>.028</b>	-.576	.011
D30	.054	.876	.152	.537	-.652	.004	.076	.784	<b>.470</b>	<b>.040</b>	-.561	.014
DTX1	-.036	.938	.182	.451	-.591	.009	-.197	.410	<b>.515</b>	<b>.024</b>	-.530	.020
DTX10A	- <sup>1</sup>	- <sup>1</sup>	.409	.075	- <sup>1</sup>	- <sup>1</sup>	-.288	.217	.439	.055	- <sup>1</sup>	- <sup>1</sup>
DTX2	-.212	.373	-.121	.631	-.561	.014	-.167	.493	<b>.591</b>	<b>.009</b>	-.561	.014
DTX3	<b>.454</b>	<b>.047</b>	- <sup>1</sup>	- <sup>1</sup>	-.500	.028	-.106	.681	<b>.515</b>	<b>.024</b>	-.500	.028
DTX4	.273	.276	.152	.537	-.515	.024	-.091	.732	.394	.086	-.530	.020
DTX5	-.030	.945	.439	.055	-.424	.064	-.288	.217	.409	.075	-.409	.075
DTX6	.291	.243	.197	.410	-.682	.002	.167	.493	<b>.515</b>	<b>.024</b>	- <sup>1</sup>	- <sup>1</sup>
DTX8A	-.273	.244	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	- <sup>1</sup>	-.409	.075	<b>.545</b>	<b>.016</b>	- <sup>1</sup>	- <sup>1</sup>

Well	Mercury		Molybdenum		Nickel		Selenium		Zinc	
	Tau	p-value	Tau	p-value	Tau	p-value	Tau	p-value	Tau	p-value
D6	-0.121	0.631	0.182	0.451	-0.348	0.131	<b>0.561</b>	<b>0.014</b>	<b>0.485</b>	<b>0.034</b>
D13	- <sup>1</sup>	- <sup>1</sup>	.303	.193	-.439	.055	.227	.337	.348	.131
D17	- <sup>1</sup>	- <sup>1</sup>	-.106	.681	-.106	.681	-.379	.100	- <sup>1</sup>	- <sup>1</sup>
D25	- <sup>1</sup>	- <sup>1</sup>	-.076	.784	-.500	.028	-.106	.681	.106	.681
D29	-.136	.583	.227	.337	-.409	.075	.242	.304	.167	.493
D30	- <sup>1</sup>	- <sup>1</sup>	.182	.451	-.424	.064	.030	.945	.273	.244
DTX1	- <sup>1</sup>	- <sup>1</sup>	<b>.470</b>	<b>.040</b>	-.348	.131	-.091	.732	.424	.064
DTX10A	- <sup>1</sup>	- <sup>1</sup>	-.273	.244	-.651	.004	.318	.170	.212	.373
DTX2	- <sup>1</sup>	- <sup>1</sup>	.318	.170	-.379	.100	-.045	.891	<b>.454</b>	<b>.047</b>
DTX3	- <sup>1</sup>	- <sup>1</sup>	.318	.170	-.288	.217	.091	.732	<b>.576</b>	<b>.011</b>
DTX4	- <sup>1</sup>	- <sup>1</sup>	.106	.681	-.561	.014	.288	.217	.197	.410
DTX5	- <sup>1</sup>	- <sup>1</sup>	.106	.681	-.530	.020	.303	.193	.424	.064
DTX6	- <sup>1</sup>	- <sup>1</sup>	<.001	1.000	-.530	.020	.136	.583	.409	.075
DTX8A	- <sup>1</sup>	- <sup>1</sup>	.015	1.000	-.515	.024	- <sup>1</sup>	- <sup>1</sup>	<b>.500</b>	<b>.028</b>

<sup>1</sup> No concentrations were greater than the laboratory minimum reporting limit.

**Table 13.** Methods used to analyze streambed-sediment samples collected near Deer Trail, Colorado, 2001.

[Samples were analyzed at the National Water Quality Laboratory in Denver, except for constituents footnoted; MRL, minimum reporting level; MDC, minimum detectable concentration (radiochemical samples); USEPA 351.2, method described in U.S. Environmental Protection Agency, 1983; ICP, inductively coupled plasma; MS, mass spectroscopy; GFAA, graphite furnace atomic absorption; AA, atomic absorption; ASF, automated segmented-flow spectrophotometry; \*, not applicable; mg/kg, milligrams per kilogram; µg/g, micrograms per gram; g/kg, grams per kilogram; pCi/g, picocuries per gram]

Constituent	Units	Analytical method	MRL or MDC
Nutrients			
Nitrogen, ammonia plus organic <sup>1</sup>	mg/kg	USEPA 351.2, Colorimetry, ASF, salicylate-hypochlorite	*
Phosphorus, total as P	mg/kg	Colorimetry, ASF, phosphomolybdate <sub>3</sub>	40
Trace elements			
Aluminum	µg/g	ICP <sup>4</sup>	2.8
Arsenic	µg/g	GFAA <sup>3</sup>	1
Cadmium	µg/g	ICP-MS <sup>4</sup>	.1
Chromium	µg/g	ICP <sup>4</sup>	.4
Copper	µg/g	ICP <sup>4</sup>	2
Lead	µg/g	ICP-MS <sup>4</sup>	.1
Mercury	µg/g	AA manual cold vapor <sup>3</sup>	.01
Molybdenum	µg/g	ICP-MS <sup>4</sup>	.1
Nickel	µg/g	ICP-MS <sup>4</sup>	.1
Selenium	µg/g	GFAA <sup>3</sup>	1
Zinc	µg/g	ICP <sup>4</sup>	3.1
Carbons			
Inorganic carbon	g/kg	Coulimetric <sup>5</sup>	.2
Organic carbon	g/kg	Wet oxidation	.2
Total carbon	g/kg	Induction furnace (Leco)	.1
Radioactivity			
Gross alpha <sup>2</sup>	pCi/g	Alpha proportional counting, Thorium-230 curve	*
Gross beta <sup>2</sup>	pCi/g	Beta proportional counting, Cesium-137 curve	*
Plutonium-238 <sup>2</sup>	pCi/g	Alpha spectrometry	*
Plutonium-239+240 <sup>2</sup>	pCi/g	Alpha spectrometry	*

<sup>1</sup> Analyses done by Severn Trent Laboratory in Arvada, Colorado. MRL calculated for each sample.

<sup>2</sup> Analyses done by Severn Trent Laboratory in Richland, Washington. MDC calculated for each sample.

<sup>3</sup> Method described by Fishman and Friedman (1989).

<sup>4</sup> Method described by Garbarino and Struzeski (1998).

<sup>5</sup> Method described by U.S. Geological Survey National Water Quality Laboratory Technical Memo 98.08 (September 29, 1998).



**Table 14.** Chemical data for streambed-sediment samples collected near Deer Trail, Colorado, 2001.

[Sampling sites are shown in figure 1; mg/kg, milligrams per kilogram; g/kg, grams per kilogram; µg/g, micrograms per gram; ER, value is an estimate because reanalysis for that constituent has been requested; <, less than]

Site	Sample date	Total nitrogen, mg/kg	Total phosphorus, mg/kg	Carbon, inorganic, g/kg	Carbon, total, g/kg	Carbon, organic, g/kg	Aluminum, µg/g	Arsenic, µg/g	Cadmium, µg/g
Biosolids applied	07/27/01	1,100	720	4.4	13	8.3	17,000	1.59	0.2
Biosolids applied	8/17/01	1,400	580	4.3	16	11	15,000	1.41	.2
Biosolids applied	9/01/01	850	1,100	6.0	14	8.2	18,000	1.23	.2
No biosolids	7/27/01	1,400	580	4.5	18	14	15,000	1.58	.2
No biosolids	8/17/01	850	620	3.6	10	6.4	15,000	1.33	< .2
No biosolids	9/01/01	580	650	5.4	11	5.7	10,000	1.19	.1

Site	Sample date	Chromium, µg/g	Copper, µg/g	Lead, µg/g	Mercury, µg/g	Molybdenum, µg/g	Nickel, µg/g	Selenium, µg/g	Zinc, µg/g
Biosolids applied	07/27/01	14	18	18	0.02	0.1	18	0.22	60
Biosolids applied	8/17/01	16	22	16	.02	ER 12	ER .2	.31	60
Biosolids applied	9/01/01	18	14	16	.03	.7	16	.16	60
No biosolids	7/27/01	13	17	17	.02	.1	18	.34	60
No biosolids	8/17/01	14	18	14	.02	< .4	11	.25	50
No biosolids	9/01/01	10	10	12	.02	.1	12	.26	40

**Table 15.** Radioactivity data for streambed-sediment samples collected near Deer Trail, Colorado, 2001.

[Sampling sites are shown in figure 1; pCi/g, picocuries per gram; analytical uncertainty reported is the two-sigma total propagated analytical uncertainty]

Site	Sample date	Gross alpha radioactivity, pCi/g	Gross alpha radioactivity, analytical uncertainty, pCi/g	Gross beta radioactivity, pCi/g	Gross beta radioactivity, analytical uncertainty, pCi/g	Plutonium-238, pCi/g	Plutonium-238, analytical uncertainty, pCi/g	Plutonium-238, minimum detectable concentration, pCi/g	Plutonium-239+240, analytical uncertainty, pCi/g	Plutonium-239+240, minimum detectable concentration, pCi/g
Biosolids applied	7/27/01	8.3	2.4	7.4	1.6	0.0064	0.0092	0.0087	0.0092	0.013
Biosolids applied	8/17/01	9.5	2.6	10	2.2	-0.00026	.00052	0.01300	.0065	0.013
No biosolids	7/27/01	10.3	2.6	9.6	1.9	0	.0097	0.0107	.00063	0.01590
No biosolids	8/17/01	10.7	2.7	9.8	2.1	0	.015	0.016	.005	0.024

**Table 16.** Comparison of chemical data for streambed-sediment and replicate samples collected near Deer Trail, Colorado, 2001.

[RPD, relative percent difference, which is defined as [(sample value - replicate value)/(sample value + replicate value)/2]] x 100; mg/kg, milligrams per kilogram; g/kg, grams per kilogram; µg/g, micrograms per gram; pCi/g, picocuries per gram; <, less than; --, not analyzed; ND, not determined because data were less than the minimum reporting limit]

Property or constituents	Biosolids-applied site		No-biosolids-applied site		Biosolids-applied site		RPD between	
	07/27/01 Sample	07/27/01 Sample	7/27/01 Sample	7/27/01 Replicate	07/27/01 Replicate	sites	RPD between sample and replicate	
Total nitrogen, (mg/kg)	1,100	1,400	1,400	1,000	1,000	-24	10	
Phosphorus (mg/kg)	720	580	580	610	610	22	17	
Carbon, inorganic, (g/kg)	4.4	4.5	4.5	4.6	4.6	-2	-4	
Carbon, total, (g/kg)	13	18	18	13	13	-32	0	
Carbon, organic, (g/kg)	8.3	14	14	8.2	8.2	-51	1	
Aluminum (µg/g)	17,000	15,000	15,000	17,000	17,000	13	0	
Arsenic (µg/g)	1.59	1.58	1.58	1.62	1.62	1	-2	
Cadmium (µg/g)	.2	.2	.2	.2	.2	0	0	
Chromium (µg/g)	14	13	13	15	15	7	-7	
Copper (µg/g)	18	17	17	21	21	6	-15	
Lead (µg/g)	18	17	17	19	19	6	-5	
Mercury (µg/g)	.02	.02	.02	.01	.01	0	67	
Molybdenum (µg/g)	.1	.1	.1	.1	.1	0	0	
Nickel (µg/g)	18	18	18	18	18	0	0	
Selenium (µg/g)	.22	.34	.34	.27	.27	-43	-20	
Zinc (µg/g)	60	60	60	70	70	0	-15	
Gross alpha radioactivity (pCi/g)	8.3	10.3	10.3	7.6	7.6	-22	9	
Gross beta radioactivity (pCi/g)	7.4	9.6	9.6	7.0	7.0	-26	6	
Plutonium-238 (pCi/g)	.0064	0	0	0	0	200	200	
Plutonium-239+240 (pCi/g)	.0062	-0.00032	-0.00032	.0040	.0040	222	43	

**Table 16.** Comparison of chemical data for streambed-sediment and replicate samples collected near Deer Trail, Colorado, 2001.—Continued

[RPD, relative percent difference, which is defined as  $[(\text{sample value} - \text{replicate value}) / ((\text{sample value} + \text{replicate value}) / 2)] \times 100$ ; mg/kg, milligrams per kilogram; g/kg, grams per kilogram;  $\mu\text{g/g}$ , micrograms per gram; <, less than; -, not analyzed; ND, not determined because data were less than the minimum reporting limit]

Property or constituents	Biosolids-applied site		No-biosolids-applied site		No-biosolids-applied site		RPD between environmental sample and replicate
	08/17/01 Sample	08/17/01 Sample	08/17/01 Sample	08/17/01 Replicate	RPD between sites	RPD between environmental sample and replicate	
Total nitrogen, (mg/kg)	1,400	850	700	49	19		
Phosphorus (mg/kg)	580	620	630	-7	-2		
Carbon, inorganic, (g/kg)	4.3	3.6	4.2	18	-15		
Carbon, total, (g/kg)	16	10	9.4	46	6		
Carbon, organic, (g/kg)	11	6.4	5.2	53	21		
Aluminum ( $\mu\text{g/g}$ )	15,000	15,000	14,000	0	7		
Arsenic ( $\mu\text{g/g}$ )	1.41	1.33	1.34	6	-1		
Cadmium ( $\mu\text{g/g}$ )	.2	< .2	.2	0	0		
Chromium ( $\mu\text{g/g}$ )	16	14	7	13	67		
Copper ( $\mu\text{g/g}$ )	22	18	17	20	6		
Lead ( $\mu\text{g/g}$ )	16	14	14	13	0		
Mercury ( $\mu\text{g/g}$ )	.02	.02	.02	0	0		
Molybdenum ( $\mu\text{g/g}$ )	.2	< .4	.4	-67	0		
Nickel ( $\mu\text{g/g}$ )	8.7	11	8.3	-23	28		
Selenium ( $\mu\text{g/g}$ )	.31	.25	.25	21	0		
Zinc ( $\mu\text{g/g}$ )	60	50	60	18	-18		
Gross alpha radioactivity (pCi/g)	9.5	10.7	7.1	-12	40		
Gross beta radioactivity (pCi/g)	10	9.8	11	2	-12		
Plutonium-238 (pCi/g)	-0.00026	0	.0041	200	-200		
Plutonium-239+240 (pCi/g)	.0030	.005	.0038	-50	27		

**Table 16. Comparison of chemical data for stream bed-sediment and replicate samples collected near Deer Trail, Colorado, 2001.—Continued**

[RPD, relative percent difference, which is defined as [(sample value - replicate value)/(sample value + replicate value)/2]] x 100; mg/kg, milligrams per kilogram; g/kg, grams per kilogram; µg/g, micrograms per gram; pCi/g, picocuries per gram; <, less than; --, not analyzed; ND, not determined because data were less than the minimum reporting limit]

Property or constituents	Biosolids-applied site		No-biosolids-applied site		RPD between sites
	09/01/01 Sample	09/01/01 Sample	09/01/01 Sample	09/01/01 Sample	
Total nitrogen, (mg/kg)	850	580	580	38	
Phosphorus (mg/kg)	1,100	650	650	51	
Carbon, inorganic, (g/kg)	6.0	5.4	5.4	11	
Carbon, total, (g/kg)	14	11	11	24	
Carbon, organic, (g/kg)	8.2	5.7	5.7	36	
Aluminum (µg/g)	18,000	10,000	10,000	57	
Arsenic (µg/g)	1.23	1.19	1.19	3	
Cadmium (µg/g)	.2	.1	.1	67	
Chromium (µg/g)	18	10	10	57	
Copper (µg/g)	14	10	10	33	
Lead (µg/g)	16	12	12	29	
Mercury (µg/g)	.03	.02	.02	40	
Molybdenum (µg/g)	.7	.1	.1	150	
Nickel (µg/g)	16	12	12	29	
Selenium (µg/g)	.16	.26	.26	-48	
Zinc (µg/g)	60	40	40	40	
Gross alpha radioactivity (pCi/g)	-	-	-	-	
Gross beta radioactivity (pCi/g)	-	-	-	-	
Plutonium-238 (pCi/g)	-	-	-	-	
Plutonium-239+240 (pCi/g)	-	-	-	-	