

Quality and Sources of Shallow Ground Water in Areas of Recent Residential Development in Salt Lake Valley, Salt Lake County, Utah

Water-Resources Investigations Report 03-4028

U.S. Department of the Interior
U.S. Geological Survey
National Water-Quality Assessment Program



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By Susan A. Thiros

U.S. GEOLOGICAL SURVEY

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FOREWORD

The U.S. Geological Survey (USGS) is committed to serve the Nation with accurate and timely scientific information that helps enhance and protect the overall quality of life, and facilitates effective management of water, biological, energy, and mineral resources (<http://www.usgs.gov/>). Information on the quality of the Nation's water resources is of critical interest to the USGS because it is so integrally linked to the long-term availability of water that is clean and safe for drinking and recreation and that is suitable for industry, irrigation, and habitat for fish and wildlife. Escalating population growth and increasing demands for the multiple water uses make water availability, now measured in terms of quantity *and* quality, even more critical to the long-term sustainability of our communities and ecosystems.

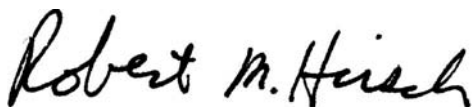
The USGS implemented the National Water-Quality Assessment (NAWQA) program to support national, regional, and local information needs and decisions related to water-quality management and policy (<http://water.usgs.gov/nawqa>). Shaped by and coordinated with ongoing efforts of other Federal, State, and local agencies, the NAWQA program is designed to answer: What is the condition of our Nation's streams and ground water? How are the conditions changing over time? How do natural features and human activities affect the quality of streams and ground water, and where are those effects most pronounced? By combining information on water chemistry, physical characteristics, stream habitat, and aquatic life, the NAWQA program aims to provide science-based insights for current and emerging water issues and priorities. NAWQA results can contribute to informed decisions that result in practical and effective water-resource management and strategies that protect and restore water quality.

Since 1991, the NAWQA program has implemented interdisciplinary assessments in more than 50 of the Nation's most important river basins and aquifers, referred to as Study Units (<http://water.usgs.gov/nawqa/nawqamap.html>). Collectively, these Study Units account for more than 60 percent of the overall water use and population served by public water supply, and are representative of the Nation's major hydrologic landscapes, priority ecological resources, and agricultural, urban, and natural sources of contamination.

Each assessment is guided by a nationally consistent study design and methods of sampling and analysis. The assessments thereby build local knowledge about water-quality issues and trends in a particular stream or aquifer while providing an understanding of how and why water quality varies regionally and nationally. The consistent, multi-scale approach helps to determine if certain types of water-quality issues are isolated or pervasive, and allows direct comparisons of how human activities and natural processes affect water quality and ecological health in the Nation's diverse geographic and environmental settings. Comprehensive assessments on pesticides, nutrients, volatile organic compounds, trace metals, and aquatic ecology are developed at the national scale through comparative analysis of the Study-Unit findings (<http://water.usgs.gov/nawqa/natsyn.html>).

The USGS places high value on the communication and dissemination of credible, timely, and relevant science so that the most recent and available knowledge about water resources can be applied in management and policy decisions. We hope this NAWQA publication will provide you the needed insights and information to meet your needs, and thereby foster increased awareness and involvement in the protection and restoration of our Nation's waters.

The NAWQA program recognizes that a national assessment by a single program cannot address all water-resource issues of interest. External coordination at all levels is critical for a fully integrated understanding of watersheds and for cost-effective management, regulation, and conservation of our Nation's water resources. The program, therefore, depends extensively on the advice, cooperation, and information from other Federal, State, interstate, Tribal, and local agencies, non-government organizations, industry, academia, and other stakeholder groups. The assistance and suggestions of all are greatly appreciated.



Robert M. Hirsch
Associate Director for Water

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CONVERSION FACTORS, DATUMS, AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
foot (ft)	0.3048	meter
gallon (gal)	3.785	liter
inch (in.)	25.4	millimeters
mile (mi)	1.609	kilometer
square mile (mi ²)	2.59	square kilometer

Water temperature in degrees Celsius (°C) and degrees Fahrenheit (°F) may be converted by using the following equations:

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

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

Vertical coordinate information is referenced to the North American Vertical Datum of 1929 (NAVD 29). Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Concentration of chemical constituents in water is reported either in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter and micrograms per liter are units expressing the concentration of chemical constituents in solution as weight (grams) of solute per unit volume (liter) of water. A liter of water is assumed to weigh 1 kilogram, except for brines or water at high temperatures because of changes in the density of the water. For concentrations less than 7,000 mg/L or 7,000,000 µg/L, the numerical value is the same as for concentrations in parts per million or parts per billion, respectively.

Specific conductance is reported in microsiemens per centimeter at 25 degrees Celsius (µS/cm). Radon concentration in water is reported as picocuries per liter (pCi/L). Stable isotope ratios are reported as per mil, which is equivalent to parts per thousand. Tritium concentration in water is reported as tritium units (TU). The ratio of 1 atom of tritium to 10¹⁸ atoms of hydrogen is equal to 1 TU or 3.2 pCi/L. Chlorofluorocarbons measured in picograms per kilogram (pg/kg) are equivalent to parts per quadrillion.

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ABSTRACT

Residential and commercial development of about 80 square miles that primarily replaced undeveloped and agricultural areas occurred in Salt Lake Valley, Utah, from 1963 to 1994. This study evaluates the occurrence and distribution of natural and anthropogenic compounds in shallow ground water underlying recently developed (post 1963) residential and commercial areas.

Monitoring wells from 23 to 153 feet deep were installed at 30 sites. Water-quality data for the monitoring wells consist of analyses of field parameters, major ions, trace elements, nutrients, dissolved organic carbon, pesticides, and volatile organic compounds.

Dissolved-solids concentration ranged from 134 to 2,910 milligrams per liter (mg/L) in water from the 30 monitoring wells. Dissolved arsenic concentration in water from 12 wells exceeded the drinking-water maximum contaminant level of 10 micrograms per liter. Water from monitoring wells in the northwestern part of the valley generally contained higher arsenic concentrations than did water from other areas. Nitrate concentration in water sampled from 26 of the 30 monitoring wells (86.7 percent) was higher than a background level of 2 mg/L, indicating a possible human influence. Nitrate concentrations ranged from less than 0.05 to 13.3 mg/L.

Fifteen of the 104 pesticides and pesticide degradation products analyzed for were detected in 1 or more water samples from the monitoring wells. No pesticides were detected at

concentrations that exceeded U.S. Environmental Protection Agency drinking-water standards or guidelines for 2002. The high detection frequency of atrazine, a restricted-use pesticide, in residential areas on the west side of Salt Lake Valley may be the result of application in agricultural or industrial areas that have been converted to residential uses or application in areas upgradient from the residential areas that was then transported by ground water.

Fifteen of the 86 volatile organic compounds analyzed for were detected in 1 or more water samples from the monitoring wells. The most frequently detected volatile organic compounds were chloroform (90 percent), bromodichloromethane (56.7 percent), tetrachloroethylene (53.3 percent), and 1,1,1-trichloroethane (50 percent). The widespread occurrence of chloroform and bromodichloromethane in shallow ground water is likely a result of the recharge of chlorinated public-supply water used to irrigate lawns and gardens in residential areas of Salt Lake Valley. Tetrachloroethylene (PCE), primarily used as a dry cleaning agent and solvent, was detected in water from 16 wells.

On the basis of stable isotope ratios, ground water from the monitoring wells is a mixture of varying amounts of local precipitation and surface water that has been subjected to evaporation. Because of evaporation, canal water diverted from the Jordan River and used for irrigation is more enriched in deuterium and oxygen-18 relative to precipitation occurring locally or on the adjacent

mountains. Several wells on the east side of the valley are upgradient from canals that divert water from the Jordan River but contain a component of water that has been concentrated by evaporation. Chloroform was detected in water from these wells; thus, water is likely a mixture of infiltration from local precipitation and seepage of water used for public supply.

Water from most of the wells had a tritium concentration from 10 to 20 tritium units, a range that most likely is made up of water recharged from the present to about 15 years ago and within the time frame of residential development in the area of the wells. The correlation between tritium concentration in recently recharged ground water and in precipitation indicates that most or all of the water in the shallow ground-water system is from the land surface with little or no mixing with older water. Ground water from most of the monitoring wells was contaminated with chlorofluorocarbons, which also indicates that the water has been in contact with the land surface.

The shallow and deeper ground-water systems in the southeastern part of the valley are separated by sequences of fine-grained deposits that perch the shallow ground water and confine the deeper aquifer. Subsurface inflow from the Wasatch Range is the main source of recharge to the deeper aquifer compared to local precipitation and unconsumed irrigation water that recharges the shallow ground-water system. As a result, the deeper aquifer in this part of the valley is probably more isolated from activities occurring at the land surface that can affect the quality of shallow ground water. Water from local precipitation and seepage from irrigation and canals, primary sources of recharge to the shallow aquifer, also may be major sources of recharge to the deeper aquifer in the southwestern part of Salt Lake Valley where thin or discontinuous confining layers are present. Where this is the case, activities occurring at land surface have the potential to affect the water quality of the deeper aquifer.

No correlation was determined between the percentage of residential land use surrounding the monitoring wells and the concentration of

dissolved solids, arsenic, atrazine and its degradation products, prometon, chloroform, or nitrate in water sampled from the wells. Relatively low concentrations of chloroform corresponded to the four highest concentrations of atrazine and its degradation products, probably because of atrazine use on agricultural or nonirrigated industrial and vacant land.

INTRODUCTION

Ground water is used for public supply in Salt Lake Valley and accounts for about one third of the water used. Withdrawals from the principal aquifer in Salt Lake Valley are regulated and limited by the Utah Division of Water Rights because the resource is over-allocated and can be adversely affected by large water-level declines and water-quality degradation. Water from the overlying shallow aquifer is not currently used for public supply and has limited use for stock and domestic supply. Leakage from the shallow aquifer to the deeper principal aquifer is possible where a downward gradient exists and confining layers are thin and/or discontinuous. Because of this connection and an increased demand for water caused by population growth, more information is needed about the shallow ground-water resource in the valley.

Residential and commercial development of about 80 mi² that primarily replaced undeveloped and agricultural areas occurred in Salt Lake Valley, Utah, from 1963 to 1994. The chemical composition and effects of human activities on the quality of shallow ground water in the recently developed residential and commercial areas were studied as part of the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) program. The Great Salt Lake Basins study unit is 1 of more than 50 study areas selected to meet the objectives of the NAWQA program. The land-use study in Salt Lake Valley consisted of 30 monitoring wells installed and sampled in 1999 in residential/commercial areas where shallow ground water has the potential to move to the deeper aquifer used for public supply. The water samples were analyzed for major ions, trace elements, radon, nutrients, pesticides, and volatile organic compounds (VOCs). Analyses also were done to determine the source and time of recharge of the shallow ground water.

Purpose and Scope

The purpose of this report is to evaluate the occurrence and distribution of natural and anthropogenic compounds in shallow ground water underlying areas of recently developed (post 1963) residential and commercial land use. The report describes the water quality in the shallow ground-water system and relates it to natural and anthropogenic factors, such as surrounding land uses and associated human activities. It also presents information on the sources and time of recharge on the basis of stable isotope and age-dating methods.

Description of Study Area

Salt Lake Valley is an urban area bounded by the Wasatch Range, Oquirrh Mountains, Traverse Mountains, and Great Salt Lake (fig. 1). It is about 28 mi long and 18 mi wide and generally corresponds to the populated part of Salt Lake County, which contains the Salt Lake City metropolitan area. The population in Salt Lake County in 2000 was about 898,000 (U.S. Census Bureau, 2002), and is growing rapidly. The population almost doubled between 1963 and 1994, corresponding to a large increase in land developed for residential and commercial use. Population in Salt Lake County is projected to be about 1,029,000 in 2010 and 1,233,000 in 2020 (Wasatch Front Regional Council, 2000), which will require more water for public supply. Because the natural boundaries of the valley restrict expansion of residential areas, population growth will occur mainly through increased population density. Changes in land use resulting from population growth will likely affect shallow ground-water quality through changes in sources and quality of recharge.

Mountain streams draining the Wasatch Range discharge into the Jordan River, which flows north along the axis of the valley and discharges into Great Salt Lake. The climate in Salt Lake Valley is semiarid, with a 1961-90 average annual precipitation of about 10 to 20 in. Lawns and gardens in the valley require irrigation to supplement precipitation during the growing season.

Ground-Water Hydrology

A generalized model of the saturated basin-fill deposits in Salt Lake Valley consists of a relatively deep unconfined aquifer near the mountain fronts that becomes confined toward the center of the valley by layers of fine-grained deposits (fig. 2). Collectively, the deeper aquifers are known as the principal aquifer. Overlying the deeper confined aquifer is a shallow, generally unconfined aquifer. The primary recharge area for the principal aquifer is near the mountain fronts where there are no substantial layers of fine-grained deposits to impede downward movement of water. Leakage of water from the shallow aquifer to the deeper confined aquifer is possible where a downward gradient exists and confining layers are thin or discontinuous. These conditions can exist in the secondary recharge area and were mapped by Anderson and others (1994, p. 6). A discharge area exists where there is an upward gradient from the deeper confined aquifer to the overlying shallow aquifer. Discharge areas generally exist in the center of the valley (fig. 2) along the Jordan River (fig. 3). Recharge and discharge areas in Salt Lake Valley are shown in figure 3.

Overlying the confining layers is shallow ground water that is either localized in extent because it is perched on fine-grained deposits or is more laterally continuous and forms an aquifer. The shallow aquifer in the valley is generally unconfined, although in some areas the first saturated zone in the subsurface was encountered beneath a confining layer (Thiros, 2003). The shallow aquifer is susceptible to contamination from activities related to land use because of its proximity to land surface and the absence of a thick confining layer. The deeper unconfined aquifer also is vulnerable because of a lack of confining layers that can impede the downward movement of contaminated ground water. Movement of contaminated water from the shallow aquifer and the deeper unconfined aquifer can degrade water quality in the deeper confined aquifer. Hydrogeologic information for the shallow basin-fill deposits collected during the land-use study is presented in Thiros (2003). Faults within and bounding the basin-fill deposits may affect ground-water movement in the valley. Water from wells in the northwestern part of the valley near faults generally is warmer, indicating movement from greater depths.

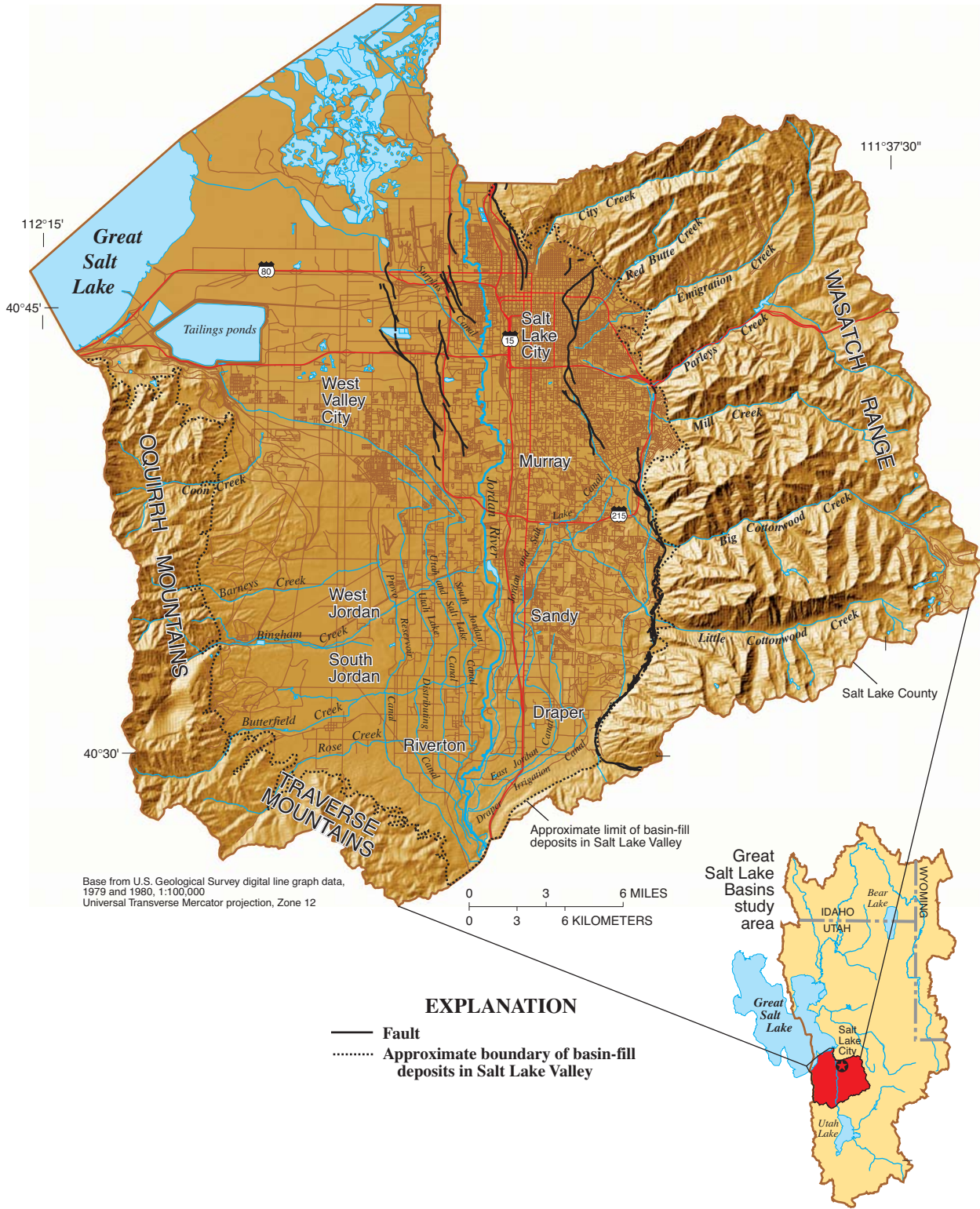


Figure 1. Location and geographic features of Salt Lake Valley, Utah.

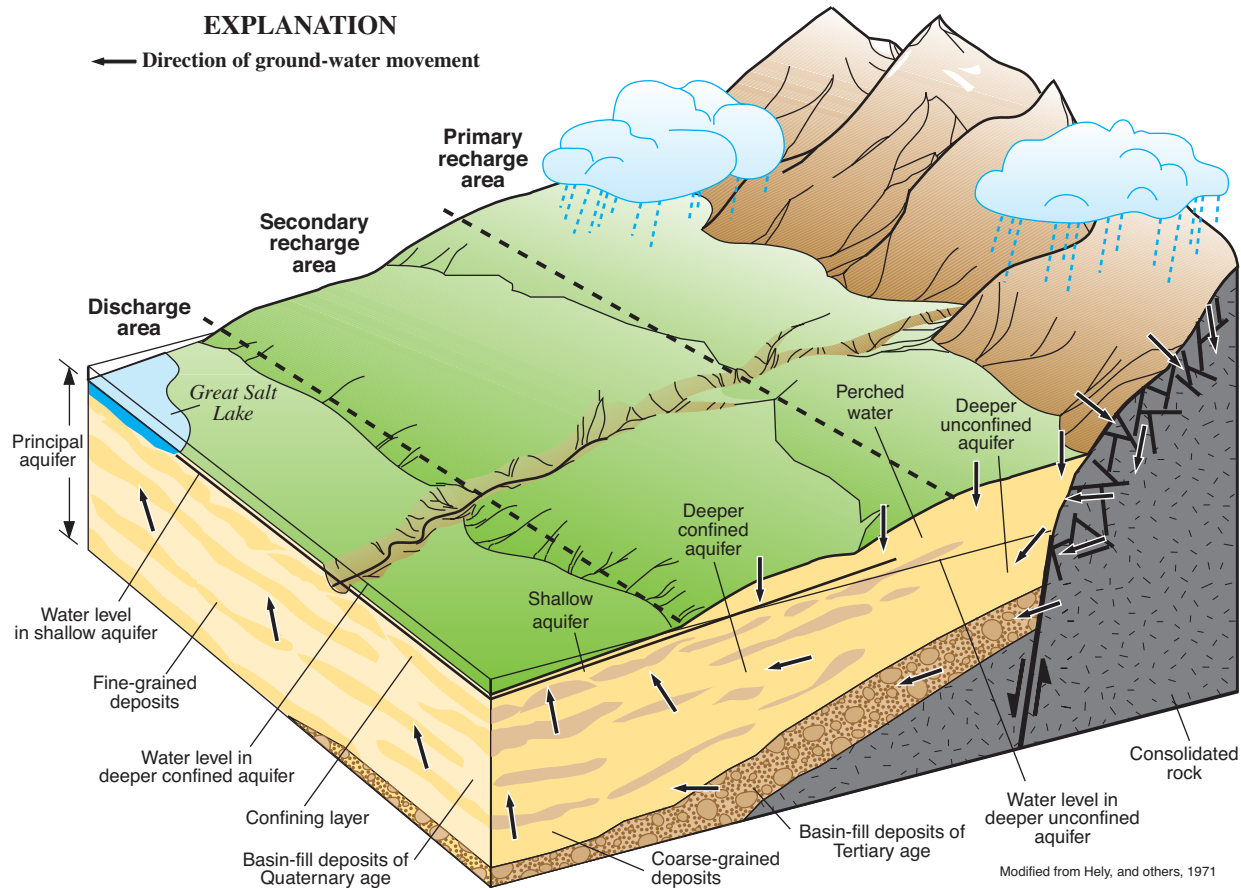


Figure 2. Generalized block diagram showing the basin-fill deposits and ground-water flow system in Salt Lake Valley, Utah.

Land Use

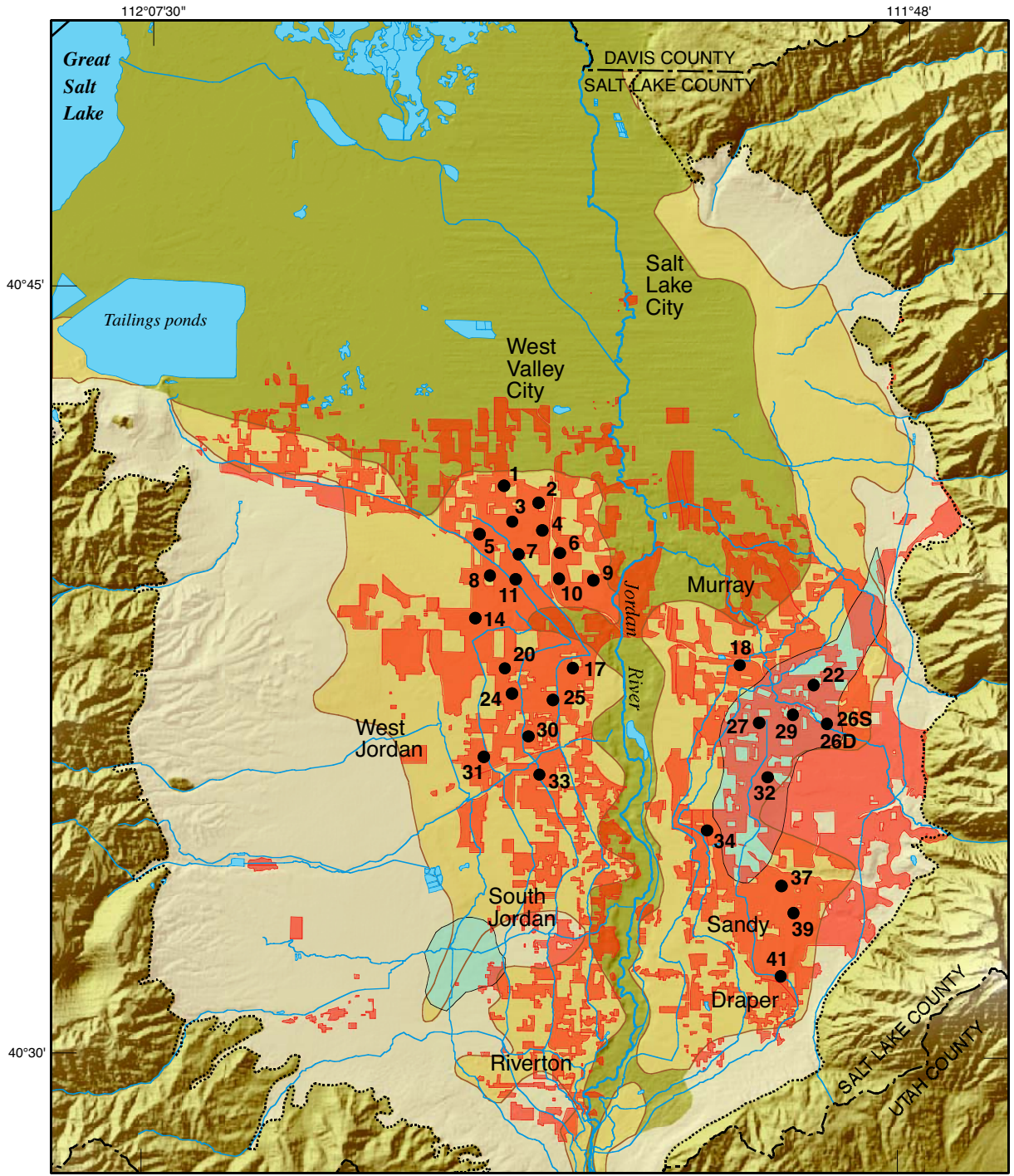
Historically, much of the industrial land use in Salt Lake Valley was located near the Jordan River with the urban area centered in the northeastern part of the valley. Agricultural land in the valley decreased from 145 mi² in 1960 to 67 mi² in 1994, while urban land increased from 89 to 198 mi² in the same period (Utah Department of Natural Resources, Division of Water Resources, 1999). Land use in urban areas of the valley in 1994 was about 63 percent residential, 6 percent commercial, 14 percent industrial, and 17 percent other (includes open spaces, idle spaces, transportation, and utilities) (Utah Department of Natural Resources, Division of Water Resources, 1995) (fig. 4). Many of the recently developed residential/commercial areas overlie the secondary recharge areas of the basin-fill ground-water system where a downward gradient exists between the shallow and deeper aquifers.

Acknowledgments

The USGS thanks the landowners and the officials of municipalities and Salt Lake County who allowed USGS personnel access to their properties for the purpose of installing and sampling the land-use study monitoring wells.

STUDY DESIGN AND METHODS

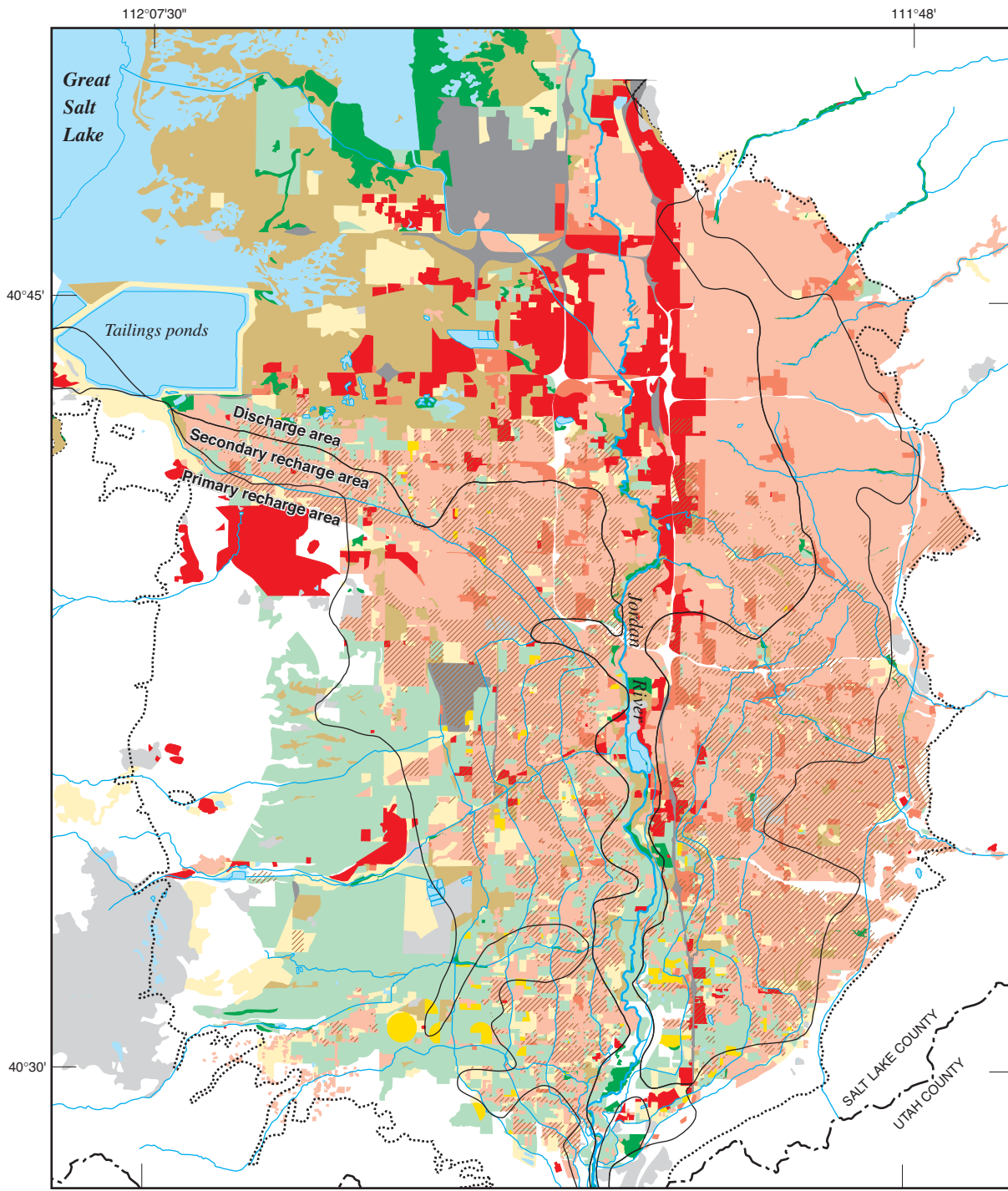
The design for NAWQA urban land-use studies focuses on the quality of recently recharged ground water in urban settings and its relation to natural factors and human activities. A study plan was provided to ensure consistency of data collection and study design (Squillace and Price, 1996) and allows for comparison among land-use studies from across the country.



EXPLANATION

- Area of recent residential and commercial land use
- Perched aquifer—Data from Hely and others, 1971
- Discharge area
- Primary recharge area
- Secondary recharge area
- Approximate boundary of basin-fill deposits in Salt Lake Valley
- Monitoring well—Number is well name in table 6

Figure 3. Location of recharge and discharge areas and monitoring wells installed in areas of recent residential development, Salt Lake Valley, Utah.



Base from U.S. Geological Survey digital line graph data, 1:100,000, 1979 and 1980
 Universal Transverse Mercator projection, Zone 12

EXPLANATION

- | | |
|---|---|
| Residential and (or) commercial land use developed during 1963-94 | Excavated |
| Residential | Water |
| Commercial | Riparian |
| Industrial | Agriculture |
| Transportation/utilities | Corn |
| Open or idle | Unknown |
| | Approximate boundary of basin-fill deposits in Salt Lake Valley |

0 3 6 MILES
 0 3 6 KILOMETERS

Figure 4. Land use in Salt Lake Valley, Utah, 1994.

Site Selection

Potential well locations were selected by using a computerized, stratified random selection process (Scott, 1990) to ensure that the data collected are unbiased and representative of the quality of water underlying recently developed residential and commercial areas. The program selected 41 sites in Salt Lake Valley that met the study criteria: (1) a location in residential and commercial areas developed during 1963-94, (2) a downward gradient between the shallow and deeper aquifers, and (3) a minimum distance between each site of 0.62 mi (1 kilometer). Areas developed after 1994 were excluded from this study because of the time necessary for new construction to affect the ground-water system (Squillace and Price, 1996). Areas developed before 1963, such as downtown Salt Lake City, also were excluded because of a greater potential for the land use to have changed with time. The sites were checked for depth to ground water, access, and permission to drill from the landowner.

Monitoring wells were installed at 30 of the 41 sites according to NAWQA protocols (Lapham and others, 1995) and were completed in the shallowest water-bearing zone capable of supplying water (fig. 3). The monitoring wells ranged from 23 to 153 ft deep and generally were completed with a 10-ft length of screen about 5 ft below the water table (table 1). One site was completed with two wells to determine variations in water quality of the shallow aquifer with depth (well 26S is screened from 26 to 31 ft below land surface and well 26D is screened from 62 to 72 ft below land surface). The water level at another site dropped below the bottom of the well and no water sample was collected. Water levels in the wells range from about 5 to 135 ft below land surface.

Land-use characteristics within a 1,640-ft (500-meter) radius around each monitoring well were determined from aerial photographs taken in September 1999. Land uses shown on the photographs were field checked and documented by using procedures described in Koterba (1998). The land-use data for this study are plotted as percentages of the total on figure 5. Single and multifamily residences were the most common land use within the prescribed radius of the monitoring wells and ranged from 24 to 96 percent of the area with an average of 70 percent. Other land uses mapped within the radius of the wells include commercial, schools, churches, parks, golf courses,

agricultural, roads, and barren property. The amount of commercial land use in the radius around each monitoring well ranged from 0 to 40 percent.

Sample Collection and Analysis

Ground-water samples were collected in the summer and fall of 1999 by using a stainless-steel submersible pump and fittings connected to Teflon tubing. Samples were collected and processed according to protocols in Koterba and others (1995). Each monitoring well was purged of three to five casing volumes of water prior to sampling. Water temperature, pH, specific conductance, dissolved oxygen, turbidity, discharge, and depth to water were monitored periodically during the purge cycle. Ground-water samples were collected after measurements of these parameters had stabilized. Analytical results for the samples are presented in tables 6 to 13 (appendix).

Five wells were sampled in the spring and fall of 2000 and the fall of 2001 in addition to the land-use study sampling done in 1999 to determine if seasonal changes in water quality occurred. Two of the wells are located on the west side of the valley (wells 5 and 33) and three are on the east side (wells 26D, 27, and 32). These monitoring wells will be sampled on a biennial schedule after the study to monitor long-term water-quality trends in the residential land-use study area. The samples will be analyzed for major ions, trace elements, radon, nutrients, pesticides, and volatile organic compounds (VOCs).

Water samples were analyzed for sulfide and chlorine in the field with a portable spectrophotometer. Sulfide concentration was measured to help determine oxidation/reduction conditions. Chlorine concentration was measured to determine if chlorinated water was present in the ground-water sample. Premeasured amounts of reagent in vacuum-sealed ampoules were mixed with the water sample after the ampoule seal was broken. Transmittance at a set wavelength through the ampoule containing the water sample and reagent is measured by the spectrophotometer and converted to a concentration on the basis of calibration tables from the reagent supplier. Alkalinity was determined onsite by incremental titration of filtered sample water with sulfuric acid.

The USGS National Water-Quality Laboratory (NWQL) in Denver, Colorado, analyzed the water samples for major ions, nutrients, dissolved organic

Table 1. Description of 30 monitoring wells sampled in Salt Lake Valley, Utah, 1999

[Well identifier, see figure 3 for well location; residential land use within 1,640 feet of well]

Well identifier	Area of valley	Residential land use (percent)	Altitude of land surface	Well depth	Top of screened interval	Bottom of screened interval	Water level March 2000
					(feet below land surface)		
1	northwest	84.5	4,308	48.5	38	48	32.77
2	northwest	64.0	4,294	38.5	28	38	19.55
3	northwest	89.3	4,371	114	103	113	79.96
4	northwest	23.6	4,331	38.5	28	38	14.01
5	northwest	39.4	4,426	43.5	33	43	27.59
6	northwest	50.6	4,324	38.5	28	38	23.46
7	northwest	71.6	4,396	43.5	33	43	27.09
8	northwest	71.8	4,487	67.5	57	67	63.37
9	northwest	41.0	4,312	38.5	28	38	12.57
10	northwest	76.9	4,350	83.5	73	83	67.94
11	northwest	83.7	4,462	83.5	73	83	70.75
14	southwest	70.5	4,579	48.5	38	48	27.97
17	southwest	57.8	4,380	38.5	28	38	17.72
18	east	79.5	4,411	106	95	105	76.85
20	southwest	72.3	4,477	92.5	82	92	84.66
22	east	77.9	4,538	36	25.5	35.5	21.61
24	southwest	93.1	4,473	124	113	123	81.98
25	southwest	96.1	4,414	68.5	58	68	49.67
26D	east	81.8	4,591	77.5	62	72	32.77
26S	east	81.8	4,591	31.5	26	31	30.43
27	east	90.4	4,499	73.5	63	73	58.69
29	east	91.0	4,532	34	23.5	33.5	9.02
30	southwest	66.7	4,455	68.5	58	68	58.12
31	southwest	72.8	4,562	154	143	153	143.19
32	east	35.0	4,640	88.5	78	88	76.18
33	southwest	38.9	4,466	95.5	85	95	74.14
34	east	49.7	4,486	77.5	67	77	57.81
37	east	92.9	4,725	73	62.5	72.5	45.18
39	east	84.0	4,758	106	95.5	106	94.02
41	east	66.9	4,550	23	12.5	22.5	5.48

carbon (DOC), selected trace elements, radon, pesticides, and VOCs. Major ions and trace elements were analyzed by using inductively coupled plasma/mass spectrometry, atomic absorption spectrometry, or ion chromatography (Fishman and Friedman, 1989; Fishman, 1993; and Faires, 1993). Nutrient concentrations were determined by colorimetry (Fishman, 1993; Patton and Truitt, 1992). DOC was analyzed for by using ultraviolet-promoted persulfate oxidation and infrared spectrometry (Brenton and Arnett, 1993). Radon was analyzed for by using liquid scintillation (American Society for Testing and Materials, 1996). Filtered water samples were analyzed for 86 pesticides by using capillary column

gas chromatography/mass spectrometry (Zaugg and others, 1995) and 65 pesticides by using high-performance liquid chromatography/mass spectrometry (HPLC/MS) (Furlong and others, 2001). The HPLC/MS method was used to analyze the samples before its final approval; therefore, concentrations of pesticides analyzed by this method are considered provisional. Unfiltered water samples were analyzed for 86 VOCs by using purge and trap capillary column gas chromatography/mass spectrometry (Conner and others, 1998).

Analyses of the stable isotopes of water, deuterium and oxygen-18 were done at the USGS Stable Isotope Laboratory in Reston, Virginia. The

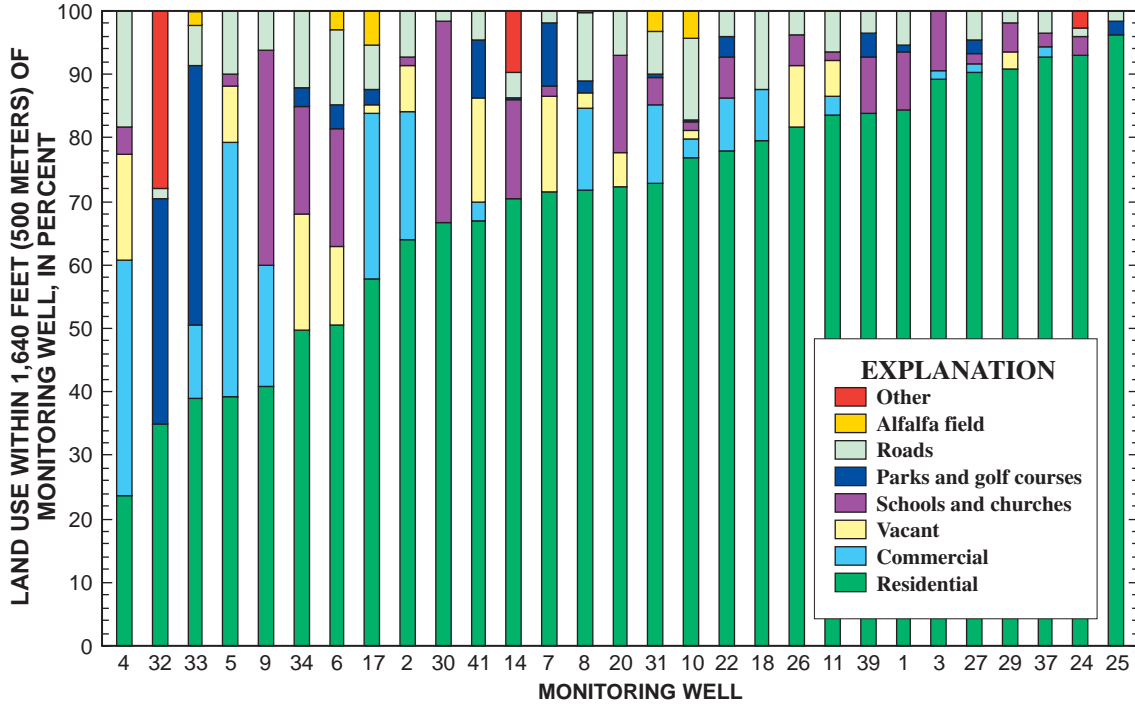


Figure 5. Percentage of land-use type mapped within a 1,640-foot radius of monitoring wells in Salt Lake Valley, Utah.

deuterium analysis uses a hydrogen equilibration method (Coplen and others, 1991) and the oxygen-18 analysis uses a carbon dioxide equilibration technique (Epstein and Mayeda, 1953). Analytical uncertainties for delta deuterium and delta oxygen-18 values are 2 and 0.2 per mil, respectively. Chlorofluorocarbons (CFCs) were analyzed at the USGS CFC Laboratory in Reston, Virginia, by using purge and trap gas chromatography (Busenberg and Plummer, 1992). The detection limit for CFCs is about 0.3 pg/kg of water, which is equivalent to 0.3 parts per quadrillion (Plummer and Friedman, 1999). The University of Utah, Department of Geology and Geophysics, Tritium and Noble Gases Laboratory in Salt Lake City, Utah, analyzed the water samples for tritium and helium-3. Tritium concentrations were determined by helium ingrowth (Bayer and others, 1989). The method involves degassing the sampled water and then isolating it under a vacuum in a special container. The sample is stored from 1 month to 1 year, and then the concentration of helium-3, the daughter product of tritium, is measured by using a magnetic sector-field mass spectrometer.

VOCs that are not detected in a water sample are reported as less than the laboratory reporting level (LRL). The LRL for each VOC represents the minimum concentration that can be identified, measured, and reported with 99 percent confidence (Childress and others, 1999). All other constituents or pesticide compounds that are not detected in a water sample are reported as less than the minimum reporting level (MRL). The MRL is defined by the NWQL (Timme, 1995) as the smallest measured concentration of a constituent that may be reliably measured by using a given analytical method. The MRL or LRL for each constituent or compound indicates relative analytical precision and detection sensitivity, but some concentrations are reported below the reporting level if the identification criteria for the method were met. Concentrations for detections below MRLs or LRLs are designated as estimated values. The MRLs for pesticides and LRLs for VOCs analyzed for by the NAWQA program are lower than those of analyses done for regulatory purposes.

Concentrations of water-quality constituents and compounds were compared to the drinking-water standards for 2002 set by the U.S. Environmental Protection Agency (USEPA) (U.S. Environmental Protection Agency, 2002). The maximum contaminant level (MCL) is the maximum concentration of a contaminant permissible in a public-water system. The MCL primarily applies to water sampled from distribution lines and at taps after being disinfected. MCLs are based on a level at which no known or anticipated adverse effects on human health occur and which allows an adequate margin of safety, but also considers the cost and feasibility of meeting the standard. The lifetime health advisory level (HAL) is the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects during a lifetime of exposure (U.S. Environmental Protection Agency, 2002). It is based on health effects information and is provided as technical guidance for regulatory and management officials.

Quality Assurance

A quality-assurance program was used in the field (Koterba and others, 1995) and in the laboratory to evaluate the bias and variability of the analytical results and to ensure data reliability. Quality-control samples were collected as part of sampling the 30 monitoring wells and included 6 field-blank samples for major ions, nutrients, VOCs, pesticides, and trace elements; 6 source-solution blank samples for DOC and 5 for VOCs; 1 trip-blank sample for VOCs; 3 replicate samples for major ions, nutrients, trace elements, and radon; 3 field-spiked samples for VOCs and selected pesticides; and 3 laboratory-spiked samples for selected pesticides. Analytical results for the field-blank and ground-water replicate samples are listed in the tables 14-18 (appendix).

Field-blank samples were collected to evaluate contamination introduced during sample collection, processing, and analysis. Water certified to have less than the MRL or LRL for the analyzed constituents and compounds was pumped through the sampling pump, tubing, and other sampling equipment in the same manner as a regular ground-water sample. Relatively large volumes of water flowed through the sampling equipment prior to collection of a ground-water sample, whereas a much smaller amount of blank water flowed through the system prior to collection of the

field-blank sample. This additional flushing and rinsing with ground water is believed to have minimized residual concentrations possibly left after the equipment cleaning procedure.

DOC was detected in water from all six field-blank samples, three at concentrations that were less than the lowest concentration measured in the ground-water samples and three within the range of measured concentrations. Because DOC was not detected in water from the source-solution blank samples, it likely results from residual cleaning agents in the sampling equipment (rinsed with 1 to 3 gal of blank water). Additional rinsing with ground water during the purging cycle of sampling (usually more than 20 gal) likely reduces DOC concentrations in the environmental samples to below those determined for the field blanks. Some of the DOC measured in water from the wells may be from the sampling equipment; therefore, DOC concentrations may be greater than what was actually present in the aquifer. Caution should be used in interpreting these data.

Nitrate plus nitrite and ammonia each were detected in one field-blank sample and ammonia plus organic nitrogen was detected in two field-blank samples. Concentrations of ammonia and ammonia plus organic nitrogen in the field-blank samples were within the range of concentrations measured in the ground-water samples; therefore, data for these constituents should be interpreted with caution. The concentration of nitrate plus nitrite in water from the field-blank sample is much lower than that for water from most of the environmental samples, and any residual contamination is probably diluted to less than the reporting level by the purging of ground water through the sampling lines. Nitrate plus nitrite concentrations measured in the ground-water samples are assumed to be uncontaminated on the basis of the field-blank data.

Zinc was detected in water from five of the six field blanks at concentrations in the range of those determined for the ground-water samples; therefore, the ground-water data are likely biased. Small amounts of chromium, nickel, and copper also were detected in water from two to four of the field blanks. Chromium and nickel are used in stainless steel and may be coming from the stainless steel connections used on the Teflon tubing. The concentration of these constituents in the field-blank samples generally is lower than those

in the ground-water samples, but contamination may bias concentrations that are in the same range. Caution should be used in interpreting these data.

Of the 104 pesticides or pesticide breakdown products analyzed for, only 4 were detected in field-blank samples. The herbicides cycloate, fenuron, and imazaquin were detected in water from one, one, and two field-blank samples, respectively; and in four, zero, and two ground-water samples, respectively, analyzed in the same sample set at the NWQL. These compounds also were detected in water from laboratory blanks at a similar concentration; therefore, their presence in the ground-water and field-blank samples is probably the result of laboratory contamination. Detection of cycloate, fenuron, and imazaquin is questioned; therefore, these compounds are not included in the pesticide data analysis.

The VOCs ethylbenzene, 1,2,4-trimethylbenzene, o-ethyltoluene, and m/p xylene were detected in two to five field-blank samples at concentrations greater than those estimated for the ground-water samples. The compounds 1,2,3-trimethylbenzene, 1,3,5-trimethylbenzene, and o-xylene also were detected in a field-blank sample and in a ground-water sample at similar concentrations. No VOCs were detected in the source-solution blanks or in the trip blank. These compounds were probably introduced into the blank sample when the blank water was poured into a cylinder containing the sampling pump. The atmosphere can receive these compounds, in addition to benzene and toluene, from the incomplete combustion of gasoline used to power the generator or nearby vehicles. Ground-water samples are not exposed to air except when they are transferred from the sample-collection chamber to the preservation chamber, so the likelihood of contamination is less than when collecting the field-blank sample. Detection of the compounds listed above in ground water is questioned and is not included in the VOC data analysis.

Sequential replicate ground-water samples were collected from three wells to determine the concentration variability for radon, major ions, and trace elements. Replicate samples collected from two wells were analyzed for DOC and nutrients. Concentrations for most constituents in the sample pairs were within 10 percent. Low concentrations of ammonia plus organic nitrogen, orthophosphorus, fluoride, and copper resulted in maximum differences between the sample pairs of about 25 percent. The zinc

concentration in water from one replicate sample was twice as much as was measured in the ground-water sample and may be related to contamination.

Surrogate pesticide and VOC compounds were added in known concentrations to the ground-water and blank-water samples and percent recovery was determined for each surrogate (tables 19 and 20, appendix). These surrogate compounds are similar chemically to other compounds that were analyzed for and provide information on sample-matrix effects and analyte recovery. Pesticide surrogate recovery in the ground-water samples ranged from 73 to 106 percent for alpha-HCH-d6, 41 to an estimated 106 percent for barban, 40 to 98 percent for caffeine, 85 to 141 percent for diazinon, and an estimated 35 to 101 percent for 2,4,5-T. Relatively low recovery of caffeine and 2,4,5-T in water from wells 6, 8, 10, 11, 24, 25, 30, 31, and 33 (all on the west side of the valley) corresponded with relatively high recovery of the surrogate diazinon. Water from the valley's west side seems to have a different effect on these surrogates than water from the east side. VOC surrogate recovery in the ground-water samples ranged from 88 to 121 percent for 1,2-dichloroethane-d4, 73 to 105 percent for 1,4-bromofluorobenzene, and 91 to 109 percent for toluene-d8.

Spike solutions containing known concentrations of target VOC and pesticide compounds were added to three replicate ground-water samples (tables 21 and 22, appendix) to determine analyte recovery in the sample matrix and to evaluate the effectiveness of the analytical methods for selected analytes. Recovery of most compounds was within 25 percent of the amount present in the unspiked sample plus the amount added in the spike solution. Recovery of the atrazine degradation products deethylatrazine and 2-hydroxyatrazine was less than (34 percent mean recovery) and greater than (140 percent mean recovery), respectively, the amount added to the three matrix-spiked samples. Low mean recovery means that the compound may not have been detected in the sample if present at low concentrations. High mean recovery means that the detections are real, but concentrations may be biased high. Recovery of chloromethane was greater than the amount added to the three matrix-spiked samples (164 percent mean recovery). Water from well 34 had the only detection of chloromethane (estimated at 0.1 µg/L) in the study, which on the basis of the spike-recovery data may be a higher concentration than actually exists in the aquifer.

Ninety percent of the ground-water samples from this study analyzed for pesticides with the HPLC/MS method exceeded the recommended 4-day holding time prior to sample extraction (Furlong and others, 2001). Degradation of pesticides during extended sample storage is likely, and concentrations and detection frequencies for the pesticides analyzed by this method may be biased low.

GROUND-WATER QUALITY

Ground-water quality data for the 30 monitoring wells sampled in recently developed residential areas of Salt Lake Valley consist of field parameters, major ions, trace elements, nutrients, DOC, pesticides, and VOCs. Summary statistics for field parameters, major ions, trace elements, nutrients, and DOC are listed in table 2; pesticides in table 3; and VOCs in table 4. Analytical results for the samples collected from the 30 wells as part of this study are listed in tables 6 to 13 (appendix). Water-quality data for these and other samples discussed in the following sections are also available on the internet at URL <http://waterdata.usgs.gov/ut/nwis/qwdata>.

Field Parameters

Field parameters measured during sampling are depth to water, water temperature, specific conductance, pH, alkalinity, dissolved oxygen, turbidity, chlorine, and sulfide concentration (table 2 and table 6, appendix). Depth to water in the wells ranged from 5.27 ft below land surface at well 41 in the southeastern part of the valley to 135.17 ft below land surface at well 31 in the southwestern part. All of the samples were within the range specified for pH to meet secondary drinking water regulations (U.S. Environmental Protection Agency, 2002). Turbidity of water sampled from the monitoring wells ranged from 0.1 to 12 nephelometric turbidity units (NTU). Turbidity measurements can be used to evaluate potential colloidal contributions to measured concentrations of iron, manganese, and other elements. Chlorine was detected in water from eight monitoring wells, seven of which are on the east side of the valley. The chlorine may be from chlorinated water that has recharged the shallow ground-water system because chloroform also was detected in the samples.

The concentration of dissolved oxygen in water from the wells varied from 0.7 to 8.7 mg/L and provides information on the oxidation-reduction (redox) state of the water. The redox state can affect what constituents are present and at what concentrations. Oxidizing conditions are generally defined by dissolved oxygen concentrations greater than 2.0 mg/L and no detectable concentrations of nitrite, ammonia, sulfide, iron, or manganese. Reducing conditions are indicated by dissolved oxygen concentrations less than 2.0 mg/L and the presence of nitrite, ammonia, sulfide, iron, or manganese. Because dissolved oxygen can be introduced to ground water during the sampling process, these other indicators were used to help determine redox conditions (tables 6, 7, 8, and 9, appendix). On the basis of these indicators, 6 wells had water under reducing conditions, 12 wells had water under oxidizing conditions, and the remaining 12 wells had water with dissolved oxygen concentrations greater than 2.0 mg/L, but the presence of nitrite, ammonia, sulfide, iron, or manganese resulted in indefinite conditions. Well 29 was the only well on the east side of the valley with definite reducing conditions.

Inorganic Constituents

Major Ions

Dissolved-solids concentration (determined as residue at 180°C) ranged from 134 to 2,910 mg/L in water from the 30 monitoring wells (fig. 6). The secondary drinking-water regulation for dissolved solids of 500 mg/L (U.S. Environmental Protection Agency, 2002) was exceeded in water from 23 wells. Water from wells on the east and west sides of the valley had median concentrations of 405 and 1,300 mg/L, respectively. The least mineralized water was from well 26S (fig. 3) next to Little Cottonwood Creek. Water in the creek (USGS site number 10167800) is primarily snowmelt runoff from the Wasatch Range in the spring and early summer and had a dissolved-solids concentration of 67 mg/L in May 2000. The most mineralized water was from well 20 and contained 1,480 mg/L of sulfate. Sulfate was the predominant anion in water from the four monitoring wells (wells 10, 17, 20, and 24), all on the west side of the valley, with more than 2,000 mg/L dissolved solids (table 7, appendix).

Table 2. Summary of field parameters, inorganic constituents, and dissolved organic carbon in water sampled from 30 monitoring wells in areas of recent residential development, Salt Lake Valley, Utah

[USEPA, U.S. Environmental Protection Agency; —, not applicable or no standard; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25 degrees Celsius; SDWR, Secondary Drinking-Water Regulations; mg/L, milligrams per liter; NTU, nephelometric turbidity units; µg/L, micrograms per liter; MCL, Maximum Contaminant Level; M, presence of constituent verified but not quantified; E, estimated; HAL, Lifetime Health-Advisory Level; pCi/L, picocuries per liter]

Parameters, constituents, and reporting units	Number of detections	Minimum reporting level	Minimum detected concentration	Maximum detected concentration	Median of detections	USEPA drinking-water standards or health advisories ¹
Field parameters						
Well depth (feet)	30	—	23	153.5	68.2	—
Water level (feet)	30	—	5.27	135.17	30.91	—
Water temperature (°C)	29	—	10.5	19	16	—
Specific conductance (µS/cm)	30	—	235	3,700	1,405	—
pH (standard units)	30	—	6.8	7.8	7.3	6.5-8.5 (SDWR)
Alkalinity (mg/L as CaCO ₃)	30	—	68	659	308	—
Oxygen, dissolved (mg/L)	29	—	.7	8.7	5.3	—
Turbidity (NTU)	30	—	.1	12	.5	—
Chlorine (µg/L)	8	30	35	100	50	—
Sulfide (µg/L)	12	10	10	240	10	—
Major ions						
Bicarbonate (mg/L as HCO ₃)	30	—	82	804	392	—
Bromide, dissolved (mg/L)	29	.01	.01	1.40	.22	—
Calcium, dissolved (mg/L)	30	.01	20.6	448	95.9	—
Chloride, dissolved (mg/L)	30	.1	12.9	456	184	250 (SDWR)
Fluoride, dissolved (mg/L)	30	.1	.1	1.9	.6	4.0 (MCL)
Iron, dissolved (µg/L)	11	10	M	540	M	300 (SDWR)
Magnesium, dissolved (mg/L)	30	.008	4.88	175	39.8	—
Manganese, dissolved (µg/L)	24	2.2	E1.4	148	11.2	50 (SDWR)
Potassium, dissolved (mg/L)	30	.09	1.35	57.8	10.6	—
Silica, dissolved (mg/L)	30	.1	6.5	51.6	37	—
Sodium, dissolved (mg/L)	30	.1	10.3	473	162	—
Sulfate, dissolved (mg/L)	30	.1	16.9	1,480	136	250 (SDWR)
Dissolved solids, residue at 180°C, (mg/L)	30	10	134	2,910	833	500 (SDWR)
Dissolved solids, sum of constituents (mg/L)	30	—	131	2,830	856	500 (SDWR)
Trace elements						
Aluminum, dissolved (µg/L)	24	1	1	10	2	50-200 (SDWR)
Antimony, dissolved (µg/L)	2	1.00	1.30	1.69	1.54	6 (MCL)
Arsenic, dissolved (µg/L)	24	1.0	1.1	19.6	10.5	10 (MCL)
Barium, dissolved (µg/L)	30	1.0	11.8	255	52.4	2,000 (MCL)
Beryllium, dissolved (µg/L)	0	1.00	—	—	—	4 (MCL)
Cadmium, dissolved (µg/L)	0	1.00	—	—	—	5 (MCL)
Chromium, dissolved (µg/L)	23	1.0	E.5	4.7	1.7	² 100 (MCL)
Cobalt, dissolved (µg/L)	2	1.00	1.05	1.09	1.07	—
Copper, dissolved (µg/L)	26	1.0	1.0	10	2.3	1,000 (SDWR)
Lead, dissolved (µg/L)	0	1.00	—	—	—	—
Molybdenum, dissolved (µg/L)	28	1.0	1.5	99.1	5.2	40 (HAL)
Nickel, dissolved (µg/L)	28	1.00	1.30	7.88	3.12	100 (HAL)
Radon-222, total (pCi/L)	30	26	243	2,190	574	300 (MCL)
Selenium, dissolved (µg/L)	15	1.0	1.2	13.0	2.6	50 (MCL)
Silver, dissolved (µg/L)	0	1.0	—	—	—	100 (HAL)
Uranium, dissolved (µg/L)	29	1.00	1.50	92.7	10.4	30 (MCL)
Zinc, dissolved (µg/L)	27	1	1	8	3	2,000 (HAL)

Table 2. Summary of field parameters, inorganic constituents, and dissolved organic carbon in water sampled from 30 monitoring wells in areas of recent residential development, Salt Lake Valley, Utah—Continued

Parameters, constituents, and reporting units	Number of detections	Minimum reporting level	Minimum detected concentration	Maximum detected concentration	Median of detections	USEPA drinking-water standards or health advisories ¹
Nutrients and dissolved organic carbon						
Ammonia, dissolved as N (mg/L)	7	.020	.021	.043	.029	30 (HAL)
Ammonia plus organic nitrogen, dissolved as N (mg/L)	27	.10	E.06	.34	.14	—
Carbon, organic, dissolved as C (mg/L)	30	.30	.60	4.6	1.5	—
Nitrite, dissolved as N (mg/L)	5	.010	.012	.107	.019	1 (MCL)
Nitrate plus nitrite, dissolved as N (mg/L)	29	.050	.200	13.3	6.85	10 (MCL)
Phosphorus, dissolved as P (mg/L)	29	.004	.006	.207	.033	—
Orthophosphorus, dissolved as P (mg/L)	27	.010	.015	.189	.031	—

¹ U.S. Environmental Protection Agency (2002).

² Maximum contaminant level is for total chromium.

Table 3. Concentration and detection frequency of pesticides detected in water sampled from 30 monitoring wells in areas of recent residential development, Salt Lake Valley, Utah

[Maximum contaminant level is the U.S. Environmental Protection Agency established drinking-water standard (U.S. Environmental Protection Agency, 2002). Lifetime health advisory level is defined as the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for a lifetime of exposure (U.S. Environmental Protection Agency, 2002). E, estimated value; —, not applicable or no standard]

Pesticide	Trade name(s) or abbreviation	Predominant use	Number of detections	Maximum	Minimum	Minimum	Maximum	Lifetime health advisory level
				concentration	detected concentration	reporting level	contaminant level	
(micrograms per liter)								
Atrazine	AAtrex	restricted use herbicide	23	1.58	E 0.004	0.001	3	—
Deethylatrazine	DEA, Desethylatrazine	degradation product of atrazine	21	E .320	E .004	.002	—	—
Deethyldeisopropylatrazine	DEIA	degradation product of atrazine	19	E .12	E .01	.06	—	—
Deisopropylatrazine	—	degradation product of atrazine and simazine	4	E .02	E .01	.07	—	—
2-Hydroxyatrazine	—	degradation product of atrazine	10	E .511	E .044	.193	—	—
Bromocil	Hyvar, Urox B	general use herbicide	1	.19	—	.081	—	90
Caffeine	—	occurs naturally in tea, coffee, and cola nuts	2	E .029	E .011	.081	—	—
Cycloate ¹	Ro-Neet	herbicide	4	E .04	E .03	.05	—	—
Diazinon	D-Z-N	restricted use insecticide	1	E .002	—	.002	—	.6
Diuron	Karmex, Direx	general use herbicide	1	.32	—	.08	—	10
Imazaquin ¹	Ala-Scept, Scepter	general use herbicide	2	E .006	E .006	.103	—	—
Malathion	Cythion	general use insecticide	1	.006	—	.005	—	100
P,P' DDE	—	degradation product of DDT	1	E .002	—	.006	—	—
Picloram	Access, Tordon	restricted use herbicide	1	.47	—	.07	500	500
Prometon	Pramitol	general use herbicide	15	.518	E .004	.018	—	100
Simazine	Aquazine, Princep	restricted use herbicide	13	.027	E .004	.005	4	4
Tebuthiuron	Brush, Spike, Perflan	restricted use herbicide	4	.120	E .012	.010	—	500

¹ Presence in the ground-water and field-blank samples may be the result of laboratory contamination.

Table 4. Concentration and detection frequency of volatile organic compounds detected in water sampled from 30 monitoring wells in areas of recent residential development, Salt Lake Valley, Utah

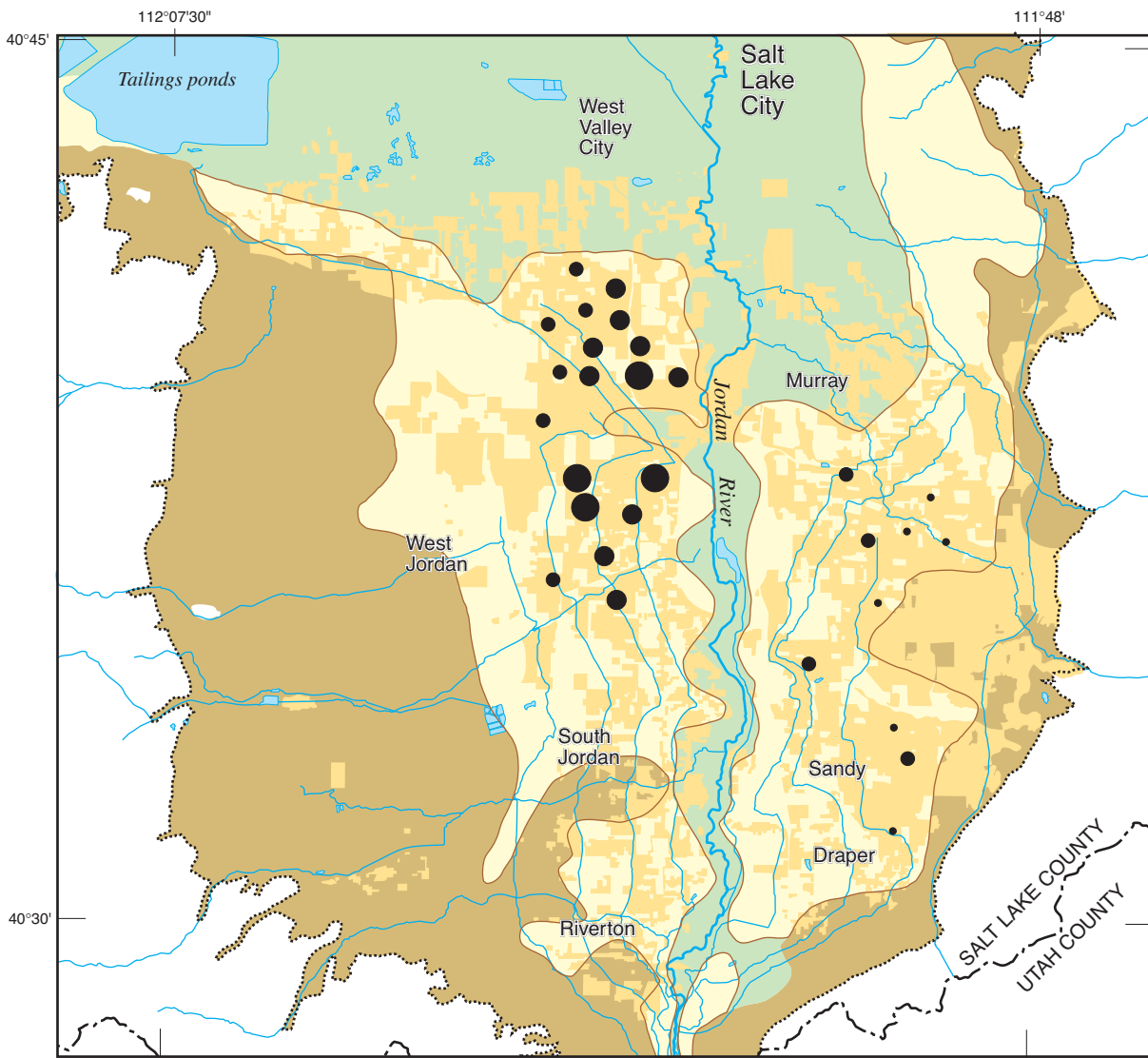
[Maximum contaminant level is the U.S. Environmental Protection Agency established drinking-water standard (U.S. Environmental Protection Agency, 2002). Lifetime health advisory level is defined as the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects for a lifetime of exposure (U.S. Environmental Protection Agency, 2002). E, estimated value; M, presence of compound verified but not quantified; —, not applicable or no standard]

Volatile organic compound	Alternative name or abbreviation	Predominant use	Number of detections	Maximum concentration	Minimum detected concentration	Laboratory reporting level	Maximum contaminant level	Lifetime health advisory level
				(micrograms per liter)				
Benzene ¹	—	fuel-related compound	2	E 0.01	M	0.04	5	—
Bromodichloromethane ²	Dichlorobromomethane	chlorination byproduct	17	.51	E .02	.05	80	—
Carbon disulfide	—	naturally occurring	3	E .10	E .01	.07	—	—
Chloroform ²	Trichloromethane	solvent, chlorination byproduct	27	2.41	E .03	.05	80	—
Chloromethane	Methyl chloride	solvent	1	E .1	—	.5	—	30
1,1-Dichloroethane	Ethylidene chloride	solvent	1	E .03	—	.07	—	—
1,2-Dichloroethane	Ethylene dichloride	metal degreaser	1	.4	—	.1	5	—
1,1-Dichloroethylene	1,1-DCE	organic synthesis	2	E .05	E .01	.04	7	6
Dichloromethane	Methylene chloride	solvent, metal degreaser	6	E .3	M	.4	5	—
Ethylbenzene ¹	Ethylbenzol	fuel-related compound	2	E .02	E .01	.03	700	700
o-Ethyl toluene ¹	—	fuel-related compound	1	E .01	—	.06	—	—
Methyl tert-butyl ether	MTBE	fuel oxygenate	1	E .1	—	.2	—	—
Tetrachloroethylene	Tetrachloroethene, PCE	solvent	16	7.8	M	.1	5	10
Tetrachloromethane	Carbon tetrachloride	solvent, metal degreaser	1	E .01	—	.06	5	—
Toluene ¹	Methylbenzene	fuel-related compound	2	E .01	E .01	.05	1,000	1,000
1,1,1-Trichloroethane	Methyl chloroform, TCA	solvent	15	.22	E .01	.03	200	200
Trichloroethylene	Trichloroethene, TCE	solvent	5	1.54	E .02	.04	5	—
Trichlorofluoromethane	Freon 11, CFC-11	refrigerant, aerosol propellant	2	E .09	E .04	.09	—	2,000
1,1,2-Trichlorotrifluoroethane	CFC-113	refrigerant, aerosol propellant	1	E .08	—	.06	—	—
1,2,3-Trimethylbenzene ¹	—	fuel-related compound	1	M	—	.1	—	—
1,2,4-Trimethylbenzene ¹	Psuedocumene	fuel-related compound	2	E .03	E .01	.06	—	—
1,3,5-Trimethylbenzene ¹	—	fuel-related compound	1	E .01	—	.04	—	—
m- and p-Xylene ¹	1,3 + 1,4-Dimethylbenzene	fuel-related compound	4	E .08	E .01	.06	³ 10,000	³ 10,000
o-Xylene ¹	1,2-Dimethylbenzene	fuel-related compound	1	E .02	—	.04	³ 10,000	³ 10,000

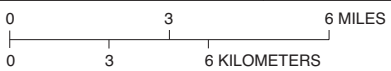
¹ Presence in the ground-water and (or) field-blank samples may be the result of contamination in the field while sampling.

² A trihalomethane, it is a byproduct of the chlorination disinfection process. The maximum contaminant level for total trihalomethanes is 80 micrograms per liter.

³ Maximum contaminant level and lifetime health advisory level are for total xylene.



Base from U.S. Geological Survey digital line graph data, 1:100,000, 1979 and 1980
 Universal Transverse Mercator projection, Zone 12



EXPLANATION

- Area of recent residential and commercial land use
- Discharge area
- Primary recharge area
- Secondary recharge area
- Approximate boundary of basin-fill deposits in Salt Lake Valley
- Dissolved-solids concentration in water sampled from monitoring wells, in milligrams per liter**
- 134 - 500
- 500 - 1,000
- 1,000 - 2,000
- 2,000 - 2,910

Figure 6. Dissolved-solids concentration in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

The secondary drinking-water regulation for sulfate (250 mg/L) (U.S. Environmental Protection Agency, 2002) was exceeded in water from 11 wells on the west side of the valley. Sulfate is the predominant anion in water from monitoring wells 17, 20, 24, 25, and 33 located south of 6200 South Street on the west side. Sulfate dissolved in ground water in the area may result from dissolution of gypsum or oxidation of pyrite and other sulfide minerals. A sand and gravel spit extends from the mountain front eastward into the valley at about 6200 South Street, formed by south-flowing Lake Bonneville currents that deposited sediment from the north end of the Oquirrh Mountains. Sediment from streams draining sulfide-mineralized rocks in the Bingham Canyon area could have been deposited behind the spit in a lower energy environment, such as a lagoon. Little natural recharge occurs in this area other than from infiltration of precipitation because the mountain-front streams are ephemeral. Oxidized water recharged from local precipitation and the canals could react with the sulfide-rich aquifer material and result in dissolved sulfate. The primary cation in water from most wells in the area is sodium rather than calcium, indicating that gypsum dissolution may not be the source of sulfate.

Chloride concentrations in water from the monitoring wells ranged from 13 to 456 mg/L and were highest in water from wells 2, 4, 6, and 10 in the northwestern part of the valley (table 7, appendix). The secondary drinking-water regulation of 250 mg/L for chloride (U.S. Environmental Protection Agency, 2002) was exceeded in water from 10 wells, all located on the west side of the valley. Water from the Utah and Salt Lake Canal (USGS site number 403524111572202) had a dissolved-solids concentration of 832 mg/L, 203 mg/L of which was chloride. Monitoring wells 2 and 4 are located near faults (fig. 1) and contained water with more than twice as much chloride as did water from the canal. Water movement along a fault may affect water quality in the area.

The inorganic chemical composition of ground water largely depends on the type of rocks and associated minerals with which it has been in contact. Basin-fill deposits in the southeastern part of the valley are derived from rocks more resistant to weathering, such as quartzite and quartz monzonite. Shallow ground water from the monitoring wells on the east

side of Salt Lake Valley is predominantly a calcium bicarbonate type that indicates less reactive aquifer material that contains quartz (fig. 7).

Basin-fill deposits on the west side of the valley have eroded from more varied rock sources. The Oquirrh Mountains are composed of Paleozoic carbonate rocks, some of which have undergone sulfide mineralization; Tertiary volcanic rocks; and Quaternary to Tertiary semiconsolidated alluvial deposits. Sodium, calcium, bicarbonate, and chloride are the predominant ions in water from monitoring wells 8, 14, and 31. These are the westernmost monitoring wells upgradient from all or most of the canals, and the chemical composition of the ground water is likely controlled by reaction with the aquifer material. The predominant ions in water from wells completed in the deeper aquifer in the area are calcium, chloride, and bicarbonate, indicating that water at greater depths has undergone similar reactions with the aquifer material.

Seepage from four irrigation canals that divert water from the Jordan River is a major source of recharge on the west side of the valley, in addition to recharge from locally derived precipitation. The Jordan River drains Utah Lake, which becomes more mineralized by mixing with geothermal water, dissolution, and evaporation. Predominant ions in water from the Utah and Salt Lake Canal near monitoring well 33 are sodium and chloride. Wells downgradient from the canals north of 6200 South Street contain water that ranges from a sodium bicarbonate type to a sodium chloride type and is likely a mixture of locally recharged water and seepage from the canals.

Trace Elements

Concentrations of the trace elements nickel, selenium, antimony, chromium, and barium, analyzed for in water from the monitoring wells, were less than the MCLs or HALs. Lead, silver, cadmium, and beryllium were analyzed for, but not detected. Molybdenum, arsenic, uranium, and radon were detected in water from some wells at concentrations that exceeded MCLs, proposed MCLs, or HALs. The lifetime HAL of 40 µg/L for molybdenum (U.S. Environmental Protection Agency, 2002) was exceeded in water from four monitoring wells (wells 2, 9, 17, and 29) (table 8, appendix).

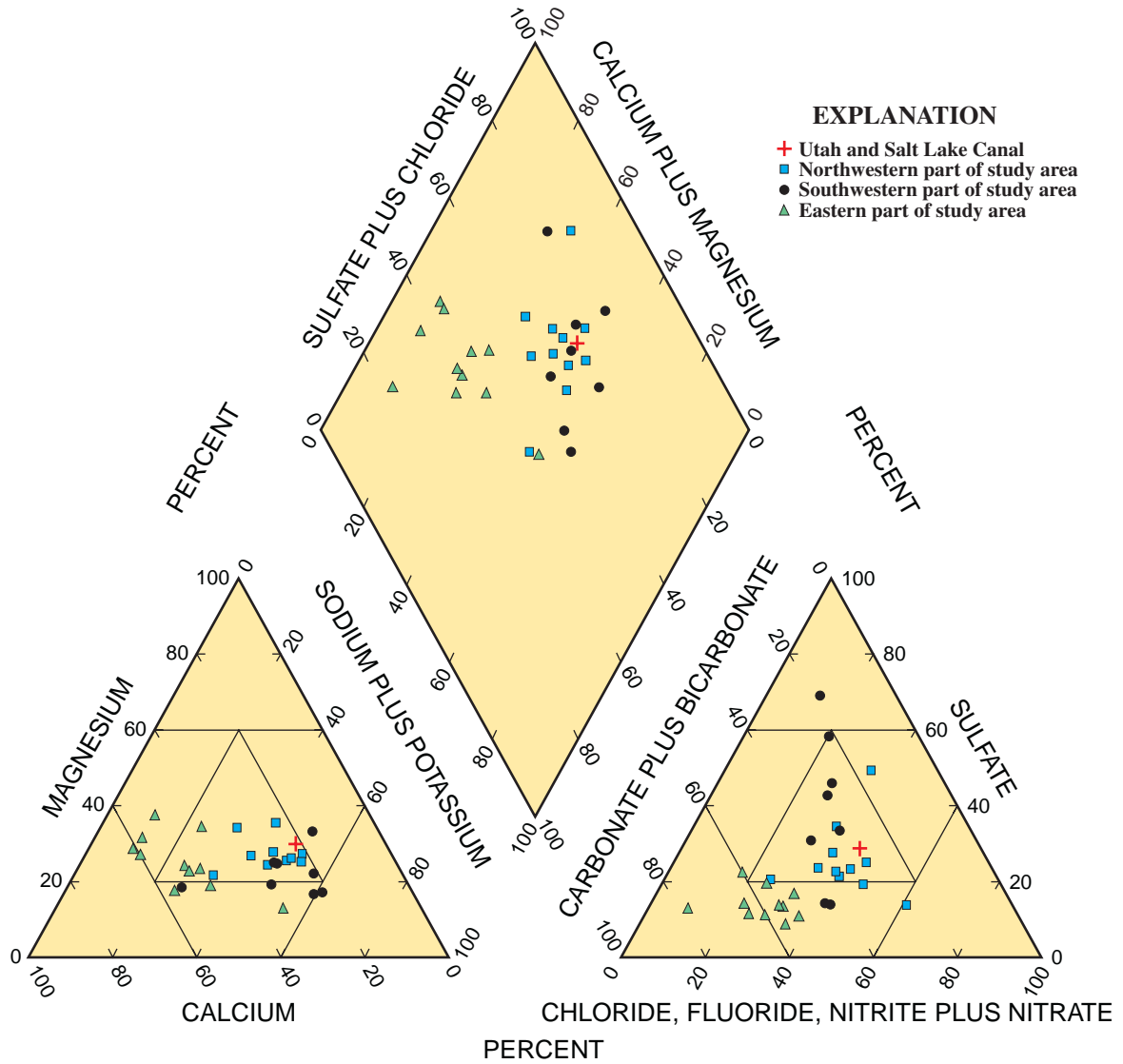


Figure 7. Major-ion composition of water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

Arsenic concentrations ranged from less than 1 µg/L in ground water from the east side of Salt Lake Valley to almost 20 µg/L in ground water from the west side (fig. 8). The median concentration for water from the 30 monitoring wells was 7 µg/L (1.1 µg/L for the east side of the valley and 11.7 µg/L for the west side). Concentrations in water from 12 wells, all of which are on the west side of the valley, exceeded the drinking water MCL of 10 µg/L (U.S. Environmental Protection Agency, 2002).

Water from monitoring wells in the northwestern part of the valley generally had higher arsenic concentrations than other areas (fig. 8). This may be related to more fine-grained deposits, and therefore a greater likelihood for reducing conditions, coupled with less recharge available to move arsenic through the system. The proximity of faults, and the potential for geothermal water to move into the basin-fill deposits, is also a potential factor for elevated arsenic concentrations in the area. Arsenic is present in volcanic gases and is a common constituent of geothermal water (Hem, 1989, p. 144).

Water in the Utah and Salt Lake Canal, a source of recharge to the west side of the valley, had 10 µg/L of dissolved arsenic. Iron oxide that adsorbs or contains arsenic can be dissolved or reduced through the addition of organic carbon, resulting in release of arsenic to the ground water (Welch and others, 2000; Welch and Lico, 1998). Reddish-orange and black staining on sediment particles indicate iron oxide and manganese oxide coatings, respectively, and were noted in the unsaturated zone while drilling many of the west-side monitoring wells. The relatively high arsenic concentration and the presence of dissolved iron (40 µg/L) and organic carbon (3.2 mg/L) in water from well 4 may indicate this process.

Tertiary-age volcanic rocks and the Salt Lake Formation exposed near the base of the Oquirrh Mountains may be a source of arsenic that is not present on the east side of the valley. The Oquirrh Mountains consist mainly of Paleozoic-age carbonate and quartzite rocks that were intruded by mid-Tertiary-age igneous rocks and associated mineralized fluids in the Bingham Canyon area. Basin-fill deposits derived from the sulfide mineralized consolidated rocks contain arsenic. Oxidation of arsenic-bearing sulfides also can release arsenic to ground water. Water from well 20 had relatively high concentrations of dissolved arsenic (17.7 µg/L) and sulfate (1,480 mg/L), possibly as a result of sulfide oxidation.

Ground water affected by mining activities of sulfide-ore deposits near Bingham Creek had a mean arsenic concentration of 14 µg/L (Kennecott Utah Copper Environmental Engineering Projects Group, written commun., 1998, table 4.9). The processed ore is transported to a smelter at the north end of the Oquirrh Mountains that may release arsenic to the air and affect concentrations in local precipitation. Arsenic concentrations averaging 17 µg/L were measured in rain and snow collected downwind from a smelter in Tacoma, Washington (Crecelius, 1975). Sediment cored from Mirror Lake, in the Uinta Mountains about 50 mi east of Salt Lake City, was enriched in arsenic, lead, zinc, copper, tin, and cadmium relative to deeper sediments (Kada and others, 1994). The start of large-scale mining and smelting of nonferrous metal ores in the Salt Lake Valley area corresponds with the increase of arsenic in the dated lake sediment.

Radionuclides

Radon occurs naturally as a gas that is soluble in ground water and is released through radioactive decay from rocks containing uranium (fig. 9). It is the direct result of decay of radium-226, a decay product of uranium-238. Higher concentrations of radon occur in areas with uranium-rich sources such as granite, metamorphic rocks, and basin-fill deposits weathered from these rocks. Because of a short half-life of 3.8 days, radon is detected near its source. The radon concentration in water is reported in terms of activity where 1 pCi/L is about equal to the decay of two atoms of radon per minute in a liter of water. Radon moves more easily through highly permeable material, such as sand, gravel, and fractures, and readily degasses from water exposed to air. Breathing radon in indoor air is the second leading cause of lung cancer and is a greater health concern than drinking water that contains radon (U.S. Environmental Protection Agency, 1999). The proposed MCL for radon in drinking water is 300 pCi/L (U.S. Environmental Protection Agency, 2002).

Radon concentrations in water from the 30 monitoring wells ranged from 243 to 2,190 pCi/L, with a median value of 574 pCi/L (table 2). Only water from wells 3 and 11, in the northwestern part of the valley, had a concentration of less than 300 pCi/L. The median concentration for water from monitoring wells on the east side of the valley was 719 pCi/L compared to 524 pCi/L on the west side. Water from wells 22, 32, 37, and 41 had radon concentrations greater than 1,000

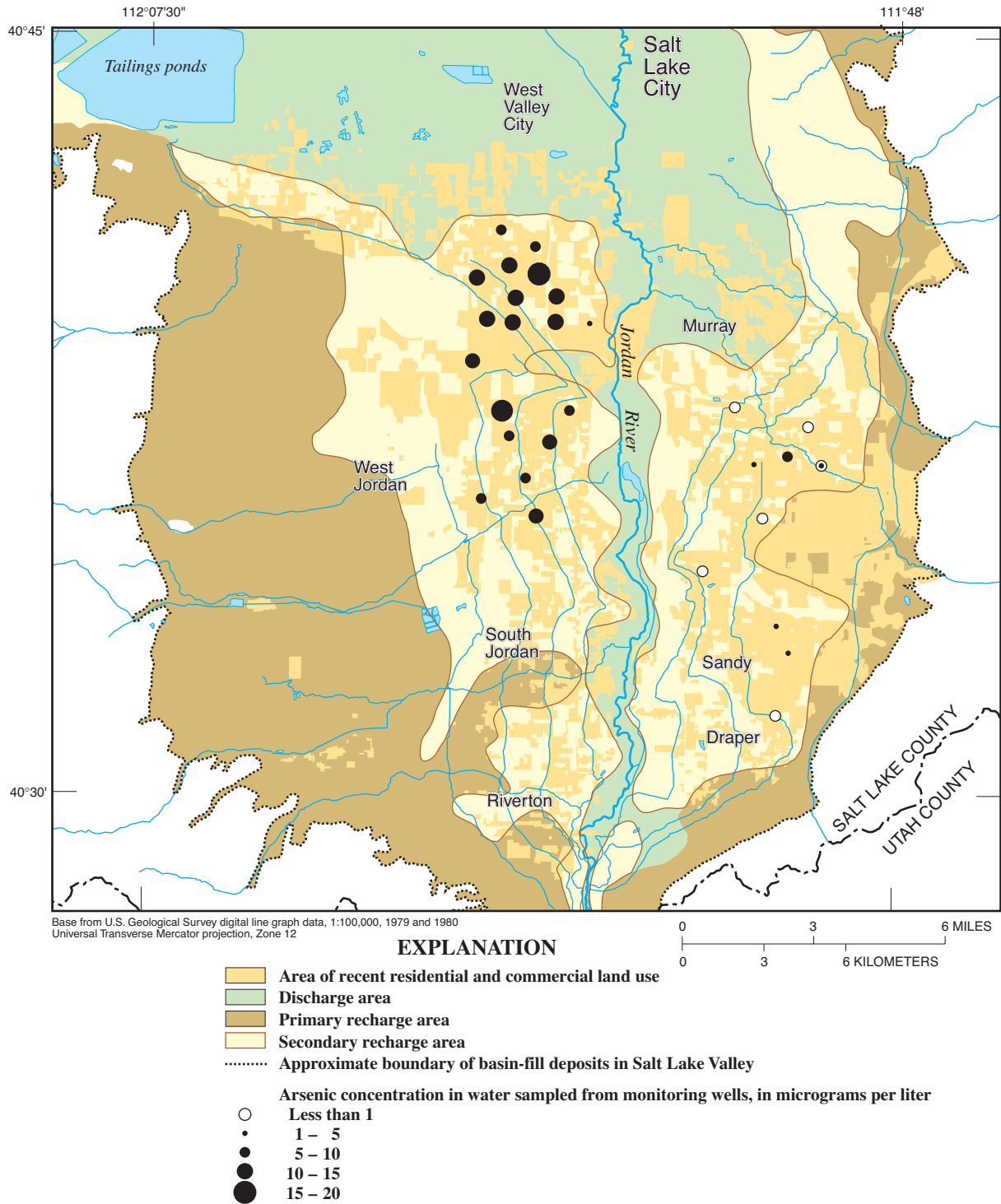
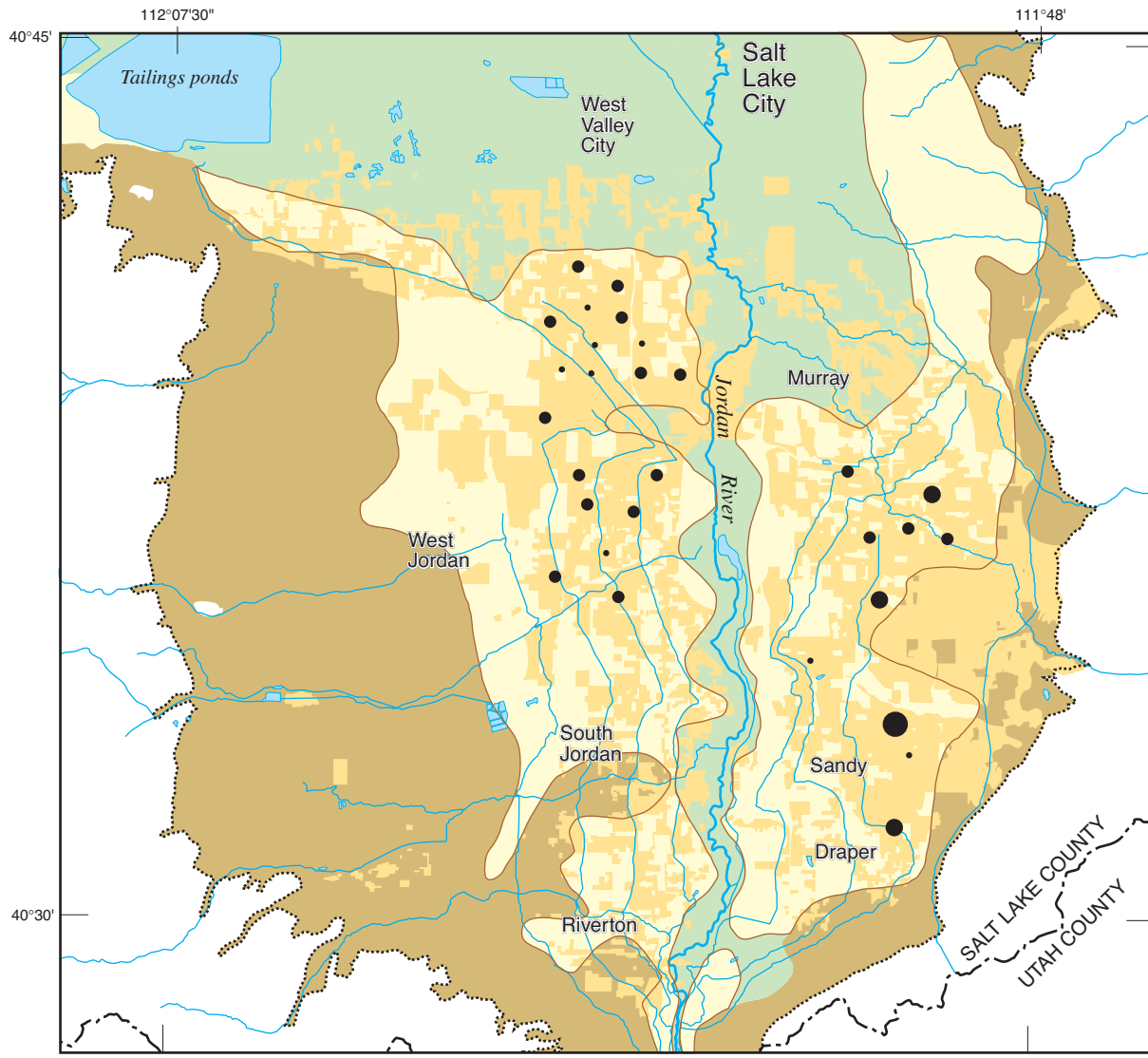


Figure 8. Arsenic concentration in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.



Base from U.S. Geological Survey digital line graph data, 1:100,000, 1979 and 1980
 Universal Transverse Mercator projection, Zone 12

EXPLANATION

- Area of recent residential and commercial land use
- Discharge area
- Primary recharge area
- Secondary recharge area
- Approximate boundary of basin-fill deposits in Salt Lake Valley
- Radon concentration in water sampled from monitoring wells, in picocuries per liter**
- 243 – 500
- 500 – 1,000
- 1,000 – 1,500
- 1,500 – 2,193

Figure 9. Radon concentration in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

pCi/L. These wells are located on the east side of valley where the mountain block is composed of quartzite and quartz monzonite.

Uranium dissolved in water from the monitoring wells ranged from less than 1 µg/L at well 29 to about 93 µg/L at well 41, both on the east side of the valley (table 8). Uranium is soluble under oxidizing conditions, and because of its long half-life (4.5×10^9 years) can be transported by ground water farther from its source areas than can radon. It is concentrated in the sediment in reducing environments because of mineral precipitation. The lack of detectable uranium in water from well 29 is a result of reducing conditions. The relatively high uranium concentration in water from well 41 may result from its proximity to intrusive rocks in the Wasatch Range. The MCL for uranium of 30 µg/L (U.S. Environmental Protection Agency, 2002) was exceeded in water from three wells, all of which are on the east side of Salt Lake Valley.

Nutrients and Dissolved Organic Carbon

Although the nutrients nitrogen and phosphorus can occur naturally in ground water, elevated concentrations in ground water are thought to be caused by human activities. Some of the potential sources of nutrients in ground water include fertilizers applied to lawns and gardens and leaking or improperly functioning septic systems and sewer pipes. Nitrogen compounds such as ammonia and ammonium fertilizers naturally transform into nitrate, which is relatively stable in oxygenated subsurface environments and is readily transported in water. Nitrite is unstable in aerated water and is seldom present in measurable concentrations under oxidizing conditions. In this report, nitrate is reported as the sum of nitrite and nitrate as nitrogen.

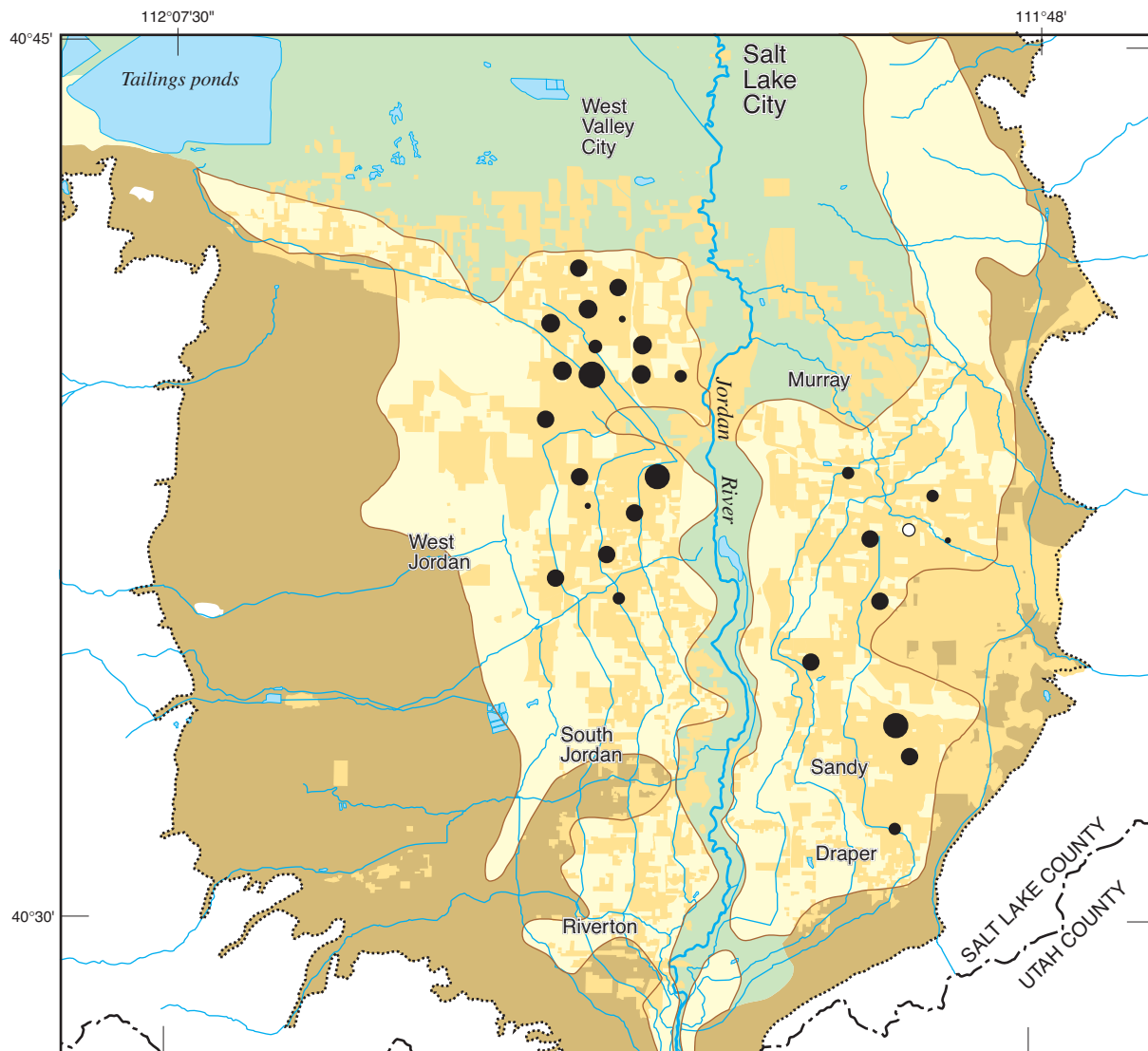
Background nitrate concentrations in ground water from areas not associated with agricultural practices commonly are less than 2 to 3 mg/L as nitrogen (Halberg and Keeney, 1993) and concentrations greater than 2 mg/L may indicate ground water affected by human activities (U.S. Geological Survey, 1999). Some existing nitrate data for ground water in the Great Salt Lake Basins study area are available from the USGS National Water Information System (NWIS) database. In urban/residential areas, the median nitrate concentration in water from wells less than 150 ft deep

was 1.1 mg/L (71 analyses); in water from wells greater than 150 ft deep, generally completed in the deeper unconfined aquifers, it was less than 1 mg/L (110 analyses).

Nitrate concentration in water sampled from 26 of the 30 monitoring wells (86.7 percent) was higher than an assumed background level of 2 mg/L, indicating a possible human influence. Concentrations ranged from less than 0.05 to 13.3 mg/L with a median concentration of 6.85 mg/L for the 30 samples (table 9, appendix). The median nitrate concentration for water from monitoring wells on the east side of the valley was 4.45 mg/L compared to 7.05 mg/L on the west side (fig. 10). The MCL of 10 mg/L for nitrate in drinking water (U.S. Environmental Protection Agency, 2002) was exceeded in water from wells 11, 17, and 37.

Concentrations of nitrite, ammonia, ammonia plus organic nitrogen, phosphorus, and orthophosphorus in water from the monitoring wells were low, 2 to 3 orders of magnitude less than MCLs or health advisory levels. Nitrite was detected in water from 5 of the 30 wells, 3 of which had other indicators of reducing conditions. The presence of nitrite in water from four of the wells corresponded to nitrate concentrations greater than 7.5 mg/L. Ammonia detected in seven ground-water samples may be the result of sample contamination because ground-water concentrations were only slightly greater than those measured in a field-blank sample. Water from four of the wells had phosphorus concentrations greater than 0.1 mg/L, and two of those also had the highest nitrate concentrations (wells 17 and 37). Water from these wells likely has been affected by anthropogenic factors such as sewer lines, septic tanks, confined animals, or fertilizers.

DOC can affect ground-water quality because it is involved in oxidation/reduction reactions with chemical constituents of the aquifer material and ground water. The median DOC concentration in water from the monitoring wells was 1.5 mg/L and ranged from 0.60 mg/L at well 26S to 4.6 mg/L at well 1 (table 9, appendix). DOC measured in water from six field-blank samples (median concentration of 0.96 mg/L) is attributed to contamination introduced from the sampling equipment cleaning procedure. Rinsing of the sampling equipment with ground water during the purge cycle likely reduces DOC contamination, but some of the DOC measured in water from the wells may be from the sampling equipment.



Base from U.S. Geological Survey digital line graph data, 1:100,000, 1979 and 1980
 Universal Transverse Mercator projection, Zone 12

EXPLANATION

- Area of recent residential and commercial land use
- Discharge area
- Primary recharge area
- Secondary recharge area
- Approximate boundary of basin-fill deposits in Salt Lake Valley

- Nitrate concentration in water sampled from monitoring wells, in milligrams per liter**
- Less than 0.05
 - 0.2 – 3.0
 - 3.0 – 5.0
 - 5.0 – 10.0
 - 10.0 – 13.3

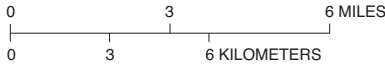


Figure 10. Nitrate concentration in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

Pesticides

Fifteen of the 104 pesticides and pesticide degradation products analyzed for were detected in 1 or more water samples collected as part of this study (table 3 and fig. 11). Breakdown products of pesticides (metabolites or degradates) are formed through the metabolic degradation of a parent compound. All of the pesticides analyzed as part of this study are listed in table 10 (appendix). Most are used as herbicides. The insecticides diazinon and malathion were detected in trace amounts in one sample each. At least one pesticide or pesticide degradation product was detected in water from 28 of the 30 monitoring wells. The two wells with no pesticide detections are located on the

east side of the valley (wells 32 and 37). Water from well 7 on the west side of the valley contained 10 different pesticide compounds, including bromacil, diuron, atrazine, and atrazine degradation products, all herbicides used to control roadside vegetation. No pesticides were detected at concentrations that exceeded USEPA drinking-water standards or guidelines (U.S. Environmental Protection Agency, 2002).

Much lower analytical reporting levels were used in this study than are typically used in routine pesticide monitoring of public-water supplies. Therefore, much higher rates of detection were obtained than would have been possible with less sensitive analytical methods. The MRL for atrazine is 0.001 µg/L, about

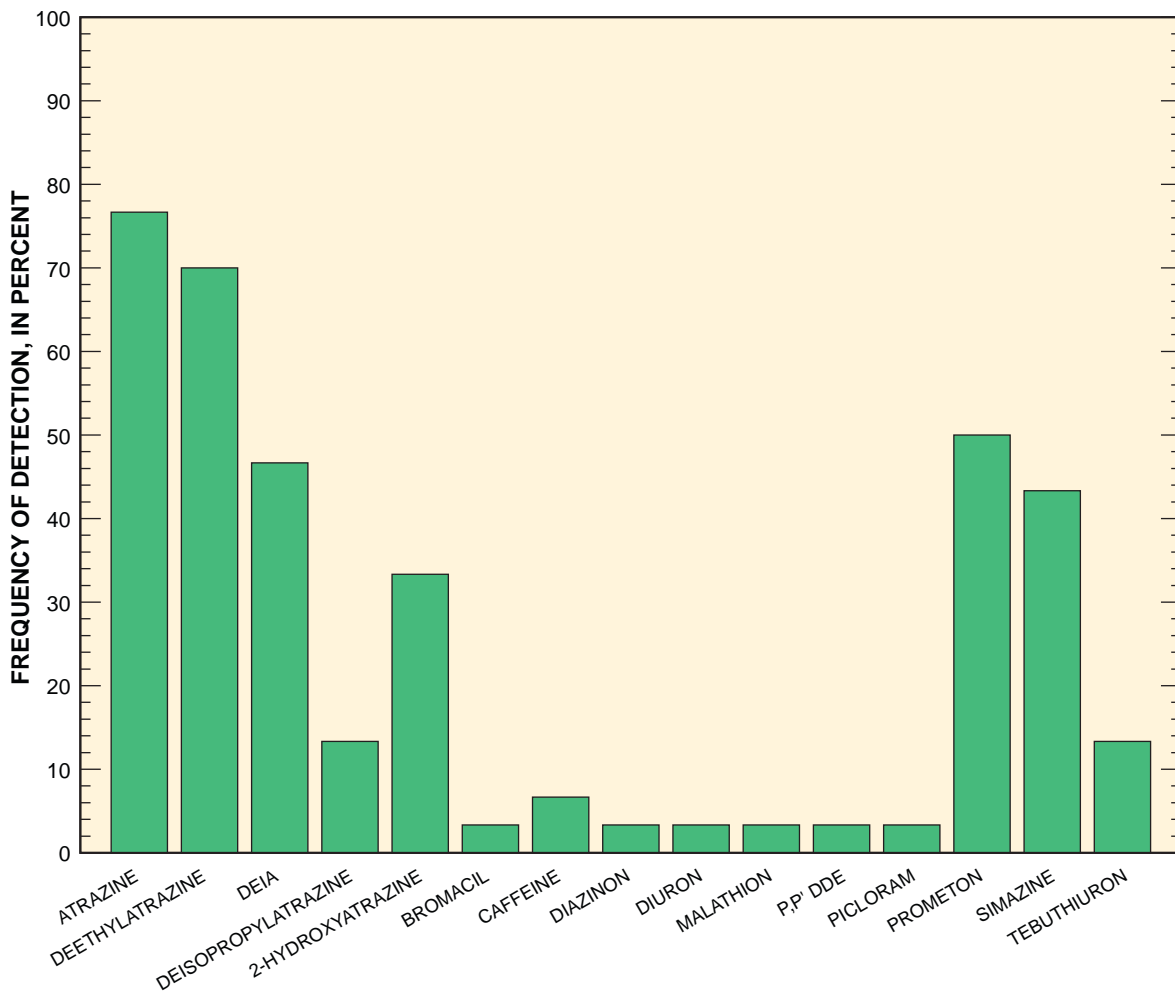


Figure 11. Detection frequency of pesticides in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

two orders of magnitude lower than that used on water from drinking-water wells for the USEPA's National Pesticide Survey done in 1988-90 (Barbash and others, 1999).

Water-quality standards are based on concentrations of individual pesticides and do not account for mixtures of pesticides. Total concentration of pesticides and pesticide degradation products in water ranged from an estimated 0.002 µg/L at well 22 (diazinon) to 2.56 µg/L at well 11 (a mixture of atrazine, atrazine degradation products, and simazine). The effects of different combinations of pesticides on human health are not known at this time; therefore, drinking-water standards have not been set for pesticide mixtures.

The herbicide atrazine and its degradation product deethylatrazine (DEA) were the most frequently detected pesticides in the study, detected in 23 and 21 of the 30 water samples, respectively. All but one of the water samples from the west side of the valley contained detectable concentrations of atrazine (well 14). Atrazine concentrations in water from the 30 monitoring wells ranged from less than 0.001 to 1.58 µg/L (table 11, appendix), all below the MCL for atrazine in drinking water of 3 µg/L (U.S. Environmental Protection Agency, 2002) (fig. 12).

Atrazine is a restricted-use pesticide that is generally used on corn and along roads, railroads, other right-of-ways, utility substations, and industrial lots to control weeds and undesired vegetation in the valley (Mark Quilter, Utah Department of Agriculture and

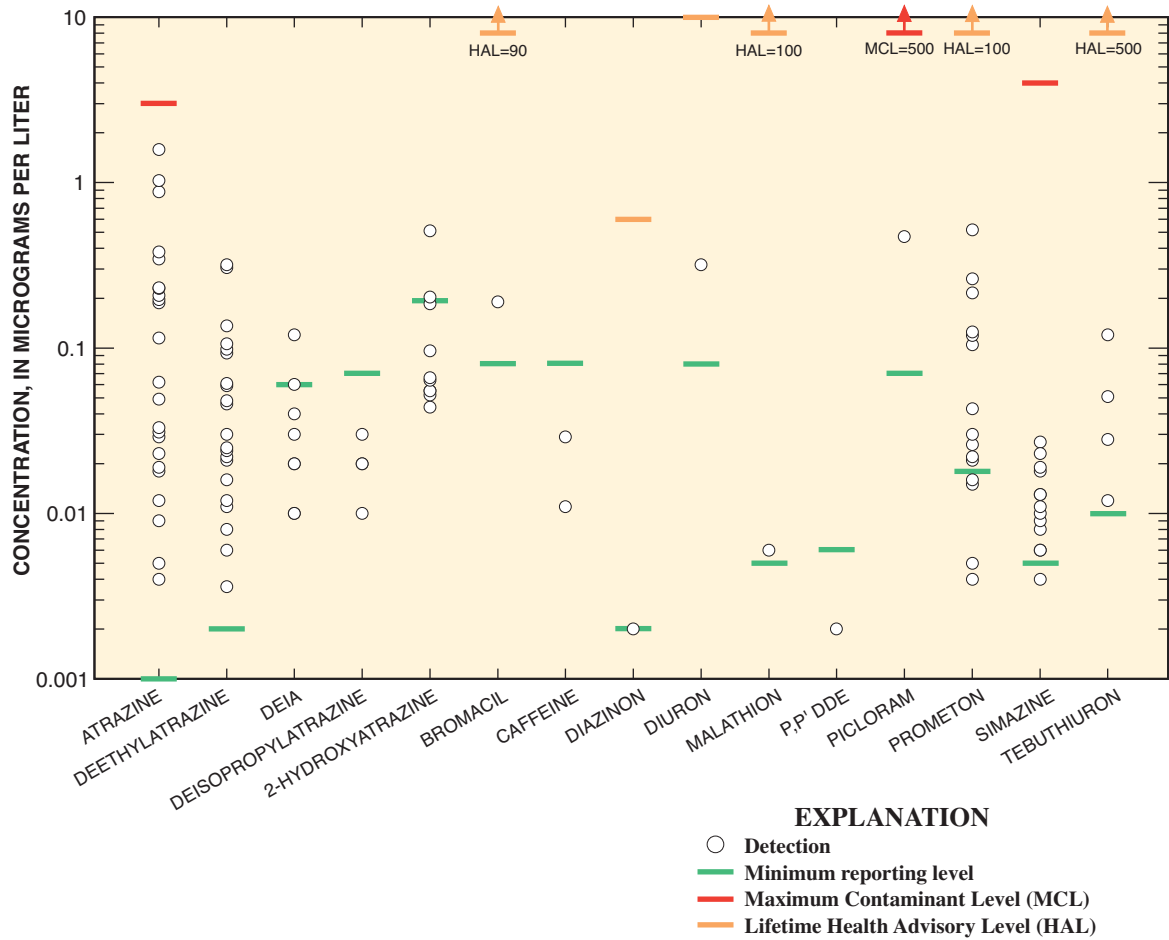


Figure 12. Concentration of selected pesticides in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

Food, oral commun., 2000). It is not for household use. The high detection frequency of atrazine in residential areas on the west side may be the result of application in agricultural or industrial areas that have been converted to residential uses or application in areas upgradient from the residential areas that was then transported by ground water. The presence of atrazine and other pesticides in ground water is likely the result of widespread use rather than small-scale point sources such as spills. Atrazine probably is transported to the ground-water system by direct sources of recharge, such as seepage from drainage systems and retention basins.

Degradation products of atrazine other than DEA that were detected include deisopropylatrazine, deethyldeisopropylatrazine (DEIA), and 2-hydroxyatrazine. Deisopropylatrazine can form from the degradation of either atrazine or simazine. The total concentration of atrazine and its degradation products in the 30 water samples ranged from not detected at six wells on the east side of the valley to 2.54 µg/L at well 11 on the west side (fig. 13). At least one of these compounds was detected in water from all 19 wells located on the west side of Salt Lake Valley. None of the cumulative concentrations of atrazine and its degradation products were greater than 0.1 µg/L in water sampled from the east side of the valley, whereas 12 of the samples from the west side contained more than 0.1 µg/L.

Prometon was the third most frequently detected pesticide, detected in water sampled from 15 wells (50 percent), including 6 of the 11 samples collected from wells on the east side of the valley (fig. 14). The maximum concentration of 0.518 µg/L in water from well 1 is much less than the HAL for drinking water of 100 µg/L (U.S. Environmental Protection Agency, 2002). Prometon is registered for use by homeowners to control vegetation and generally is used along rights-of-way (Mark Quilter, Utah Department of Agriculture and Food, oral commun., 2000). It also can be used in and under asphalt to prevent weeds from emerging through it (Ciba-Geigy Corporation, 1994). Nationally, it was the most frequently detected herbicide in ground water at urban sites sampled as part of the NAWQA program (Capel and others, 1999). Its more frequent occurrence on the east side of the valley relative to atrazine and simazine may reflect greater usage in residential areas.

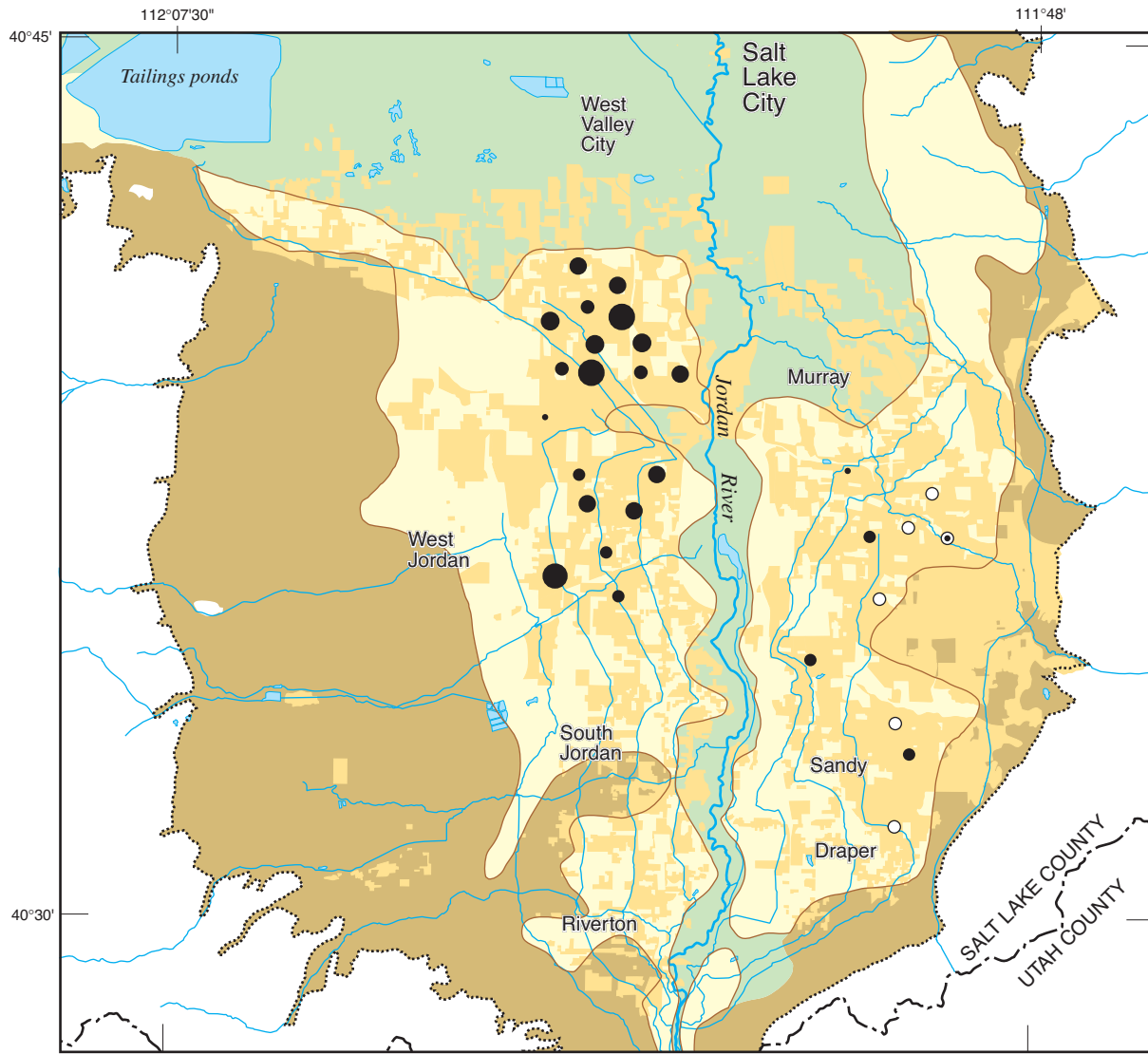
Simazine was detected in water sampled from 13 wells (43.3 percent) with a maximum concentration of 0.027 µg/L in well 1, well below the MCL of 4 µg/L (U.S. Environmental Protection Agency, 2002). Simazine is commonly used as weed control for corn fields and orchards, on rights-of-way, and utility substations (Mark Quilter, Utah Department of Agriculture and Food, oral commun., 2000). All but one of the detections were in water from wells on the west side of the valley.

Tebuthiuron was detected in water sampled from 4 wells (13.3 percent) with a maximum concentration of 0.120 µg/L in water from well 2, far below the long-term HAL of 500 µg/L (U.S. Environmental Protection Agency, 2002). It is used along rights-of-way and to control sagebrush and weeds in noncrop areas of the valley (Mark Quilter, Utah Department of Agriculture and Food, oral commun., 2000). Tebuthiuron was detected in water from wells 18 and 41 on the east side of the valley in addition to prometon.

Concentrations of atrazine, simazine, prometon, malathion, and diazinon in water samples collected from Little Cottonwood Creek near the Jordan River in Salt Lake Valley increased during storm events (Gerner, 2003). Although this site is in a ground-water discharge area and is surrounded by more industrial land use than the residential study area, it indicates that pesticides can be concentrated in stormwater runoff. Runoff that flows to potential sources of recharge such as canals or retention basins in the primary or secondary recharge areas may also transport anthropogenic compounds that have been washed from the land surface to the shallow ground-water system.

Volatile Organic Compounds

VOCs are carbon-containing chemicals that readily evaporate at normal air temperature and pressure. They are contained in many manufactured products such as gasoline, paints, adhesives, solvents, wood preservatives, dry-cleaning agents, pesticides, fertilizers, cosmetics, and refrigerants. Potential sources of VOCs to ground water are direct industrial and wastewater discharges, infiltration of spills, leaking underground storage tanks, stormwater runoff, and atmospheric deposition of vehicle and industrial emissions. Many VOCs are used in and around the home and can enter the ground-water system through spills, storm drains, septic systems, and leaking sewer



Base from U.S. Geological Survey digital line graph data, 1:100,000, 1979 and 1980
 Universal Transverse Mercator projection, Zone 12

EXPLANATION

- Area of recent residential and commercial land use
 - Discharge area
 - Primary recharge area
 - Secondary recharge area
 - Approximate boundary of basin-fill deposits in Salt Lake Valley
- Total concentration of atrazine and its degradation products in water sampled from monitoring wells, in micrograms per liter**
- Not detected
 - 0.004 – 0.010
 - 0.010 – 0.100
 - 0.100 – 1.00
 - 1.00 – 2.54



Figure 13. Total concentration of atrazine and its degradation products in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

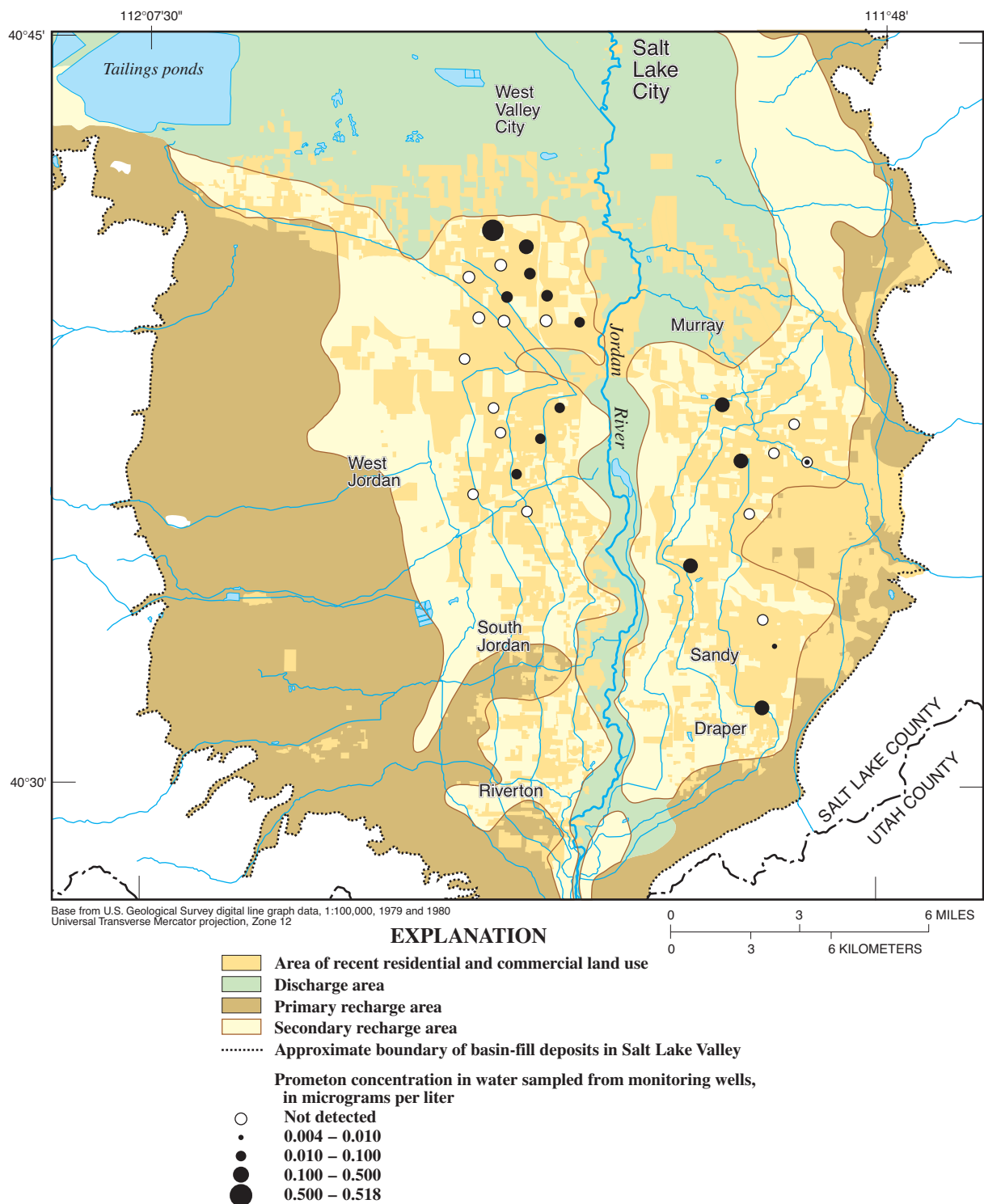


Figure 14. Prometon concentration in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

lines. The U.S. Environmental Protection Agency (2002) has established MCLs in drinking water for more than 20 VOCs because of human health concerns.

Fifteen of the 86 VOCs analyzed for were detected in 1 or more water samples collected as part of this study (table 4). All of the VOCs analyzed for as part of this study are listed in table 12 (appendix). Detection of many VOCs is the result of improved analytical methods that allow measurement of lower concentrations (Conner and others, 1998). The most frequently detected VOCs were chloroform (90 percent), bromodichloromethane (56.7 percent), tetrachloroethylene (53.3 percent), and 1,1,1-trichloroethane (50 percent) (fig. 15).

Chloroform and bromodichloromethane were detected in water from 27 and 17 wells, respectively (fig. 16). Generally, these compounds are byproducts of chlorinated ground and surface water that has reacted with organic material in the water and aquifer material, and are part of a group of VOCs known as trihalomethanes (THMs). These disinfection byproducts are regulated by the USEPA as total THMs with a cumulative MCL of 80 µg/L (U.S. Environmental Protection Agency, 2002). The widespread occurrence of chloroform and bromodichloromethane in shallow ground water is likely a result of the recharge of chlorinated public-supply water used to irrigate lawns and gardens in residential areas of Salt Lake Valley. Water disinfected

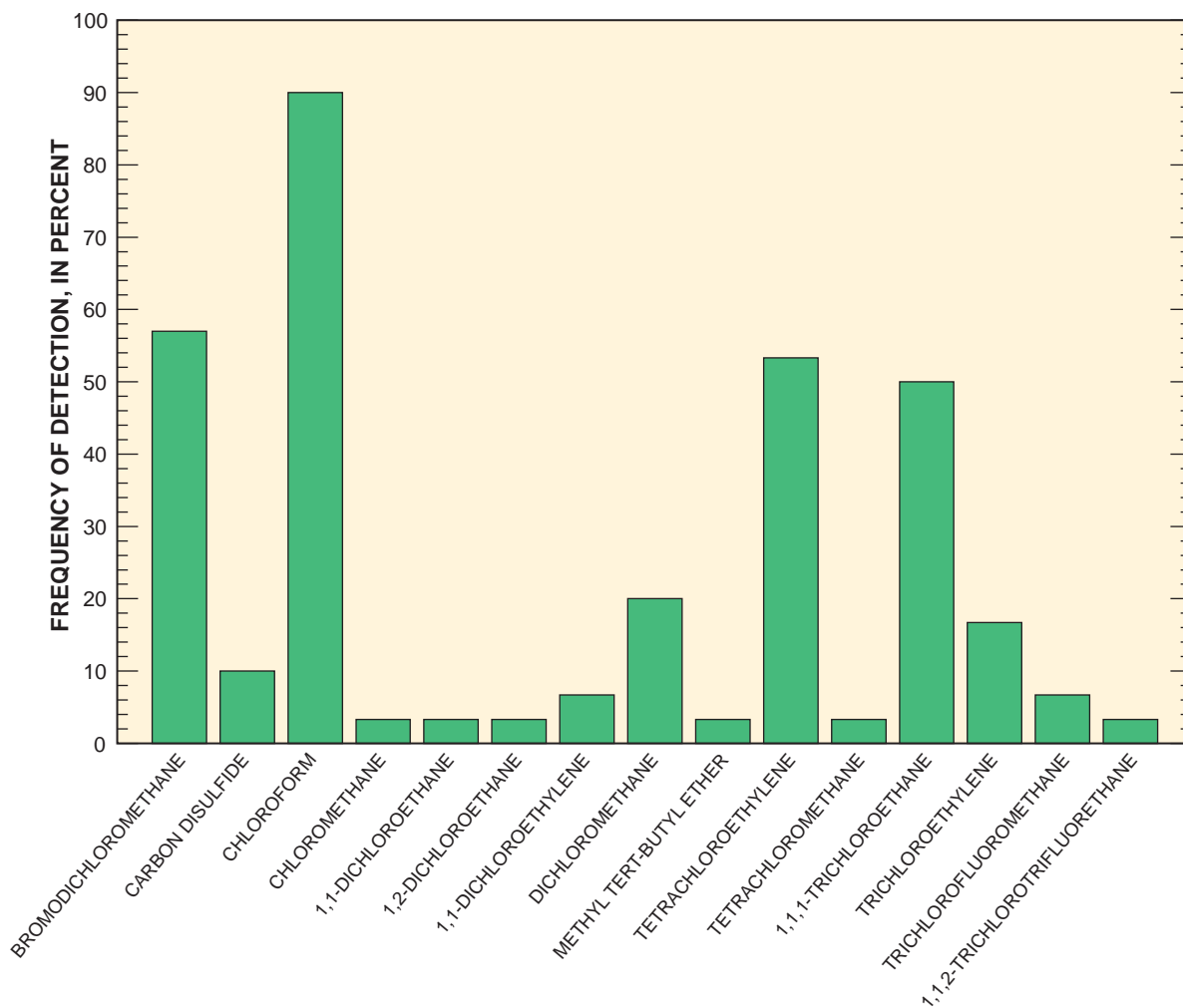


Figure 15. Detection frequency of volatile organic compounds in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

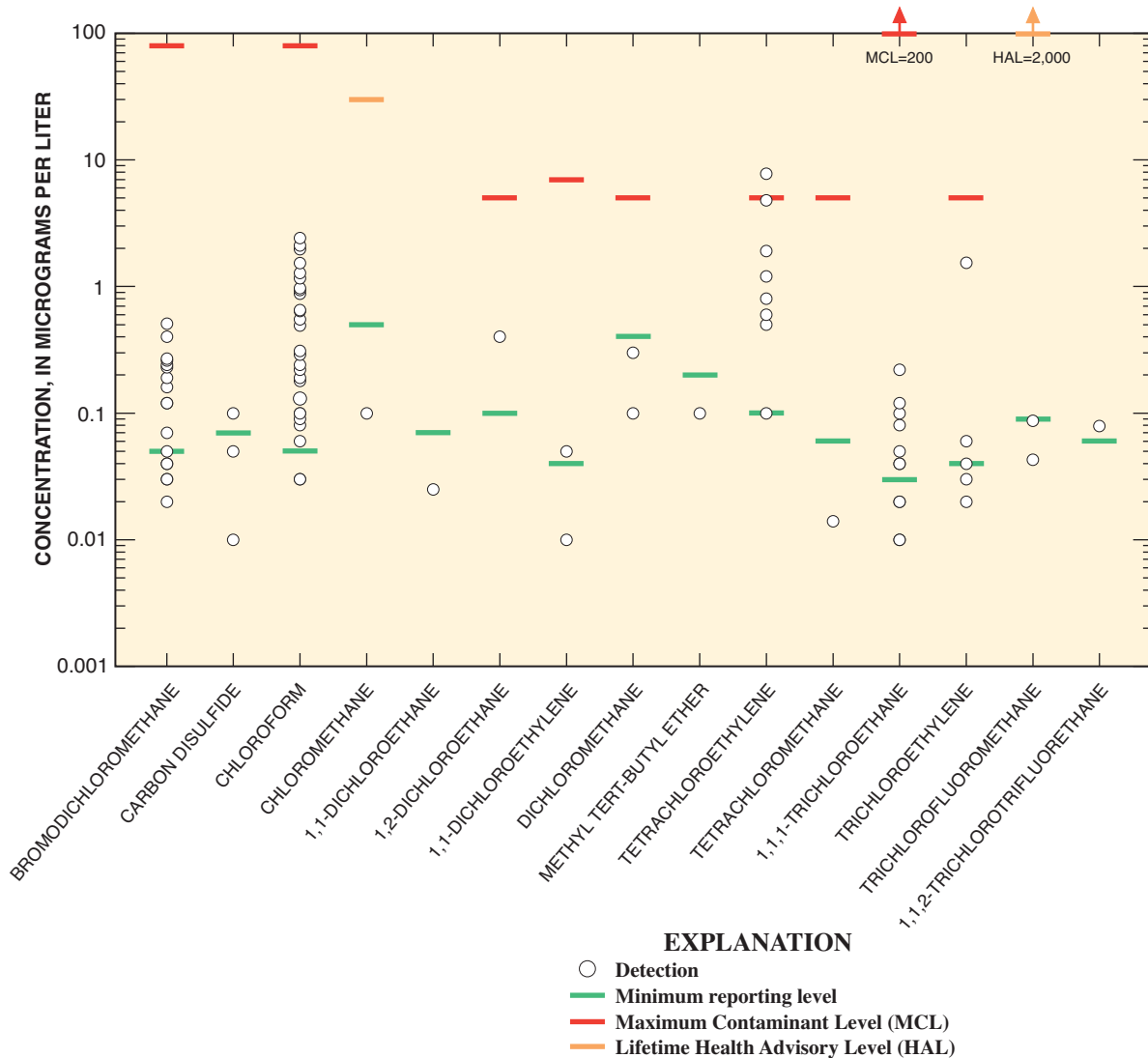
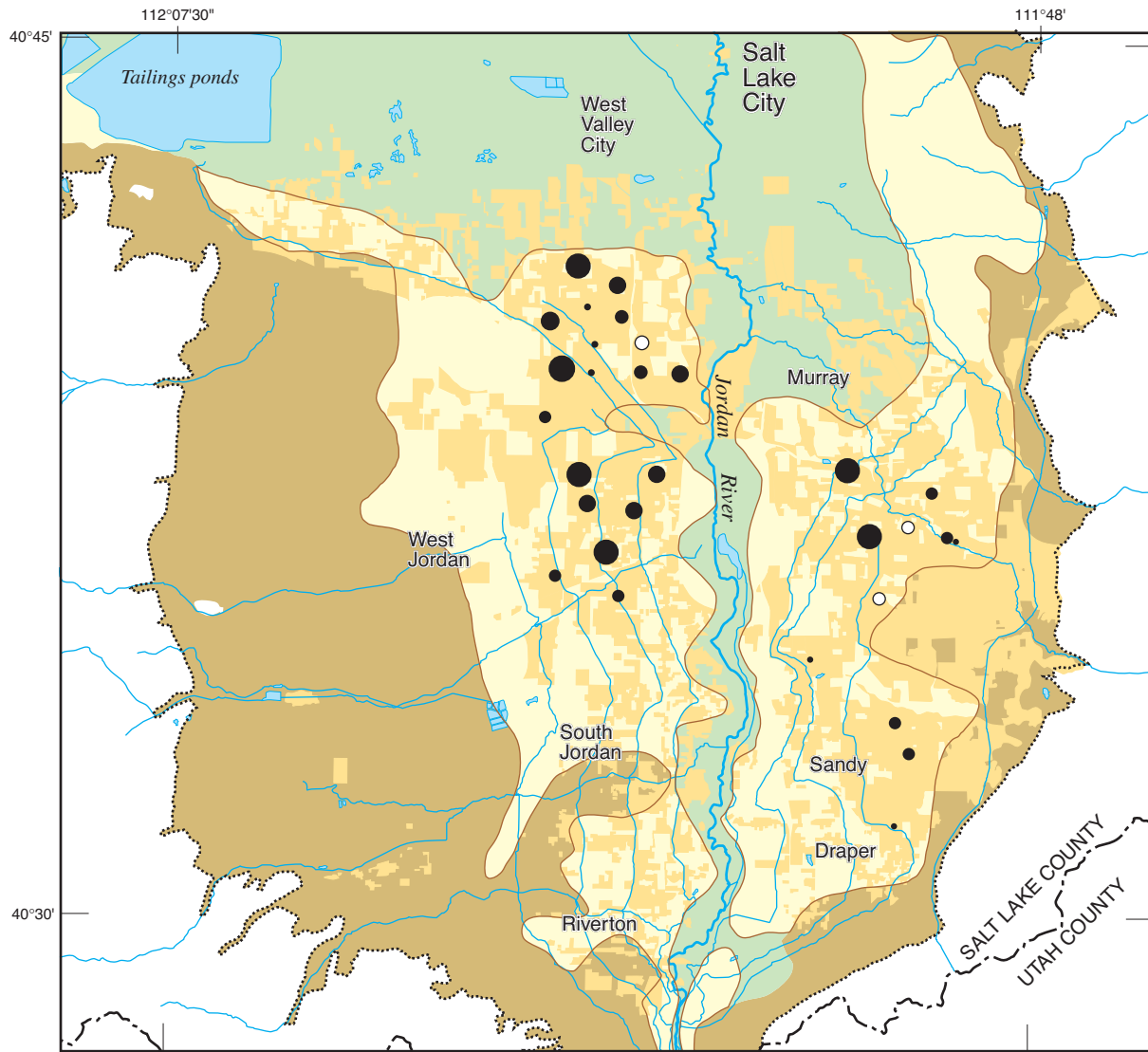


Figure 16. Concentration of selected volatile organic compounds in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

for public supply also can enter the ground-water system through leaking swimming pools, water lines, sewer lines, and septic systems.

Chloroform concentrations ranged from an estimated 0.03 µg/L to 2.41 µg/L (table 13), much less than the MCL for total THMs. Chloroform detected in monitoring wells is an indication that water treated for public supply is recharging the shallow ground-water system (fig. 17). The median chloroform concentration in water from the 30 monitoring wells was 0.28 µg/L, 0.19 µg/L in water from 11 wells on the east side, and 0.55 µg/L in water from 19 wells on the west side of the valley.

Tetrachloroethylene (tetrachloroethene, perchloroethylene, PCE), primarily used as a dry cleaning agent and solvent, was detected in water from 16 wells (fig. 18). Although the median concentration for the 30 samples was less than the LRL of 0.1 µg/L, water from 4 wells in the northwestern part of the valley had concentrations greater than 1 µg/L (wells 1, 5, 8, and 9; table 13, appendix). The maximum PCE concentration detected in water from the monitoring wells in 1999 was 7.8 µg/L (well 5), which is greater than the MCL of 5 µg/L for drinking water (U.S. Environmental Protection Agency, 2002).



Base from U.S. Geological Survey digital line graph data, 1:100,000, 1979 and 1980
 Universal Transverse Mercator projection, Zone 12

EXPLANATION

- Area of recent residential and commercial land use
- Discharge area
- Primary recharge area
- Secondary recharge area
- Approximate boundary of basin-fill deposits in Salt Lake Valley

**Chloroform concentration in water sampled from monitoring wells,
 in micrograms per liter**

- Not detected
- 0.03 – 0.10
- 0.10 – 0.50
- 0.50 – 1.00
- 1.00 – 2.41

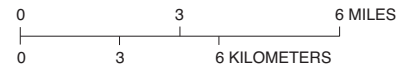
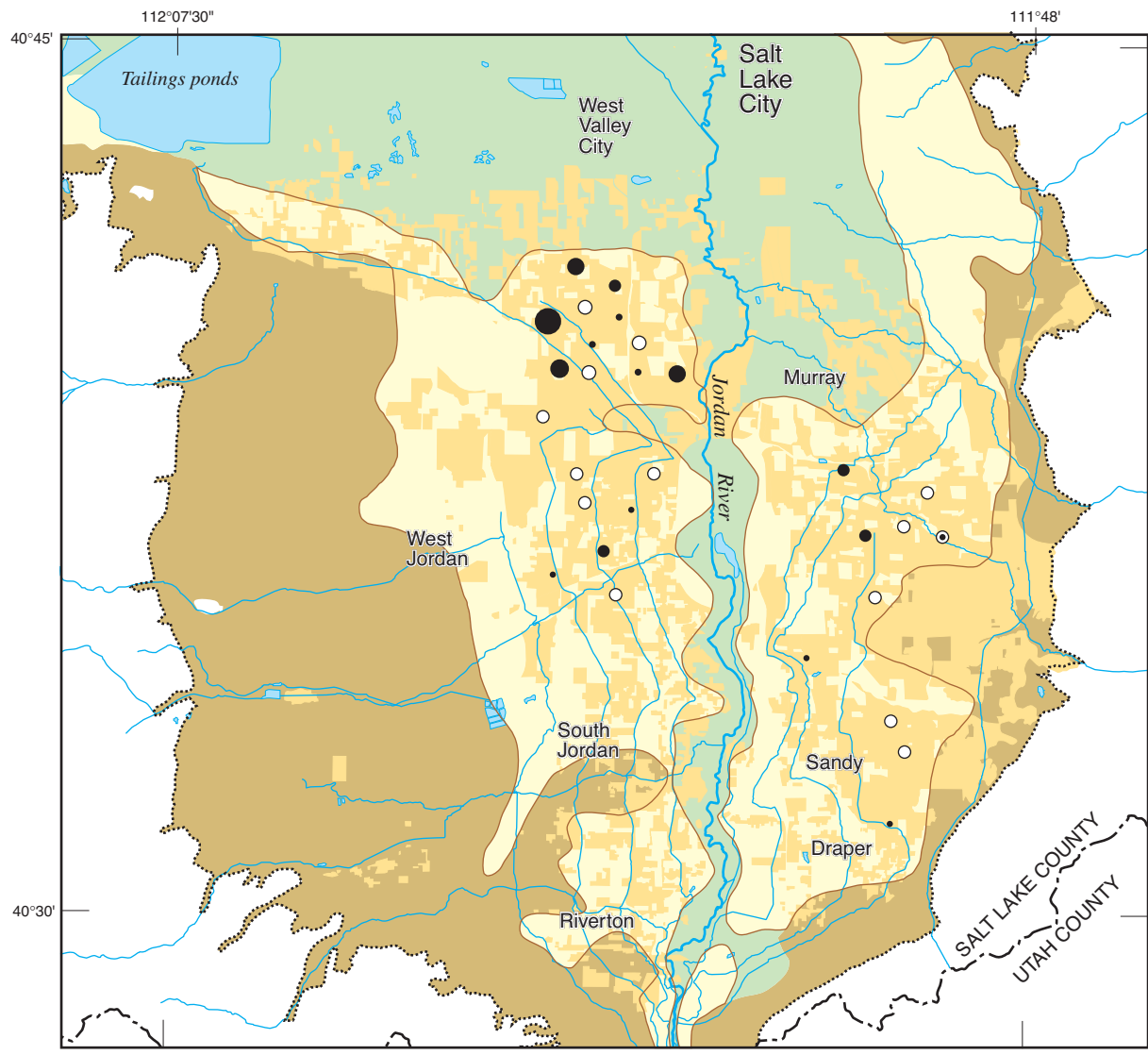


Figure 17. Chloroform concentration in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.



Base from U.S. Geological Survey digital line graph data, 1:100,000, 1979 and 1980
 Universal Transverse Mercator projection, Zone 12

EXPLANATION

- Area of recent residential and commercial land use
- Discharge area
- Primary recharge area
- Secondary recharge area
- Approximate boundary of basin-fill deposits in Salt Lake Valley

Tetrachloroethylene concentration in water sampled from monitoring wells, in micrograms per liter

- Not detected
- Detected - 0.1
- 0.1 - 1.0
- 1.0 - 5.0
- 5.0 - 7.8

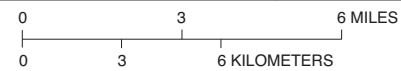


Figure 18. Tetrachloroethylene (PCE) concentration in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

Resampling of well 27 on the east side of the valley showed an increase in PCE concentration from 0.8 µg/L in 1999 to 2.5 µg/L in 2000, and to 10.0 µg/L in 2001. The increase in PCE concentration is an indication of ground water moving past the well from an upgradient source. Seasonal sampling of well 27 in 2000 showed a higher PCE concentration in June (6.0 µg/L) than in September (2.5 µg/L). Chloroform concentration also was higher in June (4.52 µg/L) as compared to September (2.03 µg/L). Water levels in well 27 fluctuated from 57.14 ft below land surface in November 1999 to 60.33 ft in June 2001 and are likely related to water applied to lawns and fields during the summer in the area that recharges the shallow aquifer. The water level in the well generally rises from June-July until November and then falls from December until May-June. The higher PCE and chloroform concentrations in June may correspond with a reduction in recharge occurring in the winter and, therefore, less dilution of the contaminant plume.

Trichloroethylene (trichloroethene, TCE) is used mainly as a solvent, metal degreaser, and drying agent. Trichloroethylene was detected in water from five wells with concentrations ranging from an estimated 0.02 µg/L (well 10) to 1.54 µg/L (well 2), less than the MCL of 5 µg/L (U.S. Environmental Protection Agency, 2002). An additional source of TCE can be the degradation of PCE under reducing conditions. Water from the five wells with TCE also contained PCE; reducing conditions were present in water from only three of these wells. Trichloroethylene concentration in water sampled from well 5 increased from an estimated 0.06 µg/L in 1999 to 0.08 µg/L in 2000, and to 0.10 µg/L in 2001, and PCE concentration remained above 7 µg/L. The increase in TCE may indicate degradation of PCE or movement of water from a different contaminant plume to the well.

1,1,1-trichloroethane (methyl chloroform, TCA) was detected in water from 15 wells at concentrations ranging from an estimated 0.01 µg/L to 0.22 µg/L (table 13, appendix). It is generally used as a solvent and has an MCL of 200 µg/L (U.S. Environmental Protection Agency, 2002). 1,1,1-trichloroethane was detected in the atmosphere at concentrations greater than 0.05 µg/L in 84 percent of the air samples collected in an urban/residential area of New Jersey, but these concentrations correspond to concentrations in water of less than 0.002 µg/L (Baehr and others, 1999). Because of the widespread occurrence of TCA in shallow ground water in Salt Lake Valley at

concentrations greater than assumed for atmospheric deposition, its presence in ground water is likely the result of activities at the land surface. TCA can degrade to dichloroethylene (DCE) under reducing conditions. Both compounds were detected in water from well 2 and, although a dissolved oxygen concentration indicative of reducing conditions was not measured, degradation of TCA may be occurring along the flow path.

The VOCs derived from gasoline were detected in five ground-water samples at concentrations lower than those estimated in the field-blank samples. Benzene; ethylbenzene; 1,2,4-trimethylbenzene; and m- and p-xylene were detected in water from wells 32 and 34 and may be from exhaust from the gasoline-powered generator used during sampling or from passing vehicles. These detections were not used in the VOC data analysis.

Methyl tert-butyl ether (MTBE) was detected at an estimated concentration of 0.1 µg/L, near the LRL, in water from well 27 with no other gasoline-derived VOCs detected. This compound is used to oxygenate gasoline to improve combustion and reduce air-quality degradation. Because of the high solubility of MTBE in water, atmospheric washout in urban areas may be the source of low concentrations in ground water (Squillace and others, 1996). No MTBE was detected during resampling of water from well 27 in 2000 and 2001.

Urban stormwater runoff that flushes spills off of the land surface may be a source of certain VOCs in shallow ground water. Many of the same VOCs, such as PCE and TCE, were commonly detected in both stormwater and shallow ground water from urban areas across the United States (Lopes and Bender, 1998). Elevated concentrations of gasoline-related compounds (1,2,4-trimethylbenzene, xylene, and toluene) and TCE were measured during storm events in water sampled from Little Cottonwood Creek near the Jordan River (Gerner, 2003). Stormwater runoff that flows through or is retained in the primary or secondary recharge areas can recharge the shallow ground-water system along with any anthropogenic compounds that have been washed from the land surface.

SOURCES OF GROUND-WATER RECHARGE

Environmental tracers were used to determine the sources of recharge to the shallow ground-water system in recently developed residential areas in the valley. The stable isotopes of water, deuterium, and oxygen-18 were used to differentiate between local precipitation and water that had been subjected to evaporation. Tritium, helium-3, and chlorofluorocarbons in the water were used to identify and approximately date ground water recharged within the past 50 years.

Stable Isotopes

The stable isotopes of water, deuterium (D or ^2H) and oxygen-18 (^{18}O), can be used to determine recharge sources because they generally are conservative once they enter shallow ground-water systems. Small amounts of ^2H and ^{18}O are incorporated into the water molecule in average proportions of about 0.01 percent and 0.2 percent, respectively (Hem, 1989, p. 162). Oxygen and hydrogen isotope ratios, expressed as delta (δ) ^{18}O or $\delta^2\text{H}$, are reported in parts per thousand (per mil) deviations from a reference standard called Vienna Standard Mean Ocean Water (VSMOW) (Coplen and others, 2000). Water with more negative per mil values has less ^{18}O and ^2H relative to ^{16}O and H, respectively, and is lighter than water with less negative per mil values (heavier $\delta^{18}\text{O}$ or $\delta^2\text{H}$ values). The relation between $\delta^{18}\text{O}$ and $\delta^2\text{H}$ in precipitation is generally expressed by the equation $\delta^2\text{H} = 8\delta^{18}\text{O} + 10$, known as the global meteoric water line (Craig, 1961). Ground water has an isotopic signature that is indicative of conditions at the time of recharge because ^{18}O and ^2H are generally conservative. Mixing with other recharge sources can alter this isotopic signature.

Values of $\delta^{18}\text{O}$ or $\delta^2\text{H}$ for water from most of the monitoring wells (table 5) plot off of the global meteoric water line because of evaporation (fig. 19). A line with a less steep slope can be drawn through water sampled from mountain-front streams, from the Jordan River at different sites and times of the year, and from canals that divert water from the Jordan River (fig. 19). Water from the mountain-front streams typically represents water that has not undergone evaporation, whereas water from canals diverted from the Jordan River has undergone evaporation. Precipitation occurring at lower altitudes, such as on the valley floor,

likely plots higher on the global meteoric water line, with some offset as a result of evaporation, than does water from the mountain-front streams. Stable isotope ratios for water from the monitoring wells plot near a mixing line connecting the recharge sources of precipitation and evaporated diversion water. Ground water from the monitoring wells is a mixture of varying amounts of local precipitation and evaporated water, on the basis of stable isotope ratios.

Precipitation on the Wasatch Range and the Oquirrh Mountains is represented isotopically by samples from streams draining the mountains where they enter the valley. This water is isotopically light because the precipitation fell at higher altitudes and at colder temperatures than did precipitation at the valley floor. Stable isotope ratios for water from monitoring wells 26S, 26D, and 29 near Little Cottonwood Creek are similar to those for water from the creek at Crestwood Park (USGS streamflow-gaging station 10167800) (fig. 19). This similarity indicates that seepage from Little Cottonwood Creek is a source of recharge to the shallow ground-water system in the area.

Because of evaporation, canal water diverted from the Jordan River and used for irrigation is heavier in ^2H and ^{18}O relative to precipitation occurring locally or on the adjacent mountains. Evaporated water can recharge the shallow ground-water system through seepage and infiltration of unconsumed irrigation water. Water from wells 3, 7, and 11 on the west side of the valley is the heaviest in ^2H and ^{18}O of the 30 monitoring wells. Isotopic concentrations in local precipitation are probably represented by water from wells 8, 14, and 31, which are upgradient from most of the canals on the west side of the valley. Water from the Utah and Salt Lake Canal in the southwestern part of the valley is much heavier isotopically because of evaporation. Water from wells 3, 7, and 11 plot about two-thirds of the way between the two potential sources of recharge—water represented by wells 8, 14, and 31 and water from the Utah and Salt Lake Canal (fig. 19). As a result, about two-thirds of the water from these wells is recharged from area canals if local precipitation and canal water are the primary sources of recharge.

Table 5. Stable isotope ratio, tritium concentration, and apparent age for water sampled from 30 monitoring wells in areas of recent residential development, Salt Lake Valley, Utah

[Well identifier, see figure 3 for well location; per mil, parts per thousand; TU, tritium units; —, no data; Contaminated, concentration greater than what was possible for equilibrium with the atmosphere; Modern, within the possible range of modern air; >, greater than]

Well identifier	Well depth (feet)	Delta oxygen-18	Delta deuterium	Tritium	Tritium error	Tritium/ Helium-3 apparent age	¹ CFC-11 apparent age	² CFC-12 apparent age	³ CFC-113 apparent age
		(per mil)							
1	48.5	-108.21	-13.73	10.23	0.51	—	Contaminated	Contaminated	Modern
2	38.5	-102.38	-13.02	12.28	.61	13	Contaminated	Contaminated	Contaminated
3	113.5	-92.09	-10.88	11.01	.56	11	Contaminated	Contaminated	Contaminated
4	38.5	-114.70	-14.90	1.67	.08	38	Contaminated	Contaminated	Modern
5	43.5	-109.15	-13.69	12.41	.62	11	Contaminated	Contaminated	11
6	38.5	-96.46	-11.58	11.83	.59	3	Contaminated	Contaminated	—
7	43.5	-92.11	-10.94	14.03	.70	—	Contaminated	Contaminated	11
8	67.5	-112.36	-14.38	14.77	.74	4	Contaminated	Contaminated	Contaminated
9	38.5	-105.88	-13.19	11.67	.58	13	Contaminated	Contaminated	10
10	83.5	-97.32	-11.78	16.60	.85	8	Contaminated	Contaminated	Contaminated
11	83.5	-93.31	-10.84	10.81	.54	—	Contaminated	Contaminated	Contaminated
14	48.5	-111.92	-14.61	8.00	.40	6	Contaminated	Contaminated	Contaminated
17	38.5	-98.31	-12.01	11.34	.57	12	21	Contaminated	23
18	106	-112.04	-14.99	10.50	.50	4	Contaminated	Contaminated	Contaminated
20	92.5	-104.24	-13.26	19.70	.99	—	Contaminated	Contaminated	12
22	36	-113.66	-14.89	19.67	.98	24	Contaminated	Contaminated	10
24	123.5	-98.03	-11.93	20.30	1.01	8	Contaminated	Contaminated	10
25	68.5	-98.00	-11.86	18.92	.95	8	Contaminated	Contaminated	Contaminated
26D	77.5	-118.96	-16.30	12.42	.62	—	Contaminated	Contaminated	Modern
26S	31	-115.92	-15.98	13.25	.66	0	Modern	Modern	10
27	73.5	-110.24	-14.42	10.43	.52	3	Contaminated	Contaminated	Contaminated
29	34	-118.98	-16.42	54.76	2.74	32	48	26	> 44
30	68.5	-100.23	-12.61	11.56	.58	1	Contaminated	Contaminated	Contaminated
31	153.5	-112.42	-14.25	17.79	.89	1	Contaminated	Contaminated	8
32	88.5	-111.23	-14.76	8.89	.44	6	Contaminated	Contaminated	12
33	96	-102.12	-12.71	19.30	.96	15	Contaminated	Contaminated	Contaminated
34	77.5	-105.30	-13.80	2.84	.42	—	Contaminated	Contaminated	Modern
37	73	-112.19	-14.77	23.96	1.20	38	Contaminated	Contaminated	14
39	106	-114.59	-15.02	9.39	.47	0	Contaminated	Contaminated	Modern
41	23	—	—	13.19	.66	0	Contaminated	Contaminated	9

¹ Trichlorofluoromethane.

² Dichlorodifluoromethane.

³ 1,1,2-Trichlorotrifluoroethane.

Because the monitoring wells are located in residential areas, a potential source of recharge to the shallow ground-water system is water used for public supply. Public-supply water in Salt Lake Valley is primarily from mountain-front streams and from the principal aquifer and is used to irrigate lawns and gardens. Stable isotope ratios for ground water from the principal aquifer on the east side of Salt Lake Valley are similar to those for water from the mountain-front streams, which indicates that precipitation

originating at higher altitudes is a main source of recharge (Thiros, 1995). Water supplied to the public may undergo some evaporation during lawn and garden irrigation and other household uses before it infiltrates into the ground. Wells 22, 32, 37, and 39 on the east side of the valley are upgradient from canals diverted from the Jordan River, but contain a component of evaporated water on the basis of stable isotope ratios (fig. 19). Chloroform was detected in water from these

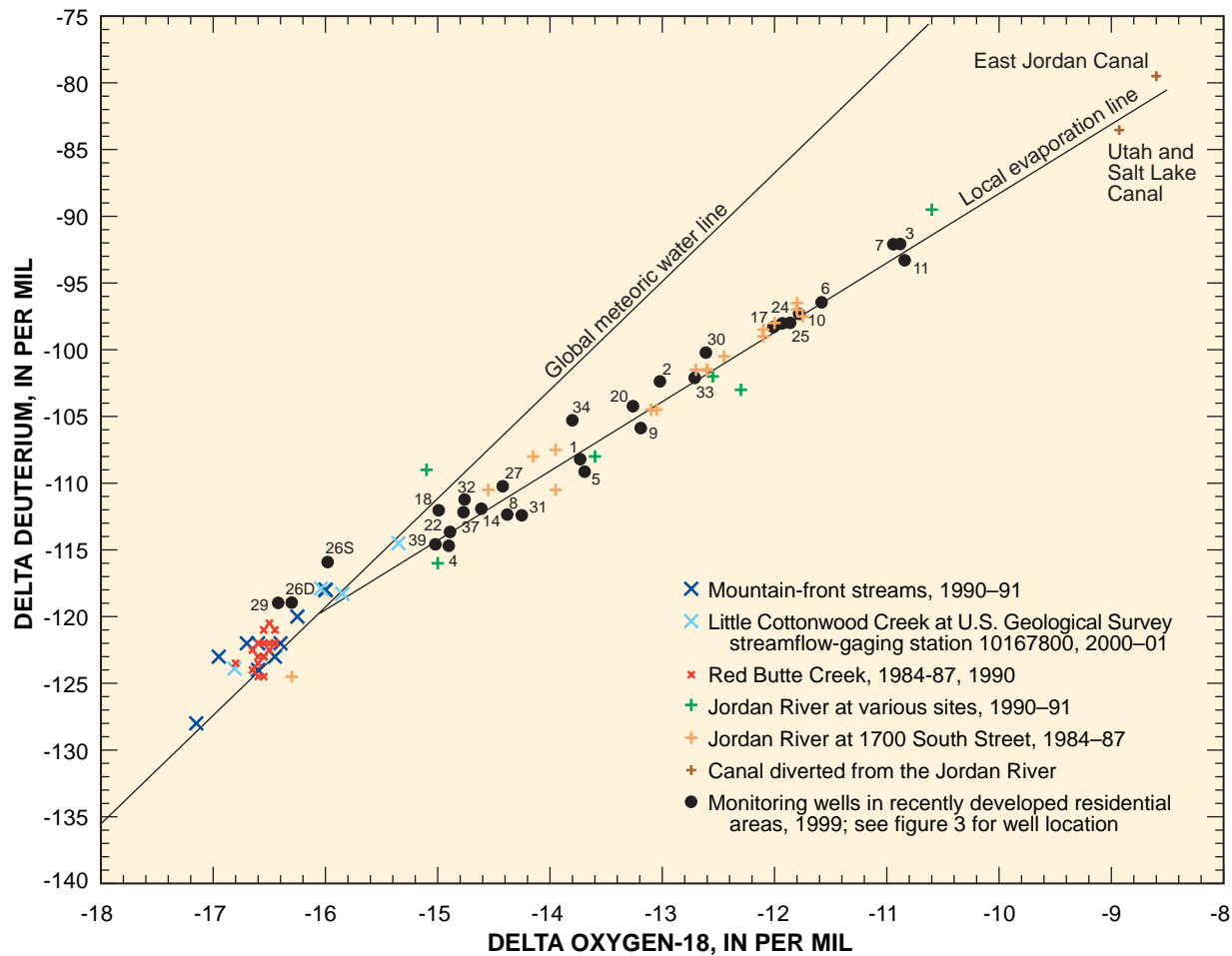


Figure 19. Relation between delta deuterium and delta oxygen-18 for shallow ground-water and surface-water samples from Salt Lake Valley, Utah.

wells; thus, the water is likely a mixture of infiltration from local precipitation and seepage of public-supply water used for irrigation.

Seasonal measurements of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ were taken from water in monitoring wells 26S, 26D, 27, and 32. Seasonal samples also were collected from a 38.5-ft-deep monitoring well about 1,270 ft downgradient from well 32 in a sprinkler-irrigated field of grass, and from Little Cottonwood Creek at Crestwood Park (USGS streamflow-gaging station 10167800) (fig. 20). These wells are on the east side of the valley near the mouth of Little Cottonwood Canyon where the unconsolidated basin fill is made up primarily of permeable deltaic deposits from the mountain front. Wells 26S and 26D are next to Little

Cottonwood Creek, and water from well 26S shows the greatest variation in stable isotope ratios with time, generally following changes in streamflow in the creek. Peak snowmelt runoff in the creek occurs in June with lighter $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values that represent higher-altitude precipitation. Some of this water recharges the shallow ground-water system monitored by well 26S, which is indicated by lighter isotopic ratios measured in ground water sampled in May as compared to other times of the year. Water temperature and water level in wells 26S and 26D fluctuate in a similar fashion.

Delta deuterium and $\delta^{18}\text{O}$ values in water from Little Cottonwood Creek at Crestwood Park measured in March, April, and August are heavier than those measured in June and may represent the effects of

evaporation of stream water, local sources of recharge, and (or) shallow ground-water discharge. Water from four public-supply wells completed in the principal aquifer in the area has a range in $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values similar to that of water from Little Cottonwood Creek (fig. 20).

Delta deuterium and $\delta^{18}\text{O}$ values for water from well 32 did not vary as much with time as did water from well 26S because the well is farther away from seasonal recharge sources and has a greater depth to the water table. Recharge of sprinkler-irrigation water to the shallow system was observed isotopically in the 38.5-ft deep monitoring well near well 32. The water level measured in the well during 2000-2001 fluctuated from a high of 23.30 ft below land surface in October (after the irrigation season) to a low of 26.33 ft in April (before the irrigation season). Stable isotope ratios were heaviest in the summer when water was applied to the area upgradient from the monitoring well and

became lighter in the winter and spring when no irrigation occurred (fig. 20). Water from well 27 showed a similar seasonal variation.

Tritium and Tritium/Helium-3

Water from the 30 monitoring wells was analyzed for tritium to determine apparent age (table 5). Tritium is a radioactive isotope of hydrogen (^3H) with a half-life of 12.43 years. Large quantities of tritium were added to the atmosphere from above ground thermonuclear testing beginning about 1952 and provide a marker for precipitation from the testing period. Concentrations in precipitation prior to atmospheric thermonuclear testing have been estimated to be 3 to 6 TU (Kaufmann and Libby, 1954). Tritium concentration in water recharged to the basin-fill deposits prior to 1952, assuming no mixing with other

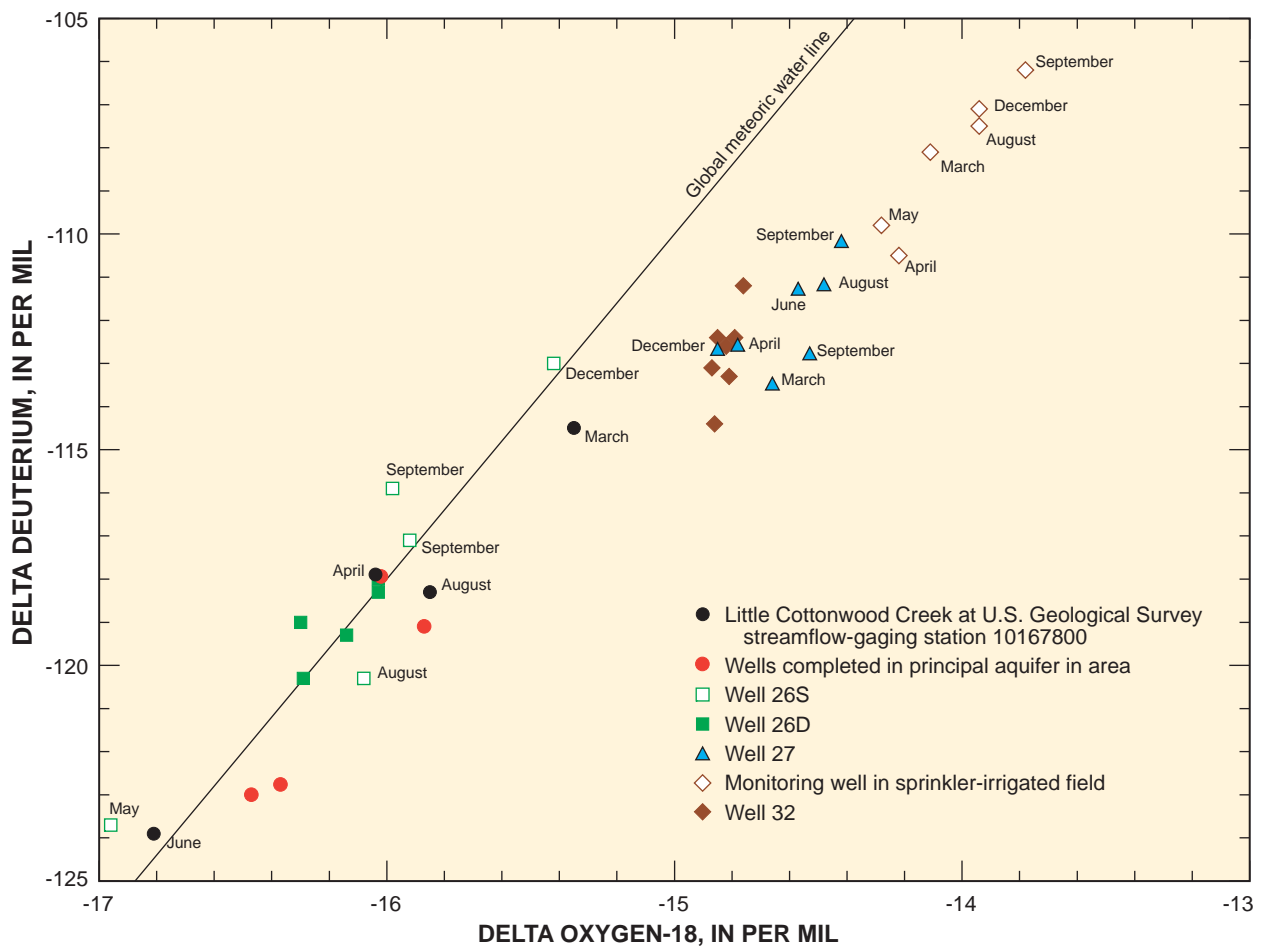


Figure 20. Relation between delta deuterium and delta oxygen-18 for water samples from selected wells and from Little Cottonwood Creek, Salt Lake Valley, Utah.

sources, would have decayed to less than 1 TU by 1999 and resulted in about a 50-year timescale. The amount of tritium in precipitation collected in Vienna, Austria, in 1999 varied from 8.0 TU in December to 17.3 TU in June (International Atomic Energy Agency, 2001) and is gradually decreasing toward pre-1952 levels. Concentrations greater than that of present day indicate that the water or a component of the water has been recharged since 1952.

Tritium decays to the noble gas helium-3 (^3He), the stable isotope of helium. The ratio of ^3H to ^3He derived from ^3H decay in a water sample can be used to determine the time from when water containing ^3H became isolated from the atmosphere (ground-water age). The $^3\text{H}/^3\text{He}$ dating method requires quantification of ^3He from ^3H by accounting for ^3He from other sources (Solomon and Cook, 2000). The $^3\text{H}/^3\text{He}$ clock does not start until water is below the water table and completely isolated from the gas phase because tritiogenic ^3He generated in the unsaturated zone is effectively lost to the atmosphere and is not measured in the water sample, resulting in younger ages determined by the method. Uncertainty in age because of analytical uncertainty is approximately ± 0.5 year. Larger uncertainties in age can result because of the variable tritium input with time, mixing caused by dispersion, and losses to the gas phase at the water table. Because of the variable nature of the ^3H input and dispersive mixing, $^3\text{H}/^3\text{He}$ dating is less certain for waters older than the mid-1960s bomb pulse.

Tritium concentrations greater than 1 TU in water from all of the monitoring wells (table 5) confirm a component of recharge to the shallow ground-water system after atmospheric thermonuclear testing began in 1952. Water from most of the wells had a tritium concentration of from 10 to 20 TU, a range that most likely is made up of water recharged from the present to about 15 years ago and within the timeframe of residential development in the area of the wells. The apparent age from $^3\text{H}/^3\text{He}$ data for water from 24 monitoring wells ranged from 1 year or less to 38 years old, relative to 1999 (table 5). Water from 20 of the wells became isolated from the atmosphere 0 to 15 years before 1999 on the basis of $^3\text{H}/^3\text{He}$ dating.

Wells 26S and 41 are the shallowest wells in the study (31 and 23 ft, respectively) and contain water 1 year or less old. Water temperature, water level, and stable isotope ratio changes confirm recent recharge to well 26S from Little Cottonwood Creek. Rapid recharge to the ground-water system is possible in

other areas where recharge sources and permeable aquifer material occur, such as along creeks and canals in the primary and secondary recharge areas. Some of the deepest monitoring wells also contained water that recharged the water table within the last 2 years. Depth to water in wells 30, 31, and 39 is about 58, 143, and 94 ft below land surface, respectively. The time spent in the unsaturated zone is not included in the $^3\text{H}/^3\text{He}$ age determination and may be considerable depending on the amount of recharge, the permeability, and the thickness of unsaturated deposits overlying the water table.

Tritium concentrations in water from the monitoring wells determined from $^3\text{H}/^3\text{He}$ ages and corrected for radioactive decay over time generally are similar to those measured in or extrapolated for precipitation (fig. 21). The correlation between tritium in recently recharged ground water and precipitation indicates that most or all of the water in the shallow system is from the land surface with little or no mixing with older water.

The lowest tritium concentration (1.67 TU) was measured in water from well 4 (table 5) and represents a component of water recharged before the tritium peak in 1963 caused by atmospheric testing. The $^3\text{H}/^3\text{He}$ apparent age determined for this water is about 1962. The tritium concentration in 1962, based on a concentration of 1.67 TU in water from well 4 in 1999 and a half-life of 12.43 years, is about 13 TU (fig. 21). Tritium concentration measured in precipitation in Salt Lake City is available for 1963-84 and has been extrapolated from 1961 to 2000 on the basis of correlation with data from Vienna, Austria (Robert Michel, U.S. Geological Survey, written commun., 2002) (fig. 21). Extrapolated monthly tritium concentrations in 1961-62 precipitation ranged from about 35 to 1,600 TU, much higher than 13 TU determined from the $^3\text{H}/^3\text{He}$ apparent age. These values would have decayed to about 4 to 200 TU in 1999 rather than the 1.67 TU measured in water from well 4. Because higher tritium concentrations were not measured in water from well 4, older water with no tritium probably is mixing with younger, tritiated water, resulting in a younger apparent age.

The highest tritium concentration (54.76 TU) was measured in water from well 29 and represents a large component of water recharged in the 1960s when the peak in tritium concentrations in the atmosphere occurred. This water, on the basis of the $^3\text{H}/^3\text{He}$ method, was isolated from the atmosphere and

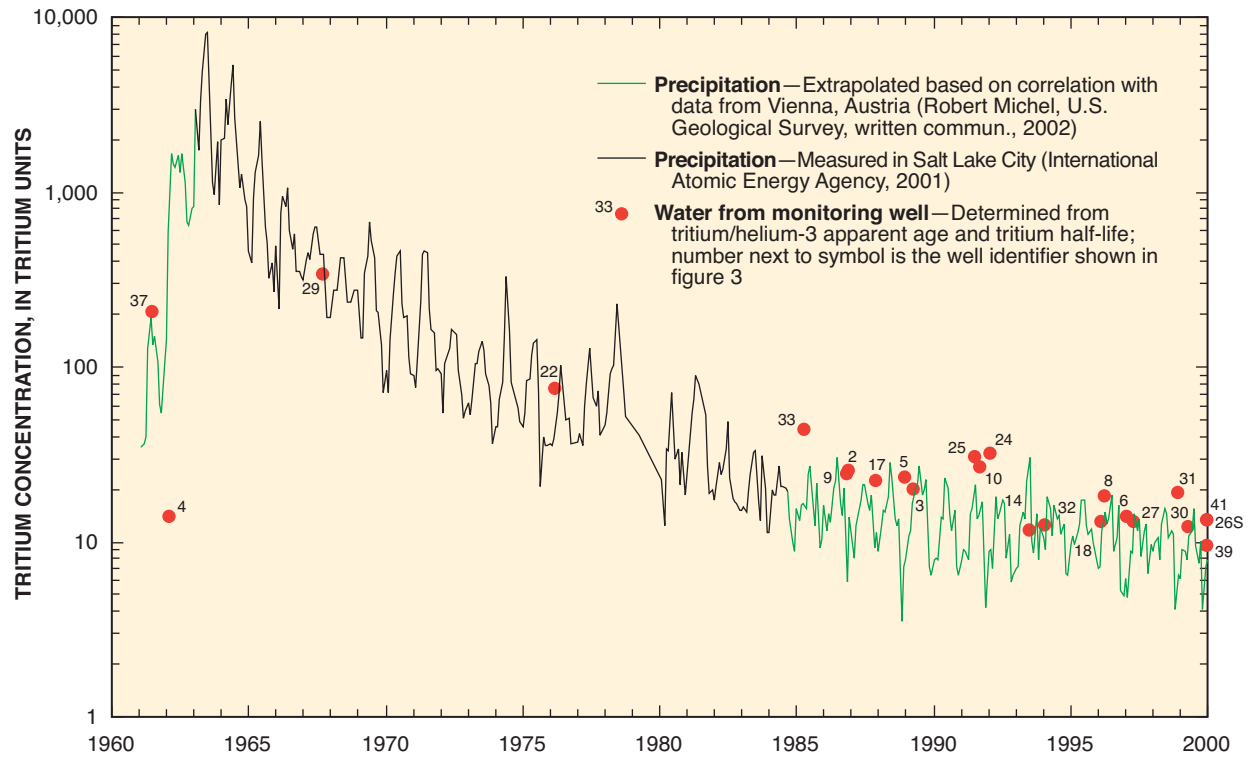


Figure 21. Tritium concentration in precipitation and in water sampled from monitoring wells in areas of recent residential development, Salt Lake Valley, Utah.

recharged the shallow ground-water system in 1967. Tritium measured in Salt Lake City precipitation in 1967 would have decayed to about the concentration measured in 1999 on the basis of a half-life of 12.43 years. Many of the samples from the monitoring wells on the west side of the valley plot slightly above the line representing tritium concentration in precipitation (fig. 21). This may be the result of mixing with water recharged during the preceding 20 to 30 years that has been impeded by clay layers.

Chlorofluorocarbons

Chlorofluorocarbons (CFCs) are synthetic organic compounds that were developed in the early 1930s as coolants in air conditioning and refrigeration (Plummer and Friedman, 1999). Other uses included blowing agents in foams, insulation, and packing materials, propellants in aerosol cans, and as solvents in the electronics industry. Chlorofluorocarbons are used as environmental tracers and dating tools for water that has been in contact with the atmosphere since the 1940s. Ground-water samples from the

monitoring wells were analyzed for CFC-11 (trichlorofluoromethane or CFCl_3), CFC-12 (dichlorodifluoromethane or CF_2Cl_2), and CFC-113 (trichlorotrifluoroethane or $\text{C}_2\text{F}_3\text{Cl}_3$) (table 5). Ground-water age is estimated by relating the measured concentration of the environmental tracer in water to the historical atmospheric concentration and to a calculated concentration expected in water in equilibrium with air.

Apparent ground-water ages determined in this study from CFC concentrations generally are similar to ages determined by using the $^3\text{H}/^3\text{He}$ method (table 5). Water sampled from well 29 had CFC-11 and CFC-113 concentrations that corresponded to a time of recharge before 1955. The water from this well is anoxic, which can degrade these compounds and result in apparent older CFC ages. CFC-12 does not decay under sulfate-reducing conditions and provided an age date of 1973 that is closer to the $^3\text{H}/^3\text{He}$ date of 1967 for this water sample. Most of the water samples had CFC concentrations that were greater than what was possible for equilibrium with the atmosphere. Ground water from these wells was contaminated with CFCs from

anthropogenically affected sources with concentrations in excess of that of atmospheric sources. CFC-11 was detected in water sampled from two monitoring wells, and CFC-113 was detected in water from one well in the parts per billion range as part of the VOC analysis. Although a recharge date cannot be determined from these contaminated samples, the presence of CFCs indicates that the water has been in contact with human activities at the land surface.

EFFECTS OF SHALLOW GROUND-WATER QUALITY ON DEEPER GROUND-WATER QUALITY

Water from the deeper aquifer underlying the shallow ground-water system is used for public supply in Salt Lake Valley. The potential exists for movement of anthropogenic compounds from shallow ground water to the deeper aquifer in recently developed residential areas where a downward hydraulic gradient exists between the aquifers. The monitoring wells installed for this study were located in areas assumed to have a downward hydraulic gradient from the shallow to the deeper aquifer on the basis of information from well-drillers' logs (Anderson and others, 1994). Contamination of the principal aquifer from activities at land surface has been documented in the valley (Waddell and others, 1987).

Water used for public supply from the principal aquifer in Salt Lake Valley was sampled as part of the NAWQA program. Many of the sampled wells in the primary and secondary recharge areas had a component of water that was recharged during the last 50 years (contained detectable tritium) and had detectable concentrations of chloroform. Even in some areas with an upward gradient between the deeper and shallow aquifers, anthropogenic compounds were detected, indicating a connection with land surface. Changes in water-level gradients caused by pumping may result in water movement from the shallow to the deeper aquifer.

Water levels in monitoring wells on the east side of the valley ranged from about 5 to 94 ft below land surface. Shallow ground water is perched about 300 ft above the deeper aquifer by confining layers in the area of wells 29, 32, and 34. The shallow and deeper ground-water systems in this area are separated by sequences of fine-grained deposits that perch the

shallow ground water and confine the deeper aquifer. Different sources of recharge also contribute to the large downward gradient between the two systems: subsurface inflow from the Wasatch Range to the deeper aquifer, and local precipitation and unconsumed irrigation water to the shallow system. Anthropogenic compounds were not detected in water sampled from monitoring well 32 or a nearby public-supply well completed in the deeper confined aquifer. The deeper confined aquifer in this part of the valley is probably more isolated from activities occurring at the land surface because of confining layers and different recharge sources.

Water levels in monitoring wells in the northwestern part of the valley ranged from about 12 to 80 ft below land surface. No large hydraulic gradient exists between the shallow and deeper aquifers in this area despite the presence of confining layers. Anthropogenic compounds are more prevalent in the shallow ground water. Pumping from the deeper aquifer may cause water to move downward from the shallow aquifer in some areas. Fewer wells pump water from the deeper aquifer in the secondary recharge area on the west side of Salt Lake Valley than on the east side generally because of poorer yield and chemical quality.

Anthropogenic compounds were detected in water from both monitoring well 8 and a nearby public-supply well completed in the deeper confined aquifer on the west side of the valley. Atrazine concentrations were about an order of magnitude higher in water from the deeper well (0.195 $\mu\text{g/L}$) than in water from the shallower monitoring well (0.023 $\mu\text{g/L}$). Water from the deeper well and well 8 had chloroform concentrations of 0.66 $\mu\text{g/L}$ and 1.16 $\mu\text{g/L}$, respectively, and PCE concentrations of 1.0 $\mu\text{g/L}$ and 1.9 $\mu\text{g/L}$, respectively. The water levels in both wells were similar under static conditions (about 60 ft below land surface) but dropped almost 100 ft in the deeper well when pumping. A thick layer of clay noted on the drillers' log of the deeper well (124-182 ft below land surface) occurs between the water table and the top of the screened interval. The specific-conductance value of water was about 1,000 $\mu\text{S/cm}$ in the shallow well under both static and pumping conditions and in water from the deeper well while pumping. The specific-conductance value of water in the deeper well at about 90 ft below land surface under static conditions was 350 $\mu\text{S/cm}$ and is probably representative of the water in the aquifer at the screened interval (172-253 ft below

land surface). The occurrence of VOCs in water pumped from the deeper well may be caused by shallow water that has moved downward despite the presence of the intervening clay layer. The higher concentration of atrazine in the deeper well may result from water recharged at land surface where the herbicide was used in the primary recharge area.

The water level in monitoring well 31 in the southwestern part of the valley is about 140 ft below land surface, similar to that of domestic wells in the area. The anthropogenic compounds chloroform, PCE, TCA, atrazine, and simazine were present in water from this well despite the relatively deep water table. The boundary between the shallow and deeper aquifers in this area is not clearly defined because of thin and (or) discontinuous confining layers. Water from local precipitation and seepage from unconsumed irrigation and canals, primary sources of recharge to the shallow aquifer, also may be major sources of recharge to the deeper aquifer in the area. Where this is the case, activities occurring at land surface have the potential to affect the water quality of the deeper confined aquifer in the southwestern part of the valley. Contamination of the principal aquifer from mine-waste water that was impounded at land surface occurred downgradient from the Bingham Canyon mining area (Waddell and others, 1987, p. 19), but upgradient from major confining layers.

RELATION BETWEEN GROUND-WATER QUALITY AND LAND USE

The relation between the concentration of selected constituents and compounds in ground-water samples collected from the monitoring wells and the type of land use within 1,640 ft of each well was examined by using statistical correlation. The Spearman rank correlation test was used to measure the strength of association between two variables (Helsel and Hirsch, 1992, p. 209-218). The correlation coefficient (ρ) varies from 1 to -1 and describes the strength of the correlation. Values closer to 1 indicate a positive correlation, values closer to -1 indicate an inverse correlation, and values closer to 0 indicate no correlation. The p-value (probability of no correlation) was used to evaluate the significance of the correlation; p-values less than 0.10 are considered statistically significant.

No correlation was determined between the percentage of residential land use surrounding the monitoring wells and the concentration of dissolved solids, arsenic, atrazine and its degradation products, prometon, chloroform, or nitrate in water sampled from the wells. The total percentage of land classified as commercial, vacant, and roads weakly correlated with the concentration of atrazine and its degradation products in water sampled from the wells ($p = 0.06$, $\rho = 0.35$). Atrazine applied to these land-use types may be a source of atrazine detected in the shallow ground water. Not enough agricultural land was delineated within 1,640 ft of the monitoring wells to determine if it is correlated to atrazine concentration in ground water. The source of atrazine and its degradation products also may be from areas more than 1,640 ft upgradient from the wells. In addition, chloroform concentration in the water samples did not correlate to percentages of these land-use types.

Dissolved-solids concentration strongly correlated with ^2H ($p = 0.0001$, $\rho = 0.76$), confirming that isotopically heavier irrigation water contains more dissolved solids than does isotopically lighter water recharged from mountain-front streams or local precipitation. Chloroform concentration did not correlate with dissolved-solids or nitrate concentration in water from the monitoring wells, probably because of mixing of recharge sources and different sources of nitrate. The relation between chloroform and the herbicides atrazine and prometon, although not statistically significant, varied differently. The three highest chloroform concentrations corresponded to three of the four highest prometon concentrations, likely because of the use of these compounds in residential areas. Relatively low concentrations of chloroform corresponded to the four highest concentrations of atrazine and its degradation products, probably because of atrazine use on agricultural or nonirrigated industrial and vacant land.

SUMMARY

Residential and commercial development of about 80 mi² that primarily replaced undeveloped and agricultural areas occurred in Salt Lake Valley, Utah, from 1963 to 1994. This study evaluated the occurrence and distribution of natural and anthropogenic constituents in shallow ground water underlying

recently developed (post 1963) residential and commercial areas. Monitoring wells from 23 to 153 ft deep were installed at 30 sites. Ground-water quality for the monitoring wells was evaluated by using analyses of field parameters, major ions, trace elements, radon, nutrients, dissolved organic carbon, pesticides, and volatile organic compounds.

Dissolved-solids concentration ranged from 134 to 2,910 mg/L in water from the 30 monitoring wells. Dissolved arsenic concentration in water from 12 wells exceeded the drinking water maximum contaminant level of 10 µg/L. Water from monitoring wells in the northwestern part of the valley generally had higher arsenic concentrations than did water from other areas. Nitrate concentration in water sampled from 26 of the 30 monitoring wells (86.7 percent) was higher than a background level of 2 mg/L, indicating a possible human influence. Nitrate concentrations ranged from less than 0.05 to 13.3 mg/L.

Fifteen of the 104 pesticides and pesticide degradation products analyzed for were detected in 1 or more water samples from the monitoring wells. No pesticides were detected at concentrations that exceeded U.S. Environmental Protection Agency drinking-water standards or guidelines. For 2002 Total concentration of pesticides and pesticide degradation products in water ranged from an estimated 0.002 µg/L (diazinon) to 2.56 µg/L (a mixture of atrazine, atrazine degradation products, and simazine). The high detection frequency of atrazine, a restricted-use pesticide, in residential areas on the west side of Salt Lake Valley may be the result of application in agricultural or industrial areas that have been converted to residential uses or application in areas upgradient from the residential areas that was then transported by ground water.

Fifteen of the 86 volatile organic compounds analyzed for were detected in 1 or more water samples from the monitoring wells. The most frequently detected volatile organic compounds were chloroform (90 percent), bromodichloromethane (56.7 percent), tetrachloroethylene (53.3 percent), and 1,1,1-trichloroethane (50 percent). The widespread occurrence of chloroform and bromodichloromethane in shallow ground water is likely a result of chlorinated public-supply water used to irrigate lawns and gardens in residential areas of Salt Lake Valley. Tetrachloroethylene (PCE), primarily used as a dry cleaning agent and solvent, was detected in water from 16 wells. Resampling of water from a well on the east

side of the valley showed an increase in PCE concentration from 0.8 µg/L in 1999, to 2.5 µg/L in 2000, and to 10.0 µg/L in 2001. This upward trend is an indication of ground water containing PCE moving past the well from an upgradient source.

Stable isotopes indicate that ground water from the monitoring wells is a mixture of varying amounts of local precipitation and evaporated water. Because of evaporation, canal water diverted from the Jordan River and used for irrigation is isotopically heavier relative to precipitation occurring locally or on the adjacent mountains. Several wells on the east side of the valley are upgradient from canals that divert water from the Jordan River but contain a component of evaporated water. Chloroform was detected in water from these wells; thus, the water is likely a mixture of infiltration from local precipitation and seepage of water used for public supply. Recharge of sprinkler-irrigation water to the shallow ground-water system was observed isotopically in a 38.5-ft-deep monitoring well. Stable isotope ratios were heaviest in the summer when water was applied to the area upgradient from the monitoring well and became lighter in the winter and spring when no irrigation occurred.

Water from most of the wells had a tritium concentration of from 10 to 20 tritium units, a range that indicates ground water recharged from the present to about 15 years ago and within the timeframe of residential development in the area of the wells. The match between tritium in shallow ground water and precipitation indicates that most or all of the water in the shallow system is recent recharge from the land surface with little or no mixing with older ground water. Water from most of the monitoring wells was contaminated with chlorofluorocarbons, which also indicates that the water has been in contact with human activities at the land surface.

Subsurface inflow from the Wasatch Range is the main source of recharge to the deeper aquifer on the east side of the valley, and local precipitation and irrigation water are the main sources of recharge to the shallow system. As a result, the deeper aquifer in this part of the valley is more isolated than the shallow ground water from activities occurring at the land surface. No large hydraulic gradient exists between the shallow and deeper aquifers in the northwestern part of the valley and anthropogenic compounds are more prevalent in the shallow ground water. Pumping from the deeper confined aquifer, however, may cause water and anthropogenic compounds to move downward

from the shallow aquifer. The anthropogenic compounds chloroform, tetrachloroethylene, 1,1,1-trichloroethane, atrazine, and simazine were present in water from a monitoring well in the southwestern part of the valley despite the relatively deep water table. Water from local precipitation and seepage from irrigation and canals, primary sources of recharge to the shallow aquifer, also may be major sources of recharge to the deeper aquifer in this area because of thin or discontinuous confining layers. Where this is the case, activities occurring at land surface have the potential to affect the water quality of the deeper aquifer.

No correlation was determined between the percentage of residential land use surrounding the monitoring wells and the concentration of dissolved solids, arsenic, atrazine and its degradation products, prometon, chloroform, or nitrate in water sampled from the wells. Chloroform concentration did not correlate with dissolved-solids or nitrate concentration in water from the monitoring wells; this may be a result of mixing of different sources of recharge and nitrate. Relatively low concentrations of chloroform corresponded to the four highest concentrations of atrazine and its degradation products; this may be a result of atrazine use on agricultural or nonirrigated industrial and vacant land.

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APPENDIX

Table 6. Field parameters for water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3; well identification number is the site number used in the U.S. Geological Survey National Water Information System; $\mu\text{S/cm}$, microsiemens per centimeter at 25 degrees Celsius; mg/L , milligrams per liter; NTU, nephelometric turbidity units; $\mu\text{g/L}$, micrograms per liter; <, less than; —, no data]

Well identifier	Well identification number	Sample date	Depth of well (feet)	Water level below land surface (feet)	Temperature (degrees Celsius)	Specific conductance ($\mu\text{S/cm}$)	pH (standard units)	Alkalinity, dissolved (mg/L as CaCO_3)	Oxygen, dissolved (mg/L)	Turbidity (NTU)	Chlorine ($\mu\text{g/L}$)	Sulfide ($\mu\text{g/L}$)
1	404104111582101	09/22/1999	48.5	30.91	15.5	1,340	7.3	375	4.9	0.6	<30	40
2	404044111572701	09/20/1999	38.5	18.66	16.0	2,740	6.9	433	4.4	.2	40	10
3	404022111580801	10/19/1999	114	74.67	19.0	1,520	7.3	294	6.3	.2	<30	10
4	404012111572101	09/20/1999	38.5	13.35	17.0	2,030	7.5	250	2.5	.6	<30	<10
5	404007111585801	09/27/1999	43.5	24.80	16.0	1,370	7.4	256	6.6	.1	<30	<10
6	403945111565401	10/07/1999	38.5	20.73	16.5	2,850	6.9	659	—	1.6	<30	<10
7	403943111575701	09/28/1999	43.5	21.38	16.5	1,790	7.3	313	5.8	.2	<30	240
8	403918111584201	10/18/1999	67.5	62.47	16.5	760	7.5	191	7.0	4.0	<30	<10
9	403914111560101	09/28/1999	38.5	7.96	15.0	2,190	7.2	374	1.8	.7	<30	<10
10	403915111565501	10/13/1999	83.5	72.48	18.5	3,000	7.3	274	5.2	.1	<30	<10
11	403914111580201	10/06/1999	83.5	67.12	18.0	2,150	7.1	369	4.7	.2	<30	10
14	403828111590401	09/30/1999	48.5	23.31	16.5	1,440	7.5	324	3.3	4.4	<30	10
17	403730111563201	09/23/1999	38.5	14.29	15.5	3,440	7.1	462	.7	.2	<30	10
18	403736111521401	09/13/1999	106	77.55	16.0	1,030	7.2	327	6.7	2.4	50	<10
20	403729111581701	10/05/1999	92.5	80.99	16.5	3,700	7.3	404	6.7	.1	<30	10
22	403713111501901	09/29/1999	36	20.29	14.0	650	7.5	191	2.0	.8	<30	<10
24	403659111580501	10/20/1999	124	76.38	15.0	3,050	7.0	453	4.6	.4	<30	—
25	403652111570201	10/12/1999	68.5	44.97	17.5	2,160	7.0	361	5.4	.6	<30	<10
26D	403627111495701	08/10/1999	77.5	22.96	10.5	350	7.8	85	5.3	2.3	—	10
26S	403627111495702	09/15/1999	31.5	20.50	16.0	235	7.0	68	3.7	.4	40	<10
27	403628111514301	09/07/1999	73.5	58.42	15.5	1,140	6.8	336	6.4	.4	100	<10
29	403638111505101	09/21/1999	34	8.81	13.5	485	7.5	192	.7	.4	<30	100
30	403609111573901	10/12/1999	68.5	51.12	17.0	1,660	7.1	350	6.9	.2	<30	<10
31	403544111584801	10/21/1999	154	135.17	14.5	1,370	7.6	304	8.7	1.5	<30	—
32	403524111512901	09/14/1999	88.5	75.87	14.0	710	7.3	239	8.0	12	<30	<10
33	403609111573901	10/14/1999	95.5	69.65	17.0	2,190	7.3	362	6.8	.1	<30	<10
34	403420111530101	09/09/1999	77.5	56.38	—	1,040	7.2	266	5.3	1.7	50	10
37	403316111510601	09/08/1999	73	45.01	15.0	600	7.5	176	5.8	5.6	80	<10
39	403244111504701	10/04/1999	106	92.80	18.5	860	7.5	298	6.2	.4	35	10
41	403129111510601	09/16/1999	23	5.27	15.5	730	6.9	228	3.4	.8	60	<10

Table 7. Concentration of dissolved major ions in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; mg/L, milligrams per liter; µg/L, micrograms per liter; °C, degrees Celsius; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; <, less than; E, estimated value; M, presence of constituent verified but not quantified]

Well identifier	Bicarbonate (mg/L as HCO ₃) (00453)	Bromide (mg/L as Br) (71870)	Calcium (mg/L as Ca) (00915)	Chloride (mg/L as Cl) (00940)	Fluoride (mg/L as F) (00950)	Iron (µg/L as Fe) (01046)	Magnesium (mg/L as Mg) (00925)
1	463	0.21	60.4	105	0.6	20	47.0
2	522	.40	164	456	.7	<10	32.4
3	360	.25	89.1	191	.6	<10	53.7
4	310	.10	101	428	.8	40	61.0
5	320	.22	62.7	185	.7	<10	42.7
6	804	.45	210	382	.5	<10	101
7	385	.24	85.8	270	.9	170	56.0
8	233	.11	93.5	126	.2	<10	27.2
9	458	.33	140	275	1.1	<10	67.1
10	334	.52	226	401	.6	<10	141
11	450	.37	104	351	.6	<10	95.5
14	400	.08	61.3	194	1.0	<10	29.6
17	564	.34	448	276	.9	M	92.3
18	401	1.40	105	131	.4	<10	25.7
20	493	.23	137	182	.5	<10	175
22	233	.05	77.9	48.6	.8	20	26.2
24	557	.32	192	322	.2	<30	99.9
25	449	.32	150	276	.2	<10	53.5
26D	103	.02	20.6	40.8	.4	<10	4.96
26S	82	<.01	25.6	13.2	.2	<10	4.88
27	410	.12	128	118	.6	M	37.0
29	238	.02	51.3	12.9	1.9	540	22.9
30	427	.22	98.3	168	.4	<10	52.0
31	371	.16	54.7	188	.4	M	34.9
32	292	.03	89.6	48.1	.6	M	25.7
33	442	.23	113	230	.2	<10	48.7
34	324	.10	99.8	101	.9	<10	30.0
37	215	.08	77.1	35.0	.1	M	21.2
39	363	.06	93.4	47.2	.5	<10	25.8
41	279	.05	65.4	64.9	.6	M	33.1

Table 7. Concentration of dissolved major ions in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Well identifier	Manganese (µg/L as Mn) (01056)	Potassium (mg/L as K) (00935)	Silica (mg/L as SiO ₂) (00955)	Sodium (mg/L as Na) (00930)	Sulfate (mg/L as SO ₄) (00945)	Solids, residue at 180°C (mg/L) (70300)	Solids, sum of constituents (mg/L) (70301)
1	148	18.4	39.4	157	139	804	829
2	<2.2	21.9	37.2	267	353	1,800	1,620
3	2.2	14.4	38.4	154	218	982	974
4	44.8	11.7	40.3	212	134	1,190	1,150
5	<2.2	9.69	42.8	162	143	818	838
6	38.4	33.8	40.2	263	361	1,850	1,810
7	49.5	19.3	37.3	189	209	1,080	1,080
8	2.9	4.74	37.2	75.8	110	636	619
9	8.0	31.4	28.5	213	394	1,410	1,390
10	<2.2	21.9	47.6	241	816	2,200	2,100
11	12.4	23.2	47.0	195	208	1,300	1,300
14	3.6	17.4	46.3	190	101	848	874
17	36.9	50.0	49.9	228	1,210	2,820	2,690
18	E1.5	6.06	16.6	82.9	49.0	618	635
20	40.5	57.8	51.6	473	1,480	2,910	2,830
22	25.5	4.64	15.4	14.8	64.4	381	386
24	12	14.4	39.8	338	749	2,180	2,030
25	2.9	14.2	36.9	246	378	1,440	1,410
26D	E1.8	1.35	6.5	38.1	16.9	189	181
26S	E1.4	1.56	6.6	12.6	24.3	134	131
27	E1.7	7.52	22.1	67.8	80.0	718	696
29	110	4.46	18.3	10.3	31.4	282	271
30	10.3	10.3	26.6	179	263	1,060	1,040
31	65.2	10.9	25.3	163	94.2	806	797
32	2.4	4.34	17.0	15.2	41.4	405	414
33	<2.2	7.72	41.8	322	505	1,510	1,500
34	<2.2	7.21	30.3	65.8	85.4	626	614
37	10.4	4.63	15.7	16.7	42.3	383	378
39	18.7	5.76	20.8	53.7	64.4	521	534
41	<2.2	5.43	18.2	40.0	40.9	445	426

Table 8. Concentration of trace elements in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; water samples for Radon-222 analysis were not filtered; µg/L, micrograms per liter; pCi/L, picocuries per liter; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; <, less than; E, estimated value]

Well identifier	Dissolved aluminum (µg/L as Al) (01106)	Dissolved antimony (µg/L as Sb) (01095)	Dissolved arsenic (µg/L as As) (01000)	Dissolved barium (µg/L as Ba) (01005)	Dissolved beryllium (µg/L as Be) (01010)	Dissolved cadmium (µg/L as Cd) (01025)	Dissolved chromium (µg/L as Cr) (01030)	Dissolved cobalt (µg/L as Co) (01035)	Dissolved copper (µg/L as Cu) (01040)
1	2	<1.00	9.9	62.7	<1.00	<1.00	0.9	<1.00	1.1
2	1	<1.00	10.2	36.6	<1.00	<1.00	2.9	<1.00	3.0
3	3	<1.00	12.2	28.3	<1.00	<1.00	E.7	<1.00	1.3
4	<1	<1.00	19.6	74.2	<1.00	<1.00	1.9	<1.00	1.1
5	1	<1.00	13.7	33.9	<1.00	<1.00	2.7	<1.00	1.3
6	2	<1.00	14.5	39.6	<1.00	<1.00	E.5	<1.00	3.9
7	1	<1.00	11.7	36.3	<1.00	<1.00	1.0	<1.00	1.2
8	3	<1.00	13.9	53.1	<1.00	<1.00	1.7	<1.00	<1.0
9	1	<1.00	2.1	24.7	<1.00	<1.00	3.5	<1.00	2.3
10	5	<1.00	13.4	19.5	<1.00	<1.00	2.6	<1.00	4.9
11	<1	<1.00	11.2	35.1	<1.00	<1.00	E.7	<1.00	1.9
14	<1	<1.00	15.4	98.8	<1.00	<1.00	.8	<1.00	1.7
17	1	<1.00	7.0	47.7	<1.00	<1.00	<1.0	1.05	10
18	1	<1.00	<1.0	202	<1.00	<1.00	1.2	<1.00	2.3
20	1	<1.00	17.7	11.8	<1.00	<1.00	.9	1.09	6.7
22	2	<1.00	<2.0	142	<1.00	<1.00	<.8	<1.00	<1.0
24	3	<1.00	7.3	20.3	<1.00	<1.00	3.1	<1.00	2.7
25	<1	<1.00	12.5	17.5	<1.00	<1.00	2.9	<1.00	6.1
26D	10	1.69	<1.0	51.7	<1.00	<1.00	<1.0	<1.00	<1.0
26S	2	1.30	2.0	71.4	<1.00	<1.00	<1.0	<1.00	1.0
27	1	<1.00	1.3	140	<1.00	<1.00	2.5	<1.00	2.3
29	2	<1.00	5.6	81.1	<1.00	<1.00	<.8	<1.00	<1.0
30	<1	<1.00	7.3	39.6	<1.00	<1.00	2.2	<1.00	3.5
31	3	<1.00	6.3	95.0	<1.00	<1.00	4.7	<1.00	1.5
32	2	<1.00	<1.0	209	<1.00	<1.00	1.4	<1.00	2.4
33	<1	<1.00	10.8	14.7	<1.00	<1.00	3.4	<1.00	3.5
34	2	<1.00	<1.0	112	<1.00	<1.00	<1.0	<1.00	2.1
37	3	<1.00	1.1	255	<1.00	<1.00	1.7	<1.00	1.3
39	2	<1.00	3.3	130	<1.00	<1.00	1.5	<1.00	2.3
41	1	<1.00	<1.0	150	<1.00	<1.00	<1.0	<1.00	1.6

¹2-Sigma precision estimate.

Table 8. Concentration of trace elements in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Well identifier	Dissolved lead (µg/L as Pb) (01049)	Dissolved molybdenum (µg/L as Mo) (01060)	Dissolved nickel (µg/L as Ni) (01065)	Total radon-222 (pCi/L) (82303)	Radon-222 2-sigma ¹ (pCi/L) (76002)	Dissolved selenium (µg/L as Se) (01145)	Dissolved silver (µg/L as Ag) (01075)	Dissolved uranium (µg/L as U) (22703)	Dissolved zinc (µg/L as Zn) (01090)
1	<1.00	8.1	2.56	700	26	1.2	<1.0	8.11	1
2	<1.00	99.1	2.17	589	23	2.1	<2.0	16.2	4
3	<1.00	5.0	1.83	243	18	2.6	<1.0	5.29	2
4	<1.00	5.5	3.91	514	23	<1.0	<1.0	4.70	3
5	<1.00	4.3	1.37	503	27	2.5	<1.0	4.44	2
6	<1.00	19.4	4.74	404	22	<2.4	<1.0	16.0	3
7	<1.00	8.3	1.95	400	21	E1.5	<1.0	7.10	<1
8	<1.00	<1.0	2.96	485	23	<2.4	<1.0	2.60	2
9	<1.00	55.7	2.61	506	24	4.0	<1.0	22.3	2
10	<1.00	11.1	5.15	559	24	13.0	<1.0	13.5	6
11	<1.00	2.7	1.97	297	20	<2.4	<1.0	10.9	2
14	<1.00	6.9	2.50	524	24	2.6	<1.0	11.5	3
17	<1.00	45.4	7.88	825	27	1.7	<1.0	26.6	6
18	<1.00	3.9	2.34	522	23	<1.0	<1.0	8.01	3
20	<1.00	2.5	3.68	678	26	4.2	<1.0	8.62	8
22	<1.00	27.8	1.30	1,250	33	3.0	<1.0	38.9	3
24	<1.00	<1.0	3.69	535	24	E3.0	<1.0	13.9	4
25	<1.00	4.3	4.19	810	27	3.0	<1.0	12.4	4
26D	<1.00	8.1	5.42	658	25	<1.0	<1.0	4.74	<1
26S	<1.00	4.3	<1.00	641	24	<1.0	<1.0	1.50	1
27	<1.00	3.0	5.81	920	28	<1.0	<1.0	5.16	1
29	<1.00	95.2	<1.00	719	26	<1.0	<1.0	<1.00	<1
30	<1.00	4.1	3.01	352	20	3.6	<1.0	10.4	4
31	<1.00	10.2	5.82	679	27	<2.4	<1.0	2.68	6
32	<1.00	2.0	4.03	1,170	32	<1.0	<1.0	22.8	2
33	<1.00	1.6	2.97	635	25	2.6	<1.0	8.89	3
34	<1.00	7.5	3.39	491	31	<1.0	<1.0	36.2	5
37	<1.00	1.5	3.29	2,190	42	<1.0	<1.0	8.04	2
39	<1.00	3.4	3.24	462	22	<2.4	<1.0	21.2	2
41	<1.00	2.8	1.43	1,130	31	<1.0	<1.0	92.7	2

Table 9. Concentration of nutrient constituents and organic carbon in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; mg/L, milligrams per liter; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; <, less than; E, estimated value]

Well identifier	Dissolved ammonia (mg/L as N) (00608)	Dissolved ammonia plus organic nitrogen (mg/L as N) (00623)	Dissolved organic carbon (mg/L as C) (00681)	Dissolved nitrite (mg/L as N) (00613)	Dissolved nitrite plus nitrate (mg/L as N) (00631)	Dissolved phosphorus (mg/L as P) (00666)	Dissolved orthophosphorus (mg/L as P) (00671)
1	<0.020	0.15	4.6	0.019	7.66	.036	.034
2	<.020	.32	2.0	<.010	7.35	.074	.063
3	<.020	.14	E1.1	<.010	8.55	.028	.028
4	.030	.14	3.2	.012	2.37	.031	.025
5	<.020	E.08	.86	<.010	7.05	.024	.032
6	<.020	.34	E4.5	<.010	5.46	.089	.084
7	<.020	.15	1.3	<.010	4.72	.017	.019
8	<.020	E.08	E.79	<.010	6.67	.033	.031
9	<.020	<.10	1.3	<.010	3.55	.029	.033
10	.029	.15	1.1	<.010	9.78	.033	.028
11	<.020	.17	1.8	<.010	12.0	.029	.028
14	<.020	.18	1.9	.100	8.15	.067	.064
17	<.020	.33	3.2	.107	12.7	.179	.162
18	<.020	.12	1.5	<.010	4.35	.013	.019
20	.021	.15	2.1	<.010	6.85	.051	.056
22	<.020	E.06	.71	<.010	4.14	.006	<.010
24	<.020	.24	E1.5	<.010	1.38	.065	.060
25	.031	.13	1.4	<.010	7.20	.058	.050
26D	<.020	<.10	1.3	<.010	.246	<.004	<.010
26S	<.020	<.10	.60	<.010	.200	.154	.133
27	<.020	.14	1.9	<.010	7.50	.013	.016
29	.043	E.07	.80	<.010	<.050	.022	.023
30	.023	.13	1.5	<.010	6.81	.037	.028
31	<.020	.12	.72	<.010	9.49	.027	.024
32	<.020	.22	2.0	<.010	6.39	.006	<.010
33	.022	.14	1.5	<.010	3.94	.058	.049
34	<.020	.12	1.9	<.010	7.71	.011	.015
37	<.020	E.07	1.1	<.010	13.3	.191	.172
39	<.020	.22	2.0	.012	9.96	.029	.027
41	<.020	.13	1.5	<.010	4.45	.207	.189

Table 10. Pesticides and degradation products analyzed for in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Parameter code is used in U.S. Geological Survey National Water Information System database; µg/L, micrograms per liter; —, no number]

Compound	Parameter code	Chemical Abstracts Service registry number	Minimum reporting level (µg/L)	Compound	Parameter code	Chemical Abstracts Service registry number	Minimum reporting level (µg/L)
Gas Chromatography/Mass Spectrometry analytical method				High-Performance Liquid Chromatography analytical method¹			
Acetochlor	49260	34256-82-1	0.002	2,4-D	39732	94-75-7	.08
Alachlor	46342	15972-60-8	.002	2,4-D methyl ester	50470	1928-38-7	.086
alpha-HCH	34253	319-84-6	.002	2,4-DB	38746	94-82-6	.05
Atrazine	39632	1912-24-9	.001	2-Hydroxyatrazine	50355	2163-68-0	.193
Azinphos-methyl	82686	86-50-0	.001	3(4-Chlorophenyl)-1-methyl urea	61692	5352-88-5	.0915
Benfluralin	82673	1861-40-1	.002	3-Hydroxycarbofuran	49308	16655-82-6	.062
Butylate	04028	2008-41-5	.002	3-Ketocarbofuran	50295	16709-30-1	.072
Carbaryl	82680	63-25-2	.003	Acifluorfen	49315	50594-66-6	.06
Carbofuran	82674	1563-66-2	.003	Aldicarb	49312	116-06-3	.08
Chlorpyrifos	38933	2921-88-2	.004	Aldicarb sulfone	49313	1646-88-4	.16
cis-Permethrin	82687	54774-45-7	.005	Aldicarb sulfoxide	49314	1646-87-3	.03
Cyanazine	04041	21725-46-2	.004	Atrazine	39632	1912-24-9	.074
Dacthal	82682	1861-32-1	.002	Bendiocarb	50299	22781-23-3	.061
Deethylatrazine	04040	6190-65-4	.002	Benomyl	50300	17804-35-2	.022
Diazinon	39572	333-41-5	.002	Bensulfuron-methyl	61693	83055-99-6	.0482
Dieldrin	39381	60-57-1	.001	Bentazon	38711	25057-89-0	.02
2,6-Diethylaniline	82660	579-66-8	.003	Bromacil	04029	314-40-9	.08
Disulfoton	82677	298-04-4	.017	Bromoxynil	49311	1689-84-5	.06
EPTC	82668	759-94-4	.002	Caffeine	50305	58-08-2	.081
Ethalfuralin	82663	55283-68-6	.004	Carbaryl	49310	63-25-2	.06
Ethoprophos	82672	13194-48-4	.003	Carbofuran	49309	1563-66-2	.06
Fonofos	04095	944-22-9	.003	Chloramben, methyl ester	61188	7286-84-2	.11
Lindane	39341	58-89-9	.004	Chlorimuron-ethyl	50306	90982-32-4	.037
Linuron	82666	330-55-2	.002	Chlorothalonil	49306	1897-45-6	.05
Malathion	39532	121-75-5	.005	Clopyralid	49305	1702-17-6	.04
Metolachlor	39415	51218-45-2	.002	Cycloate	04031	1134-23-2	.05
Metribuzin	82630	21087-64-9	.004	Dacthal monoacid	49304	887-54-7	.07
Molinate	82671	2212-67-1	.004	Deethylatrazine	04040	6190-65-4	.087
Napropamide	82684	15299-99-7	.003	Deethyldeisopropylatrazine	04039	3397-62-4	.06
p,p'-DDE	34653	72-55-9	.006	Deisopropylatrazine	04038	1007-28-9	.07
Parathion	39542	56-38-2	.004	Dicamba	38442	1918-00-9	.10
Parathion-methyl	82667	298-00-0	.006	Dichlorprop	49302	120-36-5	.05
Pebulate	82669	1114-71-2	.004	Dinoseb	49301	88-85-7	.04
Pendimethalin	82683	40487-42-1	.004	Diphenamid	04033	957-51-7	.06
Phorate	82664	298-02-2	.002	Diuron	49300	330-54-1	.08
Prometon	04037	1610-18-0	.018	Fenuron	49297	101-42-8	.07
Propachlor	04024	1918-16-7	.007	Flumetsulam	61694	98967-40-9	.0866
Propanil	82679	709-98-8	.004	Fluometuron	38811	2164-17-2	.06
Propargite	82685	2312-35-8	.013	Imazaquin	50356	81335-37-7	.103
Propyzamide	82676	23950-58-5	.003	Imazethapyr	50407	81335-77-5	.088
Simazine	04035	122-34-9	.005	Imidacloprid	61695	138261-41-3	.106
Tebuthiuron	82670	34014-18-1	.010	Linuron	38478	330-55-2	.07
Terbacil	82665	5902-51-2	.007	MCPA	38482	94-74-6	.06
Terbufos	82675	13071-79-9	.013	MCPB	38487	94-81-5	.062
Thiobencarb	82681	28249-77-6	.002	Metalaxyl	50359	57837-19-1	.057
Triallate	82678	2303-17-5	.001	Methiocarb	38501	2032-65-7	.08
Trifluralin	82661	1582-09-8	.002	Methomyl	49296	16752-77-5	.08
				Methomyl Oxime	61696	—	.0102

Table 10. Pesticides and degradation products analyzed for in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Compound	Parameter code	Chemical Abstracts Service registry number	Minimum reporting level (µg/L)
High-Performance Liquid Chromatography analytical method¹— Continued			
Metsulfuron methyl	61697	74223-64-6	.114
Neburon	49294	555-37-3	.07
Nicosulfuron	50364	111991-09-4	.065
Norflurazon	49293	27314-13-2	.08
Oryzalin	49292	19044-88-3	.07
Oxamyl	38866	23135-22-0	.02
Oxamyl Oxime	38866	—	.064
Picloram	49291	2/1/1918	.07
Propham	49236	122-42-9	.07
Propiconazole	50471	60207-90-1	.064
Propoxur	38538	114-26-1	.06
Siduron	38548	1982-49-6	.093
Sulfometuron-methyl	50337	74222-97-2	.039
Tebuthiuron	82670	34014-18-1	.010
Terbacil	04032	5902-51-2	.10
Tribenuron-methyl	61159	101200-48-0	.07
Triclopyr	49235	55335-06-3	.10

¹ The samples from this study were analyzed by the high-performance liquid chromatography/mass spectrometry method before its final approval by the U.S. Geological Survey Office of Water Quality in 2001. Although the analytical method did not change following approval, data analyzed before method approval are considered provisional. Ninety percent of the ground-water samples analyzed with this method in this study exceeded the recommended 4-day holding time prior to sample extraction (Furlong and others, 2001). Degradation of pesticides during extended sample storage is likely, and concentrations and detection frequencies for the pesticides analyzed by this method may be biased low.

Table 11. Concentration of dissolved pesticides detected in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; concentration reported in micrograms per liter; E, estimated value; <, less than; M, presence of compound verified but not quantified]

Well identifier	Atrazine (39632)	Deethyl-atrazine (04040)	Deethyl-deisopropyl-atrazine ¹ (04039)	Deisopropyl-atrazine ¹ (04038)	2-Hydroxy-atrazine ¹ (50355)	Bromacil ¹ (04029)	Caffeine ¹ (50305)	Cycloate ^{1,2} (04031)	Diazinon (39572)
1	0.196	E0.025	E0.01	<0.07	E0.044	<0.08	<0.081	<0.05	<0.002
2	.208	E.059	E.01	<.07	E.052	<.08	<.081	<.05	<.002
3	.049	E.011	E.01	<.07	<.193	<.08	<.081	<.05	<.002
4	.880	E.307	.06	E.03	E.203	<.08	<.081	<.05	<.002
5	.232	E.136	E.01	<.07	E.055	<.08	<.081	E.04	<.002
6	.062	E.048	E.01	<.07	<.193	<.08	<.081	<.05	<.002
7	.382	E.061	E.03	E.02	E.096	.19	<.081	E.03	<.002
8	.023	E.024	M	<.07	<.193	<.08	<.081	<.05	<.002
9	.188	E.046	E.01	<.07	E.064	<.08	<.081	E.04	<.002
10	.033	E.008	<.06	<.07	<.193	<.08	<.081	<.05	<.002
11	1.58	E.320	E.12	E.01	E.511	<.08	<.081	<.05	<.002
14	<.001	E.004	<.06	<.07	<.193	<.08	<.081	E.03	<.002
17	.229	E.098	E.02	<.07	E.066	<.08	<.081	<.05	<.002
18	E.004	<.087	<.06	<.07	<.193	<.08	<.081	<.05	<.002
20	.005	E.021	M	<.07	<.193	<.08	<.081	<.05	<.002
22	<.001	<.002	<.06	<.07	<.193	<.08	<.081	<.05	E.002
24	.115	E.030	E.01	<.07	<.193	<.08	<.081	<.05	<.002
25	.345	E.106	E.02	<.07	E.055	<.08	<.081	<.05	<.002
26D	.009	<.002	<.06	<.07	<.193	<.08	<.081	<.05	<.002
26S	<.001	<.002	<.06	<.07	<.193	<.08	E.011	<.05	<.002
27	.019	<.002	M	<.07	<.193	<.08	<.081	<.05	<.002
29	<.001	<.002	<.06	<.07	<.193	<.08	E.029	<.05	<.002
30	.012	E.006	M	<.07	<.193	<.08	<.081	<.05	<.002
31	1.03	E.093	E.04	E.02	E.185	<.08	<.081	<.05	<.002
32	<.001	<.002	<.06	<.07	<.193	<.08	<.081	<.05	<.002
33	.031	E.022	E.01	<.07	<.193	<.08	<.081	<.05	<.002
34	.018	E.012	M	<.07	<.193	<.08	<.081	<.05	<.002
37	<.001	<.002	<.06	<.07	<.193	<.08	<.081	<.05	<.002
39	.029	E.016	<.06	<.07	<.193	<.08	<.081	<.05	<.002
41	<.074	<.087	<.06	<.07	<.193	<.08	<.081	<.05	<.002

¹ Compound was analyzed by the high-performance liquid chromatography/mass spectrometry method before its final approval by the U.S. Geological Survey Office of Water Quality in 2001. Although the analytical method did not change following approval, data analyzed before method approval are considered provisional.

² Presence of compound in sample(s) may be the result of contamination. Compound was not included in analysis of pesticide data.

Table 11. Concentration of dissolved pesticides detected in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Well identifier	Diuron ¹ (49300)	Imazaquin ^{1,2} (50356)	Malathion (39532)	P,P' DDE (34653)	Picloram ¹ (49291)	Prometon (04037)	Simazine (04035)	Tebuthiuron (82670)
1	<0.08	<0.103	<0.005	<0.006	<0.07	0.518	0.027	<0.010
2	<.08	<.103	<.010	<.006	<.07	.105	.008	.120
3	<.08	<.103	<.005	<.006	<.07	<.018	.019	<.010
4	<.08	<.103	<.010	<.006	.47	.043	<.005	<.010
5	<.08	E.006	<.005	<.006	<.07	<.018	.006	<.010
6	<.08	<.103	<.005	<.006	<.07	.021	E.004	.051
7	.32	<.103	<.005	<.006	<.07	E.016	.023	<.010
8	<.08	<.103	<.005	<.006	<.07	<.018	<.005	<.010
9	<.08	<.103	<.005	<.006	<.07	.026	.006	<.010
10	<.08	<.103	<.005	<.006	<.07	<.018	<.005	<.010
11	<.08	<.103	<.005	<.006	<.07	<.018	.013	<.010
14	<.08	<.103	<.005	<.006	<.07	<.018	<.005	<.010
17	<.08	<.103	<.005	<.006	<.07	.022	.010	<.010
18	<.08	<.103	<.005	<.006	<.07	.216	.013	E.028
20	<.08	<.103	.006	<.006	<.07	<.018	<.005	<.010
22	<.08	E.006	<.005	<.006	<.07	<.018	<.005	<.010
24	<.08	<.103	<.005	<.006	<.07	<.018	.009	<.010
25	<.08	<.103	<.005	<.006	<.07	E.015	.011	<.010
26D	<.08	<.103	<.005	<.006	<.07	<.018	<.005	<.010
26S	<.08	<.103	<.005	<.006	<.07	E.005	<.005	<.010
27	<.08	<.103	<.005	<.006	<.07	.125	<.005	<.010
29	<.08	<.103	<.005	<.006	<.07	<.018	<.005	<.010
30	<.08	<.103	<.005	<.006	<.07	.030	<.005	<.010
31	<.08	<.103	<.005	<.006	<.07	<.018	.018	<.010
32	<.08	<.103	<.005	<.006	<.07	<.018	<.005	<.010
33	<.08	<.103	<.005	<.006	<.07	<.018	<.005	<.010
34	<.08	<.103	<.005	<.006	<.07	.119	<.005	<.010
37	<.08	<.103	<.005	<.006	<.07	<.018	<.005	<.010
39	<.08	<.103	<.005	E.002	<.07	E.004	<.005	<.010
41	<.08	<.103	<.005	<.006	<.07	.262	<.005	E.012

Table 12. Volatile organic compounds analyzed for in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Parameter code is used in U.S. Geological Survey National Water Information System database; —, no number]

Compound	Parameter code	Chemical Abstracts Service registry number	Laboratory reporting level (µg/L)
1,1,1,2-Tetrachloroethane	77562	630-20-6	0.03
1,1,1-Trichloroethane	34506	71-55-6	.03
1,1,2,2-Tetrachloroethane	34516	79-34-5	.09
1,1,2-Trichloroethane	34511	79-00-5	.06
1,1,2-Trichlorotrifluoroethane	77652	76-13-1	.06
1,1-Dichloroethane	34496	75-34-3	.07
1,1-Dichloroethylene	34501	75-35-4	.04
1,1-Dichloropropene	77168	563-58-6	.03
1,2,3,4-Tetramethylbenzene	49999	488-23-3	.2
1,2,3,5-Tetramethylbenzene	50000	527-53-7	.2
1,2,3-Trichlorobenzene	77613	87-61-6	.3
1,2,3-Trichloropropane	77443	96-18-4	.2
1,2,3-Trimethylbenzene	77221	526-73-8	.1
1,2,4-Trichlorobenzene	34551	120-82-1	.2
1,2,4-Trimethylbenzene	77222	95-63-6	.06
1,2-Dibromo-3-chloropropane	82625	96-12-8	.2
1,2-Dibromoethane	77651	106-93-4	.04
1,2-Dichlorobenzene	34536	95-50-1	.05
1,2-Dichloroethane	32103	107-06-2	.1
1,2-Dichloropropane	34541	78-87-5	.07
1,3,5-Trimethylbenzene	77226	108-67-8	.04
1,3-Dichlorobenzene	34566	541-73-1	.05
1,3-Dichloropropane	77173	142-28-9	.1
1,4-Dichlorobenzene	34571	106-46-7	.05
2,2-Dichloropropane	77170	594-20-7	.05
2-Butanone	81595	78-93-3	2
2-Chlorotoluene	77275	95-49-8	.04
2-Hexanone	77103	591-78-6	.7
3-Chloropropene	78109	107-05-1	.2
4-Chlorotoluene	77277	106-43-4	.06
4-Isopropyl-1-methylbenzene	77356	99-87-6	.07
4-Methyl-2-pentanone	78133	108-10-1	.4
Acetone	81552	67-64-1	7
Acrylonitrile	34215	107-13-1	1
Benzene	34030	71-43-2	.04
Bromobenzene	81555	108-86-1	.04
Bromochloromethane	77297	74-97-5	.04
Bromodichloromethane	32101	75-27-4	.05
Bromoform	32104	75-25-2	.06
Bromomethane	34413	74-83-9	.3
Butylbenzene	77342	104-51-8	.2
Carbon disulfide	77041	75-15-0	.07
Chlorobenzene	34301	108-90-7	.03
Chloroethane	34311	75-00-3	.1
Chloroform	32106	67-66-3	.05
Chloromethane	34418	74-87-3	.5
Dibromochloromethane	32105	124-48-1	.2
Dibromomethane	30217	74-95-3	.05

Table 12. Volatile organic compounds analyzed for in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Compound	Parameter code	Chemical Abstracts Service registry number	Laboratory reporting level (µg/L)
Dichlorodifluoromethane	34668	75-71-8	.3
Dichloromethane	34423	75-09-2	.4
Diethyl ether	81576	60-29-7	.2
Diisopropyl ether	81577	108-20-3	.1
Ethyl methacrylate	73570	97-63-2	.2
Ethyl tert-butyl ether	50004	637-92-3	.05
Ethylbenzene	34371	100-41-4	.03
Hexachlorobutadiene	39702	87-68-3	.1
Hexachloroethane	34396	67-72-1	.2
Isopropylbenzene	77223	98-82-8	.03
Methyl acrylate	49991	96-33-3	1
Methyl acrylonitrile	81593	126-98-7	.6
Methyl iodide	77424	74-88-4	.1
Methyl methacrylate	81597	80-62-6	.3
Naphthalene	34696	91-20-3	.2
Styrene	77128	100-42-5	.04
Tetrachloroethylene	34475	127-18-4	.1
Tetrachloromethane	32102	56-23-5	.06
Tetrahydrofuran	81607	109-99-9	2
Toluene	34010	108-88-3	.05
Trichloroethylene	39180	79-01-6	.04
Trichlorofluoromethane	34488	75-69-4	.09
Vinyl bromide	50002	593-60-2	.1
Vinyl chloride	39175	75-01-4	.1
cis-1,2-Dichloroethylene	77093	156-59-2	.04
cis-1,3-Dichloropropene	34704	10061-01-5	.09
m- and p-Xylene	85795	—	.06
n-Propylbenzene	77224	103-65-1	.04
o-Ethyl toluene	77220	611-14-3	.06
o-Xylene	77135	95-47-6	.04
sec-Butylbenzene	77350	135-98-8	.03
tert-Butyl methyl ether	78032	1634-04-4	.2
tert-Butylbenzene	77353	98-06-6	.06
tert-Pentyl methyl ether	50005	994-05-8	.1
trans-1,2-Dichloroethylene	34546	156-60-5	.03
trans-1,3-Dichloropropene	34699	10061-02-6	.09
trans-1,4-Dichloro-2-butene	73547	110-57-6	.7

Table 13. Concentration of volatile organic compounds detected in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; concentration reported in micrograms per liter; <, less than; E, estimated value; M, presence of compound verified but not quantified]

Well identifier	Benzene ¹ (34030)	Bromo-dichloro-methane (32101)	Carbon disulfide (77041)	Chloroform (32106)	Chloro-methane (34418)	1,1-Dichloro-ethane (34496)	1,2-Dichloro-ethane (32103)	1,1-Dichloro-ethylene (34501)	Dichloro-methane (34423)	Ethyl-benzene ¹ (34371)	o-Ethyl-toluene ¹ (77220)	Methyl tert-butyl ether (MTBE) (78032)
1	<0.04	0.27	<0.07	1.97	<0.5	<0.07	<0.1	<0.04	E0.1	<0.03	<0.06	<0.2
2	<.04	E.05	<.07	.55	<.5	E.03	<.1	E.01	<.4	<.03	<.06	<.2
3	<.04	E.02	<.07	E.08	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
4	<.04	<.05	E.05	.29	<.5	<.07	<.1	<.04	E.3	<.03	<.06	<.2
5	<.04	.16	<.07	.97	<.5	<.07	.4	<.04	M	<.03	<.06	<.2
6	<.04	<.05	<.07	<.05	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
7	<.04	<.05	E.10	E.09	<.5	<.07	<.1	<.04	E.1	<.03	<.06	<.2
8	<.04	.24	<.07	1.16	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
9	<.04	E.07	<.07	.88	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
10	<.04	E.03	<.07	.18	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
11	<.04	<.05	<.07	E.03	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
14	<.04	E.04	<.07	.49	<.5	<.07	<.1	<.04	E.1	<.03	<.06	<.2
17	<.04	<.05	<.07	.94	<.5	<.07	<.1	<.04	M	<.03	<.06	<.2
18	<.10	.19	<.37	1.53	<.2	<.07	<.1	<.04	<.4	<.03	<.10	<.2
20	<.04	.26	<.07	2.41	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
22	<.04	<.05	<.07	.10	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
24	<.04	.12	<.07	.64	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
25	<.04	.12	<.07	.65	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
26D	<.10	E.03	<.37	.22	<.2	<.07	<.1	<.04	<.4	<.03	<.10	<.2
26S	<.10	<.05	<.37	E.10	<.2	<.07	<.1	<.04	<.4	<.03	<.10	<.2
27	<.10	.51	<.37	2.11	<.2	<.07	<.1	<.04	<.4	<.03	<.10	E.1
29	<.17	<.24	<.35	<.26	<.2.5	<.33	<.7	<.20	<.1.9	<.15	<.30	<.8
30	<.04	.23	<.07	1.28	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
31	<.04	E.04	<.07	.31	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
32	M	<.05	<.37	<.05	<.2	<.07	<.1	<.04	<.4	E.02	E.01	<.2
33	<.04	<.05	<.07	.13	<.5	<.07	<.1	E.05	<.4	<.03	<.06	<.2
34	E.01	<.05	<.37	E.03	E.1	<.07	<.1	<.04	<.4	E.01	<.10	<.2
37	<.10	<.05	E.01	.19	<.2	<.07	<.1	<.04	<.4	<.03	<.10	<.2
39	<.04	E.04	<.07	.24	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2
41	<.04	<.05	<.07	E.06	<.5	<.07	<.1	<.04	<.4	<.03	<.06	<.2

¹ Presence of compound in sample(s) may be the result of contamination. Compound was not included in analysis of volatile organic compound data.

Table 13. Concentration of volatile organic compounds detected in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Well identifier	Tetrachloro-ethylene (PCE) (34475)	Tetrachloro-methane (32102)	Toluene ¹ (34010)	1,1,1-Trichloro-ethane (TCA) (34506)	Trichloro-ethylene (TCE) (39180)	Trichloro-fluoro-methane (CFC-11) (34488)	1,1,2-Trichloro-trifluoro-ethane (CFC-113) (77652)	1,2,3-Trimethyl-benzene ¹ (77221)	1,2,4-Trimethyl-benzene ¹ (77222)	1,3,5-Trimethyl-benzene ¹ (77226)	m- and p-Xylene ¹ (85795)	o-Xylene ¹ (77135)
1	4.8	<0.06	<0.05	E0.08	E0.04	<0.09	<0.06	<0.1	<0.06	<0.04	<0.06	<0.04
2	.1	<0.06	<0.05	.22	1.54	<0.09	<0.06	<.1	<0.06	<.04	<0.06	<.04
3	<.1	<0.06	<0.05	.12	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
4	M	<0.06	<0.05	<.03	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
5	7.8	<0.06	<0.05	<.03	E.06	<.09	<.06	<.1	<.06	<.04	<.06	<.04
6	<.1	<0.06	<0.05	<.03	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
7	M	<0.06	<0.05	<.03	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
8	1.9	<0.06	<0.05	E.01	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
9	1.2	<0.06	<0.05	<.03	E.03	<.09	<.06	<.1	<.06	<.04	<.06	<.04
10	M	<0.06	<0.05	E.05	E.02	<.09	<.06	<.1	<.06	<.04	<.06	<.04
11	<.1	<0.06	<0.05	<.03	<.04	<.09	<.06	<.1	<.06	<.04	E.02	<.04
14	<.1	<0.06	<0.05	E.02	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
17	<.1	<0.06	<0.05	<.03	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
18	.5	<.09	<.05	E.04	<.04	<.09	<.03	<.1	<.06	<.04	<.06	<.06
20	<.1	<0.06	<0.05	E.02	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
22	<.1	<0.06	<0.05	<.03	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
24	<.1	<0.06	<0.05	E.04	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
25	M	<0.06	<0.05	E.01	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
26D	M	<.09	<.05	<.03	<.04	<.09	<.03	<.1	<.06	<.04	<.06	<.06
26S	<.1	<.09	<.05	<.03	<.04	<.09	<.03	<.1	<.06	<.04	<.06	<.06
27	.8	<.09	<.05	E.02	<.04	<.09	<.03	<.1	<.06	<.04	<.06	<.06
29	<.5	<.30	<.25	<.16	<.19	<.45	<.30	<.6	<.28	<.22	<.30	<.19
30	.6	<.06	<.05	<.03	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
31	M	<.06	<.05	E.02	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
32	<.1	<.09	<.05	<.03	<.04	<.09	<.03	M	E.03	E.01	E.08	E.02
33	<.1	<.06	<.05	.10	<.04	E.09	E.08	<.1	<.06	<.04	<.06	<.04
34	M	<.09	E.01	<.03	<.04	<.09	<.03	<.1	E.01	<.04	E.03	<.06
37	<.1	<.09	<.05	E.01	<.04	E.04	<.03	<.1	<.06	<.04	E.01	<.06
39	<.1	E.01	<.05	E.01	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04
41	M	<.06	E.01	<.03	<.04	<.09	<.06	<.1	<.06	<.04	<.06	<.04

Table 14. Quality-control data for dissolved major ions in blank water and water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; numbers in bold indicate detection in the field-blank sample; mg/L, milligrams per liter; µg/L, microgram per liter; °C, degrees Celsius; number below parameter name is the U.S. Geological Survey National Water Information System parameter code; —, no data; <, less than; E, estimated value; M, presence of constituent is verified but not quantified]

Well identifier	Sample date	Sample time	Sample type	Bicarbonate (mg/L as HCO ₃) (00453)	Bromide (mg/L as Br) (71870)	Calcium (mg/L as Ca) (00915)	Chloride (mg/L as Cl) (00940)	Fluoride (mg/L as F) (00950)
26D	08/10/1999	1606	Field blank	—	<0.01	E0.01	<0.1	<0.1
26S	09/15/1999	1106	Field blank	—	<.01	.02	<.3	<.1
1	09/22/1999	1006	Field blank	—	<.01	<.02	<.3	<.1
22	09/29/1999	1106	Field blank	—	<.01	<.02	<.3	<.1
10	10/13/1999	1206	Field blank	—	<.01	<.02	<.3	<.1
31	10/21/1999	1106	Field blank	—	<.01	.02	<.3	<.1
34	09/09/1999	1100	Ground water	324	.10	99.8	101	.9
34	09/09/1999	1101	Replicate	324	<.01	100	100	.9
39	10/04/1999	1100	Ground water	363	.06	93.4	47.2	.5
39	10/04/1999	1101	Replicate	357	.06	93.4	47.0	.4
3	10/19/1999	1100	Ground water	360	.25	89.1	191	.6
3	10/19/1999	1101	Replicate	360	.24	86.8	185	.7
Well identifier	Sample date	Sample time	Sample type	Iron (µg/L as Fe) (01046)	Magnesium (mg/L as Mg) (00925)	Manganese (µg/L as Mn) (01056)	Potassium (mg/L as K) (00935)	Silica (mg/L as SiO ₂) (00955)
26D	08/10/1999	1606	Field blank	<10	E.002	<3.0	<.10	<.1
26S	09/15/1999	1106	Field blank	<10	<.014	<2.2	<.24	<.1
1	09/22/1999	1006	Field blank	<10	<.014	<2.2	<.24	<.1
22	09/29/1999	1106	Field blank	<10	<.014	<2.2	<.24	<.1
10	10/13/1999	1206	Field blank	<10	<.014	<2.2	<.24	<.1
31	10/21/1999	1106	Field blank	<10	E.008	<2.2	<.24	<.1
34	09/09/1999	1100	Ground water	<10	30.0	<2.2	7.21	30.3
34	09/09/1999	1101	Replicate	<10	30.4	E1.4	7.68	30.6
39	10/04/1999	1100	Ground water	<10	25.8	18.7	5.76	20.8
39	10/04/1999	1101	Replicate	<10	25.7	18.7	5.35	20.8
3	10/19/1999	1100	Ground water	<10	53.7	2.2	14.4	38.4
3	10/19/1999	1101	Replicate	<10	52.7	2.9	14.1	37.6
Well identifier	Sample date	Sample time	Sample type	Sodium (mg/L as Na) (00930)	Sulfate (mg/L as SO ₄) (00945)	Solids, residue at 180 °C (mg/L) (70300)	Solids, sum of constituents (mg/L) (70301)	
26D	08/10/1999	1606	Field blank	M	<.1	<10	—	
26S	09/15/1999	1106	Field blank	<.1	<.3	<10	—	
1	09/22/1999	1006	Field blank	<.1	<.3	<10	—	
22	09/29/1999	1106	Field blank	<.1	<.3	<10	—	
10	10/13/1999	1206	Field blank	<.1	<.3	<10	—	
31	10/21/1999	1106	Field blank	E.1	<.3	<10	—	
34	09/09/1999	1100	Ground water	65.8	85.4	626	614	
34	09/09/1999	1101	Replicate	63.6	84.6	552	578	
39	10/04/1999	1100	Ground water	53.7	64.4	521	534	
39	10/04/1999	1101	Replicate	53.0	64.3	531	528	
3	10/19/1999	1100	Ground water	154	218	982	974	
3	10/19/1999	1101	Replicate	152	218	960	962	

Table 15. Quality-control data for dissolved trace elements in blank water and water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; numbers in bold indicate detection in the field-blank sample; water samples for Radon-222 analysis were not filtered; µg/L, micrograms per liter; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; <, less than; M, presence of constituent is verified but not quantified; E, estimated value; pCi/L, picocuries per liter; —, no data]

Well identifier	Sample date	Sample time	Sample type	Aluminum (µg/L as Al) (01106)	Antimony (µg/L as Sb) (01095)	Arsenic (µg/L as As) (01000)	Barium (µg/L as Ba) (01005)	Beryllium (µg/L as Be) (01010)	Cadmium (µg/L as Cd) (01025)
26D	08/10/1999	1611	Field blank	<0.3	<0.20	<1.0	<0.2	<0.20	<0.30
26S	09/15/1999	1111	Field blank	M	<.20	<1.0	.2	<.20	<.30
1	09/22/1999	1011	Field blank	<.3	<.20	<1.0	<.2	<.20	<.30
22	09/29/1999	1111	Field blank	<.3	<.20	<2.0	<.2	<.20	<.30
10	10/13/1999	1211	Field blank	<.3	<.20	<2.0	<.2	<.20	<.30
31	10/21/1999	1111	Field blank	<.3	<.20	<2.0	<.2	<.20	<.30
34	09/09/1999	1109	Ground water	2	<1.00	<1.0	112	<1.00	<1.00
34	09/09/1999	1110	Replicate	2	<1.00	<1.0	113	<1.00	<1.00
39	10/04/1999	1109	Ground water	2	<1.00	3.3	130	<1.00	<1.00
39	10/04/1999	1110	Replicate	1	<1.00	3.1	131	<1.00	<1.00
3	10/09/1999	1109	Ground water	3	<1.00	12.2	28.3	<1.00	<1.00
3	10/09/1999	1110	Replicate	4	<1.00	12.6	27.9	<1.00	<1.00
Well identifier	Sample date	Sample time	Sample type	Chromium (µg/L as Cr) (01030)	Cobalt (µg/L as Co) (01035)	Copper (µg/L as Cu) (01040)	Lead (µg/L as Pb) (01049)	Molybdenum (µg/L as Mo) (01060)	Nickel (µg/L as Ni) (01065)
26D	08/10/1999	1611	Field blank	.3	<.20	.7	<.30	<.2	1.04
26S	09/15/1999	1111	Field blank	.3	<.20	.3	<.30	<.2	.51
1	09/22/1999	1011	Field blank	.6	<.20	<.2	<.30	<.2	<.50
22	09/29/1999	1111	Field blank	.3	<.20	.2	<.30	<.2	<.50
10	10/13/1999	1211	Field blank	<.2	<.20	<.2	<.30	<.2	<.50
31	10/21/1999	1111	Field blank	<.2	<.20	<.2	<.30	<.2	<.50
34	09/09/1999	1109	Ground water	<1.0	<1.00	2.1	<1.00	7.5	3.39
34	09/09/1999	1110	Replicate	<1.0	<1.00	1.9	<1.00	7.7	3.08
39	10/04/1999	1109	Ground water	1.5	<1.00	2.3	<1.00	3.4	3.24
39	10/04/1999	1110	Replicate	1.9	<1.00	2.3	<1.00	3.6	3.27
3	10/09/1999	1109	Ground water	E.7	<1.00	1.3	<1.00	5.0	1.83
3	10/09/1999	1110	Replicate	.9	<1.00	1.7	<1.00	5.0	2.09
Well identifier	Sample date	Sample time	Sample type	Total radon-222 (pCi/L) (82303)	Radon-222 2-sigma ¹ (pCi/L) (76002)	Selenium (µg/L as Se) (01145)	Silver (µg/L as Ag) (01075)	Uranium (µg/L as U) (22703)	Zinc (µg/L as Zn) (01090)
26D	08/10/1999	1611	Field blank	—	—	<1.0	<.2	<.20	3
26S	09/15/1999	1111	Field blank	—	—	<1.0	<.2	<.20	6
1	09/22/1999	1011	Field blank	—	—	<1.0	<.2	<.20	2
22	09/29/1999	1111	Field blank	—	—	<2.4	<.2	<.20	1
10	10/13/1999	1211	Field blank	—	—	<2.4	<.2	<.20	<.5
31	10/21/1999	1111	Field blank	—	—	<2.4	<.2	<.20	M
34	09/09/1999	1109	Ground water	491	31	<1.0	<1.0	36.2	5
34	09/09/1999	1110	Replicate	499	31	<1.0	<1.0	36.7	4
39	10/04/1999	1109	Ground water	462	22	<2.4	<1.0	21.2	2
39	10/04/1999	1110	Replicate	536	23	<2.4	<1.0	21.5	2
3	10/09/1999	1109	Ground water	243	18	2.6	<1.0	5.29	2
3	10/09/1999	1110	Replicate	222	18	2.6	<1.0	5.37	4

¹2-sigma precision estimate.

Table 16. Quality-control data for dissolved nutrient constituents and organic carbon in blank water and water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; numbers in bold indicate detection in the field-blank sample; mg/L, milligrams per liter; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; <, less than; SS blank, source-solution blank; —, no data; E, estimated value]

Well identifier	Sample date	Sample time	Sample type	Ammonia (mg/L as N) (00608)	Ammonia plus organic nitrogen (mg/L as N) (00623)	Organic carbon (mg/L as C) (00681)	Nitrite (mg/L as N) (00613)	Nitrite plus nitrate (mg/L as N) (00631)	Phosphorus (mg/L as P) (00666)	Orthophosphorus (mg/L as P) (00671)
26D	08/10/1999	1605	Field blank	<0.020	<0.10	1.8	<0.010	<0.050	<0.004	<0.010
26D	08/10/1999	1607	SS blank	—	—	<.10	—	—	—	—
26S	09/15/1999	1105	Field blank	<.020	<.10	1.5	<.010	<.050	<.004	<.010
26S	09/15/1999	1107	SS blank	—	—	<.10	—	—	—	—
1	09/22/1999	1005	Field blank	<.020	E.06	.40	<.010	.117	<.004	<.010
1	09/22/1999	1007	SS blank	—	—	<.10	—	—	—	—
22	09/29/1999	1105	Field blank	<.020	<.10	1.5	<.010	<.050	<.006	<.010
22	09/29/1999	1107	SS blank	—	—	<.33	—	—	—	—
10	10/13/1999	1205	Field blank	.020	<.10	E.31	<.010	<.050	<.006	<.010
10	10/13/1999	1207	SS blank	—	—	<.33	—	—	—	—
31	10/21/1999	1105	Field blank	<.020	E.06	.42	<.010	<.050	<.006	<.010
31	10/21/1999	1107	SS blank	—	—	<.33	—	—	—	—
39	10/04/1999	1100	Ground water	<.020	.22	2.0	.012	9.96	.029	.027
39	10/04/1999	1101	Replicate	<.020	.19	2.0	.012	9.61	.030	.020
3	10/19/1999	1100	Ground water	<.020	.14	E1.1	<.010	8.55	.028	.028
3	10/19/1999	1101	Replicate	<.020	.12	E.99	<.010	8.49	.029	.029

Table 17. Quality-control data for selected dissolved pesticides in blank water, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; numbers in bold indicate detection in the field-blank sample; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; concentration reported in micrograms per liter; <, less than; M, presence of compound verified but not quantified; E, estimated value]

Well identifier	Sample date	Sample time	Sample type	Atrazine ¹ (39632)	Deethylatrazine ¹ (04040)	Deethyl-deisopropyl-atrazine ^{1,2,3} (04039)	Deisopropyl-atrazine ^{1,3} (04038)	2-Hydroxy-atrazine ^{1,3} (50355)	Bromacil ^{1,3} (04029)
26D	08/10/1999	1605	Field blank	<0.001	<0.002	<0.06	<0.07	<0.193	<0.08
26S	09/15/1999	1105	Field blank	<.001	<.002	<.06	<.07	<.193	<.08
1	09/22/1999	1005	Field blank	<.001	<.002	M	<.07	<.193	<.08
22	09/29/1999	1105	Field blank	<.001	<.002	<.06	<.07	<.193	<.08
10	10/13/1999	1205	Field blank	<.001	<.002	<.06	<.07	<.193	<.08
31	10/21/1999	1105	Field blank	<.001	<.002	<.06	<.07	<.193	<.08
Well identifier	Sample date	Sample time	Sample type	Caffeine ^{1,3} (50305)	Cyloate ^{1,2,3} (04031)	Diazinon ¹ (39572)	Diuron ^{1,3} (49300)	Fenuron ^{2,3} (49297)	Imazaquin ^{1,2,3} (50356)
26D	08/10/1999	1605	Field blank	<.081	<.05	<.002	<.08	<.07	<.103
26S	09/15/1999	1105	Field blank	<.081	<.05	<.002	<.08	<.07	<.103
1	09/22/1999	1005	Field blank	<.081	<.05	<.002	<.08	M	E.005
22	09/29/1999	1105	Field blank	<.081	<i>E.03</i>	<.002	<.08	<.07	E.004
10	10/13/1999	1205	Field blank	<.081	<.05	<.002	<.08	<.07	<.103
31	10/21/1999	1105	Field blank	<.081	<.05	<.002	<.08	<.07	<.103
Well identifier	Sample date	Sample time	Sample type	Malathion ¹ (30532)	P,P' DDE ¹ (34653)	Picloram ^{1,3} (49291)	Prometon ¹ (04037)	Simazine ¹ (04035)	Tebuthiuron ¹ (82670)
26D	08/10/1999	1605	Field blank	<.005	<.006	<.07	<.018	<.005	<.010
26S	09/15/1999	1105	Field blank	<.005	<.006	<.07	<.018	<.005	<.010
1	09/22/1999	1005	Field blank	<.005	<.006	<.07	<.018	<.005	<.010
22	09/29/1999	1105	Field blank	<.005	<.006	<.07	<.018	<.005	<.010
10	10/13/1999	1205	Field blank	<.005	<.006	<.07	<.018	<.005	<.010
31	10/21/1999	1105	Field blank	<.005	<.006	<.07	<.018	<.005	<.010

¹ Compound detected in one or more ground-water samples.

² Compound detected in one or more blank-water samples.

³ Compound was analyzed by the high-performance liquid chromatography/mass spectrometry method before its final approval by the U.S. Geological Survey Office of Water Quality in 2001. Although the analytical method did not change following approval, data analyzed before method approval are considered provisional. Five of the six field-blank samples analyzed with this method exceeded the recommended 4-day holding time prior to sample extraction (Furlong and others, 2001). Degradation of pesticides during extended sample storage is likely, and concentrations and detection frequencies for the pesticides analyzed by this method may be biased low.

Table 18. Quality-control data for selected volatile organic compounds in blank water, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; numbers in bold indicate detection in the field-blank sample; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; concentration reported in micrograms per liter; <, less than; SS blank, source-solution blank; E, estimated value; M, presence of constituent is verified but not quantified]

Well identifier	Sample date	Sample time	Sample type	Benzene ¹ (34030)	Bromodichloro- methane ¹ (32101)	Carbon disulfide ² (77041)	Chloroform ¹ (32106)	Chloro- methane ¹ (34418)	1,1-Dichloro- ethane ¹ (34496)
26D	08/10/1999	1605	Field blank	<0.10	<0.05	<0.37	<0.05	<0.2	<0.07
26D	08/10/1999	1613	SS blank	<.10	<.05	<.37	<.05	<.2	<.07
26S	09/15/1999	1105	Field blank	<.10	<.05	E.20	<.05	<.2	<.07
26S	09/15/1999	1108	Trip blank	<.10	<.05	<.37	<.05	<.2	<.07
26S	09/15/1999	1113	SS blank	<.10	<.05	<.37	<.05	<.2	<.07
1	09/22/1999	1005	Field blank	<.04	<.05	<.07	<.05	<.5	<.07
1	09/22/1999	1013	SS blank	<.04	<.05	<.07	<.05	<.5	<.07
22	09/29/1999	1105	Field blank	<.04	<.05	<.07	<.05	<.5	<.07
22	09/29/1999	1113	SS blank	<.04	<.05	<.07	<.05	<.5	<.07
10	10/13/1999	1205	Field blank	<.04	<.05	<.07	<.05	<.5	<.07
31	10/21/1999	1105	Field blank	<.04	<.05	<.07	<.05	<.5	<.07
31	10/21/1999	1113	SS blank	<.04	<.05	<.07	<.05	<.5	<.07

Well identifier	Sample date	Sample time	Sample type	Tetrachloro- ethylene ¹ (PCE) (34475)	Tetrachloro- methane ¹ (32102)	Toluene ¹ (34010)	1,1,1-Trichloro- ethane ¹ (TCA) (34506)	Trichloro- ethylene ¹ (TCE) (39180)	Trichloro- fluoromethane (CFC-11) ¹ (34488)
26D	08/10/1999	1605	Field blank	<.1	<.09	<.05	<.03	<.04	<.09
26D	08/10/1999	1613	SS blank	<.1	<.09	<.05	<.03	<.04	<.09
26S	09/15/1999	1105	Field blank	<.1	<.09	<.05	<.03	<.04	<.09
26S	09/15/1999	1108	Trip blank	<.1	<.09	<.05	<.03	<.04	<.09
26S	09/15/1999	1113	SS blank	<.1	<.09	<.05	<.03	<.04	<.09
1	09/22/1999	1005	Field blank	<.1	<.06	<.05	<.03	<.04	<.09
1	09/22/1999	1013	SS blank	<.1	<.06	<.05	<.03	<.04	<.09
22	09/29/1999	1105	Field blank	<.1	<.06	<.05	<.03	<.04	<.09
22	09/29/1999	1113	SS blank	<.1	<.06	<.05	<.03	<.04	<.09
10	10/13/1999	1205	Field blank	<.1	<.06	<.05	<.03	<.04	<.09
31	10/21/1999	1105	Field blank	<.1	<.06	<.05	<.03	<.04	<.09
31	10/21/1999	1113	SS blank	<.1	<.06	<.05	<.03	<.04	<.09

¹ Compound detected in one or more ground-water samples.

² Compound detected in one or more ground-water and field-blank samples.

Table 18. Quality-control data for selected volatile organic compounds in blank water, 1999—Continued

Well identifier	Sample date	Sample time	Sample type	1,2-Dichloroethane ¹ (32103)	1,1-Dichloroethylene ¹ (34501)	Dichloromethane ¹ (34423)	Ethylbenzene ² (34371)	o-Ethyltoluene ² (77220)	Methyl tert-butyl ether (MTBE) ¹ (78032)
26D	08/10/1999	1605	Field blank	<0.1	<0.04	<0.4	E0.03	E0.01	<0.2
26D	08/10/1999	1613	SS blank	<.1	<.04	<.4	<.03	<.10	<.2
26S	09/15/1999	1105	Field blank	<.1	<.04	<.4	E.02	<.10	<.2
26S	09/15/1999	1108	Trip blank	<.1	<.04	<.4	<.03	<.10	<.2
26S	09/15/1999	1113	SS blank	<.1	<.04	<.4	<.03	<.10	<.2
1	09/22/1999	1005	Field blank	<.1	<.04	<.4	<.03	<.06	<.2
1	09/22/1999	1013	SS blank	<.1	<.04	<.4	<.03	<.06	<.2
22	09/29/1999	1105	Field blank	<.1	<.04	<.4	E.01	M	<.2
22	09/29/1999	1113	SS blank	<.1	<.04	<.4	<.03	<.06	<.2
10	10/13/1999	1205	Field blank	<.1	<.04	<.4	<.03	<.06	<.2
31	10/21/1999	1105	Field blank	<.1	<.04	<.4	<.03	<.06	<.2
31	10/21/1999	1113	SS blank	<.1	<.04	<.4	<.03	<.06	<.2
Well identifier	Sample date	Sample time	Sample type	1,1,2-Trichlorotrifluoroethane (CFC-113) ¹ (77652)	1,2,3-Trimethylbenzene ² (77221)	1,2,4-Trimethylbenzene ² (77222)	1,3,5-Trimethylbenzene ² (77226)	m- and p-Xylene ² (85795)	o-Xylene ² (77135)
26D	08/10/1999	1605	Field blank	<.03	M	E.06	E.02	E.15	E.03
26D	08/10/1999	1613	SS blank	<.03	<.1	<.06	<.04	<.06	<.06
26S	09/15/1999	1105	Field blank	<.03	<.1	<.06	<.04	E.10	<.06
26S	09/15/1999	1108	Trip blank	<.03	<.1	<.06	<.04	<.06	<.06
26S	09/15/1999	1113	SS blank	<.03	<.1	<.06	<.04	<.06	<.06
1	09/22/1999	1005	Field blank	<.06	<.1	<.06	<.04	E.03	<.04
1	09/22/1999	1013	SS blank	<.06	<.1	<.06	<.04	<.06	<.04
22	09/29/1999	1105	Field blank	<.06	<.1	<.06	<.04	E.03	<.04
22	09/29/1999	1113	SS blank	<.06	<.1	<.06	<.04	<.06	<.04
10	10/13/1999	1205	Field blank	<.06	<.1	<.06	<.04	<.06	<.04
31	10/21/1999	1105	Field blank	<.06	<.1	E.01	<.04	E.04	<.04
31	10/21/1999	1113	SS blank	<.06	<.1	<.06	<.04	<.06	<.04

Table 19. Percent recovery for pesticide surrogates in blank water and water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; all surrogate recoveries are reported in percent; E, estimated value]

Well identifier	Sample date	Sample time	Sample type	alpha-HCH-d6 (91065)	Barban (90640)	Caffeine ¹ (99959)	Diazinon (91063)	2,4,5-T ¹ (99958)
26D	08/10/1999	1605	Field blank	102	81	102	101	96
26S	09/15/1999	1105	Field blank	E175	E72	87	E197	48
1	09/22/1999	1005	Field blank	91	73	E107	111	61
22	09/29/1999	1105	Field blank	72	E80	E101	97	73
10	10/13/1999	1205	Field blank	99	89	50	134	47
31	10/21/1999	1105	Field blank	88	59	E80	124	59
1	09/22/1999	1000	Ground water	83	91	E99	105	64
2	09/20/1999	1400	Ground water	73	E94	70	90	58
3	10/19/1999	1100	Ground water	84	82	77	125	60
4	09/20/1999	1000	Ground water	89	E89	71	108	66
5	09/27/1999	1100	Ground water	92	E76	E81	95	66
6	10/07/1999	1100	Ground water	102	75	89	141	48
7	09/28/1999	1400	Ground water	83	E84	E90	96	73
8	10/18/1999	1200	Ground water	92	41	76	133	50
9	09/28/1999	1000	Ground water	90	E78	E86	100	71
10	10/13/1999	1200	Ground water	89	83	44	120	43
11	10/06/1999	1000	Ground water	89	73	68	124	E35
14	09/30/1999	1100	Ground water	79	E83	E87	111	66
17	09/23/1999	1100	Ground water	84	107	E90	97	62
18	09/13/1999	1200	Ground water	97	E104	78	101	60
20	10/05/1999	1200	Ground water	80	72	80	118	54
22	09/29/1999	1100	Ground water	78	62	82	107	E43
24	10/20/1999	1100	Ground water	84	53	E64	113	58
25	10/12/1999	1400	Ground water	97	96	44	139	54
26D	08/10/1999	1100	Ground water	106	76	93	103	101
26S	09/15/1999	1100	Ground water	73	E72	69	85	89
27	09/07/1999	1200	Ground water	84	E106	98	101	90
29	09/21/1999	1100	Ground water	83	E84	83	97	46
30	10/12/1999	1000	Ground water	95	85	45	128	56
31	10/21/1999	1100	Ground water	86	50	E66	119	61
32	09/14/1999	1100	Ground water	92	E93	79	101	82
33	10/14/1999	1000	Ground water	92	90	40	121	56
34	09/09/1999	1100	Ground water	89	E86	93	91	75
37	09/08/1999	1100	Ground water	99	E90	98	89	81
39	10/04/1999	1100	Ground water	88	60	81	123	E50
41	09/16/1999	1100	Ground water	85	E80	70	102	62

¹Compound was analyzed by the high-performance liquid chromatography/mass spectrometry method before its final approval by the U.S. Geological Survey Office of Water Quality in 2001. Although the analytical method did not change following approval, data analyzed before method approval are considered provisional. Five of the 6 field-blank samples and 27 of the 30 ground-water samples analyzed with this method exceeded the recommended 4-day holding time prior to sample extraction (Furlong and others, 2001). Degradation of pesticides during extended sample storage is likely, and concentrations and detection frequencies for the pesticides analyzed by this method may be biased low.

Table 20. Percent recovery for volatile organic compound surrogates in blank water and water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Well identifier corresponds to site shown in figure 3 and listed in table 6; number below the parameter name is the U.S. Geological Survey National Water Information System parameter code; all surrogate recoveries are reported in percent]

Well identifier	Sample date	Sample time	Sample type	1,2-Dichloro-ethane-d4 (99832)	1,4-Bromofluoro-benzene (99834)	Toluene-d8 (99833)
26D	08/10/1999	1605	Field blank	99	86	94
26D	08/10/1999	1613	Source-solution blank	97	85	95
26S	09/15/1999	1105	Field blank	117	97	102
26S	09/15/1999	1108	Trip blank	112	92	100
26S	09/15/1999	1113	Source-solution blank	113	91	98
1	09/22/1999	1005	Field blank	119	97	103
1	09/22/1999	1013	Source-solution blank	112	98	104
22	09/29/1999	1105	Field blank	96	97	102
22	09/29/1999	1113	Source-solution blank	95	97	102
10	10/13/1999	1205	Field blank	105	86	95
31	10/21/1999	1105	Field blank	115	101	94
31	10/21/1999	1113	Source-solution blank	113	101	96
1	09/22/1999	1000	Ground water	116	95	103
2	09/20/1999	1400	Ground water	109	100	103
3	10/19/1999	1100	Ground water	109	73	93
4	09/20/1999	1000	Ground water	112	99	103
5	09/27/1999	1100	Ground water	97	98	102
6	10/07/1999	1100	Ground water	118	99	103
7	09/28/1999	1400	Ground water	95	96	101
8	10/18/1999	1200	Ground water	108	74	95
9	09/28/1999	1000	Ground water	96	99	102
10	10/13/1999	1200	Ground water	105	77	94
11	10/06/1999	1000	Ground water	118	88	101
14	09/30/1999	1100	Ground water	96	97	100
17	09/23/1999	1100	Ground water	121	101	104
18	09/13/1999	1200	Ground water	90	98	102
20	10/05/1999	1200	Ground water	112	98	99
22	09/29/1999	1100	Ground water	95	95	101
24	10/20/1999	1100	Ground water	113	100	91
25	10/12/1999	1400	Ground water	107	89	96
26D	08/10/1999	1100	Ground water	98	84	94
26S	09/15/1999	1100	Ground water	114	95	99
27	09/07/1999	1200	Ground water	95	98	101
29	09/21/1999	1100	Ground water	107	102	109
30	10/12/1999	1000	Ground water	109	79	93
31	10/21/1999	1100	Ground water	118	105	96
32	09/14/1999	1100	Ground water	88	99	104
33	10/14/1999	1000	Ground water	110	73	95
34	09/09/1999	1100	Ground water	91	103	104
37	09/08/1999	1100	Ground water	93	99	102
39	10/04/1999	1100	Ground water	109	87	98
41	09/16/1999	1100	Ground water	104	100	100

Table 21. Percent recovery for matrix spikes of pesticides in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Parameter code is used in U.S. Geological Survey National Water Information System database; —, no data]

Parameter code	Compound	Recovery (percent)				
		Matrix spike 09/09/99	Matrix spike 10/04/99	Matrix-spike replicate 10/04/99	Matrix spike 10/19/99	Matrix-spike replicate 10/19/99
Gas Chromatography/Mass Spectrometry analytical method						
49260	Acetochlor	109	104	101	107	102
46342	Alachlor	92	107	102	104	103
39632	Atrazine	89	86	82	93	93
82686	Azinphos-methyl	198	106	99	115	100
82673	Benfluralin	78	68	67	64	61
04028	Butylate	95	112	114	93	93
82680	Carbaryl	314	213	210	238	253
82674	Carbofuran	164	192	187	199	199
38933	Chlorpyrifos	83	84	79	89	86
04041	Cyanazine	106	81	77	78	73
82682	Dacthal	102	76	72	73	73
34653	p,p'-DDE	85	92	83	93	89
04040	Deethylatrazine	31	39	24	31	28
39572	Diazinon	85	113	110	122	115
39381	Dieldrin	108	123	116	112	109
82660	2,6-Diethylaniline	75	130	129	142	133
82677	Disulfoton	56	61	60	71	68
82668	EPTC	95	92	93	98	99
82663	Ethalfuralin	93	94	88	91	91
82672	Ethoprophos	86	71	70	69	63
04095	Fonofos	103	91	85	97	92
34253	alpha-HCH	83	104	98	109	109
39341	Lindane	91	99	93	118	105
82666	Linuron	218	163	158	150	137
39532	Malathion	108	90	88	85	80
39415	Metolachlor	116	101	97	96	95
82630	Metribuzin	88	114	100	105	105
82671	Molinate	90	101	103	100	103
82684	Napropamide	98	107	101	98	89
39542	Parathion	110	112	117	110	98
82667	Parathion-methyl	118	140	142	128	120
82669	Pebulate	93	92	94	96	95
82683	Pendimethalin	102	119	121	105	100
82687	cis-Permethrin	79	86	80	95	89
82664	Phorate	63	75	73	82	86
04037	Prometon	88	98	95	103	94
04024	Propachlor	107	99	107	102	102
82679	Propanil	117	95	93	93	86
82685	Propargite	105	82	78	84	93
82676	Propyzamide	95	90	85	85	82
04035	Simazine	115	93	88	92	88
82670	Tebuthiuron	90	90	96	89	86
82665	Terbacil	159	143	120	163	161
82675	Terbufos	76	69	67	70	64
82681	Thiobencarb	102	94	95	99	91
82678	Triallate	92	91	87	95	94
82661	Trifluralin	77	63	64	64	61

Table 21. Percent recovery for matrix spikes of pesticides in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Parameter code	Compound	Recovery (percent)				
		Matrix spike 09/09/99	Matrix spike 10/04/99	Matrix-spike replicate 10/04/99	Matrix spike 10/19/99	Matrix-spike replicate 10/19/99
High-Performance Liquid Chromatography analytical method¹						
39732	2,4-D	74	37	42	57	57
50470	2,4-D methyl ester	79	52	54	43	56
38746	2,4-DB	69	24	42	39	43
50355	2-Hydroxyatrazine	165	122	131	132	134
61692	3(4-Chlorophenyl)-1-methyl urea	88	85	81	69	49
49308	3-Hydroxycarbofuran	112	85	84	64	69
50295	3-Ketocarbofuran	99	47	65	34	20
49315	Acifluorfen	71	75	69	73	74
49313	Aldicarb sulfone	50	6	4	23	22
49314	Aldicarb sulfoxide	52	29	27	26	42
39632	Atrazine	37	34	33	37	37
50299	Bendiocarb	96	71	73	33	37
50300	Benomyl	105	81	84	47	56
61693	Bensulfuron-methyl	137	108	113	80	89
38711	Bentazon	51	63	50	69	71
04029	Bromacil	81	61	59	53	54
49311	Bromoxynil	88	60	59	80	79
50305	Caffeine	96	83	84	70	79
49310	Carbaryl	87	85	86	70	76
49309	Carbofuran	102	93	96	73	79
61188	Chloramben, methyl ester	75	73	60	65	63
50306	Chlorimuron-ethyl	132	109	108	76	87
49306	Chlorothalonil	61	50	30	57	54
49305	Clopyralid	61	59	46	79	73
04031	Cycloate	94	73	78	51	59
49304	Dacthal monoacid	78	62	52	75	72
04040	Deethylatrazine	13	15	10	12	11
04039	Deethyldeisopropylatrazine	94	77	7	79	92
04038	Deisopropylatrazine	41	23	25	23	19
38442	Dicamba	84	54	43	94	88
49302	Dichlorprop	90	48	54	65	65
49301	Dinoseb	94	61	58	80	79
04033	Diphenamid	87	77	75	58	63
49300	Diuron	76	84	85	58	64
49297	Fenuron	56	58	69	56	72
61694	Flumetsulam	217	—	—	123	140
38811	Fluometuron	88	82	82	63	69
50356	Imazaquin	180	120	122	51	55
50407	Imazethapyr	—	120	129	111	101
61695	Imidacloprid	181	131	131	101	113
38478	Linuron	100	88	82	67	74
38482	MCPA	78	40	47	51	52
38487	MCPB	61	27	41	40	39
50359	Metalaxyl	90	83	82	59	66
38501	Methiocarb	96	83	85	67	74
49296	Methomyl	81	80	85	67	79
49294	Neburon	101	84	84	39	41
50364	Nicosulfuron	218	205	198	102	107
49293	Norflurazon	106	93	93	67	72
49292	Oryzalin	87	66	54	50	56
38866	Oxamyl	81	78	76	49	56

Table 21. Percent recovery for matrix spikes of pesticides in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Parameter code	Compound	Recovery (percent)				
		Matrix spike 09/09/99	Matrix spike 10/04/99	Matrix-spike replicate 10/04/99	Matrix spike 10/19/99	Matrix-spike replicate 10/19/99
High-Performance Liquid Chromatography analytical method¹—Continued						
49291	Picloram	105	65	71	84	66
49236	Propham	107	87	86	86	91
50471	Propiconazole	95	92	94	45	49
38538	Propoxur	91	80	78	63	67
38548	Siduron	100	87	84	67	72
50337	Sulfometuron-methyl	145	124	121	73	75
82670	Tebuthiuron	37	36	39	36	34
04032	Terbacil	83	73	71	72	78
49235	Triclopyr	79	44	47	53	61

¹ The samples from this study were analyzed by the high-performance liquid chromatography/mass spectrometry method before its final approval by the U.S. Geological Survey Office of Water Quality in 2001. Although the analytical method did not change following approval, data analyzed before method approval are considered provisional. All of the spiked samples analyzed with this method in this study exceeded the recommended 4-day holding time prior to sample extraction (Furlong and others, 2001). Degradation of pesticides during extended sample storage is likely, and concentrations and detection frequencies for the pesticides analyzed by this method may be biased low.

Table 22. Percent recovery for matrix spikes of volatile organic compounds in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999

[Parameter code is used in U.S. Geological Survey National Water Information System database]

Parameter code	Compound	Recovery (percent)					
		Matrix spike 09/09/99	Matrix-spike replicate 09/09/99	Matrix spike 10/04/99	Matrix-spike replicate 10/04/99	Matrix spike 10/19/99	Matrix-spike replicate 10/19/99
81552	Acetone	106	106	116	109	102	111
34215	Acrylonitrile	103	105	94	105	104	99
34030	Benzene	100	100	80	86	84	85
81555	Bromobenzene	67	86	53	77	81	57
77297	Bromochloromethane	90	92	87	83	85	91
32101	Bromodichloromethane	130	110	97	116	98	91
50002	Bromoethene	56	49	45	44	36	40
32104	Bromoform	90	92	91	84	91	85
34413	Bromomethane	115	73	55	58	52	55
81595	2-Butanone	111	113	100	113	111	97
77342	Butylbenzene	90	87	72	75	68	71
77350	sec-Butylbenzene	77	86	74	84	73	74
77353	tert-Butylbenzene	77	84	87	81	74	77
77041	Carbon disulfide	106	119	97	85	92	100
34301	Chlorobenzene	85	94	69	83	81	77
34311	Chloroethane	117	110	81	96	91	72
32106	Chloroform	145	108	87	136	89	88
34418	Chloromethane	169	175	149	158	129	148
78109	3-Chloropropene	100	103	83	77	83	89
77275	2-Chlorotoluene	70	73	60	68	69	61
77277	4-Chlorotoluene	68	79	68	73	73	66
32105	Dibromochloromethane	96	101	88	92	92	85
82625	1,2-Dibromo-3-chloropropane	71	77	67	92	83	67
77651	1,2-Dibromoethane	90	91	85	85	86	88
30217	Dibromomethane	90	95	82	90	86	81
34536	1,2-Dichlorobenzene	77	83	80	87	75	74
34566	1,3-Dichlorobenzene	76	77	71	79	73	68
34571	1,4-Dichlorobenzene	76	82	81	81	72	73
73547	trans-1,4-Dichloro-2-butene	77	117	101	84	114	98
34668	Dichlorodifluoromethane	140	137	101	95	86	94
34496	1,1-Dichloroethane	109	105	80	90	89	85
32103	1,2-Dichloroethane	103	105	91	94	94	88
34501	1,1-Dichloroethylene	119	111	95	96	85	100
77093	cis-1,2-Dichloroethylene	94	94	65	82	75	79
34546	trans-1,2-Dichloroethylene	100	104	74	85	89	85
34423	Dichloromethane	93	89	83	80	74	83
34541	1,2-Dichloropropane	106	106	84	90	91	87
77173	1,3-Dichloropropane	103	104	96	101	97	94
77170	2,2-Dichloropropane	80	79	65	63	67	67
77168	1,1-Dichloropropene	102	98	67	82	79	76
34704	cis-1,3-Dichloropropene	84	93	71	77	77	77
34699	trans-1,3-Dichloropropene	80	89	71	75	78	73
81576	Diethyl ether	93	107	96	87	94	100
81577	Diisopropyl ether	88	100	71	82	90	76
34371	Ethylbenzene	79	89	54	85	76	62
73570	Ethyl methacrylate	80	107	74	79	100	79
50004	Ethyl tert-butyl ether	94	99	60	86	83	74
77220	o-Ethyl toluene	34	42	37	35	35	36
39702	Hexachlorobutadiene	62	80	76	71	65	73

Table 22. Percent recovery for matrix spikes of volatile organic compounds in water sampled from monitoring wells in Salt Lake Valley, Utah, 1999—Continued

Parameter code	Compound	Recovery (percent)					
		Matrix spike 09/09/99	Matrix-spike replicate 09/09/99	Matrix spike 10/04/99	Matrix-spike replicate 10/04/99	Matrix spike 10/19/99	Matrix-spike replicate 10/19/99
34396	Hexachloroethane	76	94	72	73	87	72
77103	2-Hexanone	97	108	95	102	107	93
77223	Isopropylbenzene	81	85	52	86	80	57
77356	4-Isopropyl-1-methylbenzene	33	38	33	33	32	33
49991	Methyl acrylate	101	105	89	104	100	88
81593	Methyl acrylonitrile	102	116	98	105	109	100
77424	Methyl iodide	91	125	80	72	99	78
81597	Methyl methacrylate	100	125	100	102	122	103
78133	4-Methyl-2-pentanone	102	107	96	104	99	103
78032	Methyl tert-butyl ether	92	112	79	90	102	86
50005	Methyl tert-pentyl ether	100	114	84	92	102	89
34696	Naphthalene	95	85	81	88	77	81
77224	n-Propylbenzene	82	79	68	82	70	67
77128	Styrene	75	83	53	84	81	56
77562	1,1,1,2-Tetrachloroethane	84	93	84	70	80	81
34516	1,1,2,2-Tetrachloroethane	94	96	94	100	96	87
34475	Tetrachloroethylene	96	105	90	87	83	92
32102	Tetrachloromethane	111	107	88	91	90	91
81607	Tetrahydrofuran	94	105	99	104	107	98
49999	1,2,3,4-Tetramethylbenzene	118	138	159	102	116	156
50000	1,2,3,5-Tetramethylbenzene	96	106	121	80	86	117
34010	Toluene	89	99	78	86	84	71
77613	1,2,3-Trichlorobenzene	100	90	84	80	77	82
34551	1,2,4-Trichlorobenzene	96	83	76	74	71	74
34506	1,1,1-Trichloroethane	109	101	85	94	88	86
34511	1,1,2-Trichloroethane	105	104	100	98	98	96
39180	Trichloroethylene	104	98	76	85	84	85
34488	Trichlorofluoromethane	101	110	96	94	87	96
77443	1,2,3-Trichloropropane	80	83	79	78	79	74
77652	1,1,2-Trichlorotrifluoroethane	105	105	88	86	85	92
77221	1,2,3-Trimethylbenzene	110	115	99	91	93	97
77226	1,3,5-Trimethylbenzene	95	88	75	87	72	73
77222	1,2,4-Trimethylbenzene	105	95	87	89	77	109
39175	Vinyl chloride	115	120	71	87	74	78
85795	m- and p-Xylene	86	92	61	95	86	65
77135	o-Xylene	79	90	56	87	84	61

