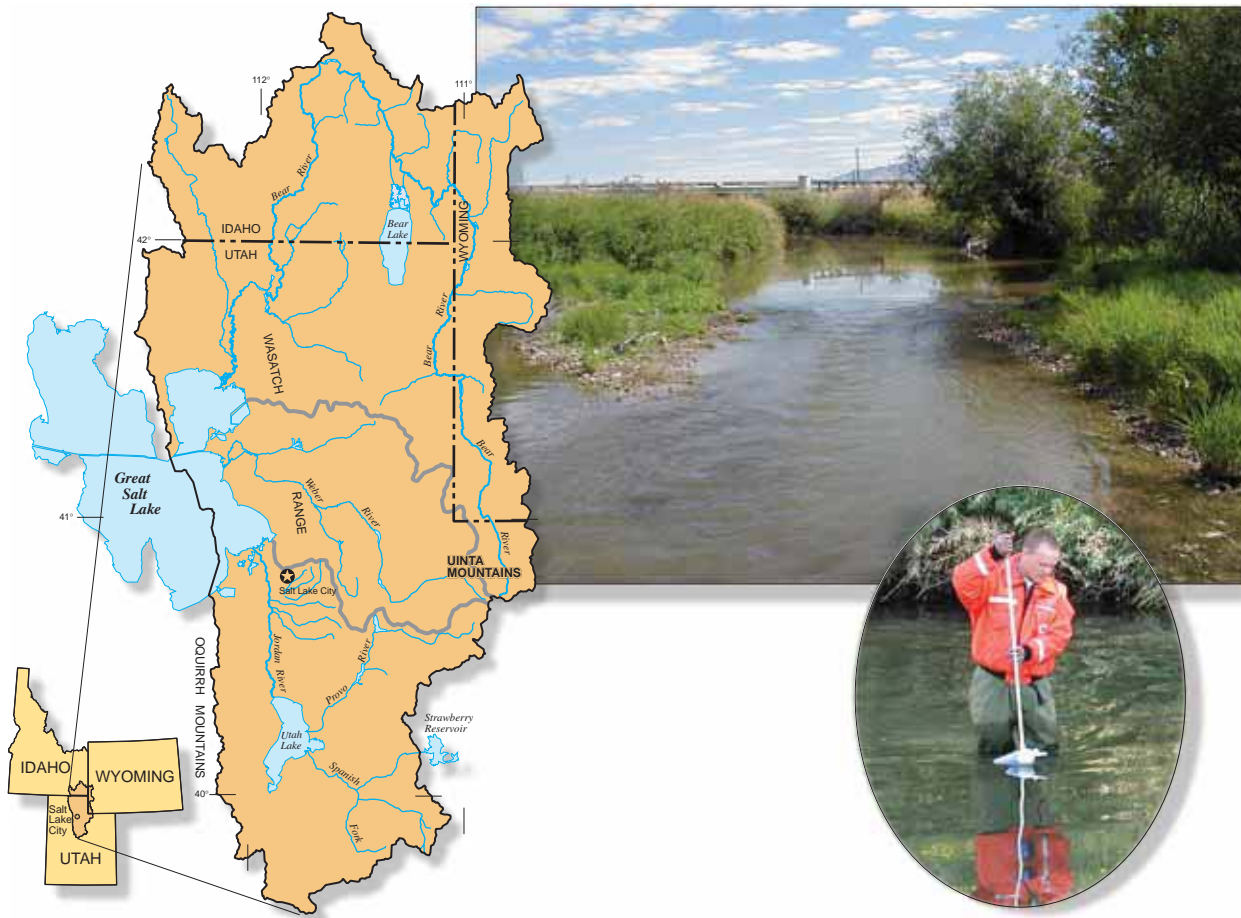


National Water-Quality Assessment Program

Water Quality at Fixed Sites in the Great Salt Lake Basins, Utah, Idaho, and Wyoming, Water Years 1999–2000



Water-Resources Investigations Report 03–4236

Water Quality at Fixed Sites in the Great Salt Lake Basins, Utah, Idaho, and Wyoming, Water Years 1999-2000

By Steven J. Gerner

U.S. Geological Survey

WATER-RESOURCES INVESTIGATIONS REPORT 03-4236

NATIONAL WATER-QUALITY ASSESSMENT PROGRAM

Salt Lake City, Utah
2003

U.S. DEPARTMENT OF THE INTERIOR

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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.

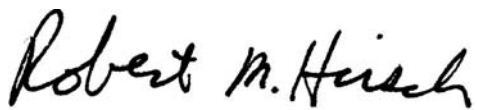
The USGS implemented the National Water-Quality Assessment (NAWQA) program to support national, regional, and local information needs and decisions related to water-quality management and policy (<http://water.usgs.gov/nawqa>). Shaped by and coordinated with ongoing efforts of other Federal, State, and 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, ABBREVIATED WATER-QUALITY UNITS, AND ACRONYMS

	Multiply	By	To obtain
acre-foot (acre-ft)	1,233		cubic meter
cubic foot per second (ft ³ /s)	0.02832		cubic meter per second
inch (in.)	25.4		millimeter
mile (mi)	1.609		kilometer
square mile (mi ²)	2.590		square kilometer

Water temperature is reported in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by the following equation:

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

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88); horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Chemical concentration and water temperature are reported only in metric units. Chemical concentration is reported in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to 1 milligram per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is reported in microsiemens per centimeter (µS/cm) at 25 degrees Celsius.

Water year is the 12-month period, October 1 through September 30. The water year is designated by the calendar year in which it ends. Thus, the 12-month period ending September 30, 1999, is water year 1999.

ACRONYMS USED IN THIS REPORT

AWQC	Ambient Water-Quality Criteria
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
GC/MS	gas chromatography/mass spectrometry
GRSL	Great Salt Lake Basins (study unit)
HPLC/MS	high-performance liquid chromatography/mass spectrometry
LT-MDL	long-term method detection level
MRL	minimum reporting level
MTBE	methyl tert-butyl ether
NAWQA	National Water-Quality Assessment (program)
NLCD	National Land Cover Dataset
QC	quality control
THM	trihalomethane
USGS	U.S. Geological Survey
VOC	volatile organic compound
WY	water year

WATER QUALITY AT FIXED SITES IN THE GREAT SALT LAKE BASINS, UTAH, IDAHO, AND WYOMING, WATER YEARS 1999-2000

By Steven J. Gerner

ABSTRACT

The Great Salt Lake Basins (GRSL) study unit of the National Water-Quality Assessment program encompasses the Bear River, Weber River, and Utah Lake/Jordan River systems, all of which discharge to Great Salt Lake in Utah. Data were collected during each month at 10 sites in the GRSL study unit from October 1998 to September 2000 to define spatial and temporal distribution and variability in concentration of nutrients, major ions, trace elements, suspended sediments, and organic compounds.

Water samples collected from rangeland and forest sites in the GRSL study unit generally contained low concentrations of dissolved solids. Median dissolved-solids concentration in water samples was highest at sites with mixed land uses. Dissolved-solids concentration in some parts of the Bear River during low flow exceeded Utah State standards for agricultural use.

Total-nitrogen concentration in water samples from GRSL sites ranged from 0.06 to 11 milligrams per liter. Water samples from predominantly forest and rangeland sites generally had a low total-nitrogen concentration. Many samples from sites with a higher percentage of agricultural and urban land cover had higher concentrations of total nitrogen. Fifty percent of the samples collected at GRSL sites had total phosphorus concentrations that exceeded 0.1 milligram per liter, the recommended limit for the prevention of nuisance aquatic-plant growth in streams not discharging directly into lakes or impoundments.

Concentration of most trace elements in water samples from the fixed sites generally was low; however, arsenic concentrations, as high as 284 micrograms per liter, sometimes exceeded aquatic-life guidelines. Forty-three pesticides and 35 volatile

organic compounds were detected in water samples from three GRSL sites; however, the concentration of most was low, less than 1 microgram per liter. The herbicides atrazine and prometon and the insecticides carbaryl and diazinon were the most frequently detected pesticides. Chloroform and toluene were detected in more than 90 percent of the samples and were the most frequently detected volatile organic compounds. The concentration of carbaryl, diazinon, malathion, and toluene in water samples from GRSL sites sometimes exceeded aquatic-life guidelines.

INTRODUCTION

The National Water-Quality Assessment (NAWQA) program of the U.S. Geological Survey (USGS) began full-scale implementation in 1991. The objectives of the NAWQA program are to describe the status of and trends in the quality of the Nation's ground-water and surface-water resources as well as to develop an understanding of the natural and human factors that affect those resources (Gilliom and others, 1995). The Great Salt Lake Basins (GRSL) study unit (fig. 1) is 1 of 51 study units that are included in this program. Water-quality investigations began in the first group of 20 study units in 1991. A second group of 16 study units began investigations in 1994, and a third group of 15 study units, including the GRSL, began in 1997.

The fixed-site assessment is a component of the NAWQA surface-water study design used to assess the spatial and temporal distribution of selected constituent groups. Fixed sites are those locations on a stream where water samples are collected at a fixed frequency and a continuous record of streamflow is available. Sites are chosen to represent specific environmental

settings, such as agricultural land or urban land, or to represent integration of multiple land uses. A site with mixed land uses is most often located at a major node in a drainage system. The fixed-site network established in the GRSL study unit consisted of 10 sites (fig. 1).

Purpose and Scope

This report describes the GRSL study unit fixed-site network and summarizes water-quality data collected at the fixed sites; which includes measurements of major ions, nutrients, trace elements, suspended sediment, and organic compounds in water samples. Occurrence and distribution of these constituents is compared to land use to evaluate the effect of land use on stream water quality.

Nutrient concentration in water samples from sites was compared with established guidelines to assess whether a site may have a propensity for eutrophication. Trace metal, pesticide, and volatile organic compound (VOC) concentrations in water samples from sites were evaluated by comparing them with established toxicity guidelines for aquatic life.

Description of Study Area

The GRSL study unit encompasses three major river systems that enter Great Salt Lake: the Bear, the Weber, and the Utah Lake/Jordan River systems (fig. 1). The headwaters of the Bear, the Weber, and the Provo (part of the Utah Lake/Jordan River system) Rivers are in the western end of the Uinta Mountains, located in the southeastern part of the study area. The rivers flow through wide valleys east of the Wasatch Range, then flow through steep-sided canyons that bisect the Wasatch Mountains, and finally discharge into Great Salt Lake. Most of the 14,500 mi² of the GRSL study unit is in Utah, but areas of Idaho and Wyoming are also included. The study unit includes Utah's three largest cities (the Salt Lake City, Ogden, and Provo metropolitan areas) and about 1.9 million people.

A physiographic province is a landform region, an area delineated according to similar terrain that has been shaped by a common geologic history. The GRSL study unit is situated in parts of three major physiographic provinces - the Basin and Range, the Middle Rocky Mountains, and the Colorado Plateau

(less than 1 percent) (fig. 2) (Fenneman, 1931). The Basin and Range Physiographic Province makes up most of the low-lying area west of the Wasatch Range and is characterized by isolated, subparallel mountain ranges between adjacent alluvial valleys. The Middle Rocky Mountains Physiographic Province includes the Wasatch and the Uinta Mountains and is characterized by high mountains with associated intermontane valleys.

Ecoregion delineation is based on the premise that relatively homogenous ecological regions can be identified through the analysis of patterns and composition of geology, physiography, vegetation, climate, soils, land use, wildlife, and hydrology (Woods and others, 2001). Five level III ecoregions are present in the GRSL study unit (fig. 3). The Wasatch and Uinta Mountains ecoregion covers 43 percent of the study unit. This region consists of high, glaciated mountains with intervening valleys and foothills, or dissected plateaus. Forestry, livestock grazing, and recreation are the dominant land uses. The Wyoming Basin ecoregion covers 17 percent of the study unit. This ecoregion is a broad intermontane basin dominated by arid grasslands and shrublands and dry or poorly developed soils. It is utilized extensively for grazing and includes some irrigated agriculture. The Central Basin and Range ecoregion covers the western part of the study unit (30 percent) and consists of northerly trending fault-block ranges and intervening dry basins. Most of the study unit within this ecoregion consists of valleys and alluvial fans. The bulk of the Central Basin and Range ecoregion is covered by sagebrush steppe vegetation on dry alkaline soils. Urban land use is much more prevalent within the Central Basin and Range than in the other ecoregions represented in the GRSL study unit. The Northern Basin and Range ecoregion covers 7 percent of the study unit. It consists of valleys, rolling hills, alluvial fans, and scattered mountains. Grazing and localized agriculture are the dominant land uses. The final ecoregion, the Middle Rocky Mountains, covers only 3 percent of the study unit in the far northeastern part of the Bear River basin and is primarily shrub and brush rangeland, and forest.

Headwaters of the Bear River, Weber River, and Utah Lake/Jordan River drainage basins originate in quartzite of Precambrian age. At the lower altitudes, below about 5,200 feet, the rivers and Utah Lake are incised into sediments of recent age. The geology of



Figure 1. Location of fixed sites in the Great Salt Lake Basins study unit.

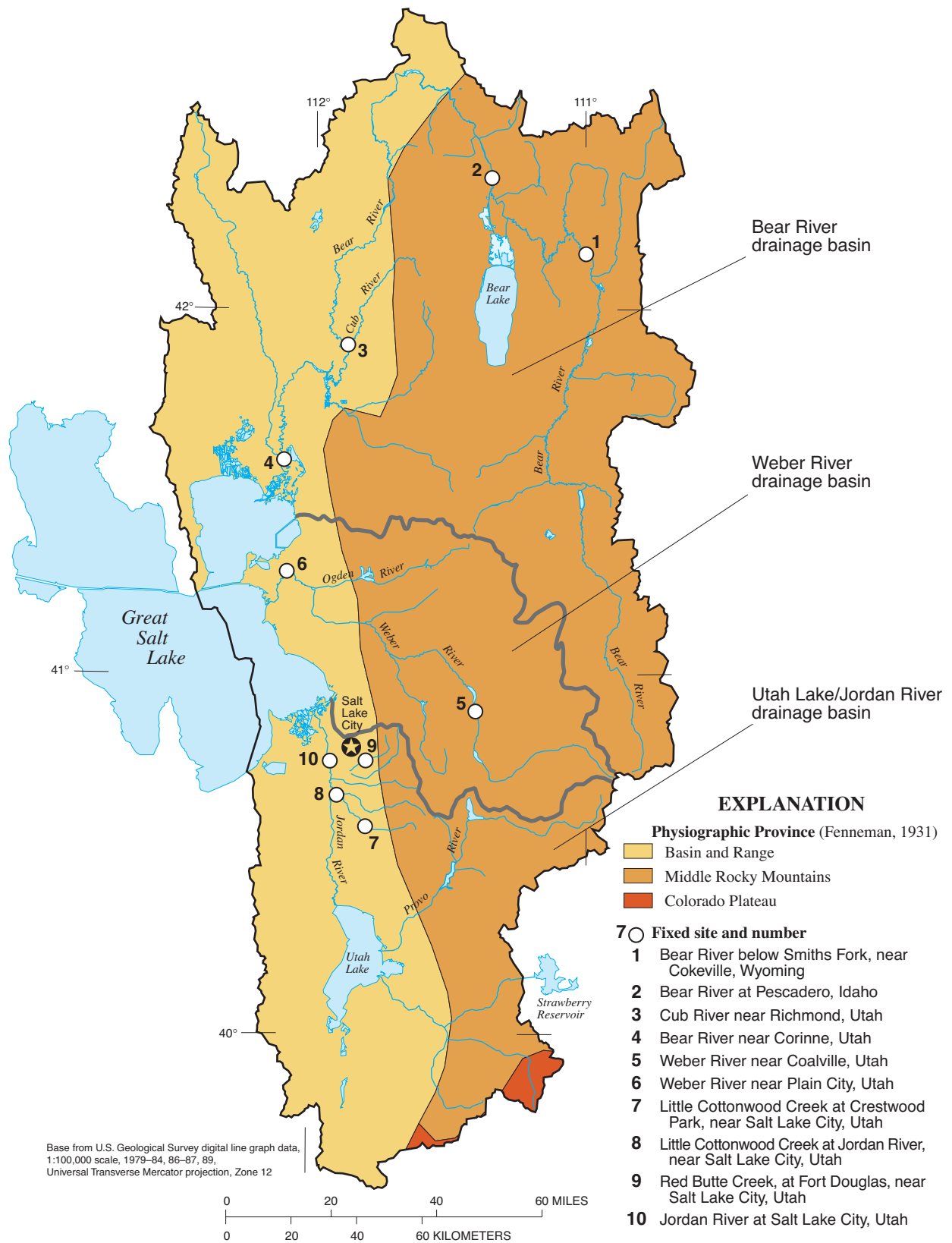


Figure 2. Physiographic provinces of the Great Salt Lake Basins study unit.

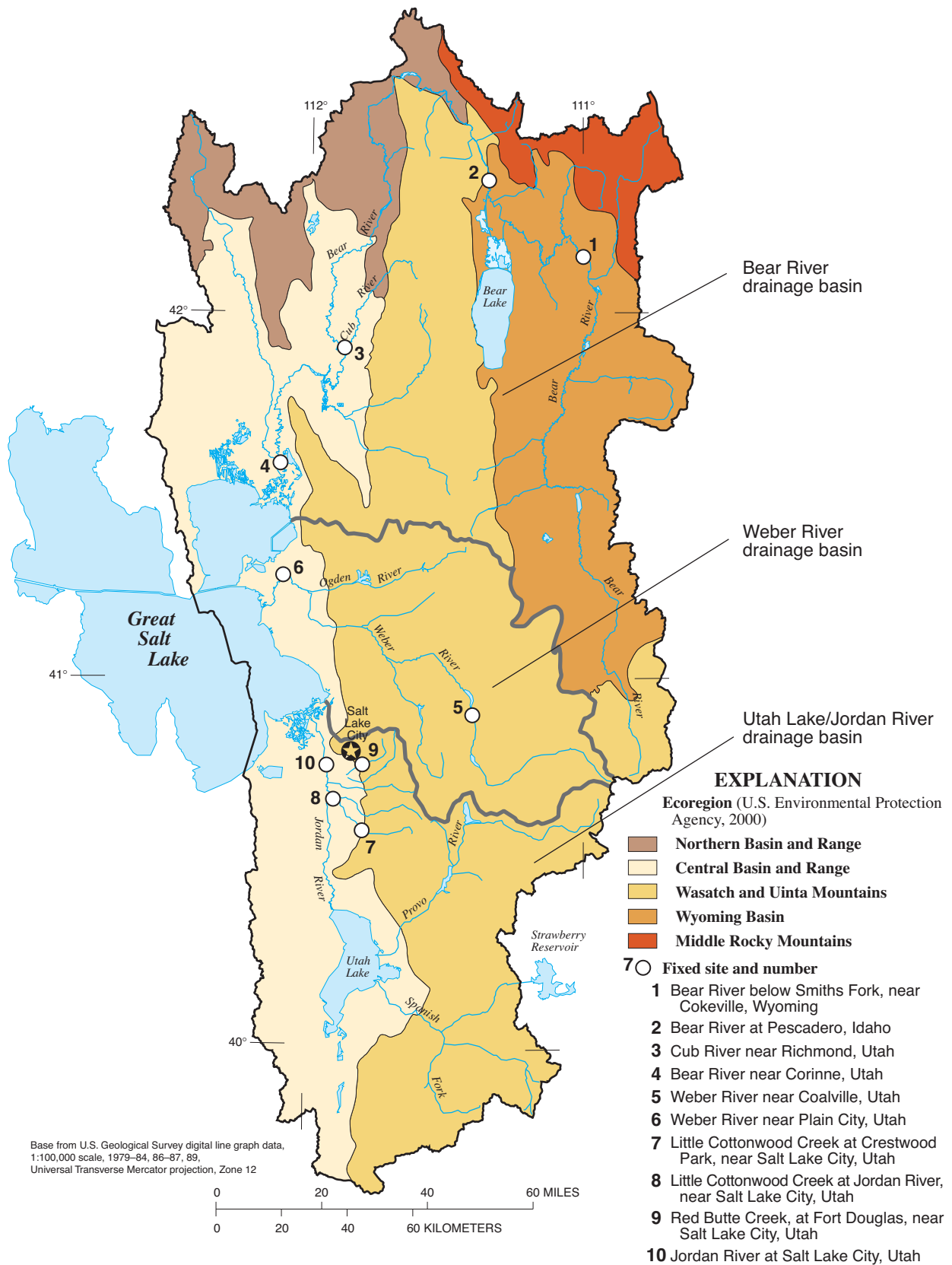


Figure 3. Ecoregions of the Great Salt Lake Basins study unit. Data from Omernik, 1987.

the intervening area varies somewhat among the three drainage basins.

Older rocks of the Bear River basin are predominantly limestone and dolomite (Dover, 1987); the younger rocks include breccias, conglomerates, and sandstones. Soils in the Bear River basin are derived from the bedrock beneath and surrounding the valleys.

The Weber River basin is made up principally of sedimentary deposits (Utah Department of Natural Resources, 1997b) underlain by older rocks of Precambrian, Paleozoic, and Mesozoic age. The formations of Paleozoic age consist mostly of limestone, dolomite, and shale with different mixtures of quartzite, sandstone, and chert. The rocks of Mesozoic age consist principally of sandstone, siltstone, and shale. Sedimentary deposits in the headwater areas of the Weber River generally consist of silts and clays, gravel, and fine-grained sands.

The western and intermontane valleys of the Utah Lake/Jordan River basin are made up of sediments of Quaternary age. The mountains to the east are made up of rocks of Paleozoic and Precambrian age. The area of the Utah Lake basin that is south of the Uinta Mountains and east of the Wasatch Range is part of the Colorado Plateau Physiographic Province and consists mostly of rocks of Tertiary and Mesozoic age (Baskin and others, 2002).

Knowledge of land use and land cover can enhance our understanding of the natural and anthropogenic factors influencing water quality.

Rangeland and forest are the most common land cover in the GRSL study unit and make up from 65 to 100 percent of total land cover in fixed-site drainage basins (table 1). Agricultural land cover makes up from 0 to 34 percent of total land cover and urban land makes up from less than 1 to 26 percent of total land cover in drainage basins. Land-use/land-cover data were derived from the National Land Cover Dataset (NLCD). This land-cover data set provides a consistent land-cover data layer for the conterminous United States based on 30-meter Landsat thematic mapper data and represents conditions in the early to mid-1990s. For this report, the NLCD land-use/land-cover classifications were aggregated to represent the level I classes defined in Anderson and others (1976).

Climate in the Bear, Weber, and Utah Lake/Jordan River basins is typical of mountainous areas in the Western United States. Generally, temperature ranges widely between summer and winter and between day and night. The high mountains have long, cold winters and short, cool summers. The lower valleys are more moderate, with less variance between maximum and minimum temperatures.

Each of the basins in the study unit receives most of its precipitation as snow during the winter months and produces most of its annual runoff during the spring snowmelt periods. Normal annual precipitation ranges from 10 to 16 in. on the valley floors to more than 70 in. in the high mountain areas. Precipitation records from weather stations at Salt Lake

Table 1. Drainage area, land use, physiographic province, and ecoregion associated with fixed sites in the Great Salt Lake Basins study unit

[<, less than; M, Middle Rocky Mountains; B, Basin and Range; WYB, Wyoming Basin; CBR, Central Basin and Range; WUM, Wasatch and Uinta Mountains]

Site number (fig. 1)	Site name	Drainage area (square miles)	Site type	Principal land use
1	Bear River below Smiths Fork, near Cokeville, Wyoming	2,444	Indicator	Rangeland
2	Bear River at Pescadero, Idaho	3,699	Indicator	Rangeland
3	Cub River near Richmond, Utah	222	Indicator	Agriculture
4	Bear River near Corinne, Utah	7,065	Integrator	Mixed/agriculture
5	Weber River near Coalville, Utah	427	Indicator	Forest/rangeland
6	Weber River near Plain City, Utah	2,072	Integrator	Mixed/urban
7	Little Cottonwood Creek at Crestwood Park, at Salt Lake City, Utah	36	Indicator	Urban
8	Little Cottonwood Creek at Jordan River, near Salt Lake City, Utah	45	Indicator	Urban
9	Red Butte Creek, at Fort Douglas, near Salt Lake City, Utah	7.21	Indicator	Forest/rangeland
10	Jordan River at Salt Lake City, Utah	3,508	Integrator	Mixed/urban

¹ This site lies in the Basin and Range Physiographic Province; however, much of the drainage basin above this site is in the Middle Rocky Mountains Physiographic Province.

City National Weather Service Forecast Office, Utah, and Silver Lake near Brighton, Utah, were used to calculate departure of monthly precipitation from the 1971-2000 average monthly precipitation (Desert Research Institute Western Region Climate Center, 2002) (fig. 4). Monthly precipitation during the 1999 water year (WY) generally was less than average during the winter and slightly greater than average during the summer. WY 2000 was very dry in the GRSL study unit, with 8 of 12 months having less-than-average precipitation.

Combined average annual surface-water runoff from the three river systems in the GRSL was 2.98 million acre-ft during 1931-76 (Waddell and Barton, 1980). Annual surface-water runoff from the GRSL was about 3.1 million acre-ft in WY 1999 and 1.5 million acre-ft in WY 2000. Mean streamflow ranged from 2.36 ft³/s in Red Butte Creek (WY 2000) to 2,568 ft³/s in the Bear River (WY 1999) (table 2). When compared to mean annual streamflow (ft³/s) for the period of record, streamflow at sites in the Bear River drainage basin were 141 to 168 percent of average in WY 1999 and 69 to 122 percent of average in WY 2000. Streams at fixed sites in the Weber and Utah Lake/Jordan River drainage basins were 105 to 125 percent of average for WY 1999 and 47 to 86 percent of average for WY 2000. Annual runoff at all fixed sites during WY 1999 exceeded the average annual runoff for those sites (table 2). The period of record for sites 3, 7, and 8 was insufficient to calculate average

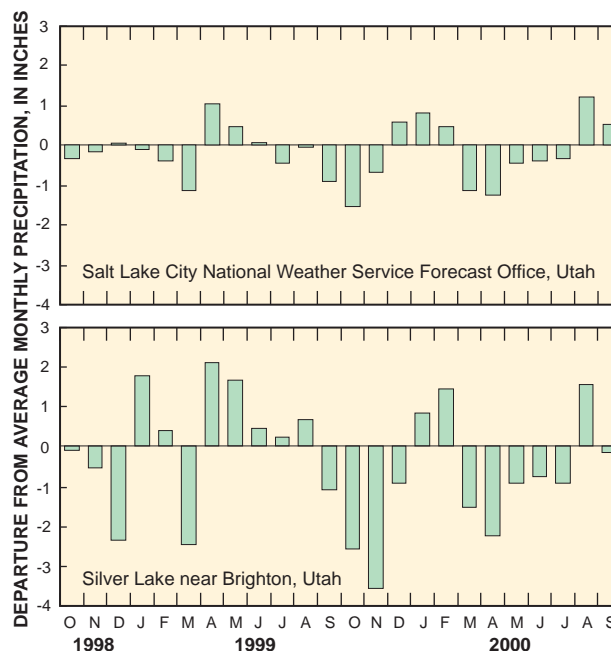


Figure 4. Departure of monthly precipitation from 1971-2000 average at Salt Lake City National Weather Service Forecast Office, Utah, and Silver Lake near Brighton, Utah, weather stations.

annual runoff. Annual runoff during WY 2000 at most fixed sites was less than the average for those sites. Annual runoff at site 2 during WY 2000 was greater than average because of increased flow from reservoir storage for irrigation.

Site number (fig. 1)	Land use/land cover (percent)								Physio- graphic province	Dominant ecoregion
	Rangeland	Forest	Agri- culture	Urban	Wetland	Water	Snow/ ice	Barren		
1	75	15	7	<1	2	<1	<1	<1	M	WYB
2	70	15	8	<1	3	4	<1	<1	M	WYB
3	43	22	34	<1	<1	<1	<1	<1	B	CBR
4	61	16	18	<1	2	2	<1	<1	B	CBR
5	32	61	5	<1	<1	<1	<1	<1	M	WUM
6	57	35	5	2	<1	<1	<1	<1	B	WUM
7	35	46	1	10	<1	<1	<1	7	M/B ¹	CBR
8	29	37	2	26	<1	<1	<1	6	B	CBR
9	56	44	0	<1	0	<1	0	0	M/B ¹	WUM
10	40	42	7	5	<1	4	<1	1	B	CBR

Data Collection and Analysis

Water samples were collected monthly at the sites and analyzed for major ions, nutrients, suspended sediment, and organic carbon (table 3). Additionally, multiple samples from sites 5, 7, 8, and 10 were analyzed for trace elements. Water samples were collected weekly to biweekly at sites 3, 8, and 10 during March to August 1999 and were analyzed for the constituents mentioned above plus pesticides and VOCs (VOCs at sites 8 and 10 only). Additional samples were collected at some sites during periods of

extreme flow. Streamflow and temperature were continuously monitored at all sites. Specific conductance was continuously monitored at sites 3, 7, 8, 9, and 10.

Water samples were collected at each of the 10 sites by using field procedures outlined in Shelton (1994, 1997) and were processed in the field immediately after collection to reduce the possibility of chemical or biological alteration. Samples were analyzed at the USGS National Water Quality Laboratory in Denver, Colorado.

Table 2. Streamflow statistics for fixed sites in the Great Salt Lake Basins study unit

[WY, water year; ft³/s, cubic feet per second; **Highest annual mean:** Year of record flow in parentheses; **Lowest annual mean:** Year of record flow in parentheses; na, not available]

Site number (fig. 1)	Site name	USGS identification number	Period of streamflow record	Runoff (acre-feet)		
				WY 1999	WY 2000	Mean annual (period of record)
1	Bear River below Smiths Fork, near Cokeville, Wyoming	10038000	1955-2000	497,100	199,200	327,600
2	Bear River at Pescadero, Idaho	10068500	1923-2000	769,800	561,300	459,000
3	Cub River near Richmond, Utah	10102200	1963, 1999-2000	130,800	55,440	na
4	Bear River near Corinne, Utah	10126000	1950-2000	1,859,000	904,400	1,315,000
5	Weber River near Coalville, Utah	10130500	1958-2000	191,800	120,300	160,600
6	Weber River near Plain City, Utah	10141000	1949-2000	448,600	171,700	366,500
7	Little Cottonwood Creek at Crestwood Park, at Salt Lake City, Utah	10167800	1999-2000	12,479	10,639	na
8	Little Cottonwood Creek at Jordan River, near Salt Lake City, Utah	10168000	1980-81, 1999- 2000	16,501	15,313	na
9	Red Butte Creek, at Fort Douglas, near Salt Lake City, Utah	10172200	1964-2000	3,960	1,710	3,160
10	Jordan River at Salt Lake City, Utah	10171000	1944-2000	109,000	90,180	104,300

Site number (fig. 1)	USGS identification number	Streamflow (ft ³ /s)								
		Annual mean		Mean annual (period of record)	Highest annual mean		Lowest annual mean		Highest daily	Lowest daily
		WY 1999	WY 2000		(1984)	(1977)	(1984)	(1977)		
1	10038000	687	274	452	1,049	(1984)	112	(1977)	5,400	31.0
2	10068500	1,063	773	634	1,733	(1984)	266	(1945)	4,280	23.0
3	10102200	181	76.4	na	181	(1999)	76.4	(2000)	949	5.0
4	10126000	2,568	1,246	1,815	5,050	(1984)	435	(1992)	14,300	47.0
5	10130500	265	166	222	485	(1986)	71.1	(1961)	1,860	7.0
6	10141000	620	237	506	1,427	(1986)	65.3	(1988)	9,970	1.0
7	10167800	34.2	14.6	na	34.2	(1999)	14.7	(2000)	359	1.3
8	10168000	45.2	21.0	na	45.2	(1999)	21.1	(2000)	357	1.3
9	10172200	5.47	2.36	4.37	12.5	(1983)	1.12	(1990)	95	.38
10	10171000	151	124	144	223	(1985)	92.3	(1964)	337	.00

Table 3. Number and type of water samples collected and sampling frequency at fixed sites in the Great Salt Lake Basins study unit

[GC/MS, gas chromatography/mass spectrometry; HPLC/MS, high-performance liquid chromatography/mass spectrometry]

Site number	Number and type of sample						Sample frequency				
	Major ions	Nutrients	Trace elements	Suspended sediment	Organic carbon	Pesticides		Volatile organic compounds	Monthly sampling period	Weekly or biweekly sampling period	Extreme-flow sample
						GC/MS	HPLC/MS				
1	24	24	1	24	24	0	0	0	10/98-9/00	None	No
2	24	24	1	23	23	0	0	0	10/98-9/00	None	No
3	32	32	1	29	32	26	16	0	10/98-9/00	4/99 - 9/99	Yes
4	25	25	2	24	25	0	0	0	10/98-9/00	None	Yes
5	24	24	20	23	24	1	0	0	10/98-9/00	None	No
6	26	26	1	26	26	0	0	0	10/98-9/00	None	Yes
7	29	29	25	26	29	9	4	2	10/98-9/00	None	Yes
8	45	45	49	44	43	42	24	32	10/98-9/00	3/99-9/99	Yes
9	27	27	2	27	26	1	1	1	10/98-9/00	None	Yes
10	36	35	36	37	35	32	22	26	10/98-9/00	3/99-9/99	Yes

Data collected during this study are available in the USGS National Water Information System database and the USGS NAWQA Data Warehouse. These databases are subject to periodic review and possible revision. Major ion, nutrient, trace metal, dissolved and suspended organic carbon, and sediment data also are available in USGS Water-Data Reports (Herbert and others, 2000, 2001, and 2002).

In this report, the term “dissolved” refers to solutes detected in a water sample after it has passed through a 0.45-micron filter or a 0.70-micron filter (pesticide samples only). Dissolved-solids concentrations in this report refer to measurements derived from analysis of sample residue on evaporation at 180°C.

A minimum reporting level (MRL) is the smallest measured concentration of a constituent that may be reliably reported when using a given analytical method. Concentrations are reported as less than the MRL for samples in which the constituent either was not detected or was detected at a concentration less than the MRL. Constituents that were detected at concentrations between the long-term method detection level (LT-MDL) and MRL were estimated. The LT-MDL controls false positive error, and the chance of falsely reporting a concentration at or greater than the LT-MDL for a sample that did not contain the analyte is predicted to be less than or equal to 1 percent. Estimated concentrations are noted with a remark code of “e.” These data should be used with the understanding that their uncertainty is greater than that of data reported without the “e” remark code. Concentrations with the “e” remark code were

considered as detections in the data analysis and were included in statistical analysis.

The MRL of a constituent can be the largest influence on the detection frequency of that constituent. A common reporting limit of 0.05 µg/L is sometimes used in the report to compare the detection frequencies of pesticides that have different MRLs. Censoring detections less than 0.05 µg/L resulted in a slight loss of detection information; however, with a common reporting limit, a more uniform comparison of detection frequencies is possible. The same method was applied to VOC data by using a common reporting limit of 0.2 µg/L.

Quality-control (QC) samples were collected at the GRSL sites following NAWQA protocols (Shelton, 1994; Mueller and others, 1997). These samples consisted of field blanks, equipment blanks, replicates, and field matrix spikes. On the basis of QC results, it was concluded that measurements of concentration in the environmental samples were of sufficiently high quality that presence or absence of most constituents, concentration distributions, and comparisons to water-quality criteria could be determined. Concentrations of total and dissolved ammonia plus organic nitrogen and orthophosphate may have a positive bias because of contamination from equipment or field procedures. Concentrations of aluminum and zinc, near the MRL, probably have a positive bias because of contamination. A detailed discussion of QC samples and results from GRSL study-unit sites is available in Gerner (2003).

Water-Quality Issues

A liaison committee of Federal, State, and local agencies, universities associated with water management and water quality, and interested citizen groups was formed in 1994 to discuss the major water-quality issues relative to the GRSL study unit. Several water-quality issues related to surface water were identified by this group including nutrient releases into streams from nonpoint sources, increased sediment transport as a result of urbanization and streamflow fluctuations downstream from dams, transport of contaminants associated with suspended sediment, and leachate from mine tailings and metal refineries.

A State listing of impaired water bodies is required by Section 303(d) of the Clean Water Act. Section 305(b) of the Clean Water Act requires States to assess their water quality biennially and report those findings to the U.S. Environmental Protection Agency (EPA). A review of the 2002 303(d) listing of impaired water bodies and 305(b) assessment of beneficial-use support provided by the Utah Department of Environmental Quality for the State of Utah provides further insight into some of the water-quality issues affecting streams in the GRSL study unit. Areas of concern identified in these reports include (1) nutrients, dissolved oxygen, hydrologic modification, and sediment in the Bear River drainage basin; (2) nutrients, dissolved oxygen, and sediment in the Weber River drainage basin; and (3) metals, dissolved-solids concentration, sediment, fecal coliform, and flow and riparian alteration in the Utah Lake/Jordan River drainage basin (Utah Department of Environmental Quality, 2002a, 2002b).

Description of Fixed-Site Network

The fixed sites in the GRSL study unit (fig. 1) are stream-sampling sites that were established for monitoring stream quality during a 2-year period. Sites were categorized as either indicator or integrator sites (table 1). Indicator sites are located near the mouth of drainage basins that are relatively homogenous with a dominant land use and physiographic condition. Stream samples from indicator sites provide documentation of water-quality conditions relative to that dominant land use (Gilliom and others, 1995). Seven indicator sites were selected for the GRSL study unit: Bear River below Smiths Fork, Bear River at

Pescadero, Cub River near Richmond, Weber River near Coalville, Little Cottonwood Creek at Crestwood Park, Little Cottonwood Creek at Jordan River, and Red Butte Creek at Fort Douglas. Integrator sites are located near the mouth of large rivers in drainage basins with complex mixes of land use/land cover and multiple natural and human-related factors that affect water quality. These sites are on streams with large drainage basins that include a substantial part of the study unit. Because of the complex mix of land uses affecting water quality at these sites, they are further categorized and referred to as mixed-land-use sites in this report. Three integrator (mixed-land-use) sites were selected for the GRSL study unit: Bear River near Corinne, Weber River at Plain City, and Jordan River at Salt Lake City. About 95 percent of the drainage area of the study unit contributes runoff to the three mixed-land-use sites. Sites are referred to throughout this report by either site name or number (fig. 1, table 1).

Bear River Drainage Basin

The Bear River is the longest river in North America that does not drain into an ocean. The Bear River meanders through Utah, Wyoming, and Idaho before it enters Utah again where it ends in Great Salt Lake (fig. 1). Near Montpelier, Idaho, the Bear River is usually diverted into the Mud Lake/Bear Lake reservoir system. About 140,000 years ago, lava flows from near Soda Springs, Idaho, blocked the Bear River channel and diverted the river from the Snake River Plain into the Great Basin. After isolation from each other for thousands of years, a Bear Lake/Bear River connection was reestablished in 1911-12 to use the lake as a water-storage reservoir. The Rainbow canal diverts water from the Bear River into Mud Lake. This water can then either be diverted into Bear Lake or returned to the Bear River. Water from Bear Lake can later be pumped through the Lifton pumping station to the outlet canal and back to the Bear River. Enrichment of Bear Lake with nutrients and sediment from the Bear River has been an ongoing concern of water managers and users in the Bear River drainage basin.

About 62 percent of the total average annual runoff of surface water (1931-76) to Great Salt Lake is from the Bear River. Above Bear Lake most of this basin is composed of forest and rangeland, whereas agricultural and urban land cover predominate downstream from Bear Lake. A network of dams, reservoirs, and diversion structures regulates flow in

the Bear River for irrigation and hydroelectric power production, and modifies the natural hydrologic variability of the stream and the physical, chemical, and biological conditions of the stream. Flow modification from dams and reservoirs affects stream-bank stability and sediment concentration. Bear Lake has a usable storage capacity of 1,421,000 acre-ft and is the largest reservoir on the Bear River system.

During 1995, irrigation for agriculture accounted for an estimated 92 percent of all water use, and public supply accounted for an estimated 4 percent of all water use in the Bear River drainage (Baskin and others, 2002). Nutrient and sediment loading related to agricultural land cover are the primary water-quality issues on the Bear River. Channelization, streamflow modification, and grazing of rangelands contribute to sediment loads in the upper part of the drainage basin. Feedlots, dairy operations, and irrigated crops contribute to nutrient loads in the lower drainage basin. Most tributaries to the Bear River are seasonally diverted for irrigation. Irrigation return flow, with generally high dissolved-solids concentration, affects the water quality of the Bear River.

Bear River below Smiths Fork

Site 1, the Bear River below Smiths Fork, is 61 mi above Mud Lake and just upstream from the Wyoming/Idaho state line. The drainage basin above site 1 is 2,444 mi² in area and lies within the Wyoming Basin and Wasatch and Uinta Mountains ecoregions. This site was selected because it provided a reference for effects of rangeland use on water quality and is an indicator of water quality in the Bear River above Bear Lake.

Land cover in the drainage basin is primarily rangeland (75 percent) and forest (15 percent) (table 1). Daily streamflow ranged from 102 ft³/s to 2,860 ft³/s (fig. 5). Twenty-four water samples were collected at this site for chemical analysis, and corresponding streamflow ranged from 108 ft³/s to 2,160 ft³/s.

Bear River at Pescadero

Site 2, the Bear River at Pescadero, is 19 mi downstream from Bear Lake and was selected as a sampling site because of its historical streamflow and water-quality record and proximity to the outflow from the Mud Lake/Bear Lake reservoir system. Comparison of water chemistry upstream from Bear Lake at site 1

with water chemistry at site 2 provides insight into the changes that occur as the Bear River travels through Mud Lake or receives inflow from water pumped out of Bear Lake.

The drainage basin above site 2 is 3,699 mi² in area and is primarily in the Wyoming Basin ecoregion. Land cover in the drainage basin is mainly rangeland (70 percent) and forest (15 percent). Streamflow was greatly influenced by managed releases from Bear Lake. Daily mean streamflow ranged from 94 to 1,760 ft³/s (fig. 6). Twenty-four water samples were collected at site 2 for chemical analysis, and corresponding streamflow ranged from 180 to 1,650 ft³/s.

Cub River near Richmond

Site 3, Cub River near Richmond, is near the mouth of the Cub River drainage basin, 3.9 mi upstream from the confluence with the Bear River. The drainage basin above site 3 is 222 mi² in area and lies within the Central Basin and Range and Wasatch and Uinta Mountains ecoregions. Land cover in the basin is mainly rangeland (43 percent), agriculture (34 percent), and forest (22 percent).

This site was selected to determine the effects of agriculture on water quality in the GRSL study unit. The percentage of agricultural land cover in this basin is high relative to that of most basins in the GRSL study unit (table 1). During the summer, most of the flow from the upper Cub River drainage basin is withdrawn for irrigation, and streamflow at this site consists mainly of irrigation return, treated waste water, and ground-water inflow. Snowmelt is the largest component of streamflow from March through June. Daily mean streamflow ranged from 5.6 to 949 ft³/s (fig. 7). Thirty-three water samples were collected at this site for chemical analysis, and corresponding streamflow ranged from 15 to 960 ft³/s.

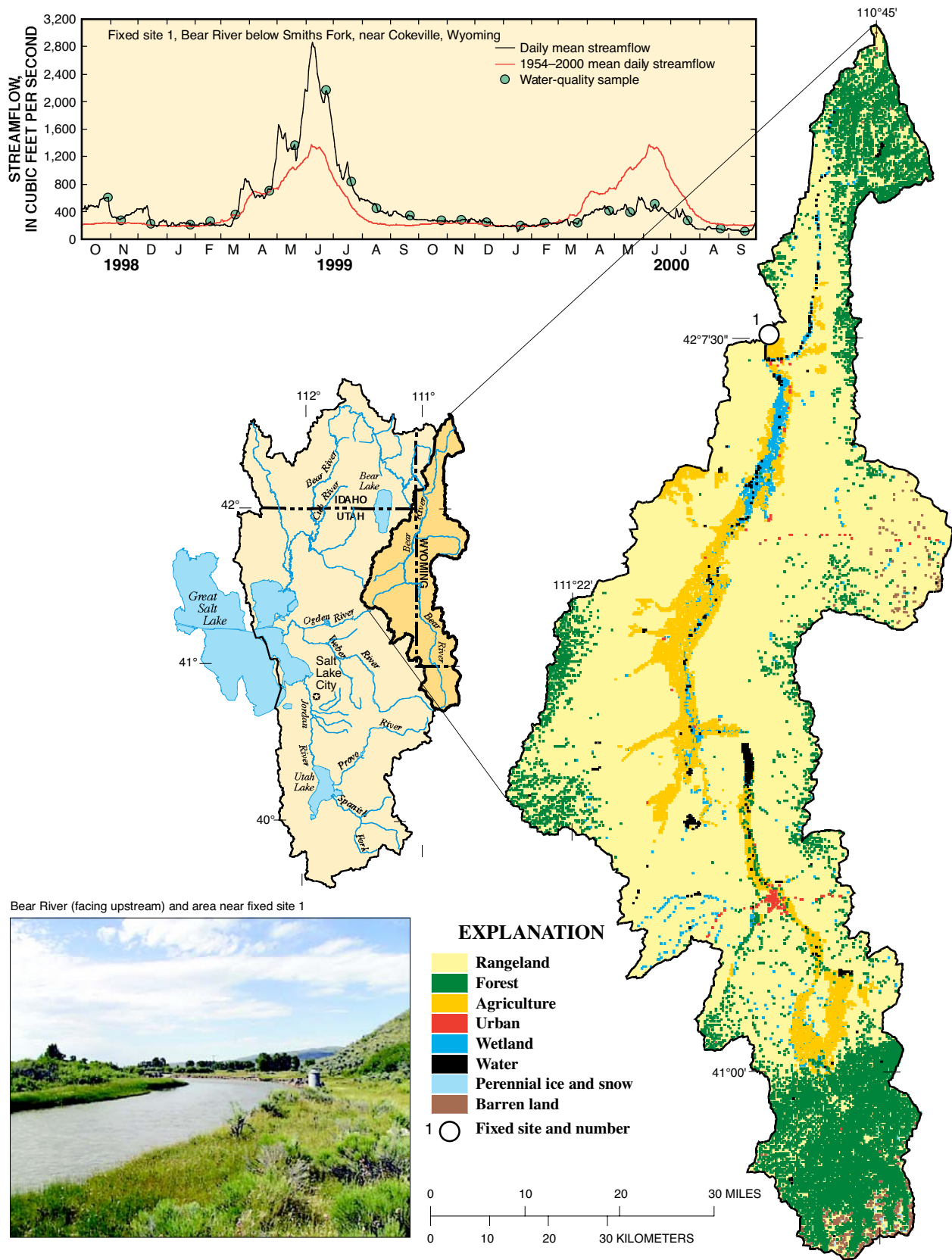


Figure 5. Land use/land cover, drainage basin location, and streamflow for the Bear River below Smiths Fork, near Cokeville, Wyoming.

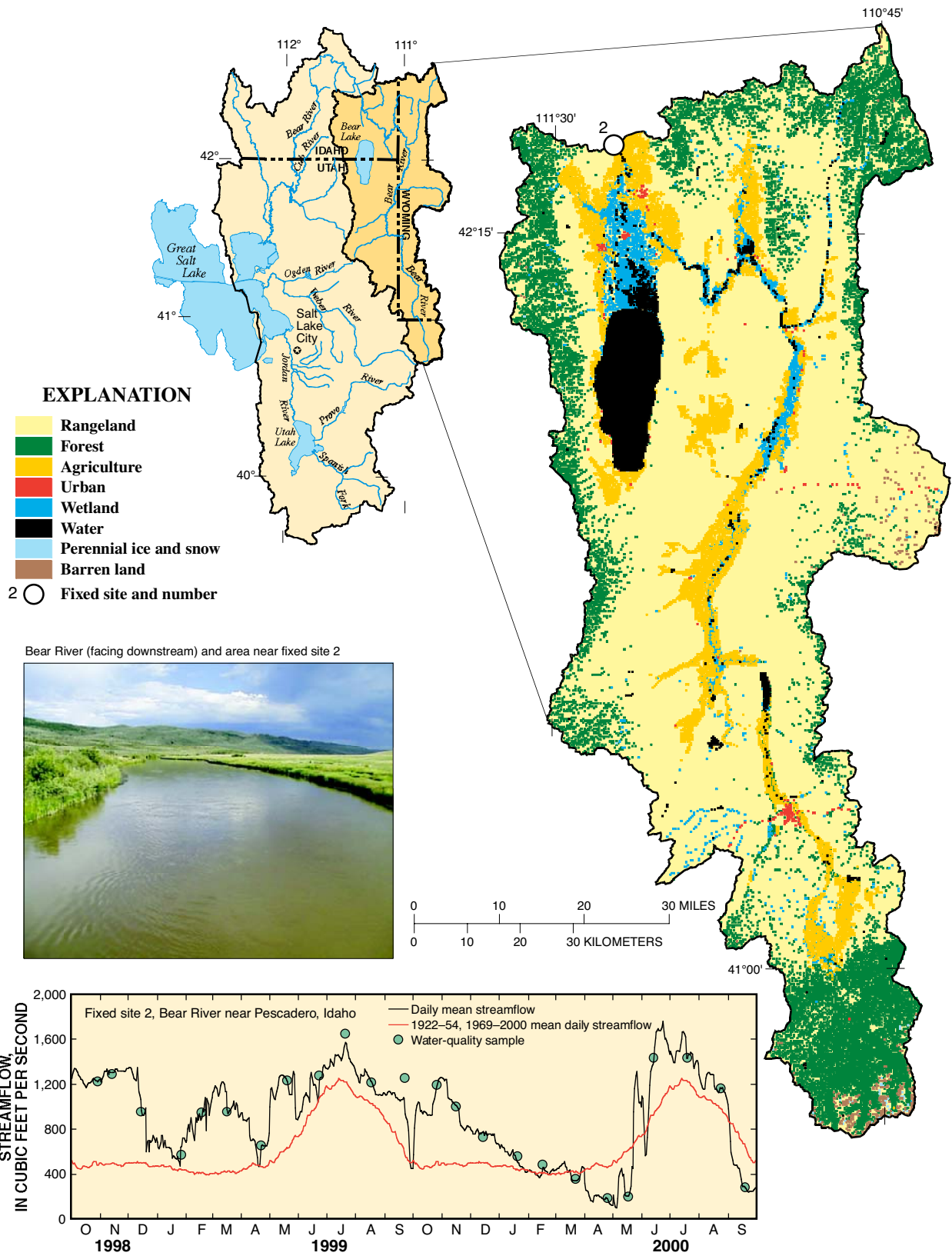


Figure 6. Land use/land cover, drainage basin location, and streamflow for the Bear River at Pescadero, Idaho.

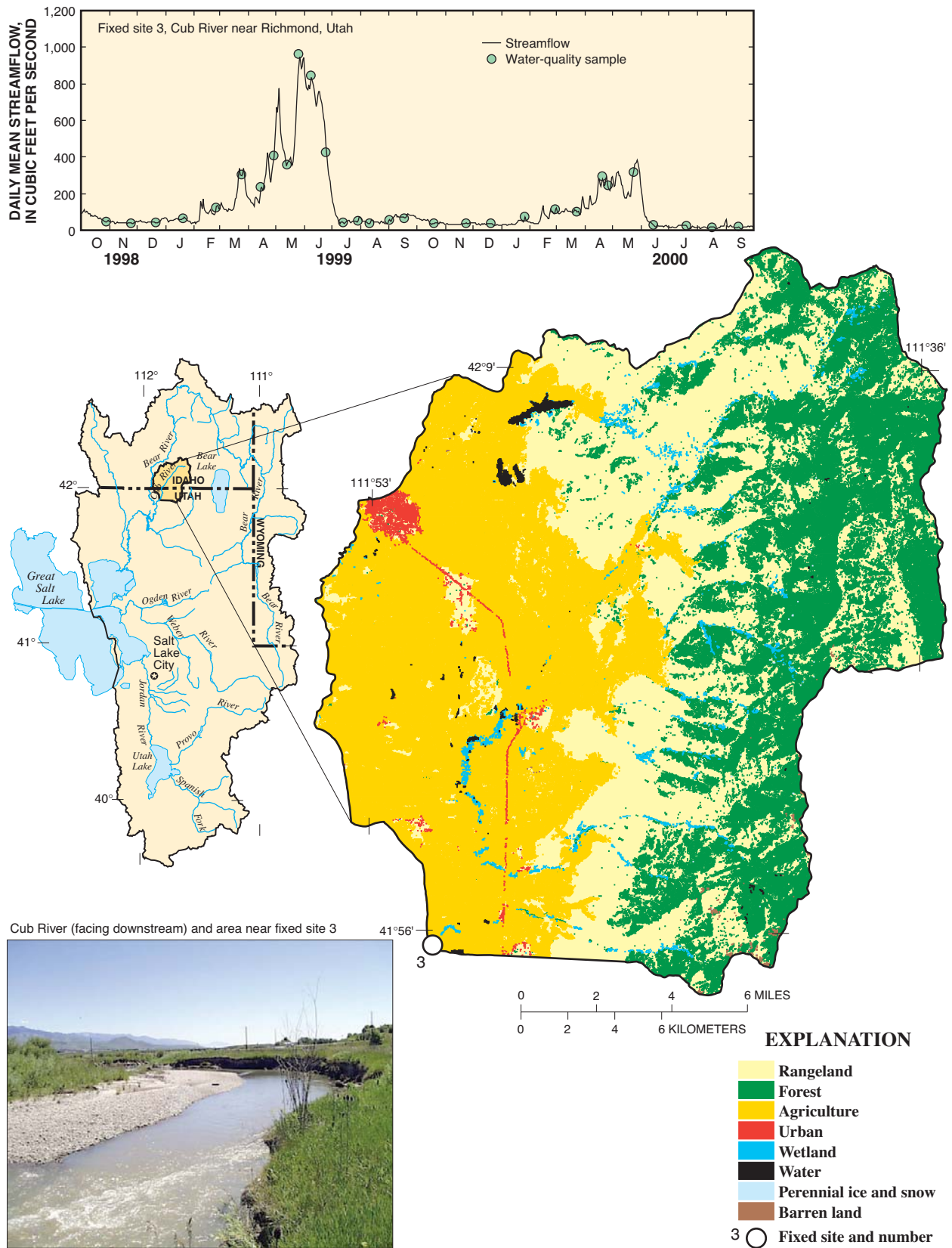


Figure 7. Land use/land cover, drainage basin location, and streamflow for the Cub River near Richmond, Utah.

Bear River near Corinne

Site 4, the Bear River near Corinne, is near the mouth of the Bear River, 21 mi above Great Salt Lake. The drainage basin above site 4 is about 7,065 mi² in area. Site 4 lies within the Central Basin and Range ecoregion. Land cover in the area above this site is mainly rangeland (61 percent), forest (16 percent), and agriculture (18 percent) (table 1). Agriculture is probably the dominant land use influencing water quality at this site.

The natural flow of the river is affected by upstream reservoirs, power development, diversions for irrigation, and return flow from irrigated areas. Daily mean streamflow ranged from 74 to 6,020 ft³/s (fig. 8). Twenty-five water samples were collected at this site for chemical analysis, and corresponding streamflow ranged from 92 to 5,380 ft³/s.

Weber River Drainage Basin

About 23 percent of the total average annual runoff of surface water (1931-76) to Great Salt Lake is from the Weber River. The Weber River drainage basin is primarily forest and rangeland in the upper drainage basin with increasing agricultural and urban land uses toward the mouth of the Weber River at Great Salt Lake. Intensive urban development is occurring in parts of the upper drainage basin, including the areas surrounding Park City, Heber City, and Kamas, and in the lower drainage basin in the Ogden area near the mouth of the Weber River. The basin is affected by historical mining activities that occurred in some upper drainage-basin areas.

Much of the water in the main stem of the Weber River is diverted for irrigation during the summer months, although minimum streamflows are maintained below most reservoirs on the Weber and Ogden Rivers (Utah Department of Natural Resources, 1997b). During 1995, irrigation for agriculture accounted for an estimated 82 percent of all water use, and public supply accounted for an estimated 16 percent of all water use in the Weber River drainage basin (Baskin and others, 2002). Residential and commercial developments are replacing farms and ranches in many parts of the basin, resulting in more municipal and industrial use of water and less agricultural use. Eight major reservoirs provide storage and redistribution of water in the Weber River drainage basin, as well as providing for flood control and recreational opportunities.

Weber River near Coalville

Site 5, the Weber River near Coalville, is 9 mi downstream from Rockport Reservoir. Streamflow at this site is highly regulated with many diversions for irrigation upstream from the site. The drainage basin above site 5 is 427 mi² in area and lies within the Wasatch and Uinta Mountains ecoregion. Land use in the drainage basin includes forest (61 percent), rangeland (32 percent), and agriculture (5 percent). This site was selected as an indicator of the effects of rangeland and agricultural land use on stream chemistry in the GRSL study unit. This site is about 5.6 mi downstream from the confluence with Silver Creek, a tributary affected by historical mining practices in the Park City area and a source of metal-enriched sediment for the Weber River (Giddings and others, 2001).

Daily mean streamflow ranged from 43 to 1,310 ft³/s (fig. 9). Twenty-four water samples were collected at this site, and corresponding streamflow ranged from 48 to 421 ft³/s.

Weber River near Plain City

Site 6, Weber River near Plain City, is near the mouth of the drainage basin, 13 mi upstream of where the river empties into Great Salt Lake. The drainage basin above site 6 is 2,072 mi² in area and lies within the Central Basin and Range and Wasatch and Uinta Mountains ecoregions. Land cover in the drainage is mainly rangeland (57 percent), and forest (35 percent). The amount of urban land cover in this basin is only about 2 percent (table 1). This site is immediately downstream from the waste-water treatment plant for the Ogden metropolitan area, an urban area that has a substantial effect on water quality.

During the irrigation season (generally May through September), most of the flow from the upper Weber River drainage basin was diverted for irrigation and public supply, and streamflow at this site consisted mainly of irrigation return, urban runoff, waste-water effluent, and ground-water inflow. Daily mean streamflow ranged from 51 to 3,220 ft³/s (fig. 10). Twenty-six water samples were collected at this site, and the corresponding streamflow ranged from 58 to 3,130 ft³/s.

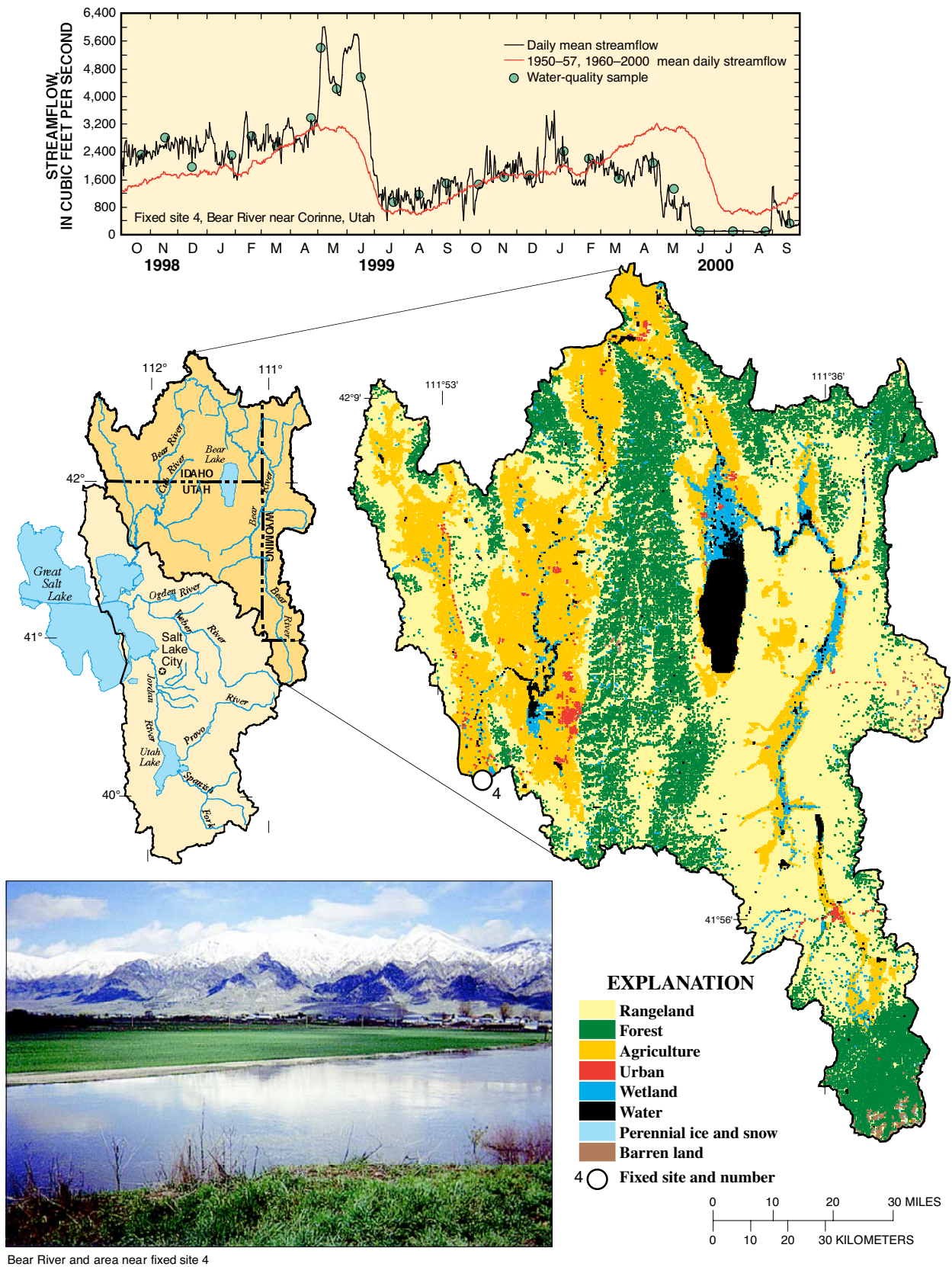


Figure 8. Land use/land cover, drainage basin location, and streamflow for the Bear River near Corinne, Utah.

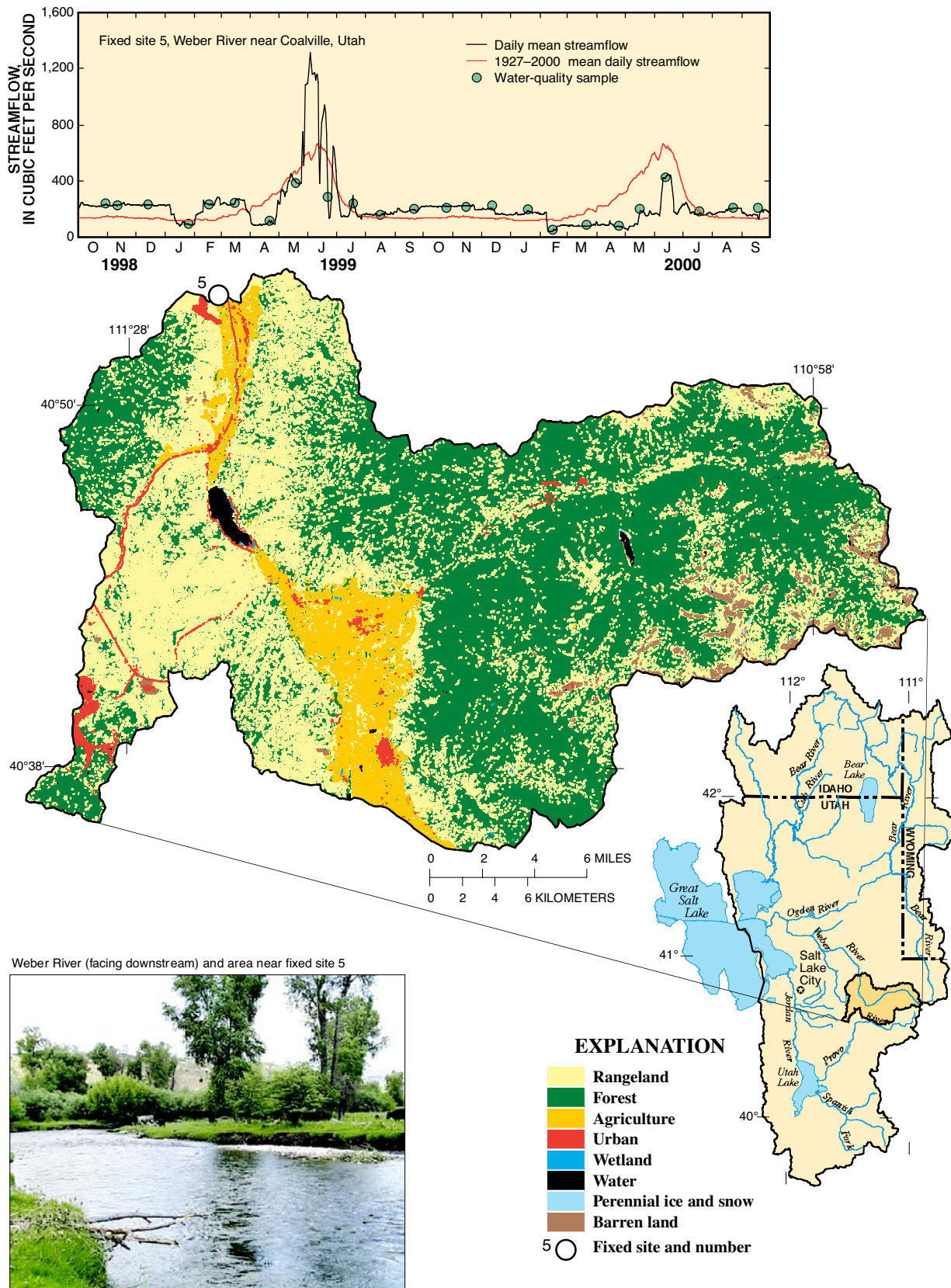


Figure 9. Land use/land cover, drainage basin location, and streamflow for the Weber River near Coalville, Utah.

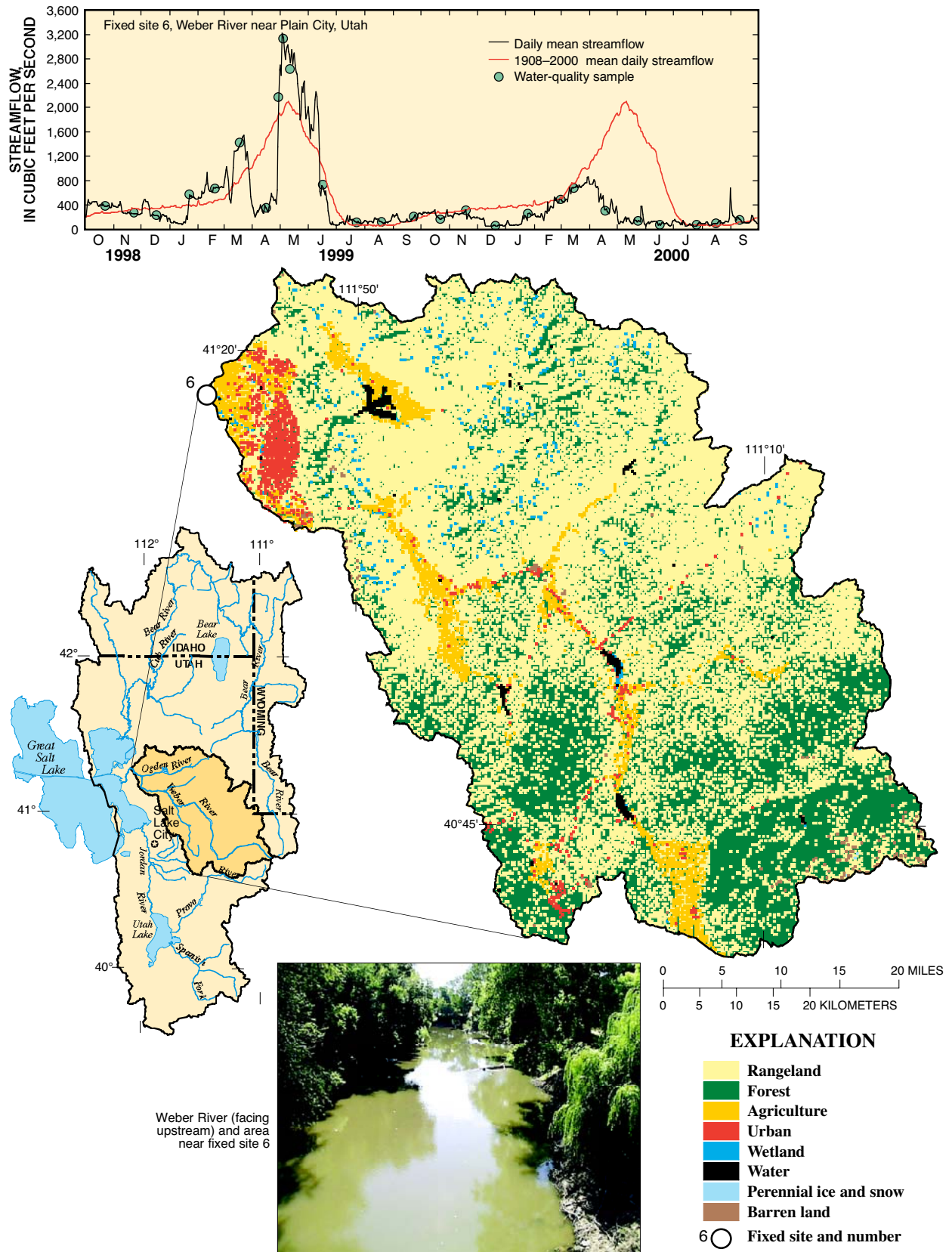


Figure 10. Land use/land cover, drainage basin location, and streamflow for the Weber River near Plain City, Utah.

Utah Lake/Jordan River Drainage Basin

The Utah Lake/Jordan River drainage basin includes the Provo and Spanish Fork Rivers, which terminate in Utah Lake, and the Jordan River drainage basin. During 1995, irrigation for agriculture accounted for an estimated 70 percent of all water use, and public supply accounted for an estimated 26 percent of all water use in the Utah Lake/Jordan River drainage basin (Baskin and others, 2002). The Jordan River starts at the outflow from Utah Lake and flows northward through the Salt Lake City metropolitan area before discharging into Great Salt Lake. Inflow to Utah Lake is primarily affected by agricultural and urban land uses and imports from the Colorado River Basin as part of the Central Utah Project. About 15 percent of the total average annual surface-water runoff (1931-76) to Great Salt Lake is from the Jordan River. Most urban development and more than 75 percent of the population of Utah is along the Wasatch Front, extending north from Provo to Ogden and including the Jordan River drainage basin. Factors that affect the water quality of the Jordan River include urban and industrial uses and past mining and metal-processing activities.

Two sites were established on Little Cottonwood Creek, a tributary to the Jordan River, with the purpose of determining the effect of urban land use on water quality in the GRSL study unit (fig. 1). These sites bracket a reach of Little Cottonwood Creek that has a drainage area of 9 mi² that is nearly 100 percent urban land cover. The distance between the sites is about 5.7 mi. By using the data from water samples collected at both sites, effects of the urban land cover on water quality in Little Cottonwood Creek was evaluated.

Little Cottonwood Creek at Crestwood Park

Site 7, Little Cottonwood Creek at Crestwood Park, is 4.8 mi downstream from the mouth of Little Cottonwood Canyon. The drainage basin above site 7 is 36 mi² in area and lies within the Central Basin and Range and Wasatch and Uinta Mountains ecoregions. Land cover is mainly rangeland (35 percent), forest (46 percent), and urban (10 percent).

Snowmelt runoff dominates the streamflow at this site from about April through June. The rest of the year most of the water in Little Cottonwood Creek is withdrawn for the Metropolitan Water Treatment Plant near the canyon mouth, and flows are greatly reduced. Daily mean streamflow ranged from 0.1 to 359 ft³/s

(fig. 11). Twenty-nine water samples were collected for chemical analysis at site 7, and the corresponding streamflow ranged from 0.2 to 227 ft³/s.

Little Cottonwood Creek at Jordan River

Site 8, Little Cottonwood Creek at Jordan River, is 0.7 mi upstream from the confluence with the Jordan River. The drainage basin above site 8 is 45 mi² in area and lies within the Central Basin and Range and Wasatch and Uinta Mountains ecoregions. Land cover for the basin is mainly forest (37 percent), rangeland (29 percent), and urban (26 percent). A sharp demarcation between rangeland/forest land cover and urban land cover occurs near the Wasatch-Cache National Forest and Wasatch and Uinta Mountains ecoregion boundaries. Land use downstream from these boundaries is nearly 100 percent urban.

Site 8 is situated in, and downstream from, an urban area that consists mainly of recently developed, low density, residential land use. Water-quality influences at this site include runoff from urban land cover, runoff from historical metals-processing facilities within the urban area, historical mining in Little Cottonwood Canyon, and road-salting activities throughout the drainage basin.

Snowmelt runoff dominates the streamflow at this site from about April through June. Streamflow at this site consists mainly of irrigation return and ground-water discharge during the summer months. Daily mean streamflow ranged from 1.3 to 357 ft³/s (fig. 12). Forty-five water samples were collected for chemical analysis, and corresponding streamflow ranged from 1.5 to 298 ft³/s.

Red Butte Creek at Fort Douglas

Site 9, Red Butte Creek at Fort Douglas, is in Red Butte Canyon, a Research Natural Area east of Salt Lake City in the Wasatch-Cache National Forest. The drainage basin above this site is 7.21 mi² in area and lies within the Wasatch and Uinta Mountains ecoregion. This site was selected as a reference site for range and forest land use, which account for nearly 100 percent of the land use in the basin. Red Butte Canyon is a closed and protected watershed. It is set aside primarily for research and education and is managed by the U.S. Forest Service. A detailed description of the basin and analysis of an extensive water-chemistry data set is available in Mast and Clow (2000).

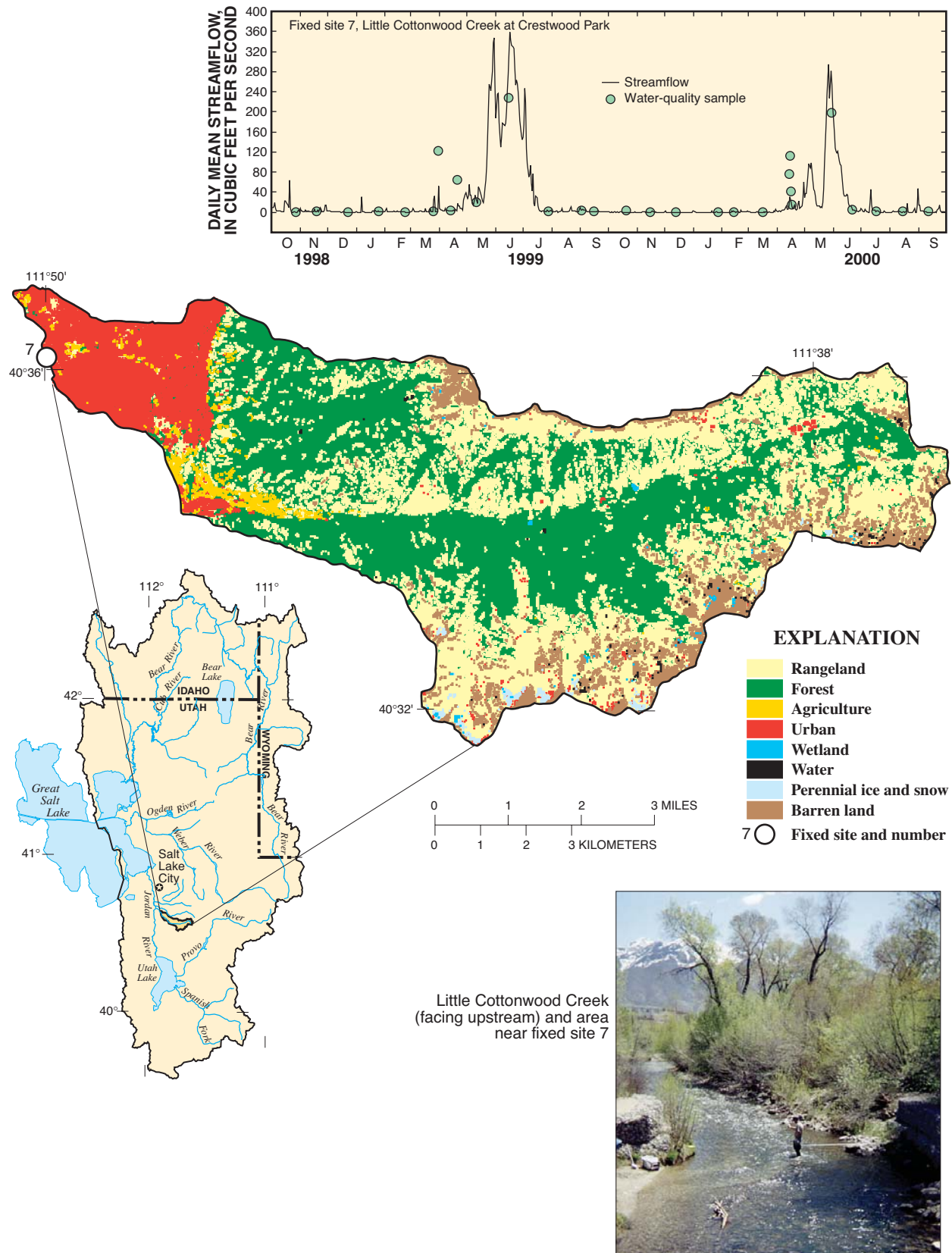


Figure 11. Land use/land cover, drainage basin location, and streamflow for Little Cottonwood Creek at Crestwood Park, Salt Lake City, Utah.

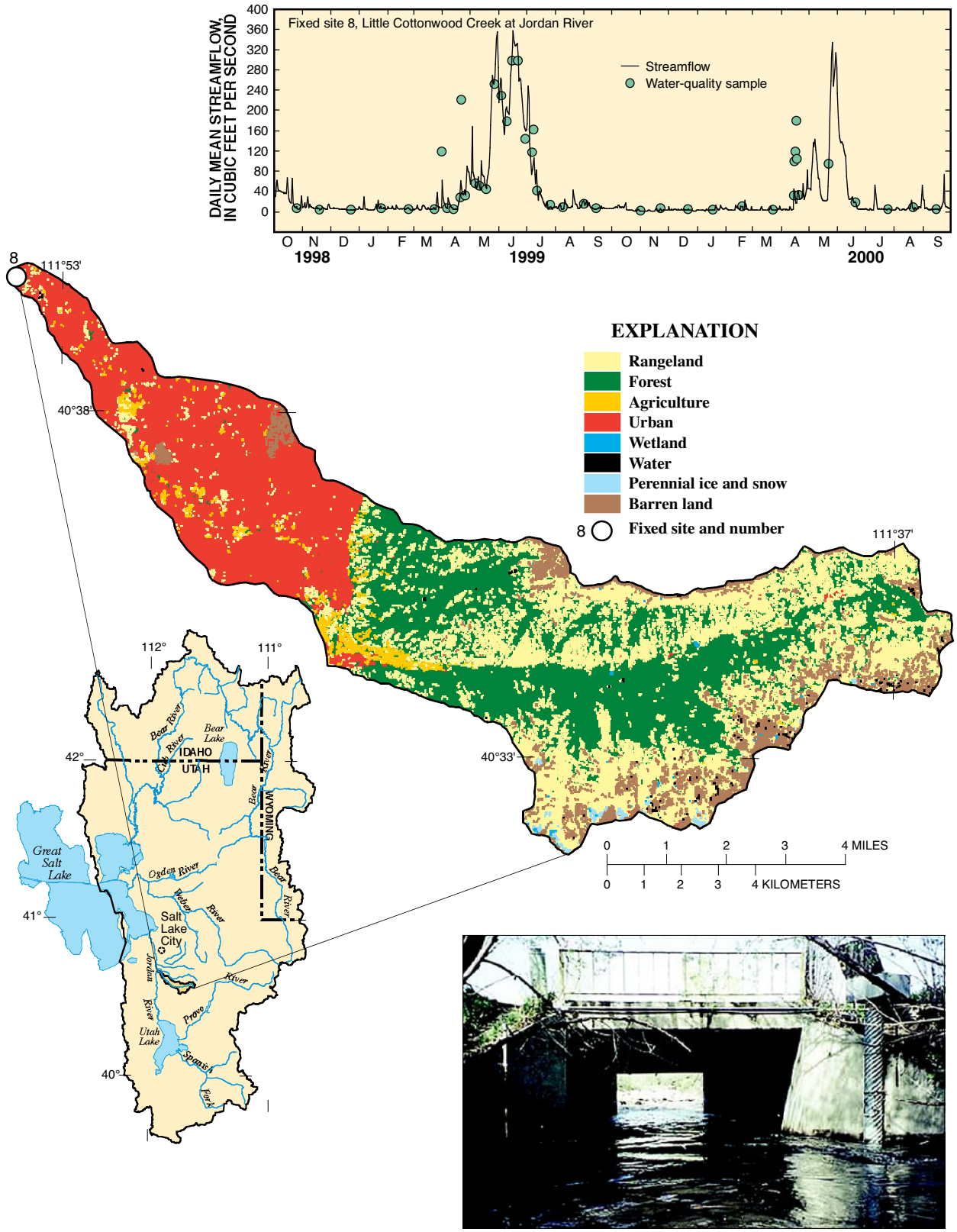


Figure 12. Land use/land cover, drainage basin location, and streamflow for Little Cottonwood Creek at Jordan River, Salt Lake City, Utah.

Daily mean streamflow ranged from 0.7 to 22 ft³/s (fig.13). Twenty-seven water samples were collected at this site, and corresponding streamflow ranged from 1 to 20 ft³/s.

Jordan River at Salt Lake City

Site 10, Jordan River at Salt Lake City, was selected to represent the multiple land uses and physical settings in the Utah Lake/Jordan River drainage basin. The drainage basin above this site is about 3,508 mi² in area and lies within the Central Basin and Range and Wasatch and Uinta Mountains ecoregions. Although land cover for the drainage basin is mainly forest (42 percent) and rangeland (40 percent), urban land uses (5 percent) probably have the largest effect on water quality. Two waste-water treatment plants upstream from this site discharge about 93,000 acre-ft of water annually to the Jordan River (Utah Department of Natural Resources, 1997a), which represents about 23 percent of the annual streamflow upstream from site 10. Water quality at this site also is affected by historical mining.

Flow at site 10 is affected by regulation at Utah Lake and the Surplus Canal diversion. Site 10 is located about 0.2 mi below the Surplus Canal flood-control diversion, where most of the flow is diverted. The chemistry of water samples at site 10 is expected to be very similar to the chemistry of water from the Jordan River above the Surplus Canal diversion and of water from the Surplus Canal itself.

The daily mean streamflow of the Jordan River above the Surplus Canal diversion ranged from 228 to 2,270 ft³/s. Daily mean streamflow at site 10 ranged from 6.7 to 203 ft³/s (fig. 14). Thirty-three water samples were collected at this site, and the corresponding streamflow ranged from 10 to 190 ft³/s. During reconstruction of the Surplus Canal diversion gates in August and September 1999, four fixed-frequency samples were collected at the Surplus Canal rather than at the Jordan River site and the corresponding streamflow ranged from 139 to 720 ft³/s.

WATER QUALITY

The natural factors of physiography, geology, soils, climate, and hydrology largely determine the natural background quality of water. The cultural

factors of population, manipulation of land cover, water use, and waste-management practices determine the human influence on water quality. Analysis of water samples collected at the fixed sites provides a tool to evaluate water quality at the time the samples are collected. Data from these water samples were used to evaluate differences in water quality at the sites over time or among sites. In many cases, box plots are used in this report to illustrate statistical characteristics of the data, including median, quartile range, and data range.

The concentrations of some trace metals, pesticides, and VOCs in water samples from the fixed sites were compared with Ambient Water Quality Criteria (AWQC) for aquatic organisms. These criteria are used as a basis for States to develop water-quality standards (U.S. Environmental Protection Agency, 1999a). In those cases where criteria representing both acute and chronic exposure were available, sample concentrations were compared to the chronic criteria. The AWQC for some metals was developed with respect to water hardness, with maximum exposure levels increasing as water hardness increases. Constituents of water samples at concentrations exceeding the AWQC could pose a threat to the health of aquatic organisms.

Physical Properties, Dissolved Solids, and Alkalinity

Measurements of alkalinity, streamflow, dissolved oxygen (DO), pH, specific conductance, and water temperature were made in the field each time samples were collected at a site (table 4). Continuous water-temperature measurements were made at all sites. Continuous specific-conductance measurements were made at sites 3, 7, 8, 9, and 10. Daily streamflow, specific-conductance, and water-temperature values were published in Herbert and others, (2000, 2001, and 2002).

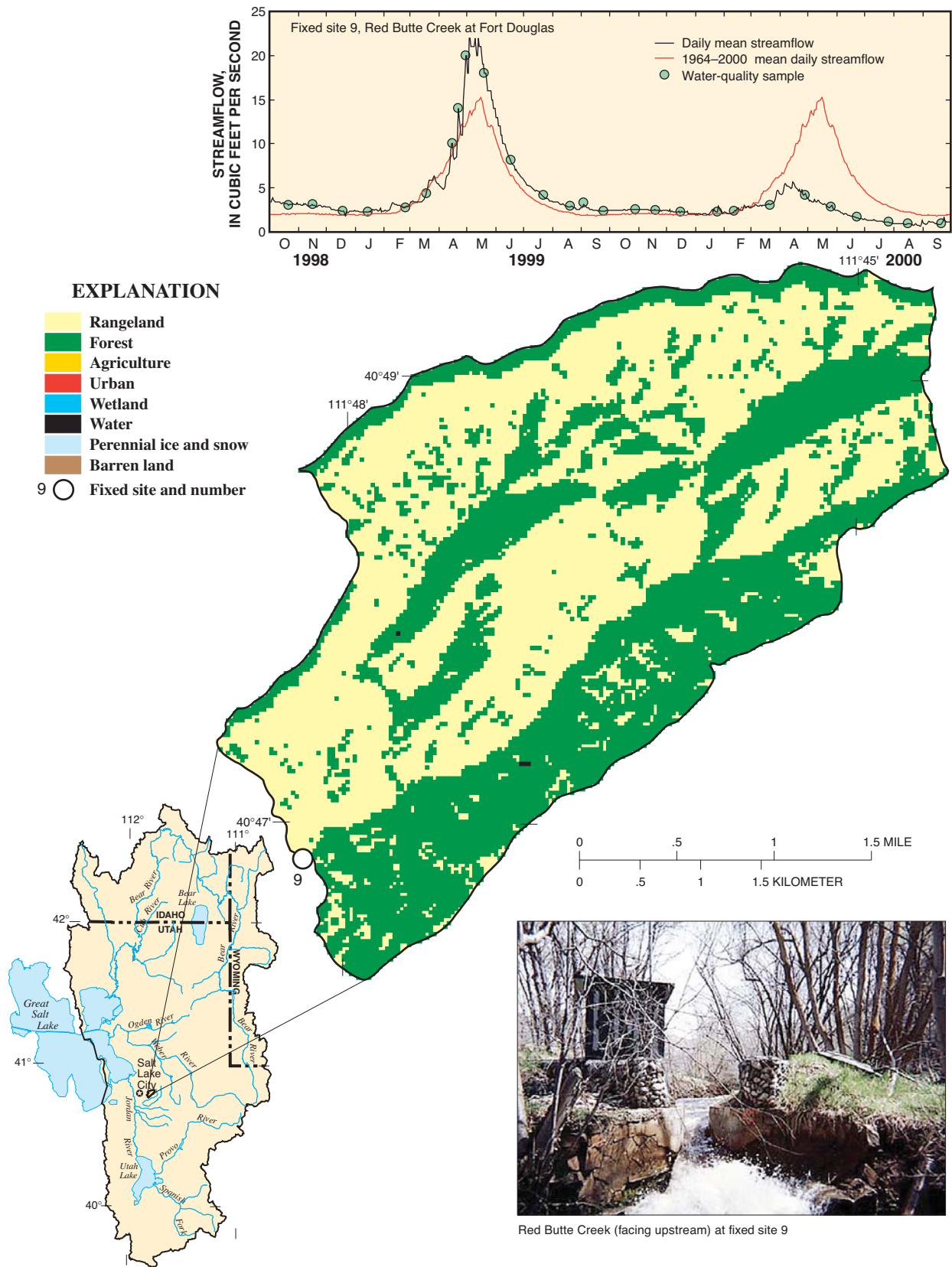


Figure 13. Land use/land cover, drainage basin location, and streamflow for Red Butte Creek at Fort Douglas, near Salt Lake City, Utah.

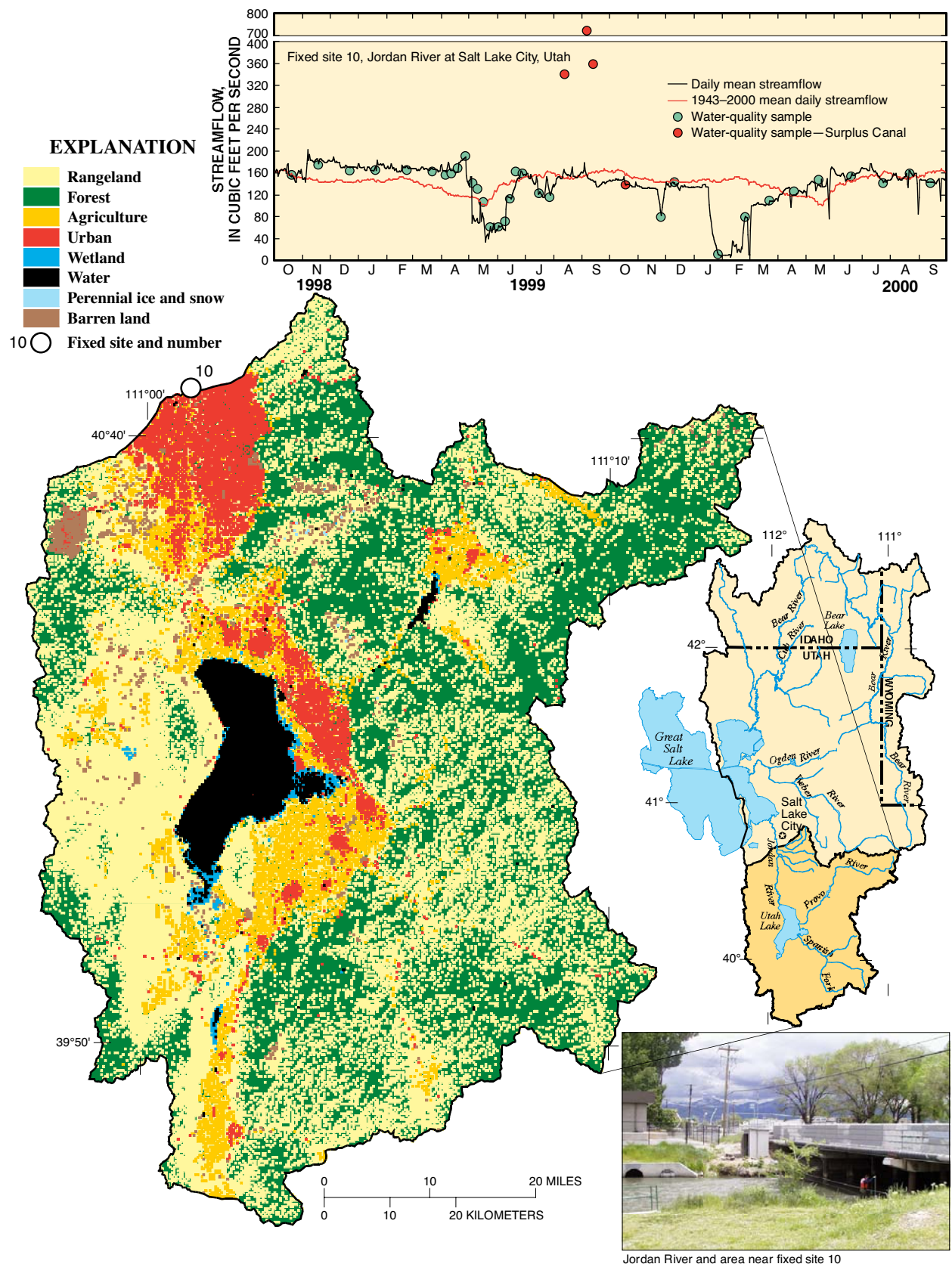


Figure 14. Land use/land cover, drainage basin location, and streamflow for the Jordan River at Salt Lake City, Utah.

Table 4. Minimum reporting level of physical properties and chemical constituents measured at fixed sites in the Great Salt Lake Basins study unit

[mg/L, milligrams per liter; µg/L, micrograms per liter]

Activity	Physical property or chemical constituent	Minimum reporting level	Unit
Field measurement			
	Physical properties		
	Discharge	0.01	Cubic foot per second
	Specific conductance	1	Microsiemen per centimeter at 25 degrees Celsius
	pH	.1	Standard unit
	Water temperature	.1	Degree Celsius
	Dissolved oxygen	.1	mg/L
	Alkalinity	1	mg/L
Laboratory analyses			
	Major ions		
	Calcium, dissolved	.02	mg/L
	Chloride, dissolved	.1 and .29	mg/L
	Dissolved solids, residue on evaporation	10	mg/L
	Fluoride, dissolved	.1	mg/L
	Magnesium, dissolved	.004 and .014	mg/L
	Manganese, dissolved	3.0 and 2.2	µg/L
	Potassium, dissolved	.1 and .24	mg/L
	Silica, dissolved	.05 and .09	mg/L
	Sodium, dissolved	.06 and .09	mg/L
	Sulfate, dissolved	.1 and .31	mg/L
	Nutrients		
	Nitrogen, ammonia, dissolved	.02	mg/L
	Nitrogen, nitrite, dissolved	.01	mg/L
	Nitrogen, nitrite plus nitrate, dissolved	.05	mg/L
	Nitrogen, organic, plus ammonia, dissolved	.1	mg/L
	Nitrogen, organic, plus ammonia, total	.1	mg/L
	Phosphorus, orthophosphate, dissolved	.01	mg/L
	Phosphorus, dissolved	.004 and .008	mg/L
	Phosphorus, total	.004 and .006	mg/L
	Organic carbon		
	Dissolved	.1 and .33	mg/L
	Suspended	.1 and .2	mg/L
	Trace elements		
	Aluminum, dissolved	1	µg/L
	Antimony, dissolved	1	µg/L
	Arsenic, dissolved	1 and 2	µg/L
	Barium, dissolved	1	µg/L
	Beryllium, dissolved	1	µg/L
	Boron, dissolved	16	µg/L
	Cadmium, dissolved	1	µg/L
	Chromium, dissolved	1 and .8	µg/L
	Cobalt, dissolved	1	µg/L
	Copper, dissolved	1	µg/L
	Iron, dissolved	10	µg/L
	Lead, dissolved	1	µg/L
	Lithium, dissolved	1	µg/L
	Molybdenum, dissolved	1	µg/L
	Nickel, dissolved	1	µg/L
	Selenium, dissolved	1 and 2.4	µg/L
	Silver, dissolved	1	µg/L
	Strontium, dissolved	1	µg/L
	Thallium, dissolved	.9	µg/L
	Uranium, dissolved	1	µg/L
	Vanadium, dissolved	1	µg/L
	Zinc, dissolved	1	µg/L

Table 4. Minimum reporting level of physical properties and chemical constituents measured at fixed sites in the Great Salt Lake Basins study unit—Continued

Activity	Physical property or chemical constituent	Minimum reporting level	Unit
	Sediment		
Datalogger	Suspended	1	mg/L
	Streamflow, 15-minute interval	.01	Cubic foot per second
	Specific conductance, 15-minute interval	1	Microsiemen per centimeter at 25 degrees Celsius
	Water temperature, 15-minute interval	.1	Degree Celsius

The specific-conductance value of water samples from the sites ranged from 4,870 $\mu\text{S}/\text{cm}$ at Bear River near Corinne (site 4) to 111 $\mu\text{S}/\text{cm}$ at Little Cottonwood Creek at Crestwood Park (site 7). The highest median specific-conductance value of water samples was 1,320 $\mu\text{S}/\text{cm}$ at site 10, Jordan River at Salt Lake City (fig. 15). Streamflow components contributing to the high median specific-conductance value calculated for this site include discharge from Utah Lake, effluent from waste-water treatment plants, and inflow from tributary streams that drain urban areas. Specific-conductance values and dissolved-solids concentration measured in samples from the GRSL study-unit sites correlate very well. The coefficient of determination (R^2) when all fixed-site specific-conductance and dissolved-solids measurements were compared was 0.99. Three measurements of specific-conductance values above 4,000 $\mu\text{S}/\text{cm}$ were made at site 4 during June to August 2000 when streamflow was very low. Site 8, Little Cottonwood Creek at Jordan River, had the largest range of specific-conductance values; a maximum of 4,020 $\mu\text{S}/\text{cm}$ and a minimum of 200 $\mu\text{S}/\text{cm}$.

Dissolved-solids concentration was lowest at most sites during March to June, when snowmelt runoff was a major streamflow component (fig. 16). Dissolved-solids concentration was highest at most sites from July through October, when water with a lower dissolved-solids concentration was removed at upstream diversions and irrigation return was a major streamflow component. When grouped by basin, median dissolved-solids concentrations were highest at sites with mixed land uses (sites 4, 6, and 10). Site 10 had the highest median concentration of dissolved solids for each of the periods shown in figure 16. Throughout the study period, site 4 had the largest range of dissolved-solids concentration, from 339 to 2,750 mg/L. Rangeland and forest sites in all three

GRSL river systems generally had low concentrations (less than 500 mg/L) of dissolved solids throughout the year. Dissolved-solids concentrations at site 8, Little Cottonwood Creek at Jordan River, generally were high except when runoff from mountain snowmelt or summer rainstorms were large components of streamflow (fig. 17). Site 8 had the second highest median concentration of dissolved solids during two of the periods shown in figure 16. High dissolved-solids concentrations at this site were likely a result of road salting and inflows from subsurface drains.

Irrigation is the primary water use in the GRSL study unit. Utah waters protected for agricultural uses, such as irrigation of crops and stock watering, need a dissolved-solids concentration of less than 1,200 mg/L to meet the beneficial-use designation (Utah Department of Administrative Services, 2003). Five of 290 samples from the sites exceeded a concentration of 1,200 mg/L (fig. 16): three samples from site 4 during the summer of 2000, and one sample each from sites 7 and 8. High dissolved-solids concentrations at sites 7 and 8 were associated with winter storm runoff. Samples collected for dissolved-solids concentration during this study indicate that water at the sites is generally not limited in its use for agricultural purposes, except for parts of the lower Bear River during extremely low flows.

Streams in the GRSL study unit generally have a pH near the upper range of natural water (6.5 to 8.5) described by Hem (1992) (fig. 15). The highest pH measured in water samples from the sites was 8.9 at site 5; the lowest was 7.1 at site 10. The median pH of all samples from the sites was 8.2. Water at urban site 8 and mixed-land-use sites 6 and 10 had the lowest median pH; rangeland/forest sites 2 and 5 had the highest median pH at 8.5.

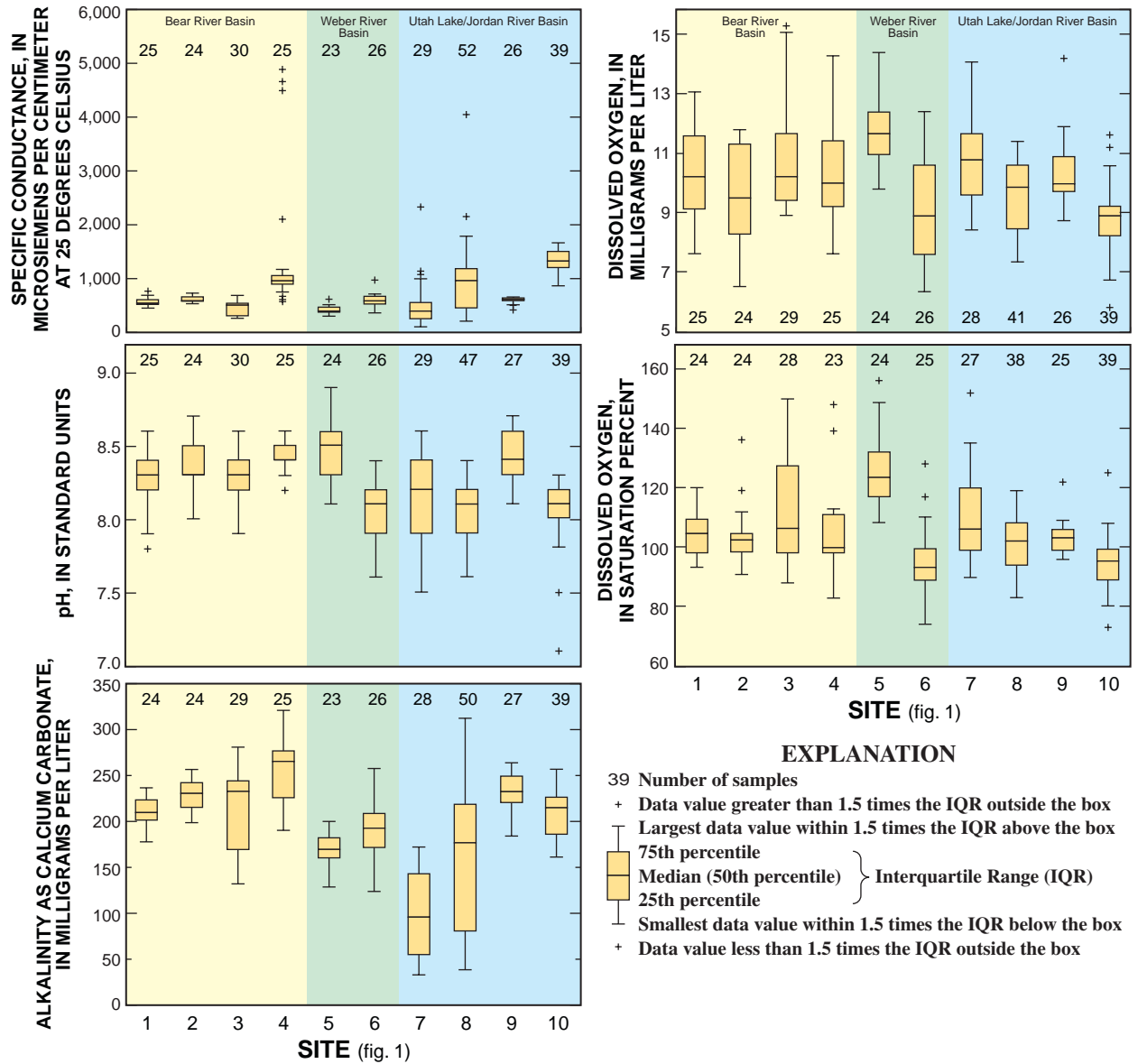


Figure 15. Specific-conductance value, pH, alkalinity, and dissolved oxygen in water samples from fixed sites in the Great Salt Lake Basins study unit.

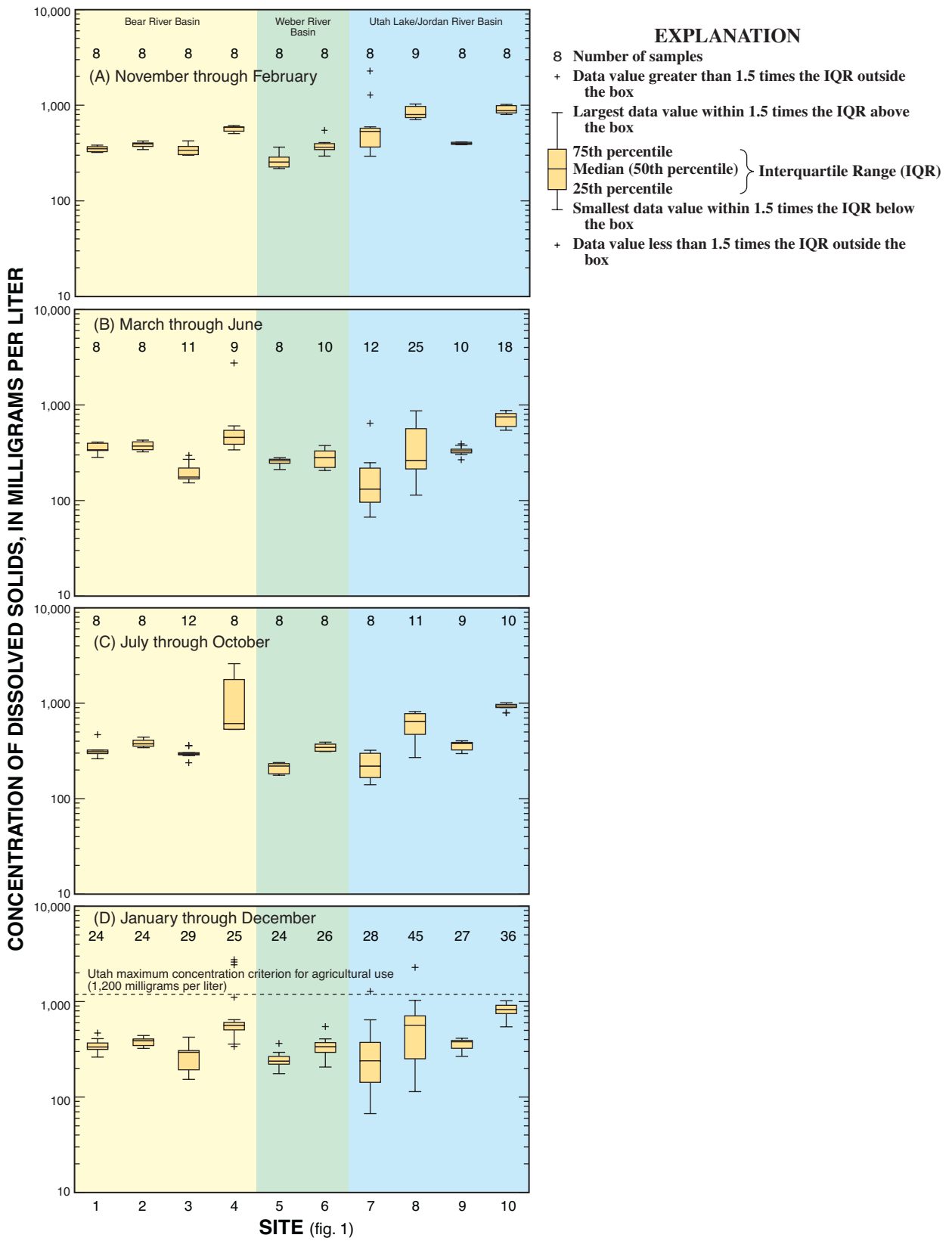


Figure 16. Range and distribution of dissolved solids in water samples from fixed sites during (A) November through February, (B) March through June, (C) July through October, and (D) January through December, Great Salt Lake Basins study unit.

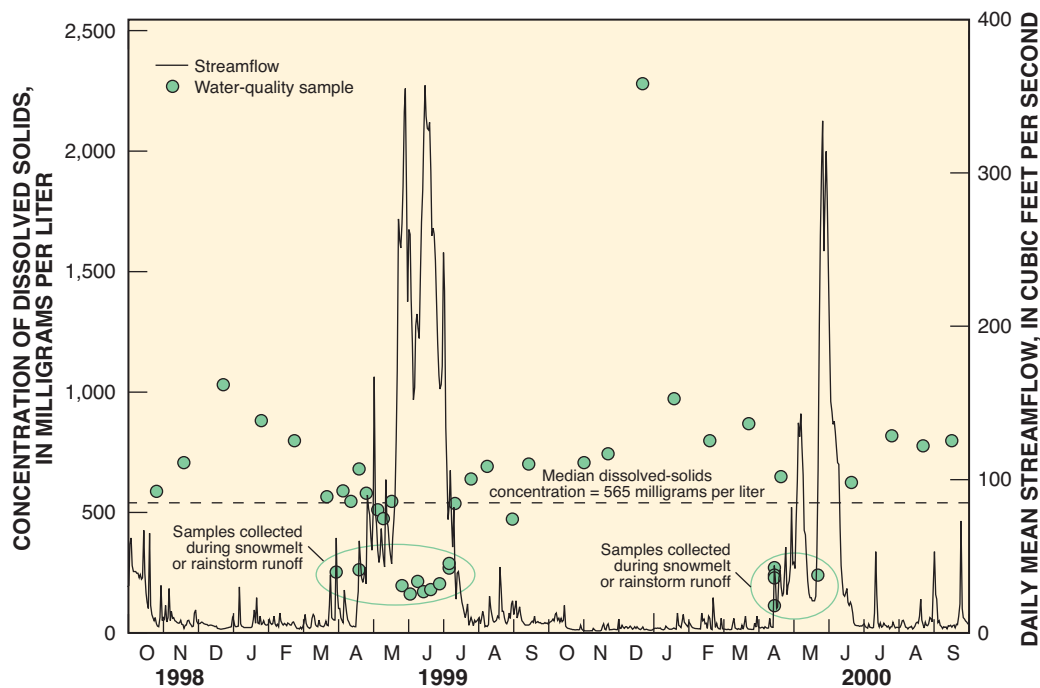


Figure 17. Dissolved-solids concentration and streamflow at site 8, Little Cottonwood Creek at Jordan River, Salt Lake City, Utah.

Water temperature was monitored continuously at the sites. There are gaps in the water-temperature record for most sites because of malfunctions or loss of equipment; however, eight of the sites have water-temperature data for more than 85 percent of the study period. Sites 4 and 5 have water-temperature data for about 60 percent of the study period. The data gaps, in most cases, did not preclude comparisons of water temperature among sites. Water temperatures were slightly warmer at most sites during WY 2000 than in WY 1999 because of lower flows and warmer air temperatures. Daily water temperature generally increased in each GRSL river basin from upstream to downstream sites (fig. 18). The increase in water temperature probably was a result of differences in altitude, land use, streamflow, and regulation.

Mean daily water temperature followed a similar pattern at all of the fixed sites on the Bear River with near-freezing temperatures at most sites during winter

and near or above 20°C during the summer. Because it is in a smaller subbasin with a different flow regime, the Cub River near Richmond (site 3) has a slightly different temperature pattern than that of the Bear River sites. Winter and spring water temperatures are slightly warmer and the effect of snowmelt is more pronounced, causing water temperatures in May and June to be colder than at the other sites in the Bear River basin. The Bear River near Corinne (site 4) had the highest daily temperatures, as high as 27.7°C.

The few data for the Weber River near Coalville (site 5) indicate that releases from upstream reservoirs moderate the water temperature at this site, resulting in winter temperatures several degrees above freezing and summer temperatures well below 20°C. Daily water temperatures at the Weber River near Plain City (site 6) were warmer in both summer and winter than those at upstream site 5.

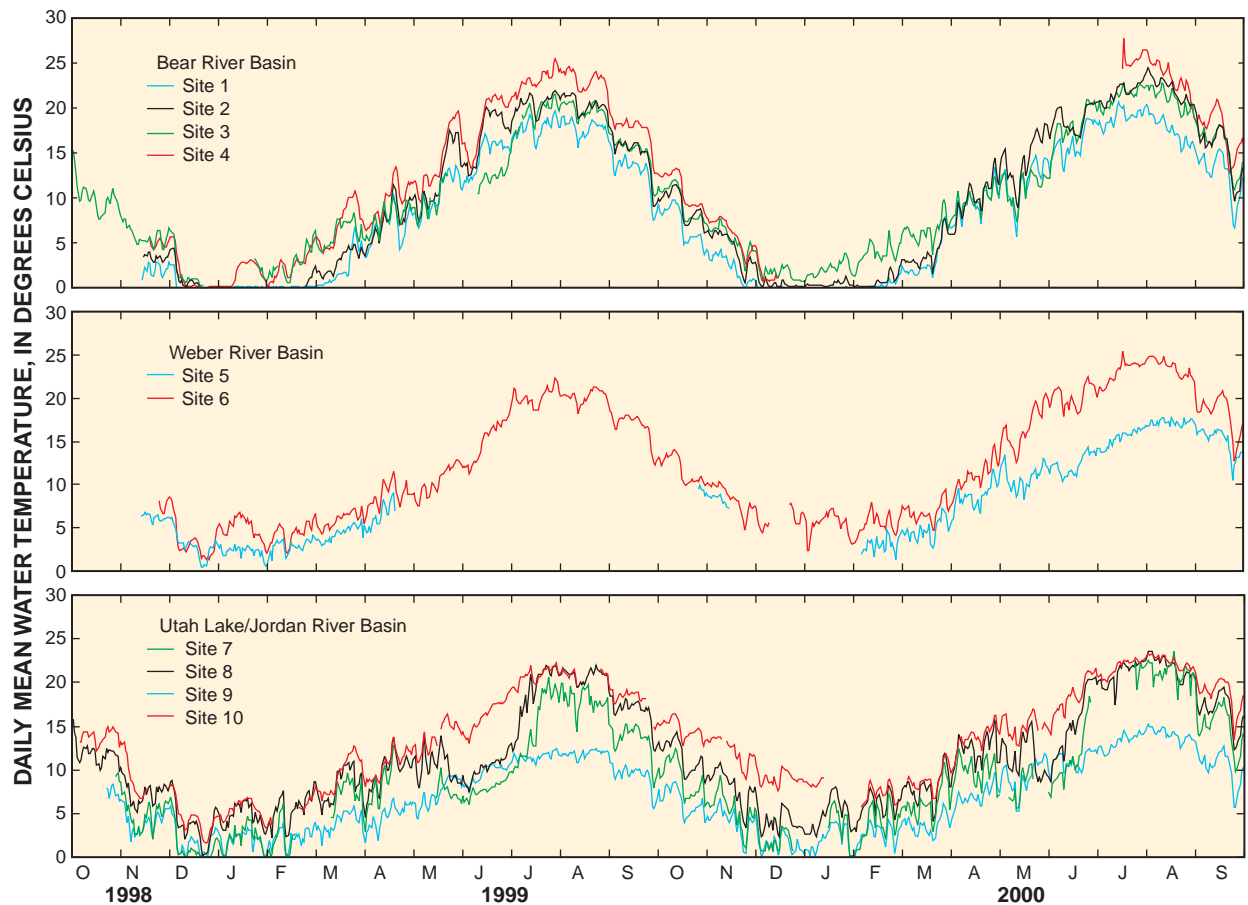


Figure 18. Daily mean water temperature at fixed sites in the Great Salt Lake Basins study unit.

Daily mean water temperature at site 9 on Red Butte Creek was, on average, 4.5°C cooler than at site 8 on Little Cottonwood Creek, and 6.6°C cooler than at site 10 on the Jordan River. Daily water temperatures generally were 7 to 10°C cooler at site 9, relative to sites 8 and 10, during July to September. The cooler water temperatures at site 9 may be attributed to cooler air temperature, more riparian cover and ground-water inflow, and minimal effect from urbanization. A substantial decrease in daily water temperature occurred at sites 7 and 8 during May and June as snowmelt became the primary source of flow. Water temperatures at sites 8 and 10 generally were much warmer during the winter than those at the other sites in the Jordan River basin, possibly because of the inflow of warmer water from urban runoff or waste-water treatment plants.

DO concentration at most sites at the time of sample collection generally was at or above saturation and ranged in concentration from 5.8 to 15.3 mg/L. DO concentration at site 6, Weber River near Plain City, and site 10, Jordan River at Salt Lake City, generally was less than saturated at the time of sample collection (fig. 15). Lower DO concentration at sites 6 and 10 probably was a result of increased biological oxygen demand from microbial degradation of organic matter, as well as less natural aeration because of minimal channel slope and stream turbulence. The highest median DO saturation percent was 124 at site 5, Weber River near Coalville. The stream reach near site 5 has a fairly steep gradient to support aeration, flow is generally cold and clear, and there is abundant algal and macrophytic growth.

Streams and rivers in the GRSL study unit are typically alkaline. Alkalinity generally was higher in

the Bear River basin than in other basins in the study unit, increasing from upstream sites to downstream sites (fig. 15). Most alkalinity (as calcium carbonate (CaCO₃)) concentrations in this basin were greater than 200 mg/L. Site 4, the mixed-land-use site near the mouth of the Bear River basin, had the highest alkalinity measured, 321 mg/L; and the highest median alkalinity concentration among the fixed sites, 273 mg/L. Alkalinity at the Weber River sites was lower than that at Bear River sites and increased slightly from upstream to downstream. Most alkalinity concentrations from this basin were less than 200 mg/L. Site 7, an urban site on Little Cottonwood Creek, had the lowest alkalinity measured, 31 mg/L, and the lowest median alkalinity concentration among the fixed sites, 94 mg/L. Many of the samples from sites 7 and 8 on Little Cottonwood Creek had large components of snowmelt runoff or rainstorm runoff, both having low dissolved-solids concentrations. The median alkalinity concentration at site 9 on Red Butte Creek was 231 mg/L, higher than that at other sites in the Jordan River basin. Calcite deposits in the stream reach near site 9 are evidence of the high calcium carbonate concentration in the stream.

Major Ions

Major-ion chemistry at GRSL sites is affected by environmental and anthropogenic influences and varies by basin, season, and predominant land use/land cover. The similar geology in the common headwater areas of the Uinta Mountains of the Bear, Weber, and Utah Lake/Jordan River basins influences the major-ion chemistry of water in each of the basins.

Chemical analysis of water samples from site 1 in the Bear River basin, site 5 in the Weber River basin, and site 9 in the Utah Lake/Jordan River basin indicates that the water from each site was of a similar calcium bicarbonate type (fig. 19). These three sites are the nearest to the headwaters of their respective basins, and the major-ion chemistry is mostly the result of dissolution of minerals in the mountain block. Because of their location, these sites provide a reference for comparing downstream sites in their respective basins. Seasonal changes in major-ion chemistry at these sites were small, with some dilution from snowmelt during spring runoff and some increased concentration of solutes during base flow.

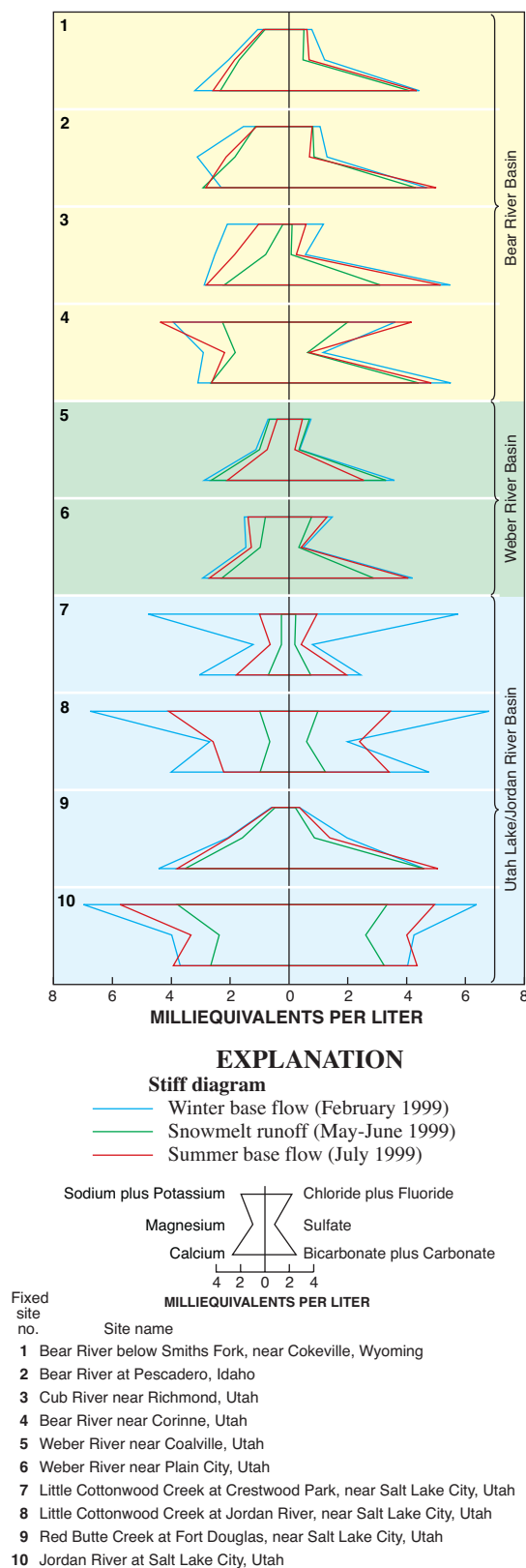


Figure 19. Chemical composition of water samples collected during winter base flow, snowmelt, and summer base flow conditions at fixed sites in the Great Salt Lake Basins study unit, 1999 water year.

The predominant land use/land cover associated with sites 1 and 2 is rangeland. The major-ion chemistry of water samples collected from these sites is very similar, indicating the dissolution of calcium carbonate type rock and soils. The winter base-flow sample from site 2 was enriched with magnesium and depleted in calcium. Ground water discharged to the stream in the vicinity of Bear Lake, or Bear Lake water itself (both enriched with magnesium), may have been components of streamflow during winter base-flow conditions and contributed to magnesium enrichment.

Water samples from site 3, an agriculture indicator site on the Cub River, had concentrations of major ions similar to those from rangeland sites 1 and 2 during summer base-flow conditions, lower concentrations during snowmelt runoff, and were enriched in sodium and chloride in the winter base-flow sample (fig. 19). Although potassium concentration was much lower than sodium concentration in water samples from the sites in the Bear River basin, potassium was enriched in water samples from site 3. The median potassium to sodium ratio in water samples from most sites varied from 0.04 to 0.06 (fig. 20). The median potassium to sodium ratio in samples from site 3, however, was 0.15. Runoff and

leaching from fertilized agricultural areas may be the cause of potassium enrichment at site 3.

Site 4, Bear River near Corinne, is a mixed-land-use site near the outlet of the Bear River basin. Water samples from site 4 were enriched with sodium, chloride, and potassium during all flow regimes, probably because of solutes in inflow from the Malad River and Salt Creek, and in irrigation return flow.

Calcium and bicarbonate are the dominant ions in water samples from sites 5 and 6 in the Weber River basin. Sulfate concentrations are particularly low at these sites relative to concentrations at other sites. Major-ion concentrations in water samples from site 5 did not vary much seasonally but were lowest during those periods when a large volume of streamflow was released from upstream reservoirs. The chemical composition and major-ion concentration in water samples from site 6 were very similar to those from site 5 during periods of snowmelt runoff. At site 6, upstream removal of water with low dissolved-solids concentration for irrigation and municipal supply use left inflows from urban and agricultural areas as primary streamflow components during base-flow conditions and caused water samples to be enriched with sodium and chloride.

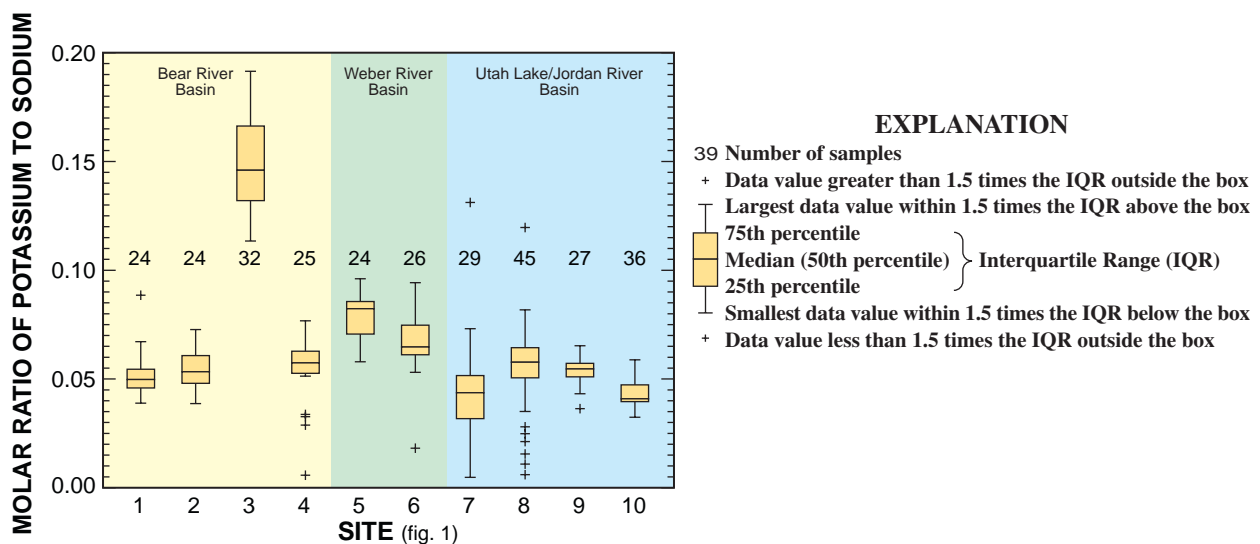


Figure 20. Molar ratio of potassium to sodium in water samples from fixed sites in the Great Salt Lake Basins study unit.

Samples from each of the four sites in the Utah Lake/Jordan River basin had markedly different major-ion chemistry. The calcium bicarbonate type water in all samples from site 9 on Red Butte Creek, a forest/rangeland indicator site, is representative of that of most headwaters in this basin. Site 9 is in an undeveloped subbasin, and ground-water discharge and surface runoff of precipitation are the only streamflow components. Geochemical reactions among minerals in the aquifer material and in the ground water, which is discharged to the stream, largely determine the major-ion composition of water at this site. Samples from sites 7 and 8, urban indicator sites on Little Cottonwood Creek, showed the largest range of major-ion concentrations. Calcium and bicarbonate were the predominant ions in the May-June samples, whereas sodium and chloride were dominant during winter base-flow conditions. Dissolved-solids concentrations measured in samples collected during May-June were less than one-fourth of those measured in some samples collected during winter base-flow conditions. The winter base-flow samples had been enriched with sodium and chloride, probably from road salt (Gerner, 2003). Summer base flow at sites 7 and 8 consisted mostly of ground-water inflow and runoff from lawn irrigation. Differences in major-ion composition at these two sites during summer base-flow conditions may be a result of differences in source water. The ground-water component of streamflow at site 7 is mostly from a localized, shallow, perched aquifer, and the irrigation-return component generally is from residential systems that use water from the public-supply system. Base flow at site 8 includes ground-water seepage from the shallow aquifer in the basin-fill deposits and irrigation return from residential systems that use water from the public-supply system and from canals that transport water from the Jordan River. The urban area associated with site 8 is much larger than that with site 7, and most of the increase in major-ion concentrations between the two sites can be attributed to the influence of urban land cover.

Site 10 on the Jordan River generally had the highest concentration of major ions of all the sites. Winter base-flow samples were slightly enriched with sodium and chloride, probably as a result of road salt dissolved in surface runoff to the Jordan River and tributary streams. Less seasonal change in major-ion chemistry occurred at site 10 than at sites 7 and 8, mostly because Utah Lake is a consistent source of major ions for the Jordan River, but also because

ground-water inflow and discharge from waste-water treatment facilities are fairly large and consistent components of flow at site 10.

Nutrients and Suspended Sediment

Nutrients, including nitrogen and phosphorus, are essential to the health and function of natural ecosystems. Insufficient amounts of nutrients can lower growth rates of primary producers, such as aquatic vegetation, and limit the diversity and productivity of the ecosystem. Excessive nutrient loading can result in public health concerns and a general decline of the aquatic ecosystem health caused by accelerated growth of algae (U.S. Environmental Protection Agency, 1998). Nutrients occur naturally in streams as a result of mineral weathering and biological activity in the streambed sediment. Streams may receive additional nutrients from agricultural and urban runoff, atmospheric deposition, and waste-water discharge.

Nitrogen species analyzed for included ammonia, nitrite, nitrite plus nitrate, ammonia plus organic nitrogen, and total ammonia plus organic nitrogen (table 4). From these measured constituents, particulate organic nitrogen, dissolved organic nitrogen, dissolved nitrate, and total nitrogen can be calculated (table 5). Phosphorus species analyzed for at the fixed sites included total phosphorus, orthophosphate, and dissolved phosphorus.

The total-nitrogen concentration measured at sites 1, 2, 5, and 9 generally was less than 1 mg/L, as low as 0.06 at site 9. The drainage basins above these sites are predominantly rangeland and forest land cover. Total-nitrogen concentration at sites 3 and 4, with more agricultural land use, ranged from 0.5 to 4.6 mg/L. Total-nitrogen concentration at sites 6, 7, 8, and 10, with larger amounts of urban land cover, ranged from 0.3 to 11 mg/L. Nitrogen in outflow from waste-water treatment plants and urban runoff contributed to site 10 having the highest median total-nitrogen concentration (2.79 mg/L) among the sites (fig. 21). Agricultural runoff and outflow from waste-water treatment plants entering Cub River contributed to site 3 having the second highest median total-nitrogen concentration (1.80 mg/L) among fixed sites.

Table 5. Nitrogen species analyzed for and calculated from water samples collected at fixed sites in the Great Salt Lake Basins study unit

[NWIS, National Water Information System; NA, not applicable]

Nitrogen species	Derivation	NWIS parameter code	Algorithm for calculated species	Remark
Total				
Nitrogen	Calculated	600	(Ammonia plus organic nitrogen) plus (nitrite plus nitrate)	Total nitrogen is made up of dissolved inorganic and organic nitrogen and particulate organic and inorganic nitrogen, with N ₂ gas subtracted.
Ammonia plus organic	Measured	625	NA	Total Kjeldahl nitrogen.
Particulate				
Particulate organic	Calculated	None	(Total ammonia plus organic nitrogen) minus (dissolved ammonia plus organic nitrogen)	Particulate organic nitrogen is composed of detritus and other dead cell matter in addition to phytoplankton and other living protoplasm.
Dissolved¹				
Nitrogen	Calculated	602	(Dissolved ammonia plus organic nitrogen) plus (nitrite plus nitrate)	
Ammonia plus organic	Measured	623	NA	Filtered Kjeldahl nitrogen.
Organic	Calculated	607	(Dissolved ammonia plus organic nitrogen) minus (dissolved ammonia)	Dissolved organic nitrogen consists of humic and fulvic acids, macromolecules, organic colloids, and other organic molecule fragments.
Ammonia	Measured	608	NA	Ammonia is present in aquatic systems mainly as the ion NH ₄ ⁺ in waters with pH below 9.2. It is rapidly taken up by phytoplankton and other aquatic plants for growth.
Nitrite	Measured	613	NA	Nitrite, a serious pollutant in high concentrations, is formed by the bacterial reduction of nitrate to nitrite or the incomplete oxidation of NH ₃ .
Nitrite plus nitrate	Measured	631	NA	
Nitrate	Calculated	618	(Nitrite plus nitrate) minus (nitrite)	Nitrate is formed by the oxidation of ammonia and nitrite.

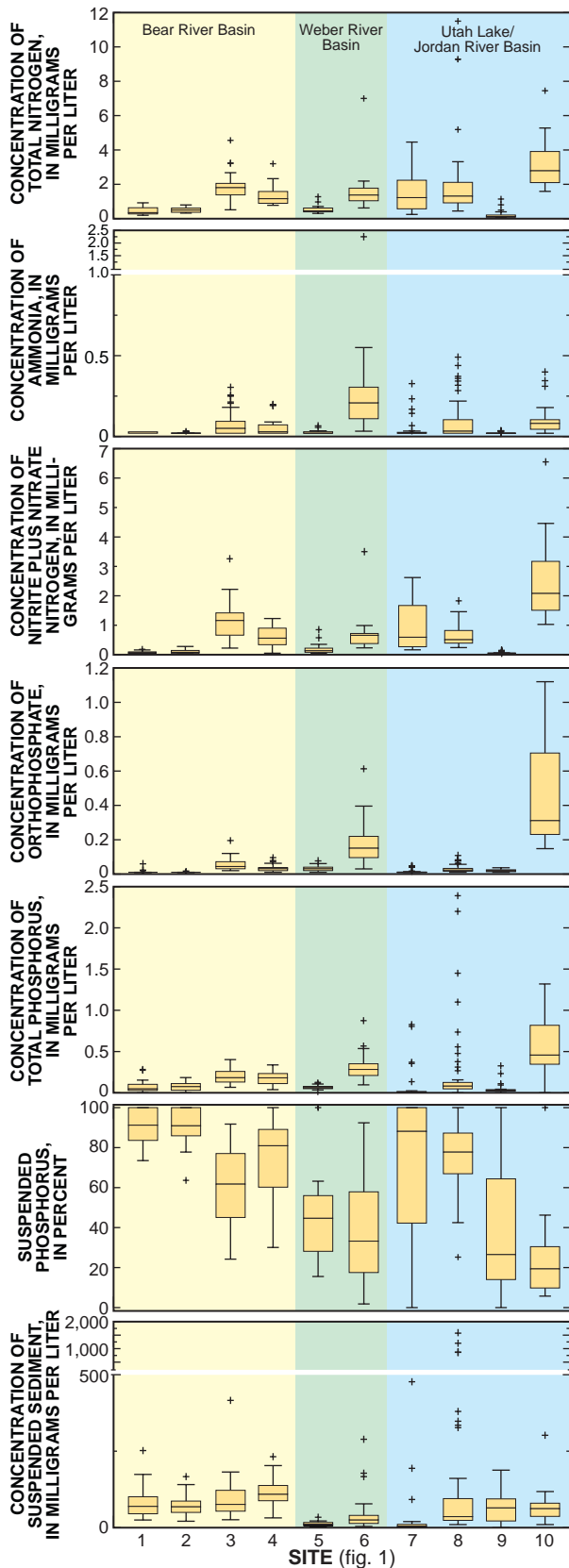
¹“Dissolved” refers to the solute phase of a sample that has passed through a 0.45-micron filter.

Seasonal changes in total-nitrogen concentration occurred at most sites. Total-nitrogen concentration increased at most sites during base-flow conditions when discharge was low, ground water or treated waste water was the primary streamflow component, and uptake by aquatic vegetation was reduced. Total-nitrogen concentration decreased at most fixed sites during periods of snowmelt runoff. Because of discharge from upstream reservoirs, less seasonal change in total-nitrogen concentration occurred at sites 2 and 5 than at other sites.

The median concentration of dissolved ammonia at GRSL sites ranged from less than 0.02 mg/L (at sites 1, 2, 5, 7, and 9) to 0.21 mg/L (site 6) (fig. 21). Ammonia concentrations generally were higher at sites

6 and 10, probably because of contributions from waste-water treatment plants. Elevated concentrations of ammonia were detected at sites 7 and 8 in samples that had storm runoff from urban areas.

The median nitrite plus nitrate concentration at the GRSL sites ranged from less than 0.05 mg/L (site 9) to 2.08 mg/L (site 10) (fig. 21). Nitrite plus nitrate concentrations were lowest at sites 1, 2, 5, and 9 where the drainages mostly have rangeland and forest land cover. Nitrite plus nitrate concentrations were highest at sites with runoff from agricultural land (sites 3 and 4) and sites with more urban land cover (sites 6, 7, 8, and 10).



EXPLANATION

- + Data value greater than 1.5 times the IQR outside the box
- Largest data value within 1.5 times the IQR above the box
- 75th percentile
- Median (50th percentile)
- 25th percentile
- } Interquartile Range (IQR)
- Smallest data value within 1.5 times the IQR below the box
- + Data value less than 1.5 times the IQR outside the box

The concentration of nitrogen species varies as the components of streamflow vary. Distribution of nitrogen species in a representative sample from each site (fig. 22) is shown during two base-flow periods (January and July 2000), low-altitude snowmelt runoff (March 2000), and high-altitude snowmelt runoff (May 2000). The overall height of the stacked bars in figure 22 is equal to total-nitrogen concentration in each sample.

Dissolved nitrate was the principal nitrogen component in water samples collected during January and March from GRSL sites. Dissolved ammonia and nitrite concentrations were elevated in water samples collected from many sites in January, possibly in part because of reduced uptake of nitrogen by aquatic vegetation. A retrospective analysis of nitrate data from the GRSL study unit by Thiros (2000) concluded that nitrate concentration was highest in water from wells associated with agricultural and urban land uses. A ground-water component may have contributed to the elevated nitrate concentrations in samples from sites 3 and 4 in the Bear River basin, site 6 on the Weber River, and sites 7, 8, and 10 in the Jordan River basin. Lower altitude snowmelt runoff was a major component of streamflow and a nutrient source at some sites during March 2000. Animal manure, either spread as fertilizer or resulting from livestock feeding operations and transported to streams in snowmelt runoff, may have been a substantial source of nitrate in samples collected during March.

Water samples from most GRSL sites had a much lower total-nitrogen concentration during May when higher altitude snowmelt was the major streamflow component. Dissolved and particulate organic nitrogen were the principal forms of nitrogen in water samples collected during May and generally made up a higher percentage of total nitrogen in samples relative to the percentage in samples collected during other periods.

Figure 21. Concentration of suspended sediment, percentage of particulate phosphorus, and different forms of phosphorus and nitrogen in water samples from fixed sites in the Great Salt Lake Basins study unit.

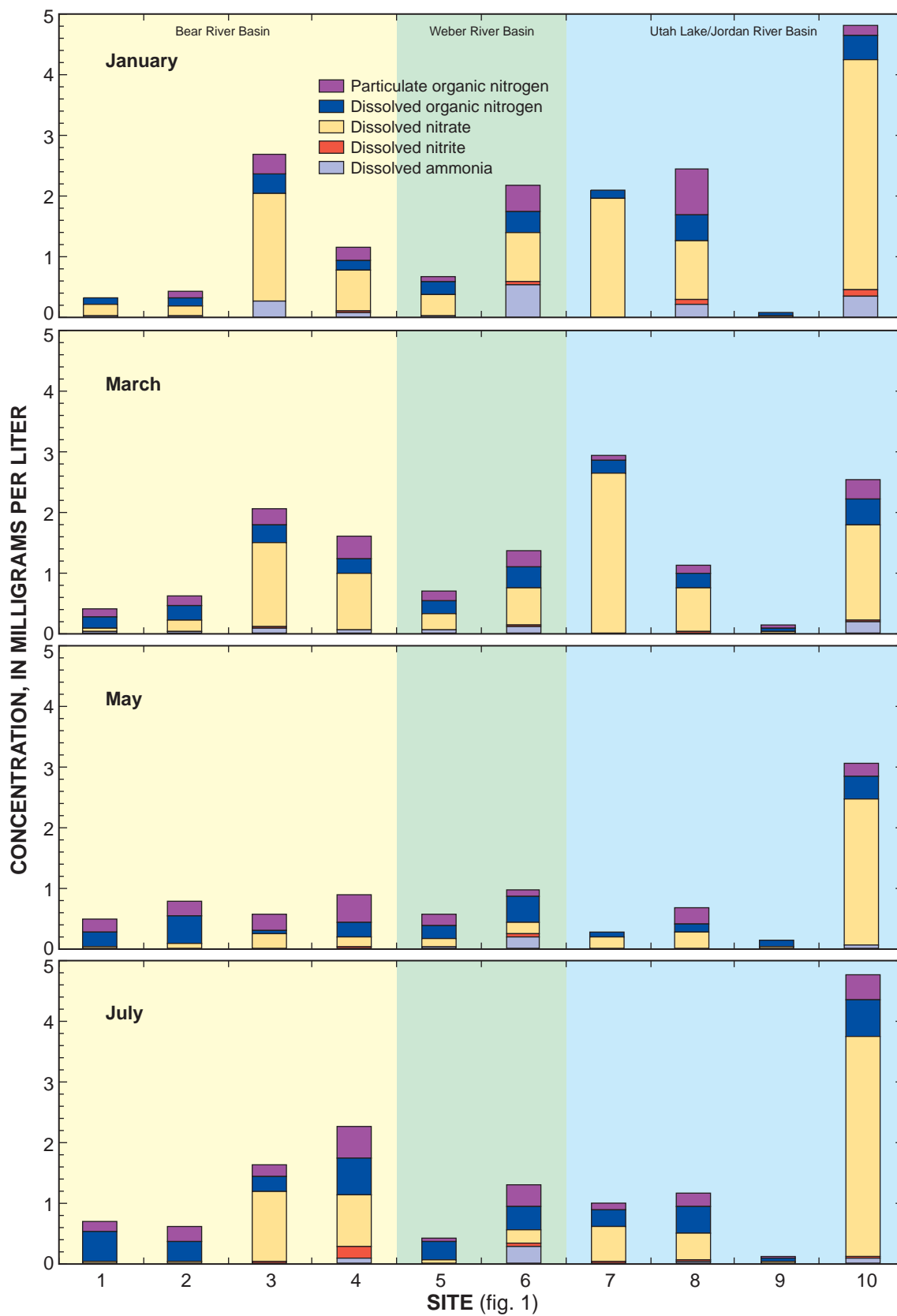


Figure 22. Concentration of dissolved and particulate nitrogen in water samples from fixed sites in the Great Salt Lake Basins study unit, January, March, May, and July 2000.

During July, withdrawal of water (with a lower concentration of nutrients) from basin headwaters for irrigation resulted in lower streamflow and higher nitrogen concentration at some GRSL fixed sites. Streamflow components included ground-water discharge and irrigation return flow at most sites, and discharge from waste-water treatment plants at several sites. Organic nitrogen and nitrate were the principal forms of nitrogen in water samples collected during July.

The EPA has established AWQC for maximum ammonia concentrations in surface water (U.S. Environmental Protection Agency, 1999b). This criterion varies with pH and water temperature. Concentrations of dissolved ammonia in 95 percent of the samples from GRSL sites were less than 0.31 mg/L. Within the ranges of pH (7.1 to 8.9) and water temperature (0 to 25°C) associated with samples from GRSL sites, ammonia concentrations did not exceed the chronic criterion. The maximum dissolved ammonia concentration was 2.25 mg/L (site 6). None of the samples from the GRSL sites had a nitrate concentration above the EPA drinking-water standard of 10 mg/L. The maximum dissolved nitrate concentration at the sites was 6.54 mg/L (site 10). The Utah Department of Environmental Quality has designated a nitrate concentration of above 4.0 mg/L as an indicator of pollution. This level was exceeded three times at site 10, but was not exceeded at the other sites.

Orthophosphate concentrations were elevated at mixed-land-use sites 6 and 10 relative to at the other sites, probably as a result of a higher percentage of treated waste water in streamflow at these sites. Orthophosphate concentration in water samples from site 6 ranged from 0.03 to 0.61 mg/L with a median concentration of 0.15 mg/L (fig. 21). Orthophosphate concentration in water samples from site 10 ranged from 0.15 to 1.12 mg/L with a median concentration of 0.31 mg/L. Orthophosphate concentrations were less than 0.21 mg/L in water samples from the other sites and the median concentration was less than 0.1 mg/L.

Site 8 had the largest range in concentration of total phosphorus; from 0.029 mg/L during snowmelt runoff to 2.39 mg/L when storm runoff from the urban area was a large component of streamflow (fig. 21). Site 10, a mixed-land-use site heavily influenced by urban land uses, had a median total phosphorus concentration of 0.47 mg/L, highest among the sites. Site 9, a forest/rangeland site located in an undeveloped watershed, had a median total phosphorus

concentration of 0.03 mg/L, the lowest among the sites. According to Clark and others (2000), the median flow-weighted concentration of total phosphorus at 85 sites on streams in undeveloped areas of the United States was 0.022 mg/L.

National criteria have not been established for the concentration of either dissolved or total phosphorus in streams. The EPA recommends that to prevent nuisance aquatic-plant growth, total phosphorus concentration should not exceed 0.10 mg/L in streams not discharging directly to lakes or impoundments (U.S. Environmental Protection Agency, 1986). Fifty percent of the samples collected at the sites exceeded a total phosphorus concentration of 0.10 mg/L. The median total phosphorus concentration at sites 3, 4, 6, and 10 exceeded 0.10 mg/L (fig. 21), indicating that the potential for eutrophication exists. Sites 1, 2, 5, 7, 8, and 9 had a median concentration of total phosphorus ranging from 0.01 mg/L to 0.08 mg/L.

The percentage of particulate phosphorus was highest in samples from sites in the Bear River basin (fig. 21). The phosphorus contained in water samples from urban mixed-land-use sites 6 and 10 generally was less than 50 percent particulate.

Total phosphorus concentration was well correlated with suspended sediment concentration in water samples from sites 1 (fig. 23), 7, and 8. When total phosphorus concentration in water samples was compared to suspended sediment the R^2 for these sites ranged from 0.690 to 0.890, with total phosphorus generally increasing with increased suspended sediment. Much of the phosphorus present in these samples was bound to sediment. The coefficient of determination for the relation between sediment and total phosphorus in samples collected from the rest of the sites ranged from 0.003 to 0.426.

The highest concentrations of suspended sediment at GRSL sites were measured in water samples collected during a spring storm at site 8, the urban indicator site on Little Cottonwood Creek. These samples contained concentrations of suspended sediment as high as 1,580 mg/L (fig. 21). The median concentration for all samples collected at this site was 36 mg/L. Although the highest concentration occurred on Little Cottonwood Creek (Utah Lake/Jordan River basin), suspended-sediment concentrations generally were higher in the Bear River basin than in the Weber or Utah Lake/Jordan River drainage basins. Median concentrations of suspended sediment at sites in the

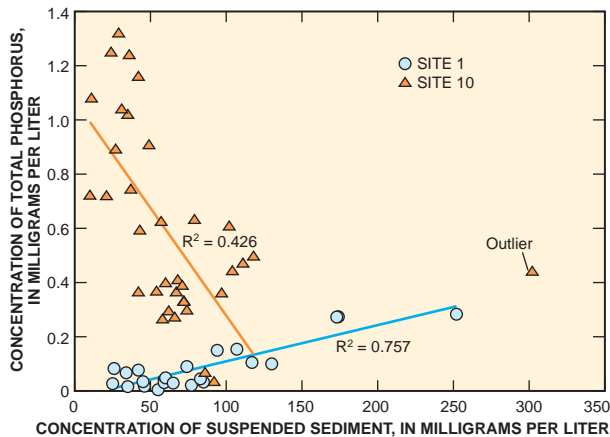


Figure 23. Concentration of total phosphorus in relation to suspended sediment in water samples from fixed sites 1 and 10 in the Great Salt Lake Basins study unit.

Bear River basin ranged from 68 to 110 mg/L. Cutting of unstable stream banks during high or fluctuating streamflows, presence of livestock in riparian areas, and runoff from cropland during fallow periods are probably contributors to the higher sediment concentrations measured in samples from these sites.

The median concentration of suspended sediment in water samples collected from sites 5 and 6 on the Weber River and site 7 on Little Cottonwood Creek was the lowest among GRS L sites, less than 30 mg/L. Upstream from these sites, streambeds generally are made up of gravel, cobbles, and boulders; hence, banks are less prone to erosion. Rockport Reservoir captures much of the sediment in streamflow above site 5. Additionally, streamflow at site 7 often consists primarily of ground-water inflow that contributes little or no suspended sediment to the stream.

Trace Elements

Water samples analyzed for dissolved trace elements were collected at all sites to determine occurrence of these constituents and compare them with water-quality standards. Twenty or more samples were collected at sites 5, 7, 8, and 10 (table 3). One or two samples were collected from each of the remaining sites. Samples were analyzed for a suite of 22 trace elements (table 4).

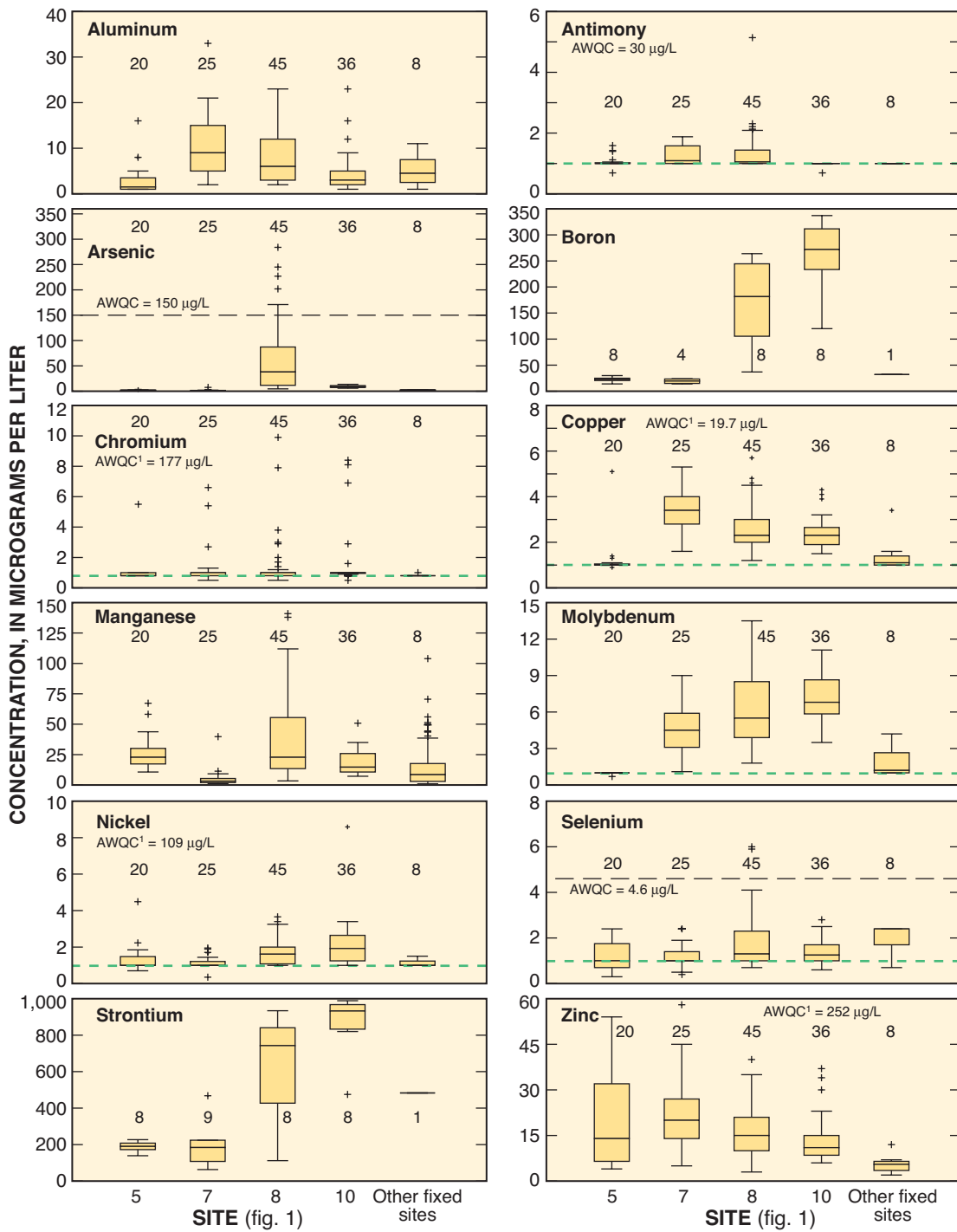
Beryllium, cadmium, cobalt, and silver were not detected in any sample above the MRL of 1 µg/L. Chromium was detected in 22 of 134 samples. The maximum concentration of chromium detected in samples from the sites was 9.9 µg/L at site 8 (fig. 24). Lead was detected in 5 of 134 samples and the maximum concentration, 1.58 µg/L, occurred at site 5. Nickel was detected in 90 of 134 samples and the maximum concentration, 8.6 µg/L, occurred at site 10. Concentrations of chromium, lead, and nickel did not exceed the AWQC guidelines. Boron, molybdenum, and strontium concentrations were enriched in samples from urban sites (8 and 10).

Arsenic was detected in 127 of 139 water samples. Concentrations were less than 15 µg/L at all sites except site 8. Arsenic was detected in all 49 water samples from site 8 and the concentration ranged from 4.7 to 284 µg/L. The AWQC for arsenic, 150 µg/L, was exceeded in 8 of 49 samples at site 8. Surface runoff and ground-water seepage near smelter tailings are the likely source of arsenic solutes in samples from site 8 (Gerner, 2003).

Copper was detected in 116 of 134 water samples from GRS L sites. Concentration ranged from 0.9 µg/L to 5.7 µg/L. Copper concentration is generally too low and water hardness too high for copper in water samples from GRS L sites to exceed AWQC. Runoff from a spring rainstorm, however, lowered the hardness of the water in Little Cottonwood Creek and the AWQC for copper was exceeded twice in water samples collected from site 7 on Little Cottonwood Creek during that storm. Site 7 is located downstream from a historical mining district in an urban area, both of which may contribute to copper solutes in water samples from this site.

Selenium concentrations generally were low at all sites relative to the chronic AWQC, which is 4.6 µg/L for dissolved selenium. Two samples from site 8, Little Cottonwood Creek at Jordan River, exceeded the AWQC; the maximum concentration was 6.0 µg/L.

Zinc concentration was highest in samples from sites 5, 7, and 8. These three sites are downstream from historical mining districts and tailings are the most likely source of zinc to these streams. The maximum zinc concentration was 58 µg/L at site 7. None of the samples from this study had zinc concentrations above the AWQC when the criterion was adjusted for hardness.



EXPLANATION

- 8 Number of samples
- + Data value greater than 1.5 times the IQR outside the box
- + Largest data value within 1.5 times the IQR above the box
- 75th percentile
- Median (50th percentile) } Interquartile Range (IQR)
- 25th percentile
- Smallest data value within 1.5 times the IQR below the box
- + Data value less than 1.5 times the IQR outside the box
- - - - Minimum reporting level
- AWQC Ambient water-quality criteria for protection of aquatic wildlife, chronic exposure
- AWQC¹ Ambient water-quality criteria— Adjusted for average hardness of fixed-site samples (240 milligrams per liter as CaCO₃)
- µg/L Micrograms per liter

Figure 24. Concentration of selected trace elements in water samples from fixed sites in the Great Salt Lake Basins study unit.

Organic Compounds

Uncertainty in the risks associated with contamination of surface water by pesticides and VOCs exists; however, their presence may affect the use of surface water for drinking water and recreation and for support of aquatic life. Water samples from some sites were analyzed for these organic compounds to determine their occurrence in the GRSL study unit (table 3).

Because organic carbon in aqueous systems is important for a number of chemical and biological processes, water samples from GRSL sites were analyzed for dissolved organic carbon. Dissolved organic carbon can affect the transport and degradation of pollutants and can participate in reactions that result in either the dissolution or formation of minerals.

Pesticides

Pesticides (herbicides and insecticides) are applied in many agricultural and nonagricultural settings in the GRSL study unit. They are used to control unwanted vegetation and destructive insects. Pesticides become environmental contaminants when they are transported from the site of application and enter the broader environment. They can reach surface water through direct application, surface runoff, atmospheric deposition, and ground-water inflow. Most pesticides are applied in agricultural and urban areas that generally drain into surface-water systems, making these systems particularly vulnerable to pesticide contamination. Pesticides in streams and rivers become widely dispersed as they move through surface-water systems (Larson and others, 1997).

Water samples collected from sites 3, 5, 7, 8, 9, and 10 were analyzed for pesticides (table 3). Sites 3, 8, and 10 were sampled more frequently for pesticides because their drainage basins were most likely to experience pesticide application for agricultural or urban use. Results from pesticide sampling reported here are from only these three sites. Samples collected for pesticide analysis targeted those periods and events most likely to result in pesticide detections. Detection frequencies are likely biased because periods with minimal pesticide application were sampled less often than periods during which pesticides were applied.

Water samples were analyzed for pesticides by using both gas chromatography/mass spectrometry (GC/MS) and high-performance liquid chromatography/mass spectrometry (HPLC/MS) (table 3).

Samples were analyzed for 107 pesticides; 48 of them by GC/MS and 59 by HPLC/MS (table 6). The HPLC/MS method was a new method that was being validated at the USGS National Water Quality Laboratory during this study; hence, data from these analyses remain provisional. Pesticides detected in water samples analyzed by HPLC/MS are listed in table 7; however, no summary statistics associated with concentration are reported here. Most of the samples analyzed by HPLC/MS were held beyond the normal limit of 4 days, which may have resulted in degradation of some compounds initially present in the water samples to a concentration below the method reporting level.

Forty-three different pesticides were detected in samples from sites 3, 8, and 10 (tables 7 and 8): 21 at the Cub River agricultural site (site 3), 32 at the Little Cottonwood Creek urban site (site 8), and 33 at the Jordan River mixed-land-use site (site 10). Thirty-one of the pesticides detected were herbicides, 4 were herbicide metabolites, 7 were insecticides, and 1 was a fungicide. Among the pesticides analyzed by GC/MS, the herbicides atrazine and prometon, and the insecticides carbaryl and diazinon, were the most frequently detected. The highest average number of pesticides detected per sample was at site 8 and the least at site 3 (table 9).

Atrazine is an herbicide that selectively controls broadleaf weeds without injury to the target crop. It is moderately persistent, with a half-life of about 60 days. Atrazine was the most frequently detected pesticide at site 3. It was detected in more than 90 percent of the samples analyzed by GC/MS from sites 3 and 10. The median atrazine concentration detected was 0.010 µg/L at sites 3 and 8, and 0.012 µg/L at site 10. The highest concentration of atrazine, 0.13 µg/L, was detected at site 8. Deethylatrazine and deethyldeisopropylatrazine, metabolites or transformation products of atrazine, were detected in water samples analyzed by HPLC/MS at all three sites.

Table 6. Minimum reporting level of pesticides analyzed for in water samples collected at fixed sites in the Great Salt Lake Basins study unit

[MRL, minimum reporting level; µg/L, micrograms per liter; GC/MS, gas chromatography/ mass spectrometry; HPLC, high-performance liquid chromatography/mass spectrometry; H, herbicide; HM, herbicide metabolite; I, insecticide; IM, insecticide metabolite; F, fungicide]

Pesticide	Type	MRL (µg/L)	Pesticide	Type	MRL (µg/L)
Pesticides analyzed by GC/MS¹			Pesticides analyzed by HPLC/MS²—Continued		
Acetochlor	H	0.002	Aldicarb sulfone	IM	³ .1599
Alachlor	H	.002	Aldicarb sulfoxide	IM	.0271
Aniline, 2,6-diethyl	HM	.003	Bendiocarb	I	.0612
Atrazine	H	.001	Benomyl	F	.0219
Atrazine, Desethyl	HM	.002	Bensulfuron-methyl	H	.0482
Azinphos-methyl	I	.001	Bentazon	H	³ .0193
Benefin	H	.002	Bromacil	H	³ .0807
Butylate	H	.002	Bromoxynil	H	³ .0572
Carbaryl	I	.003	Chloramben methyl ester	H	³ .1139
Carbofuran	I	.003	Chlorimuron-ethyl	H	.0367
Chlorpyrifos	I	.004	Chlorothalonil	H	³ .0485
Cyanazine	H	.004	Clopyralid	H	.0411
Dacthal	H	.002	Cycloate	H	³ .0543
Deethylatrazine	HM	.006	Dacthal monoacid	HM	.0722
<i>p,p'</i> -DDE	IM	.006	Deethyldeisopropylatrazine	HM	³ .0599
Diazinon	I	.002	Deisopropylatrazine	HM	³ .0737
Dieldrin	I	.001	Dicamba	H	.096
Disulfoton	I	.017	Dichlorprop	H	.05
EPTC	H	.002	Dinoseb	H	.0429
Ethalfuralin	H	.004	Diphenamid	H	.0581
Ethoprop	I	.003	Diuron	H	.0793
Ethyl Parathion	I	.004	Fenuron	H	.0735
Fonofos	I	.003	Flumetsulam	H	³ .0866
HCH, -alpha	IM	.002	Fluometuron	H	.0617
Lindane (Gamma-hch)	I	.004	Imazaquin	H	³ .103
Linuron	H	.002	Imazethapyr	H	³ .0879
Malathion	I	.005	Imidacloprid	I	.106
Methyl Parathion	I	.006	Linuron	H	.0695
Metolachlor	H	.002	MCPA	H	.0585
Metribuzin	H	.004	MCPB	H	³ .0625
Molinate	H	.004	Metalaxyl	H	.0571
Napropamide	H	.003	Methiocarb	I	³ .0795
Pebulate	H	.004	Methomyl	I	³ .0768
Pendimethalin	H	.004	Methomyl oxime	IM	³ .0102
Permethrin	I	.005	Metsulfuron methyl	H	³ .1138
Phorate	I	.002	Neburon	H	.0747
Prometon	H	.018	Nicosulfuron	H	.0653
Pronamide (Propyzamide)	H	.003	Norflurazon	H	³ .0774
Propachlor	H	.007	Oryzalin	H	.0711
Propanil	H	.004	Oxamyl	I	.016
Propargite	I	.013	Oxamyl oxime	IM	³ .0644
Simazine	H	.005	Picloram	H	.0712
Tebuthiuron	H	.01	Propham	H	.0717
Terbacil	H	.007	Propiconazole	F	.0643
Terbufos	I	.013	Propoxur	I	.0594
Thiobencarb	H	.002	Siduron	H	.0933
Triallate	H	.001	Sulfometuron-methyl	H	.0388
Trifluralin	H	.002	Terbacil	H	³ .0954
Pesticides analyzed by HPLC/MS²			Tribenuron-methyl	H	³ .0678
2,4-D	H	0.0774	Triclopyr	H	.1008
2,4-D methyl ester	H	.0865	¹ GC/MS, U.S. Geological Survey National Water Quality Laboratory schedule 2001, 2010.		
2,4-DB	H	³ .0538	² HPLC/MS, U.S. Geological Survey National Water Quality Laboratory schedule LC9060.		
2-Hydroxyatrazine	HM	³ .1927	³ Concentration is always reported as “estimated” because of variability of recovery.		
3(4-Chlorophenyl)-1-methyl urea	HM	.0915			
3-Hydroxycarbofuran	IM	.0623			
3-Ketocarbofuran	IM	³ .0723			
Acifluorfen	H	.0622			
Aldicarb	I	³ .0815			

Table 7. Pesticides detected in water samples from three fixed sites by using high-performance liquid chromatography/mass spectrometry, Great Salt Lake Basins study unit

Site 3 (Cub River near Richmond)	
2,4 D	Dicamba
2,4 D Methyl ester	Diuron
2-Hydroxyatrazine	Picloram
Deethyldeisopropylatrazine	
Site 8 (Little Cottonwood Creek at Jordan River)	
2,4 D	Deisopropylatrazine
2,4 DB	Dicamba
2,4 D Methyl ester	Diuron
2-Hydroxyatrazine	Flumetsulam
Benomyl	Imazaquin
Bromacil	MCPA
Deethyldeisopropylatrazine	Triclopyr
Site 10 (Jordan River at Salt Lake City)	
2,4 D	Dichlopro
2,4 D Methyl ester	Dinoseb
2-Hydroxyatrazine	Diuron
Bromacil	MCPA
Deethyldeisopropylatrazine	Methomyl
Deisopropylatrazine	Metsulfuron methyl
Dicamba	Sulfometuron-methyl
	Triclopyr

Prometon was the most frequently detected pesticide at the urban and mixed-land-use sites. Prometon is a persistent, broad-spectrum herbicide, used for bare-ground weed control around buildings, along fences and roadways, and in other noncrop areas. It inhibits plant growth for 1 year or more. The physical and chemical properties of prometon indicate that it can become widely distributed throughout the environment (Capel and others, 1999), however, the toxicity of prometon to humans and aquatic organisms is largely unknown. Prometon was detected in more than 95 percent of the samples analyzed by GC/MS from sites 8 and 10. The maximum prometon concentration was 5.61 µg/L at site 8 and 0.537 µg/L at site 10. Prometon was detected at site 3 in 73 percent of the samples analyzed by GC/MS, but the maximum concentration did not exceed 0.030 µg/L.

Carbaryl is a broad-spectrum carbamate insecticide that controls more than 100 species of insects. It is most often used in agricultural areas of Utah to control cereal leaf beetle and aphids on barley and wheat crops (Deer and Roe, 1997). Carbaryl was the most frequently detected insecticide at site 3 on the Cub River, having been detected in 38.5 percent of the samples analyzed by GC/MS. Carbaryl also was frequently detected at sites 8 and 10. It is used in urban

areas to control insects, particularly caterpillars and beetles, on lawns, ornamental plants, vegetables, and fruit trees.

Diazinon is an organophosphate insecticide and is one of the most widely used insecticides in the United States, especially for household lawn and garden pest control. The highest concentration of diazinon detected in the GRSL study unit was 0.343 µg/L at site 8. Diazinon was the most frequently detected pesticide at site 8 and concentrations exceeded the aquatic-life criterion of 0.08 µg/L (International Joint Commission United States and Canada, 1989) in 8 of 42 water samples collected. Diazinon was detected in 46.9 percent of the samples from site 10 and in only one sample from site 3. It did not exceed the aquatic-life criterion at either site.

Pesticides analyzed by GC/MS and detected above a common reporting limit of 0.05 µg/L are summarized in table 8. Adjusting the MRL to 0.05 µg/L censors detections less than 0.05 µg/L and results in a loss of detection information; however, with a common reporting limit a more uniform comparison of detection frequencies among constituents is possible. At a common reporting limit of 0.05 µg/L, atrazine was the most frequently detected pesticide at site 3, and prometon was the most frequently detected pesticide at sites 8 and 10. Carbaryl was the only pesticide detected above the common reporting limit in water samples from all three sites.

Pesticides detected by GC/MS in water samples from sites in the GRSL study unit were compared to those from 14 NAWQA study units (fig. 25) that measured pesticide concentration in surface-water samples during WY 1999-2000. These study units are referred to in this report as the national group. The number and frequency of pesticides detected at site 3 generally were much less than those detected in samples from agricultural sites in the national group (fig. 26). The pesticides carbaryl and diazinon, however, were detected at site 3 more often than they were detected at the national group agricultural sites. Carbaryl and prometon were detected more frequently at sites 8 and 10 than at the national group urban and mixed-land-use sites. Atrazine was detected much more frequently in samples aggregated from the national group than in samples from GRSL sites. This is reflective of the widespread use of atrazine on crops, especially corn, which cover large areas of many study units in the national group but do not cover much of the land area of the GRSL study unit.

Table 8. Summary of pesticides detected in water samples from three fixed sites by using gas chromatography/mass spectrometry, Great Salt Lake Basins study unit

[µg/L, microgram per liter; ≥, greater than or equal to; e, estimated; **Type:** H, herbicide; I, insecticide; HM, herbicide metabolite; AWQC, Ambient Water Quality Criteria for the protection of freshwater aquatic ecosystems; —, not established; concentrations in bold italics exceed AWQC]

Pesticide	Type	Number of samples	Detections (percent)		Concentration (µg/L)			Human Health Guideline ¹	AWQC
			Method reporting limit	Common reporting limit (≥ 0.05 µg/L)	Minimum	Median	Maximum		
Site 3 (Cub River near Richmond)									
Atrazine	H	26	92.3	7.7	0.004	0.010	0.075	3	² 1.8
Carbaryl	I	26	38.5	3.8	.003e	.014e	.174e	700	² .2
Chlorpyrifos	I	26	3.8	.0	.003e	.003e	.003e	20	³ .041
Cyanazine	H	26	11.5	.0	.008	.010	.036	—	-
Dacthal	H	26	3.8	.0	.002e	.002e	.002e	70	-
Deethylatrazine	HM	26	76.9	.0	.003e	.008e	.033e	—	-
Diazinon	I	26	3.8	3.8	.052	.052	.052	.6	⁴ .08
EPTC	H	26	7.7	.0	.008	.010	.013	—	-
Malathion	I	26	3.8	.0	.003e	.003e	.003e	100	³ .1
Metolachlor	H	26	7.7	.0	.006	.006	.006	100	² 7.8
Prometon	H	26	73.1	.0	.003	.008	.030	100	-
Tebuthiuron	H	26	19.2	.0	.005e	.008e	.019e	500	² 1.6
Triallate	H	26	19.2	.0	.002e	.003e	.016e	—	² .24
Site 8 (Little Cottonwood Creek at Jordan River)									
Alachlor	H	42	2.4	.0	.024	.024	.024	2	—
Atrazine	H	42	76.2	7.1	.004	.010	.130	3	² 1.8
Benefin	H	42	2.4	.0	.002e	.002e	.002e	—	—
Carbaryl	I	42	66.7	23.8	.006e	.021e	.411e	700	² .2
Chlorpyrifos	I	42	7.1	.0	.004	.005e	.007	20	³ .041
Dacthal	H	42	45.2	.0	.001e	.004e	.027	70	—
Deethylatrazine	HM	42	45.2	.0	.003e	.005e	.022e	—	—
Diazinon	I	42	90.5	21.4	.003e	.024	.343	.6	⁴ .08
EPTC	H	42	14.3	.0	.001e	.003e	.033	—	—
Fonofos	I	42	2.4	.0	.015	.015	.015	10	—
Malathion	I	42	33.3	4.8	.004e	.014	.144	100	³ .1
Metolachlor	H	42	2.4	.0	.004e	.004e	.004e	100	² 7.8
Napropamide	H	42	14.3	.0	.008e	.038	.048	—	—
Pendimethalin	H	42	35.7	9.5	.010	.026	.174	—	—
Prometon	H	42	95.2	33.3	.005e	.034	5.61	100	—
Simazine	H	42	21.4	2.4	.003e	.005e	.419	4	² 10
Tebuthiuron	H	42	35.7	2.4	.008e	.017e	.690e	500	² 1.6
Trifluralin	H	42	16.7	.0	.001e	.002e	.004e	5	² .2
Site 10 (Jordan River at Salt Lake City)									
Atrazine	H	32	100.0	.0	.007	.012	.028	3	² 1.8
Carbaryl	I	32	43.8	12.5	.009	.022	.093	700	² .2
Chlorpyrifos	I	32	3.1	.0	.005	.005	.005	20	³ .041
Dacthal	H	32	18.8	.0	.001e	.002e	.008	70	—
Deethylatrazine	HM	32	84.4	.0	.003e	.007e	.018e	—	—
Diazinon	I	32	46.9	.0	.004e	.012	.040	.6	⁴ .08
EPTC	H	32	12.5	3.1	.004	.006	.202	—	—
Ethalfuralin	H	32	3.1	.0	.005	.005	.005	—	—
Lindane	I	32	6.3	.0	.004e	.004e	.004e	—	—
Malathion	I	32	37.5	3.1	.004e	.016	.102	100	³ .1
Metolachlor	H	32	9.4	.0	.004	.006	.007	100	² 7.8
Metribuzin	H	32	3.1	.0	.011	.011	.011	200	² 1.0
Pendimethalin	H	32	3.1	3.1	.091	.091	.091	—	—
Prometon	H	32	100.0	18.8	.004e	.026	.537	100	—
Simazine	H	32	37.5	.0	.005e	.006	.030	4	² 10
Tebuthiuron	H	32	18.8	.0	.007	.010	.015	500	² 1.6
Triallate	H	32	3.1	3.1	.075	.075	.075	—	² .24
Trifluralin	H	32	6.3	.0	.003e	.004e	.004e	5	² .2

¹U.S. Environmental Protection Agency, 2002.

²Canadian Government aquatic-life guidelines (Canadian Council of Ministers of the Environment, 2001, update).

³U.S. Environmental Protection Agency chronic aquatic-life guidelines (U.S. Environmental Protection Agency, 1999a).

⁴Great Lakes water-quality objectives (International Joint Commission United States and Canada, 1989).

Table 9. Minimum, maximum, and average number of pesticides detected in water samples from three fixed sites, Great Salt Lake Basins study unit

[GC/MS, gas chromatography/mass spectrometry; HPLC/MS, high-performance liquid chromatography/mass spectrometry]

Site number (fig. 1)	Principal land use	Analytical method	Number of samples	Number of detections per sample		
				Minimum	Maximum	Average
3	Agricultural	GC/MS	26	2	10	5.6
		HPLC/MS	16	0	6	1.9
8	Urban	GC/MS	42	3	13	8.1
		HPLC/MS	24	0	8	3.0
10	Mixed/urban	GC/MS	33	4	13	7.3
		HPLC/MS	22	0	7	2.7

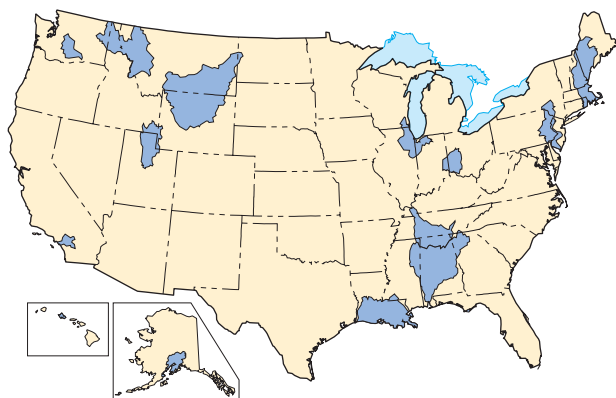


Figure 25. National Water-Quality Assessment program study units with pesticide and volatile organic compound concentration data, water years 1999-2000.

The 90th-percentile concentration of pesticides detected by GC/MS in water samples collected at agricultural, urban, and mixed-land-use sites in the GRSL study unit was compared to that in samples aggregated from sites in the national group with similar land use (fig. 27). The 90th-percentile concentration is that which exceeds 90 percent of the detected values and is used in this report to indicate the upper limit of normal values. In water samples from site 3 in the GRSL study unit, the 90th-percentile concentration of diazinon was slightly higher than in samples aggregated from agricultural sites in the national group of study units. The 90th-percentile concentration of all other pesticides detected in water samples from site 3 was much lower than in the samples from agricultural sites in the national group. The 90th-percentile concentration of carbaryl and diazinon was slightly higher, and prometon was much higher, in water samples from site 8 than in water samples from urban sites in the national group. At site 10, the 90th-percentile concentration of carbaryl and prometon was

slightly higher, and triallate was much higher relative to mixed-land-use sites in the national group.

Eighteen of the 43 pesticides detected at GRSL sites have associated AWQC (table 8). At site 8, carbaryl concentrations exceeded the AWQC of 0.2 µg/L four times and diazinon concentrations exceeded the AWQC of 0.08 µg/L eight times. Malathion concentrations exceeded the AWQC of 0.1 µg/L once at sites 8 and 10. Human health guidelines for drinking water have been established by the EPA for 22 of the 43 pesticides detected at GRSL sites. None of the pesticides detected exceeded EPA human health guidelines.

Volatile Organic Compounds

Samples collected at GRSL sites were analyzed for 86 VOCs, 35 of which were detected (table 10). VOCs are a class of compounds used in large quantities for numerous industrial, household, and agricultural purposes. They are present in fuels, exhaust, paint, adhesives, solvents, refrigerants, pesticides, and fumigants. Some likely pathways for VOCs to enter surface waters include (1) direct discharge into a stream from accidental spills and industrial or waste-water discharge, and (2) industrial and vehicle emissions, scavenged from air by precipitation, deposited directly into a stream, or transported in runoff. VOCs may enter a stream with highway runoff and urban stormwater and in ground water discharged to the stream.

Thirty-two samples for VOC analysis were collected at site 8, and 26 were collected at site 10 (table 3). Sites 8 and 10 were chosen for intensive sampling for VOCs because of the high percentage of urban land use associated with them. Twenty-eight different VOCs were detected in samples from site 8 and 33 different VOCs were detected in samples from site 10 (table 11). All VOC samples collected at sites 8 and 10 had at least two VOCs detected. The number of VOCs detected per sample ranged from 2 to 19 at Little Cottonwood Creek

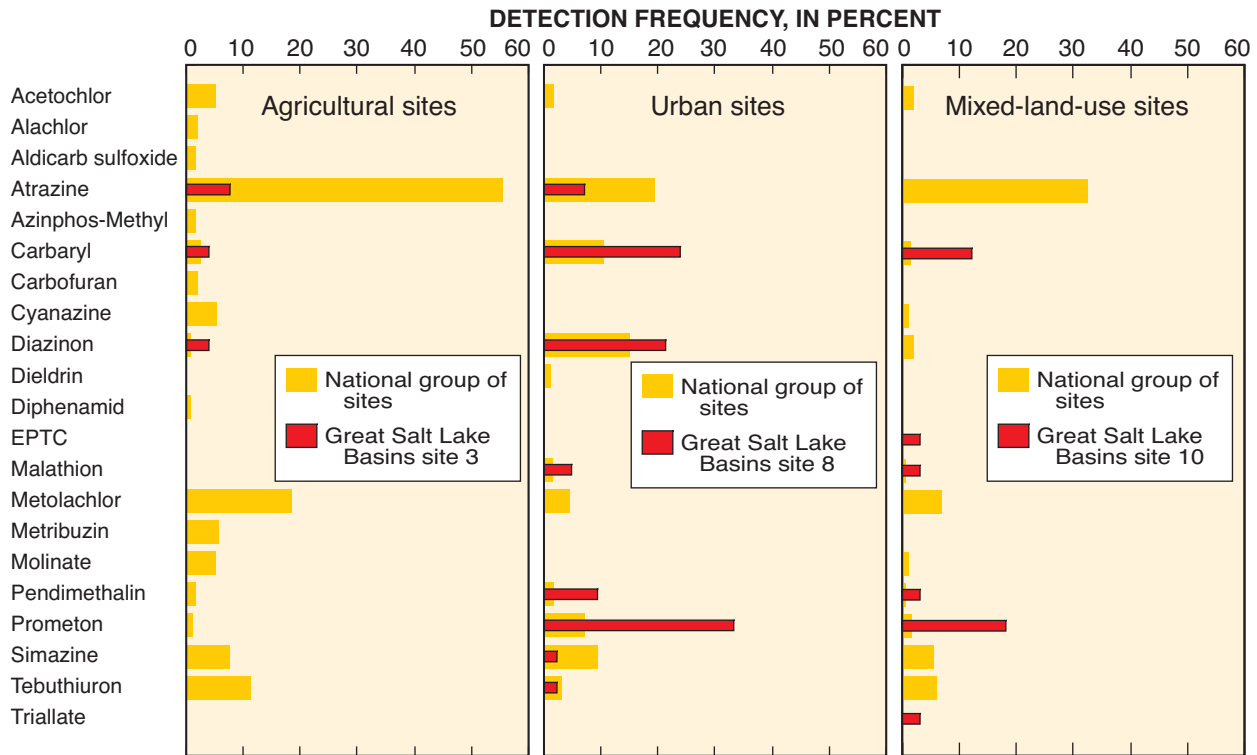


Figure 26. Detection frequency, based on a common reporting limit of 0.05 microgram per liter, of pesticides in water samples analyzed by gas chromatography/mass spectrometry from agricultural, urban, and mixed-land-use sites in the Great Salt Lake Basins study unit and at sites with similar land uses in study units across the Nation, water years 1999-2000.

(site 8) and 5 to 23 at Jordan River (site 10). The average number of VOCs detected per sample was 10.1 at site 8 and 12.1 at site 10. Concentrations of most VOCs detected were low, less than $1\mu\text{g/L}$. Concentrations of acetone, bromodichloromethane, chloroform, methyl-ethylketone, methylisobutylketone, and toluene exceeded $1\mu\text{g/L}$ in some samples.

Acetone was the VOC with the highest concentration, a maximum of $20\mu\text{g/L}$ at site 8 and $4.47\mu\text{g/L}$ at site 10. Chloroform and toluene were detected in more than 90 percent of the samples from sites 8 and 10 and were the most frequently detected VOCs. Four of the VOCs detected in samples from the GRSL sites (bromoform, bromodichloromethane, chloroform, and chlorodibromomethane) commonly are referred to as trihalomethanes (THMs). These compounds are formed when chlorine, used to treat drinking water, reacts with naturally occurring organic materials. THMs were detected much more frequently at site 10 than at site 8, probably because treated waste water was a larger component of streamflow at site 10. Fuel-

related BTEX compounds (benzene, toluene, ethylbenzene, and the xylenes) were frequently detected in samples from sites 8 and 10. Other VOCs detected in samples were solvents and those used in organic synthesis, fumigation, and plastics manufacturing.

One water sample collected at site 9 was analyzed to evaluate VOC occurrence in an undeveloped basin. Toluene was detected at a concentration of $0.02\text{e}\mu\text{g/L}$ (estimated). No other VOCs were detected. Two water samples collected at site 7 were analyzed for VOCs, and benzene ($0.01\text{e}\mu\text{g/L}$) and chloroform (0.01e and $0.05\text{e}\mu\text{g/L}$) were detected.

A comparison was made between VOCs detected in water samples from urban and mixed-land-use sites in the GRSL study unit with those detected in water samples from similar sites in a national group of NAWQA study units (fig. 25). A common reporting limit of $0.2\mu\text{g/L}$ was used to censor data. Eight VOCs at site 8 and 10 VOCs at site 10 were detected at or above the common reporting limit. Twice as many

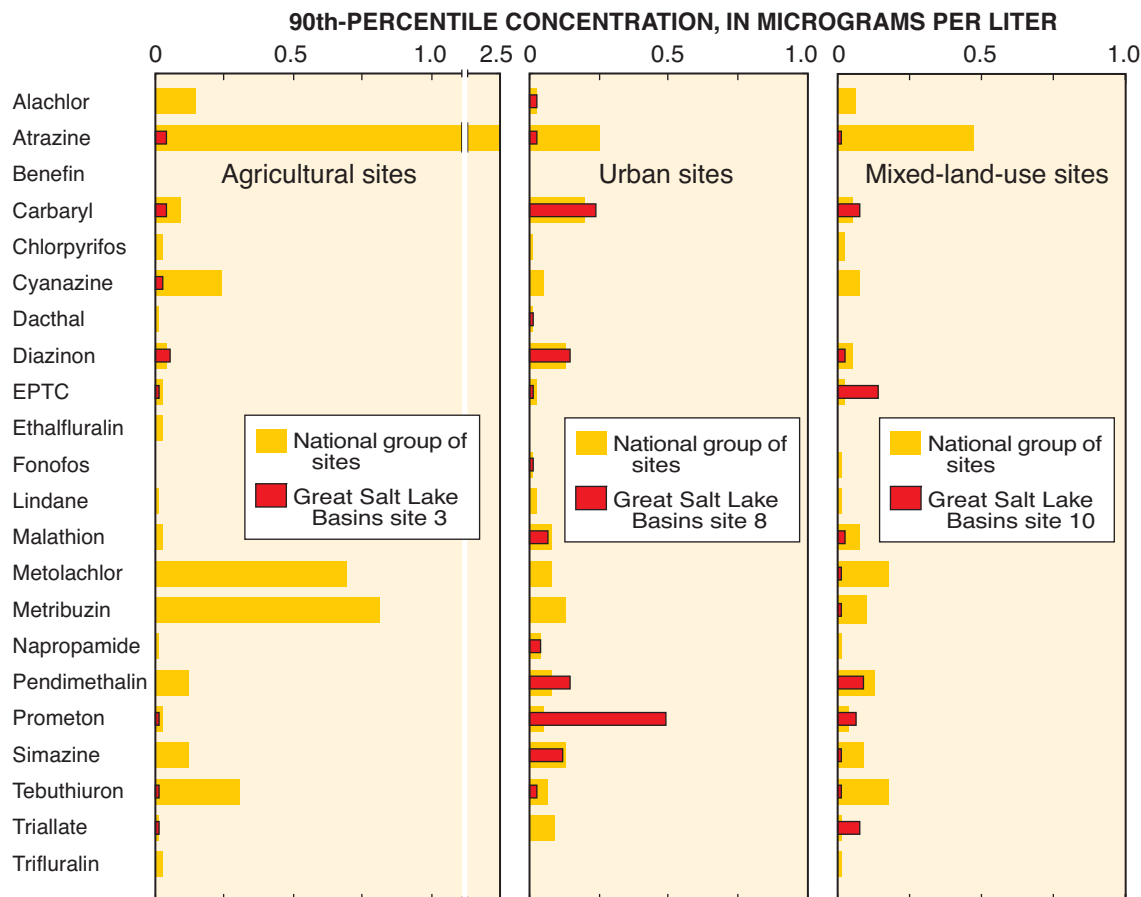


Figure 27. Ninetieth-percentile concentration of pesticides detected in water samples analyzed by gas chromatography/mass spectrometry from agricultural, urban, and mixed-land-use sites in the Great Salt Lake Basins study unit and sites with similar land uses in study units across the Nation, water years 1999-2000.

VOCs were detected in samples from similar sites in the national group of study units (fig. 28). The frequency of VOC detections in samples from GRSL sites 8 and 10, however, generally was higher than in samples from the national group. At the common reporting limit, three THMs (bromodichloromethane, chloroform, and chlorodibromomethane) were detected at site 10 but none were detected at site 8. These THMs were detected at site 10 in much higher frequencies and concentrations than in mixed land-use sites from the national group of study units (fig. 28). Toluene was detected above the common reporting limit in more than 20 percent of the samples from both site 8 and 10, but in less than 10 percent of an aggregation of samples from urban and mixed-land-use sites in the national group. Other BTEX compounds, including xylenes and benzene, were detected at a higher frequency at site 8

than in samples from urban sites in the national group of study units. The solvents acetone, methylethylketone, and methylisobutylketone also were detected much more frequently at site 8.

The 90th-percentile concentration of VOCs detected in water samples collected at GRSL sites was compared to that of samples from the national group of study units shown in figure 25. As with pesticides, the 90th-percentile concentration is used to indicate the upper limit of normal values. The 90th-percentile concentration of three THMs (bromodichloromethane, chlorodibromomethane, and chloroform) in water samples from site 10 was much higher than that in water samples from mixed-land-use sites in the national group of study units (fig. 29). BTEX compounds toluene, xylene, and 1,2,4-trimethylbenzene, and the solvents methylethylketone

Table 10. Minimum reporting level of volatile organic compounds analyzed for in water samples collected at fixed sites in the Great Salt Lake Basins study unit

[CAS number, Chemical Abstract Service number; MRL, minimum reporting level; µg/L, micrograms per liter]

Compound code name	Compound code	Preferred compound name	CAS number	MRL (µg/L)
DIISOPROPYL ETHER	81577	Diisopropyl ether	108-20-3	0.098
1,1,1-TRICHLOROETHANE	34506	1,1,1-Trichloroethane	71-55-6	.032
1,1,2-TRICHLOROETHANE	34511	1,1,2-Trichloroethane	79-00-5	.064
1,1-DICHLOROETHANE	34496	1,1-Dichloroethane	75-34-3	.066
1,1-DICHLOROETHYLENE	34501	1,1-Dichloroethene	75-35-4	.044
1,1-DICHLOROPROPENE	77168	1,1-Dichloropropene	563-58-6	.026
1,2,3-TRICHLOROPROPANE	77443	1,2,3-Trichloropropane	96-18-4	.16
1,2-DIBROMOETHANE	77651	1,2-Dibromoethane	106-93-4	.036
1,2-DICHLOROETHANE	32103	1,2-Dichloroethane	107-06-2	.13
1,2-DICHLOROPROPANE	34541	1,2-Dichloropropane	78-87-5	.068
1,2-TRANSDICHLOROETHENE	34546	trans-1,2-Dichloroethene	156-60-5	.032
2,2-DICHLOROPROPANE	77170	2,2-Dichloropropane	594-20-7	.078
2-BUTENE, TRANS-1,4-DICHLORO-	73547	trans-1,4-Dichloro-2-butene	110-57-6	.7
2-HEXANONE	77103	2-Hexanone	591-78-6	.7
ACETONE	81552	Acetone	67-64-1	5
ACRYLONITRILE	34215	2-Propenenitrile	107-13-1	1.2
BENZENE	34030	Benzene	71-43-2	.1
BENZENE, 1,2,3-TRICHLORO-	77613	1,2,3-Trichlorobenzene	87-61-6	.27
BENZENE, 1,2,3-TRIMETHYL-	77221	1,2,3-Trimethylbenzene	526-73-8	.12
BENZENE, 1,2,4-TRICHLORO-	34551	1,2,4-Trichlorobenzene	120-82-1	.19
BENZENE, 1,2,4-TRIMETHYL-	77222	1,2,4-Trimethylbenzene	95-63-6	.056
BENZENE, 1,3,5-TRIMETHYL-	77226	1,3,5-Trimethylbenzene	108-67-8	.044
BENZENE, 1,3-DICHLORO-	34566	1,3-Dichlorobenzene	541-73-1	.054
BENZENE, 1,4-DICHLORO-	34571	1,4-Dichlorobenzene	106-46-7	.05
BENZENE, ISOPROPYL-	77223	(1-Methylethyl)benzene	98-82-8	.032
BENZENE, N-BUTYL-	77342	n-Butylbenzene	104-51-8	.19
BENZENE, N-PROPYL-	77224	n-Propylbenzene	103-65-1	.042
BENZENE, O-DICHLORO-	34536	1,2-Dichlorobenzene	95-50-1	.048
BENZENE, SEC-BUTYL-	77350	(1-Methylpropyl)benzene	135-98-8	.048
BENZENE, TERT-BUTYL-	77353	(1,1-Dimethylethyl)benzene	98-06-6	.1
BROMOBENZENE	81555	Bromobenzene	108-86-1	.036
BROMOETHENE	50002	Bromoethene	593-60-2	.1
BROMOFORM	32104	Tribromomethane	75-25-2	.1
CARBON DISULFIDE	77041	Carbon disulfide	75-15-0	.37
CARBONTETRACHLORIDE	32102	Tetrachloromethane	56-23-5	.088
CHLOROENZENE	34301	Chlorobenzene	108-90-7	.028
CHLORODIBROMOMETHANE	32105	Dibromochloromethane	124-48-1	.18
CHLOROETHANE	34311	Chloroethane	75-00-3	.12
CHLOROFORM	32106	Trichloromethane	67-66-3	.052
CIS-1,2-DICHLOROETHENE	77093	cis-1,2-Dichloroethene	156-59-2	.038
CIS-1,3-DICHLOROPROPENE	34704	cis-1,3-Dichloropropene	10061-01-5	.09
DIBROMOCHLOROPROPANE	82625	1,2-Dibromo-3-chloropropane	96-12-8	.21
DIBROMOMETHANE	30217	Dibromomethane	74-95-3	.05
DICHLOROBROMOMETHANE	32101	Bromodichloromethane	75-27-4	.048
DICHLORODIFLUOROMETHANE	34668	Dichlorodifluoromethane	75-71-8	.14
ETHANE, 1,1,1,2-TETRACHLORO-	77562	1,1,1,2-Tetrachloroethane	630-20-6	.044
ETHANE, 1,1,2,2-TETRACHLORO-	34516	1,1,2,2-Tetrachloroethane	79-34-5	.13
ETHANE, HEXACHLORO-	34396	1,1,1,2,2,2-Hexachloroethane	67-72-1	.36
ETHER, ETHYL-	81576	Diethyl ether	60-29-7	.17
ETHER, TERT-BUTYL ETHYL-	50004	Ethyl tert-butyl ether	637-92-3	.054
ETHER, TERT-PENTYL METHYL-	50005	tert-Amyl methyl ether	994-05-8	.11
ETHYLBENZENE	34371	Ethylbenzene	100-41-4	.03
FREON 113	77652	1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	.032
FURAN, TETRAHYDRO-	81607	Tetrahydrofuran	109-99-9	9
HEXACHLOROBUTADIENE	39702	Hexachlorobutadiene	87-68-3	.14
ISODURENE	50000	1,2,3,5-Tetramethylbenzene	527-53-7	.2
METHACRYLATE METHYL	81597	Methyl methacrylate	80-26-6	.35
METHACRYLATE, ETHYL-	73570	Ethyl methacrylate	97-63-2	.28
METHACRYLONITRILE	81593	Methyl acrylonitrile	126-98-7	.57
METHANE, BROMOCHLORO-	77297	Bromochloromethane	74-97-5	.044
METHYL ACRYLATE	49991	Methyl acrylate	96-33-3	1.4

Table 10. Minimum reporting level of volatile organic compounds analyzed for in water samples collected at fixed sites in the Great Salt Lake Basins study unit—Continued

Compound code name	Compound code	Preferred compound name	CAS number	MRL (µg/L)
METHYL IODIDE	77424	Iodomethane	74-88-4	.21
METHYL TERTIARY-BUTYL ETHER (MTBE)	78032	Methyl tert-butyl ether	1634-04-4	.17
METHYLBROMIDE	34413	Bromomethane	74-83-9	.15
METHYLCHLORIDE	34418	Chloromethane	74-87-3	.25
METHYLENECHLORIDE	34423	Dichloromethane	75-09-2	.38
METHYLETHYLKETONE	81595	2-Butanone	78-93-3	1.6
METHYLISOBUTYLKETONE	78133	4-Methyl-2-pentanone	108-10-1	.37
M-XYLENE/P-XYLENE	85795	1,3 & 1,4-Dimethylbenzene	106-42-3:108-38-3	.06
NAPHTHALENE	34696	Naphthalene	91-20-3	.25
O-CHLOROTOLUENE	77275	1-Chloro-2-methylbenzene	95-49-8	.042
O-XYLENE	77135	1,2-Dimethylbenzene	95-47-6	.06
P-ISOPROPYLTOLUENE	77356	1-Isopropyl-4-methylbenzene	99-87-6	.11
PREHNITENE	49999	1,2,3,4-Tetramethylbenzene	488-23-3	.23
PROPANE, 1,3-DICHLORO-	77173	1,3-Dichloropropane	142-28-9	.12
PROPENE, 3-CHLORO-	78109	3-Chloro-1-propene	107-05-1	.2
STYRENE	77128	Ethenylbenzene	100-42-5	.042
TETRACHLOROETHYLENE	34475	Tetrachloroethene	127-18-4	.1
TOLUENE	34010	Methylbenzene	108-88-3	.05
TOLUENE, O-ETHYL-	77220	2-Ethyltoluene	611-14-3	.1
TOLUENE, P-CHLORO-	77277	1-Chloro-4-methylbenzene	106-43-4	.056
TRANS-1,3-DICHLOROPROPENE	34699	trans-1,3-Dichloropropene	10061-02-6	.13
TRICHLOROETHYLENE	39180	Trichloroethene	79-01-6	.038
TRICHLOROFLUOROMETHANE	34488	Trichlorofluoromethane	75-69-4	.09
VINYLCHLORIDE	39175	Chloroethene	75-01-4	.11
1,3, and 1,4-DIMETHYLBENZENE	85795	m/p-Xylene (Dimethyl benzene)	108-38-3	.06

and methylisobutylketone had higher 90th-percentile concentrations in water samples from site 8 than in samples from the urban land-use sites in the national group of study units.

Methyl tert-butyl ether (MTBE), in particular, stands out as a VOC that was detected in higher concentrations and at much higher frequency in the national group than in samples from either site 8 or 10 (fig. 28 and 29). MTBE is a fuel oxygenate added to gasoline to increase octane levels and reduce emissions. Although oxygenated fuels are mandated in parts of the Utah Lake/Jordan River basin to control carbon monoxide emissions, the fuel oxygenate used is ethanol. This may explain why MTBE concentrations are lower in the study unit than in the national group. Possible sources of MTBE in the GRSL study unit include atmospheric washout and runoff from road surfaces contaminated by spills or emissions from vehicles fueled in out-of-state areas requiring MTBE or fueled in Utah with gasoline having MTBE added as an octane booster.

AWQC for the protection of aquatic organisms have been established for 15 of the 33 VOCs detected at GRSL sites. Toluene was the only VOC that exceeded the AWQC. Toluene exceeded the AWQC of 2 µg/L established by the Canadian Government (Canadian Council of Ministers of the Environment, 2001) in one sample from site 8 and very nearly exceeded it in a second sample from site 8. These two samples, with concentrations of 3.15 µg/L and 1.99 µg/L, contained stormwater runoff from predominantly urban land cover. EPA human health guidelines have been established for 18 of the 33 VOCs detected at GRSL sites. None of the detections exceeded these guidelines.

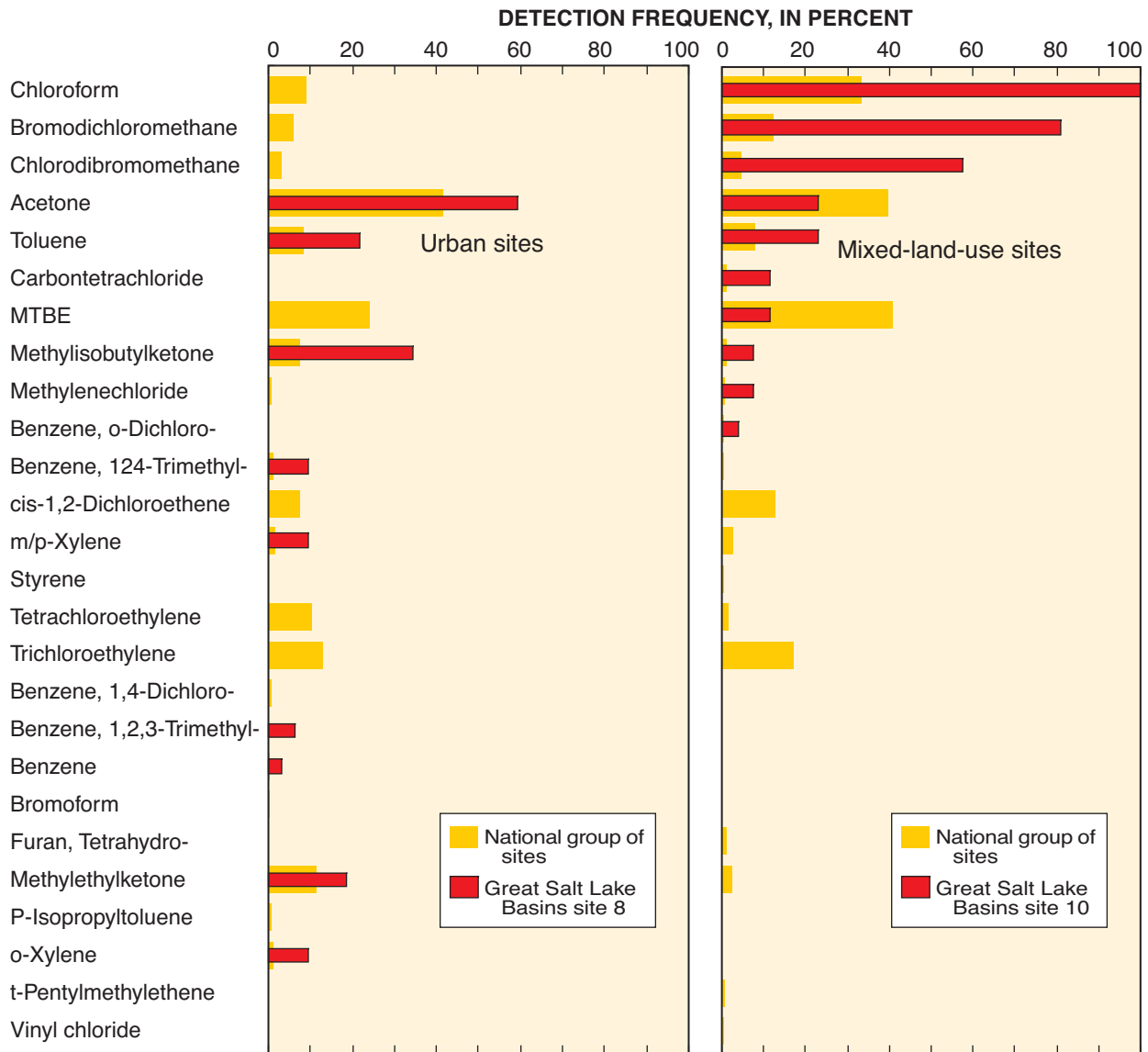


Figure 28. Detection frequency, based on a common reporting limit of 0.2 microgram per liter, of volatile organic compounds in water samples from urban and mixed-land-use sites in the Great Salt Lake Basins study unit and at sites with similar land uses in study units across the Nation, water years 1999-2000.

Table 11. Summary of volatile organic compound concentrations detected in water samples from two sites in the Great Salt Lake Basins study unit

[µg/L, micrograms per liter; ≥, greater than or equal to; AWQC, Ambient Water Quality Criteria for the protection of freshwater aquatic ecosystems; NR, not recorded; BTEX, benzene, toluene, ethylbenzene, and xylenes; DBP, disinfection by-product of chlorination (THMs); —, not established; nd, none detected; e, estimated; concentration in bold italics exceeds AWQC]

		Site 8 (Little Cottonwood Creek at Jordan River)				
Volatile organic compound	Predominant use	Detections ¹ (percent)		Concentration (µg/L)		
		Method reporting limit	Common reporting limit (≥ 0.2 µg/L)	Minimum	Median	Maximum
1,1,1-Trichloroethane	solvent	0.0	0.0	nd	nd	nd
1,2,3,4-Tetramethylbenzene	NR	0	0	nd	nd	nd
1,2,3-Trimethylbenzene	NR	12.5	0	.008 e	.153 e	.168 e
1,2,4-Trimethylbenzene	gasoline-related hydrocarbon	59.4	9.4	.008 e	.025 e	.662 e
1,3,5-Trimethylbenzene	NR	9.4	0	.106 e	.148 e	.172 e
1,4-Dichlorobenzene	fumigant	6.3	0	.008 e	.027 e	.046 e
Acetone	solvent	59.4	59.4	1.11 e	3.52 e	20.0 e
Benzene	BTEX	84.4	3.1	.013 e	.031 e	.212 e
Bromodichloromethane	DBP	6.3	0	.013 e	.014 e	.016 e
Bromoform	DBP	6.3	0	.132	.144	.156
Carbon disulfide	NR	9.4	0	.016 e	.076 e	.084 e
Carbontetrachloride	solvent	0	0	nd	nd	nd
Chlorobenzene	solvent	0	0	nd	nd	nd
Chlorodibromomethane	DBP	0	0	nd	nd	nd
Chloroform	DBP	90.6	0	.011 e	.023 e	.144 e
cis-1,2-Dichloroethene	solvent	28.1	0	.008 e	.021 e	.037 e
Ethylbenzene	BTEX	62.5	0	.004 e	.012 e	.132 e
Ethyl-ether	NR	0	0	nd	nd	nd
Isodurene	NR	9.4	0	.100 e	.125 e	.135 e
m/p Xylene	BTEX	75.0	9.4	.010 e	.041 e	.692
Methyl tert-butyl ether (MTBE)	oxygenate	40.6	0	.027 e	.043 e	.075 e
Methylchloride	solvent	9.4	0	.053 e	.055 e	.061 e
Methylene chloride	solvent	37.5	0	.013 e	.021 e	.038 e
Methylethylketone	NR	34.4	34.4	.509 e	1.04 e	3.03 e
Methylisobutylketone	NR	37.5	34.4	.144 e	.884 e	1.48 e
n-Butylbenzene	gasoline-related hydrocarbon	9.4	0	.014 e	.014 e	.014 e
n-Propylbenzene	solvent	9.4	0	.025 e	.049 e	.052 e
o-Dichlorobenzene	solvent	0	0	nd	nd	nd
o-Ethyl-toluene	NR	9.4	0	.072 e	.091 e	.100 e
o-Xylene	BTEX	59.4	9.4	.012 e	.022 e	.355
p-Isopropyltoluene	NR	37.5	0	.004 e	.015 e	.107 e
Styrene	gasoline-related hydrocarbon	40.6	0	.003 e	.025 e	.103
Tetrachloroethylene	solvent	46.9	0	.006 e	.012 e	.082 e
Toluene	BTEX	100	21.9	.039 e	.115	3.15
Trichloroethylene	solvent	21.9	0	.013 e	.036 e	.071 e

¹Percent detections per 32 samples.

²Percent detections per 26 samples.

³U.S. Environmental Protection Agency, 2002.

⁴EPA freshwater aquatic-life acute criteria/guidelines (Rowe and others, 1997).

⁵Canadian Government aquatic-life guidelines (Canadian Council of Ministers of the Environment, 2001).

⁶EPA freshwater aquatic-life chronic criteria/guidelines (Rowe and others, 1997).

Table 11. Summary of volatile organic compound concentrations detected in water samples from two fixed sampling sites in the Great Salt Lake Basins study unit—Continued

Volatile organic compound	Site 10 (Jordan River at Salt Lake City)						Human health guideline ³	AWQC
	Detections ² (percent)		Concentration (µg/L)					
	Method reporting limit	Common reporting limit (≥ 0.2 µg/L)	Minimum	Median	Maximum			
1,1,1-Trichloroethane	3.8	0.0	0.131 e	0.131 e	0.131 e	200	⁵ 18,000	
1,2,3,4-Tetramethylbenzene	3.8	0	.045 e	.045 e	.045 e	—	—	
1,2,3-Trimethylbenzene	7.7	0	.017 e	.023 e	.029 e	—	—	
1,2,4-Trimethylbenzene	23.1	0	.017 e	.033 e	.106 e	—	—	
1,3,5-Trimethylbenzene	7.7	0	.016 e	.024 e	.032 e	—	—	
1,4-Dichlorobenzene	34.6	0	.006 e	.016 e	.022 e	75	⁵ 26	
Acetone	23.1	23.1	1.60 e	2.00 e	4.47 e	—	—	
Benzene	84.6	0	.011 e	.019 e	.040 e	—	⁵ 370	
Bromodichloromethane	100	80.8	.113	.399	1.96	80	⁴ 11,000	
Bromoform	23.1	0	.028 e	.080 e	.105 e	80	⁴ 11,000	
Carbon disulfide	53.8	0	.017 e	.030 e	.048 e	—	⁶ 2	
Carbontetrachloride	30.8	11.5	.016 e	.040 e	.402 e	5	⁵ 13.3	
Chlorobenzene	3.8	0	.010 e	.010 e	.010 e	100	⁵ 1.3	
Chlorodibromomethane	100	42.3	.040 e	.183	.992	80	⁴ 11,000	
Chloroform	100	100	.250	.812	3.99	80	⁵ 1.8	
cis-1,2-Dichloroethene	53.8	0	.009 e	.013 e	.035 e	70	⁴ 11,600	
Ethylbenzene	19.2	0	.005 e	.013 e	.044 e	700	⁵ 90	
Ethyl-ether	7.7	0	.019 e	.043 e	.067 e	—	—	
Isodurene	0	0	nd	nd	nd	—	—	
m/p Xylene	50.0	0	.017 e	.025 e	.177 e	10,000	—	
Methyl tert-butyl ether (MTBE)	69.2	11.5	.038 e	.069 e	.416	20	—	
Methylchloride	11.5	0	.040 e	.070 e	.081	30	—	
Methylene chloride	69.2	0	.013 e	.033 e	.186 e	5	⁵ 98.1	
Methylethylketone	3.8	3.8	.542 e	.542 e	.542 e	—	—	
Methylisobutylketone	7.7	3.8	.166 e	.190 e	.214 e	—	—	
n-Butylbenzene	0	0	nd	nd	nd	—	—	
n-Propylbenzene	3.8	0	.013 e	.013 e	.013 e	—	—	
o-Dichlorobenzene	3.8	3.8	.365	.365	.365	—	—	
o-Ethyl-toluene	3.8	0	.021 e	.021 e	.021 e	—	—	
o-Xylene	26.9	0	.010 e	.015 e	.084 e	10,000	—	
p-Isopropyltoluene	3.8	0	.011 e	.011 e	.011 e	—	—	
Styrene	34.6	0	.004 e	.007 e	.017 e	—	⁴ 72	
Tetrachloroethylene	96.2	0	.014 e	.033 e	.103	5	⁴ 111	
Toluene	100	23.1	.033 e	.081 e	.829	1,000	⁴ 2	
Trichloroethylene	42.3	0	.008 e	.018 e	.039 e	5	⁴ 21	

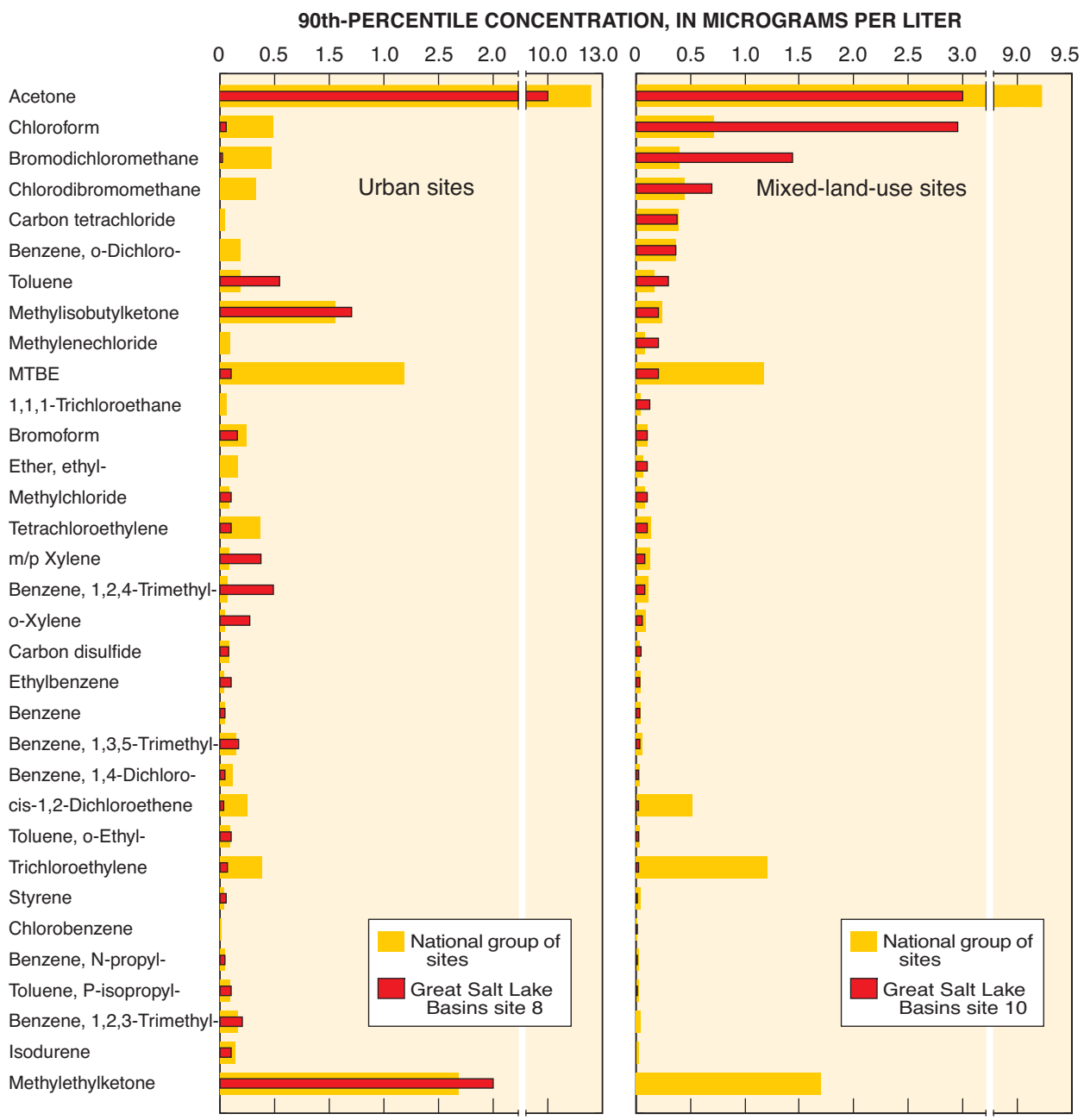


Figure 29. Ninetieth-percentile concentration of volatile organic compounds detected in water samples from urban and mixed-land-use sites in the Great Salt Lake Basins study unit and at sites with similar land uses in study units across the Nation, water years 1999-2000.

Organic Carbon

Dissolved organic carbon concentrations in water samples from the sites ranged from 0.7 to 16 mg/L (fig. 30). The highest concentrations of dissolved organic carbon were detected in water samples collected from Little Cottonwood Creek when spring storm runoff was a large component of streamflow. Dissolved organic carbon concentration in nonstorm samples generally was higher at site 8 than at site 7, indicating that runoff from urban areas is a source of dissolved organic carbon for Little Cottonwood Creek. Dissolved organic carbon concentrations were lowest in samples from Red Butte Creek. The median dissolved organic carbon concentration at most sites was between 2 and 4 mg/L. Dissolved organic carbon was slightly enriched in the Bear River as it was diverted through Mud Lake and resulted in generally higher concentrations at site 2 relative to site 1. Chlorinating water that contains dissolved organic carbon can result in the formation of THMs, which could become a water-quality issue if additional municipal water supplies are developed from the Bear River.

SUMMARY

The Great Salt Lake Basins (GRSL) study unit is 1 of 51 study units that are included in the National Water-Quality Assessment (NAWQA) program. A

group of 15 study units, including the GRSL, began in 1997. The GRSL study unit encompasses three major river systems that enter Great Salt Lake: the Bear, the Weber, and the Utah Lake/Jordan River systems. Most of the 14,500 mi² of the GRSL study unit is in Utah, but areas in Idaho and Wyoming also are included. The study unit includes Utah's largest cities (the Salt Lake City, Ogden, and Provo metropolitan areas) and about 1.9 million people.

A fixed-site assessment was used to assess the spatial and seasonal distribution of selected constituents. Sites were chosen to represent specific environmental settings, such as agricultural land or urban land, or to represent integration of multiple land uses. Ten sites were selected in the GRSL for the NAWQA program and were sampled during water years 1999-2000.

Annual runoff at all fixed sites during water year 1999 exceeded the long-term average for those sites. Water year 2000 was a very dry year in the GRSL study unit, with 8 of 12 months having less-than-average precipitation. Runoff during water year 2000 at most sites was less than the average annual runoff for those sites.

Median dissolved-solids concentrations were highest at mixed-land-use fixed sites. Dissolved-solids concentration was highest at most sites during July to October, when water with lower dissolved-solids concentration is removed at upstream diversions and irrigation return is a major component of streamflow.

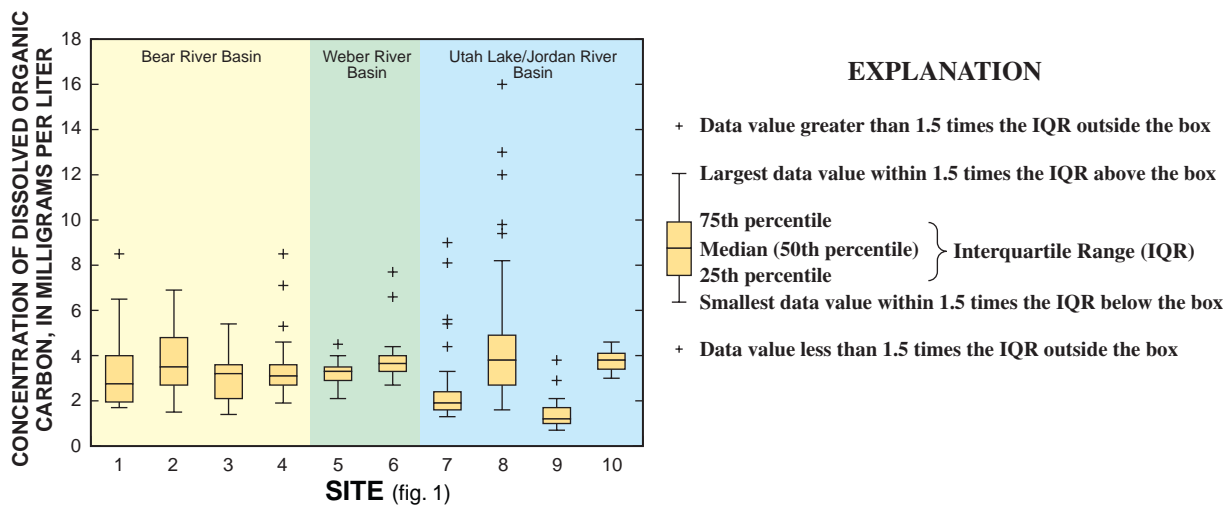


Figure 30. Dissolved organic carbon concentration in water samples from fixed sites in the Great Salt Lake Basins study unit.

Water samples analyzed for dissolved-solids concentration show that water at GRSL sites generally is acceptable for agricultural uses, except possibly in sections of the Bear River during low streamflows.

Seasonal patterns in total-nitrogen concentration were evident at most sites. Total-nitrogen concentration increased at most sites during periods of base flow when streamflow was low, ground water or treated waste water was the primary streamflow component, and nutrient uptake by aquatic vegetation was reduced. Nitrite plus nitrate concentration was highest at sites with runoff from agricultural land and sites with more urban land cover. None of the samples from the GRSL sites had nitrate concentrations above the U.S. Environmental Protection Agency drinking-water standard of 10 mg/L. The maximum nitrate concentration was 6.54 mg/L at Jordan River at Salt Lake City (site 10). The Utah Department of Environmental Quality designates a concentration of nitrate above 4.0 mg/L as an indicator of pollution. This level was exceeded three times at site 10, the Jordan River at Salt Lake City, but no other sites had nitrate concentrations that exceeded this level.

Orthophosphate concentrations were elevated at sites with mixed land use, probably as a result of a higher percentage of treated waste water in streamflow at these sites. The maximum total phosphorus concentration at the GRSL sites was 2.39 mg/L at Little Cottonwood Creek at Jordan River (site 8), which was associated with storm runoff. The median total phosphorus concentration at several sites exceeded 0.10 mg/L, indicating that the potential for eutrophication exists.

Sites in the Bear River drainage basin had the highest median concentrations of suspended sediment, ranging from 68 to 110 mg/L. Water samples collected at Little Cottonwood Creek at Jordan River (site 8) had a median suspended-sediment concentration of 36 mg/L; however, samples collected when a large component of streamflow was storm runoff from urban land had concentrations as high as 1,580 mg/L.

Beryllium, cadmium, cobalt, and silver were not detected in water samples from GRSL sites above the minimum reporting level of 1 µg/L. Boron, molybdenum, and strontium concentrations were enriched in samples from urban sites. Chromium, lead, nickel, and zinc were detected in some samples, but concentrations did not exceed the Ambient Water Quality Criteria (AWQC) established for those elements. Arsenic was detected in 127 of 139 water

samples. It was detected in all 49 water samples collected from Little Cottonwood Creek at Jordan River (site 8) and exceeded the AWQC of 150 µg/L in 8 samples. Copper was detected in 116 of 134 water samples from GRSL sites in concentrations from 0.9 to 5.7 µg/L. The AWQC for copper was exceeded twice at Little Cottonwood Creek at Crestwood Park (site 7). The maximum concentration of selenium in samples was 6.0 µg/L. Selenium concentrations generally were low, but two samples from Little Cottonwood Creek at Jordan River (site 8) exceeded the AWQC of 4.6 µg/L (for dissolved selenium).

Forty-three of the 107 pesticides analyzed for in water samples from GRSL sites were detected: 21 at Cub River near Richmond (site 3), an agricultural site; 32 at Little Cottonwood Creek at Jordan River (site 8), an urban site; and 33 at Jordan River at Salt Lake City (site 10), a mixed-land-use site. Thirty-one of the pesticides detected were herbicides, 4 were herbicide metabolites, 7 were insecticides, and 1 was a fungicide. The herbicides atrazine and prometon, and the insecticides carbaryl and diazinon were the most frequently detected pesticides. Carbaryl concentration exceeded the AWQC of 0.2 µg/L four times and diazinon concentration exceeded the AWQC of 0.08 µg/L eight times. Malathion concentration exceeded the AWQC of 0.1 µg/L twice.

Thirty-five of the 86 volatile organic compounds (VOCs) analyzed for in water samples from GRSL sites were detected: 28 in samples from Little Cottonwood Creek at Jordan River (site 8) and 33 in samples from Jordan River at Salt Lake City (site 10). All VOC samples had at least two VOCs detected. In water samples from the GRSL sites most VOC concentrations were less than 1 µg/L; however, concentrations of acetone, bromodichloromethane, chloroform, methylethylketone, methylisobutylketone, and toluene, exceeded 1 µg/L in some samples. Chloroform and toluene were detected in more than 90 percent of the water samples and were the most frequently detected VOCs. Trihalomethanes (bromoform, bromodichloromethane, chloroform, and chlorodibromomethane) and fuel-related BTEX compounds (benzene, toluene, ethyl benzene, and the xylenes) were the most frequently detected groups of VOCs. Toluene exceeded the AWQC of 2 µg/L in one sample.

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