

Analysis of Nitrate and Volatile Organic Compound Data for Ground Water in the Great Salt Lake Basins, Utah, Idaho, and Wyoming, 1980-98, National Water-Quality Assessment Program

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ABSTRACT

In 1995, ground water was the source of drinking water to about 52 percent of the population served by public drinking water systems in the Great Salt Lake Basins study unit, which includes parts of Utah, Idaho, and Wyoming. Existing nitrate and volatile organic compound data for ground water collected in the study unit were compiled and summarized as part of the National Water-Quality Assessment Program's objective to describe water-quality conditions in the Nation's aquifers. Prerequisites for the inclusion of nitrate and volatile organic compound data into this retrospective analysis are that the data set is available in electronic form, the data were collected during 1980-98, the data set is somewhat regional in coverage, and the locations of the sampled sites are known. Ground-water data stored in the U.S. Geological Survey's National Water Information System and the Idaho and Utah Public Drinking Water Systems databases were reviewed. Only the most recent analysis was included in the data sets if more than one analysis was available for a site.

The National Water Information System data set contained nitrate analyses for water from 480 wells. The median concentration of nitrate was 1.30 milligrams per liter for the 388 values above minimum reporting limits. The maximum contaminant level for nitrate as established by the U.S. Environmental Protection Agency was exceeded in water from 10 of the 200 wells less than or equal to 150 feet deep and in water from 3 of 280 wells greater than 150 feet deep. The Public Drinking Water Systems data set contained nitrate analyses for water from 587 wells. The median concentration of nitrate was 1.12 milligrams per liter for the 548 values above minimum reporting limits. The

maximum contaminant level for nitrate was exceeded at 1 site and 22 sites had concentrations equal to or greater than 5 milligrams per liter.

The types of land use surrounding a well and the well depth were related to measured nitrate concentrations in the sampled ground water. Overall, water sampled from wells in rangeland areas had a lower median measured nitrate concentration (0.76 milligrams per liter) than water from areas with an agricultural or urban/residential land use (1.41 and 1.20 milligrams per liter, respectively). In the National Water Information System data set, the median measured nitrate concentration in water from urban/residential areas varied from 1.00 milligrams per liter for wells greater than 150 feet deep to 1.84 milligrams per liter for wells less than or equal to 150 feet deep.

The Public Drinking Water Systems and the National Water Information System data sets contained analyses for most of the State and Federally regulated volatile organic compounds in water from about 368 and 74 wells, respectively. Fifteen different volatile organic compounds were detected at least once in ground water sampled from the Great Salt Lake Basins study unit. Water from 21 wells contained at least 1 volatile organic compound at detectable concentrations. About 68 percent of the volatile organic compounds detected were in water sampled from wells in Salt Lake County, Utah. Tetrachloroethylene was the most commonly detected volatile organic compound in ground water sampled from the study unit, present in 8 out of 442 samples. Maximum contaminant levels for tetrachloroethylene and 1,1-dichloroethylene as established by the U.S. Environmental Protection Agency were exceeded in water from one well each.

INTRODUCTION

In 1991, the U.S. Geological Survey (USGS) implemented the National Water-Quality Assessment (NAWQA) Program to describe the status and trends in water quality of a large and representative part of the Nation's surface- and ground-water resources. This program is being accomplished through investigation of 59 study units ranging in size from 1,200 to 60,000 mi². The Great Salt Lake Basins (GSLB) study-unit investigation began in 1997, part of the third group of study units in the NAWQA Program.

Ground water is an important source of drinking water in the GSLB study unit. An initial phase of this study includes the compilation and evaluation of existing electronically available water-quality data. A retrospective analysis targeting nitrate and volatile organic compound (VOC) data for ground water from the study unit was done. The occurrence of VOCs and elevated concentrations of nitrate typically is an indication of ground-water contamination introduced into the subsurface by human activities. Factors such as land use, recharge areas, depth to water, and the presence of confining layers and reducing conditions in the subsurface can affect the occurrence and concentration of nitrate and VOCs in ground water.

Purpose and Scope

This report describes the occurrence and distribution of nitrate and selected VOCs in ground water from the GSLB study unit on the basis of available electronically stored data. Ground-water data collected at a regional scale during 1980-98 by the USGS and public drinking-water suppliers were reviewed. The relation of nitrate concentration and selected VOCs detected in ground water to well depth, land use, and location is presented. Information from this report will be used with data collected by the NAWQA Program to better assess the ground-water quality of the study unit.

Description of Study Unit

The GSLB study unit is in the northeast part of Utah, the southeast part of Idaho, and the southwest part of Wyoming (fig. 1). The total drainage area is about 14,500 mi². Major tributaries discharge to Great Salt Lake in Utah. The area generally consists of valleys or basins bounded by mountains or Great Salt Lake.

The population in the GSLB study unit in 1995 that received drinking water from public-supply systems was about 1,660,000. Ground water was the source of drinking water to about 52 percent of this population. The self-supplied population in 1995 was about 45,000, with most of the water coming from ground-water sources. Land uses in the valley and basin parts of the study unit include agricultural, residential, commercial, industrial, wetland, and undeveloped rangeland. More residential and commercial areas are being developed in the study unit, primarily at the expense of agricultural areas.

Ground-Water Hydrology

Ground water is contained in both consolidated and unconsolidated material in the GSLB study unit. The deeper unconsolidated valley- and basin-fill aquifers in the area are a major source of drinking and irrigation water. A generalized model of the saturated valley- or basin-fill material in the study unit consists of a deeper unconfined aquifer near the mountain fronts that becomes confined toward the center of the valley or basin by interbedded, discontinuous layers of silt and clay (fig. 2). Overlying this confined aquifer is a shallow unconfined aquifer or water-table aquifer. Water-bearing consolidated-rock formations are considered part of the deeper aquifer system where they contribute water to the valley- or basin-fill material.

The primary recharge areas for the deeper aquifers are near mountain fronts where there are no substantial layers of fine-grained material to impede infiltration of surface water or downward ground-water movement (fig. 2). Downward leakage of water from the shallow unconfined aquifer to the deeper confined aquifer is possible where there is a downward gradient. These conditions are found beneath the secondary recharge area despite the presence of confining layers. A discharge area exists where ground water moves upward from the deeper confined aquifer to the overlying shallow unconfined aquifer. Recharge to the unconsolidated valley- and basin-fill aquifers in the study unit is from infiltration of snowmelt runoff, precipitation, and unconsumed irrigation water; subsurface inflow from adjacent fractured consolidated rock; and seepage from streams and canals.

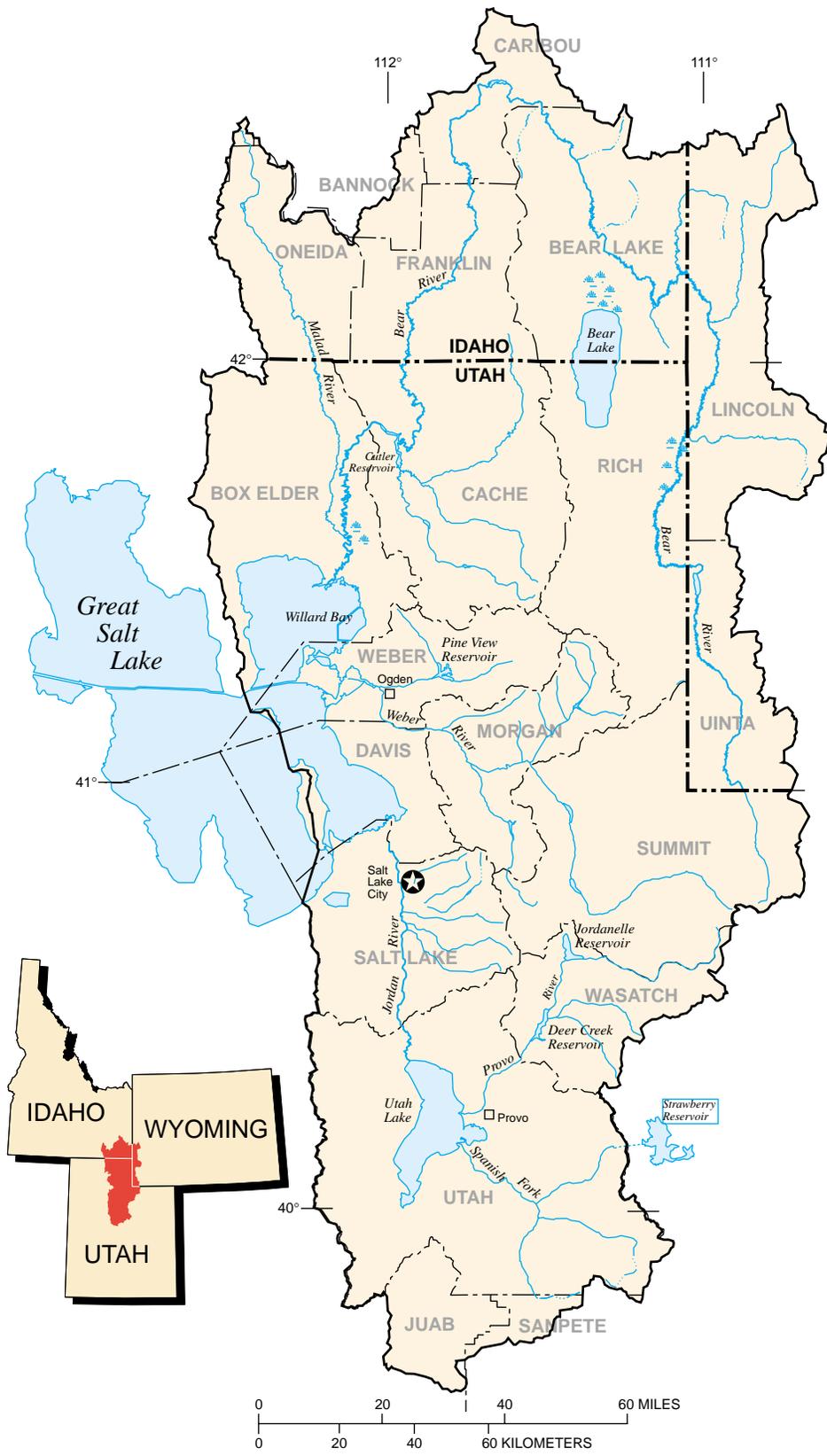


Figure 1. Location of the Great Salt Lake Basins study unit, Utah, Idaho, and Wyoming.

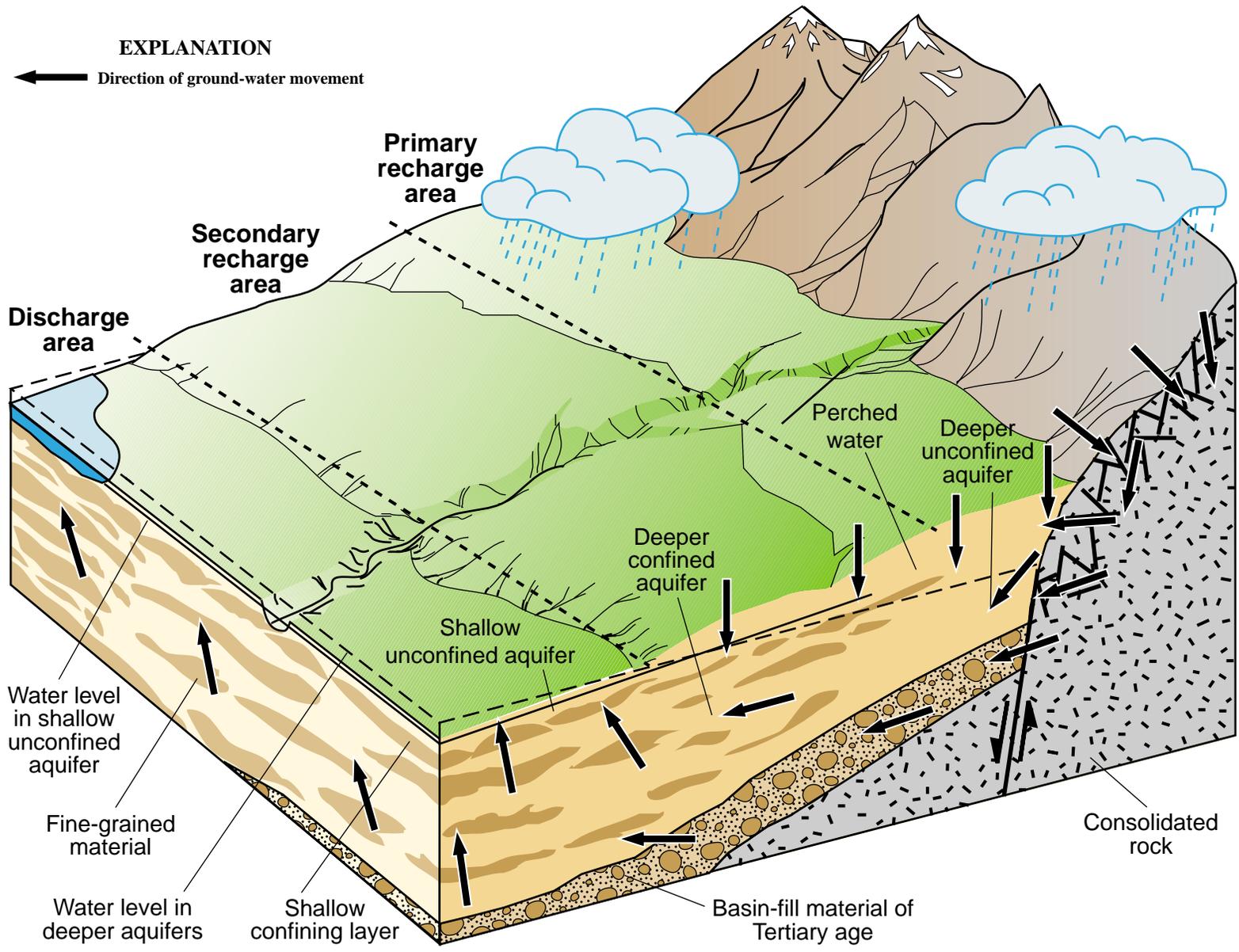


Figure 2. Generalized block diagram showing the basin-fill ground-water flow system, Great Salt Lake Basins study unit (modified from Hely and others, 1971).

The shallow unconfined aquifer is the most susceptible to contamination from activities related to land use because of its proximity to land surface. The deeper unconfined aquifer also is vulnerable because of a lack of confining layers that can impede the downward movement of contaminated ground water. Water quality in the deeper confined aquifer can be degraded by the secondary recharge of contaminated water from the shallow and deeper unconfined aquifers.

Characteristics of Nitrate

Nitrogen is primarily present in water as nitrate, nitrite, or ammonium ions. Nitrate is relatively stable in oxygenated subsurface environments and is readily transported in water. Nitrite is unstable in aerated water and is seldom present in measureable concentrations. Nitrification is a microbial process that changes ammonium (NH_4^+) to nitrite (NO_2^-) to nitrate (NO_3^-) under aerobic conditions. Nitrate is reduced (denitrification) by bacteria under anaerobic conditions. These biogeochemical processes are a major reason why nitrate concentrations generally decrease as depth below land surface and residence time increase.

Agricultural practices and disposal of organic wastes are primary contributors of nitrate to ground water. Potential sources of nitrate in ground water include nitrate leaching from areas where manure has been applied, leaking or improperly functioning septic systems and sewer pipes, applied nitrogen-based fertilizers, and naturally occurring nitrogen-containing salts or organic matter. In both agricultural and urban areas, fertilizers are commonly applied to crops and lawns, although alfalfa, the most abundant crop in Utah, is not usually fertilized with nitrogen-based compounds. Alfalfa is a legume which fixes nitrogen from the atmosphere and has been used to scavenge nitrate from the soil profile (Alley, 1993, p. 303). More studies are needed to show if significant nitrate leaching can occur after plowing unfertilized alfalfa fields. Ammonium sulfate and ammonium phosphate fertilizers are commonly applied to lawns. Irrigation can leach fertilizers into the underlying unconfined aquifers. In some areas, nitrate in relatively high concentrations is found naturally in ground water. The source of the nitrate is likely from soluble salts deposited with the sediments.

Background nitrate concentrations in ground water from areas not associated with agricultural practices commonly are less than 2 to 3 mg/L as nitrogen (Halberg and Keeney, 1993, p. 316). In high concentrations, nitrate and nitrite can be toxic to humans, espe-

cially infants, and animals. Methemoglobinemia or "blue-baby syndrome" in small children is the most common effect of high nitrate concentrations and results from the reduced oxygen-carrying capacity of blood after the body converts nitrate to nitrite. The U.S. Environmental Protection Agency (USEPA) maximum contaminant level (MCL) for nitrate in water that is delivered to any user of a public-water supply is 10 mg/L as nitrogen (U.S. Environmental Protection Agency, 1996).

Characteristics of Volatile Organic Compounds

Volatile organic compounds are carbon-containing chemicals that readily evaporate at normal air temperature and pressure. They are contained in many commercial products such as gasoline, paints, adhesives, solvents, wood preservatives, dry-cleaning agents, pesticides, fertilizers, cosmetics, and refrigerants. Because most VOCs are manmade, their presence in ground water is typically an indication of a release or spill at land surface. Contamination of drinking-water supplies from VOCs is a human health concern because many are toxic and are known or suspected human carcinogens (U.S. Environmental Protection Agency, 1996). Regulatory limits and uses of selected VOCs analyzed for in ground-water samples collected in the study unit are listed in table 1.

In the first cycle of NAWQA Program water-quality assessments during 1991-95, about 1,600 ground-water samples from 20 study units located throughout the country were collected (VOC National Synthesis Project, U.S. Geological Survey, written commun., 1998). The most frequently detected VOCs included chloroform, methyl tert-butyl ether (MTBE), tetrachloroethylene (perchloroethylene, PCE), and trichloroethylene (TCE). These compounds were most frequently detected in shallow ground water in urban areas at low concentrations that were almost always less than MCLs or health advisories for drinking water.

Sources of Available Ground-Water-Quality Data

Prerequisites for the inclusion of data into this retrospective analysis are that the database is available in electronic form, the data were collected during 1980-98, the data are somewhat regional in coverage, and the

Table 1. Minimum reporting limits, drinking-water standards or guidelines, health advisory for cancer risk, and major uses of selected volatile organic compounds analyzed for in ground-water samples collected in the Great Salt Lake Basins study unit

[NWIS, National Water Information System; PDWS, Public Drinking Water Systems; µg/L, micrograms per liter; —, not available or no data; Drinking water standards are U.S. Environmental Protection Agency (USEPA) maximum contaminant levels for drinking water (USEPA, 1996) unless otherwise footnoted; Health advisory for cancer risk, USEPA (1996) risk-specific dose health advisory for drinking water associated with a 1 in a million cancer risk; Major uses or sources from Montgomery (1996), USEPA (1995)]

Volatile organic compound (VOC)	Common name	Minimum reporting limit				Drinking water standard or guideline (µg/L)	Health advisory for cancer risk (µg/L)	Major use or source
		NWIS data set		PDWS data set				
		Utah (µg/L)	Idaho (µg/L)	Utah (µg/L)	Idaho (µg/L)			
Benzene	—	3.0	0.5	0.5	—	5	—	Gasoline, solvent, manufacture of other organic chemicals
Bromobenzene	Phenyl bromide	—	.5	1.0	—	—	—	Chemical intermediate, solvent, motor oil additive
Bromochloromethane	Methylene chlorobromide	—	.5	1.0	.5	¹ 10	—	Fire-extinguishing agent, organic synthesis
Bromodichloromethane ²	Dichlorobromomethane	3.0	.5	.5	.5	100	.6	Flame retardant, solvent, degreaser, chemical intermediate
Bromoform ²	Tribromomethane	3.0	.5	.5	—	100	4	Solvent, chemical intermediate, component of fire-resistant chemicals
Bromomethane	Methyl bromide	3.0	.5	1.0	—	¹ 10	—	Soil fumigant, organic synthesis, fire-extinguishing agent, refrigerant
n-Butylbenzene	Butylbenzene, 1-Phenylbutane	—	.5	1.0	.5	—	—	Pesticide manufacturing, plasticizer, asphalt component
sec-Butylbenzene	(1-Methylpropyl)benzene, 2-Phenylbutane	—	.5	1.0	.5	—	—	Solvent for coating compositions, plasticizer
tert-Butylbenzene	2-Methyl-2-phenylpropane (1,1-Dimethyl)benzene	—	.5	1.0	.5	—	—	Polymerization solvent, polymer linking agent, organic synthesis
Carbon tetrachloride	Tetrachloromethane	3.0	.5	.5	—	5	.3	Preparation of fluorocarbons, metal degreaser, solvent
Chlorobenzene	Monochlorobenzene, Benzene chloride	3.0	.5	.5	—	100	—	Solvent in pesticides and dry cleaning, heat-transfer agent
Chlorodibromomethane ²	Dibromochloromethane	3.0	.5	.5	.5	100	—	Manufacture of fire-extinguishing agents, propellants, and refrigerants
Chloroethane	Ethyl chloride	3.0	.5	1.0	—	—	—	Topical anesthetic, organic synthesis, refrigeration, solvent
2-Chloroethylvinyl ether	(2-Chloroethoxy)ethene	3.0	—	—	—	—	—	Anesthetics, sedatives, and cellulose ethers
Chloroform ²	Trichloromethane	3.0	.5	.5	.5	100	6	Manufacture of fluorocarbon refrigerants, plastics, and propellant, solvent
Chloromethane	Methyl chloride	3.0	.5	1.0	—	¹ 3	—	Coolant, herbicide, fumigant, organic synthesis
1,2-Dibromoethane	Ethylene dibromide, EDB	3.0	—	—	—	.05	.0004	In antiknock gasolines, soil fumigant, insecticide, solvent
m-Dichlorobenzene (1,3-DCB)	1,3-Dichlorobenzene	3.0	.5	1.0	—	¹ 600	—	Fumigant, insecticide, organic synthesis
o-Dichlorobenzene	1,2-Dichlorobenzene	3.0	.5	.5	—	600	—	Organic synthesis of herbicides, solvent, degreasing agent, insecticide
p-Dichlorobenzene	1,4-Dichlorobenzene	3.0	.5	.5	—	75	—	Insecticide, fumigant, disinfectant, chemical intermediate
1,1-Dichloroethane	Ethylidene chloride	3.0	.5	1.0	—	—	—	Solvent, insecticide, fumigant, paint remover, metal degreaser
1,2-Dichloroethane	Ethylene dichloride	3.0	.5	.5	—	5	.4	Chemical manufacture, lead scavenger in gasoline, metal degreaser
1,1-Dichloroethylene (1,1-DCE)	1,1-Dichloroethene, Vinylidene chloride	3.0	.5	.5	—	7	—	Synthetic fibers and adhesives, comonomer for food packaging
cis-1,2-Dichloroethylene	cis-1,2-Dichloroethene	—	.5	.5	—	70	—	Solvent, refrigerant, organic synthesis
trans-1,2-Dichloroethylene	trans-1,2-Dichloroethene	3.0	.5	.5	—	100	—	Solvent, refrigerant, organic synthesis
Dichlorodifluoromethane	Fluorocarbon-12, Freon 12	3.0	.5	1.0	.5	¹ 1,000	—	Refrigerant, aerosol propellant, plastics
Dichloromethane (DCM)	Methylene chloride	3.0	.5	.5	—	5	5	Solvent, ingredient in paint removers, metal degreaser, fumigant
1,3-Dichloropropane	Trimethylene dichloride	—	.5	1.0	—	—	—	—
1,2-Dichloropropane	Propylene dichloride	3.0	.5	.5	—	5	.6	Chemical intermediate, lead scavenger in antiknock fluids, soil fumigant, organic synthesis
1,3-Dichloropropene	—	3.0	—	1.0	—	—	.2	Soil fumigant

Table 1. Minimum reporting limits, drinking-water standards or guidelines, health advisory for cancer risk, and major uses of selected volatile organic compounds analyzed for in ground-water samples collected in the Great Salt Lake Basins study unit—Continued

Volatile organic compound (VOC)	Common name	Minimum reporting limit				Drinking water standard or guideline (µg/L)	Health advisory for cancer risk (µg/L)	Major use or source
		NWIS data set		PDWS data set				
		Utah (µg/L)	Idaho (µg/L)	Utah (µg/L)	Idaho (µg/L)			
cis-1,3-Dichloropropene	cis-1,3-Dichloropropylene	3.0	.5	—	—	—	.2	Soil fumigant
trans-1,3-Dichloropropene	trans-1,3-Dichloropropylene	3.0	.5	—	—	—	.2	Soil fumigant
Ethylbenzene	Ethylbenzol, phenylethane	3.0	.5	.5	—	700	—	Intermediate for styrene monomer production, solvent, hydrocarbon
Hexachlorobenzene	Perchlorobenzene	—	—	.2	—	1	—	Manufacture of pentachlorophenol, seed fungicide, wood preservative
Hexachlorobutadiene	HCBD	—	.5	1.0	.5	¹ 1	—	Solvent for elastomers and rubber, heat-transfer fluid
Isopropylbenzene	Cumene, (1-Methylethyl)benzene	—	.5	1.0	.5	—	—	Constituent of motor fuel and asphalt, octane booster for gasoline, organic synthesis
p-Isopropyltoluene	p-Cymene	—	.5	1.0	.5	—	—	—
Napthalene	Camphor tar	—	.5	1.0	.5	¹ 20	—	Mothball manufacturing, preparation of pesticides, detergents, hydrocarbon
n-Propylbenzene	1-Phenylpropane, Isocumene	—	.5	1.0	.5	—	—	Textile dyeing and printing, solvent
Styrene	Ethyenyl benzene, Vinyl benzene	3.0	.5	.5	—	100	—	Preparation of polystyrene, synthetic rubber, resins, plastics
1,1,1,2-Tetrachloroethane	—	—	.5	1.0	—	¹ 70	1	—
1,1,2,2-Tetrachloroethane	Acetylene tetrachloride, Tetrachloroethane	3.0	.5	1.0	—	—	—	Solvent, insecticide and bleach manufacturing, metal cleaner
Tetrachloroethylene (PCE)	Tetrachloroethene, Perchloroethylene	3.0	.5	.5	—	5	.3	Dry cleaning fluid, degreasing and drying agent, solvent
Toluene	Methylbenzene	3.0	.5	.5	—	1,000	—	Production of benzene, gasoline blending, solvent, hydrocarbon
1,2,3-Trichlorobenzene	—	—	.5	1.0	.5	—	—	Isomeric mixture is used to control termites, organic synthesis
1,2,4-Trichlorobenzene	1,2,4-TCB	—	.5	.5	—	70	—	Dye carrier, solvent, degreasing agent, insecticide
1,1,1-Trichloroethane	Methyl chloroform	3.0	.5	.5	—	200	—	Vapor degreasing of metals, solvent
1,1,2-Trichloroethane	Vinyl trichloride; 1,1,2-TCE	3.0	.5	.5	—	5	—	Solvent, organic synthesis
Trichloroethylene (TCE)	Trichloroethene	3.0	.5	.5	—	5	3	Metal degreasing and drying agent, solvent
Trichlorofluoromethane	Fluorotrichloromethane, Fluorocarbon-11	3.0	.5	1.0	.5	¹ 2,000	—	Aerosol propellant, refrigerant, solvent, chemical intermediate
1,2,3-Trichloropropane	Glycerin trichlorohydrin	—	.5	1.0	—	¹ 40	5	Solvent, degreaser, paint and varnish removers
1,2,4-Trimethylbenzene	Pseudocumene	—	.5	1.0	.5	—	—	Manufacture of dyes, resins, perfumes, organic synthesis
1,3,5-Trimethylbenzene	Mesitylene	—	.5	1.0	.5	—	—	Ultraviolet oxidation stabilizer for plastics, hydrocarbon
Vinyl chloride	Chloroethene	3.0	.5	.5	—	2	.015	Degradation product of chlorinated solvents
Xylenes, total	Dimethylbenzene	3.0	—	.5	—	10,000	—	Solvent, motor fuels, hydrocarbon

¹U.S. Environmental Protection Agency (1996) lifetime-health advisory level for a 70-kilogram adult.

²A trihalomethane, it is a by-product of the chlorination disinfection process; the 1994 proposed rule for disinfectants and disinfection by-products is that the total for all trihalomethanes combined cannot exceed 80 µg/L (U.S. Environmental Protection Agency, 1996).

locations of the sampled sites are known. Ground-water data from the USGS National Water-Quality Information System (NWIS) and the Idaho and Utah Public Drinking Water Systems (PDWS) databases were reviewed. Water-quality data were not available for public drinking-water systems in the Wyoming part of the study unit. The PDWS databases contain chemical analyses of water sampled from wells used for public drinking-water supply. The wells in these databases are sampled only to ensure compliance with State and Federal drinking-water regulations, not as part of a randomly distributed network. The NWIS database contains chemical analyses of water sampled from wells as part of geohydrologic and water-quality studies or as part of a water-quality monitoring network.

Data Screening, Comparability, and Distribution

For this report, only the most recent analysis was included in the data sets if more than one analysis was available for a site. Older analyses were removed to avoid creating a bias toward frequently sampled wells. Nitrate data in the NWIS data set were required to have well location and depth information to be included in this retrospective analysis. The NWIS data set for VOCs included some wells where the total depth was not known. Well depth was not available electronically from the PDWS databases, but an assumption was made that wells used for public supply generally are greater than 100 ft deep. The source of the ground-water samples was not differentiated by withdrawal from consolidated or unconsolidated rocks.

Nitrate data in the PDWS and NWIS data sets were collected for 1990-98 and 1980-97, respectively. Federal requirements for public-water suppliers to test for VOCs became effective in 1992. Volatile organic compound data submitted to the Utah PDWS database during the first few years contained a higher percentage of detection, that after further study, proved to be false (Larry Scanlan, Utah Division of Drinking Water, oral commun., 1998). Most of the VOC data set representing the PDWS database extends from 1994 to 1998, a period during which the data have been proven more reliable.

Chlorinated public-water systems serving 10,000 or more people have been required to test for the disinfection by-products chloroform, bromoform, bromodichloromethane, and chlorodibromomethane since 1979. Only samples listed as not undergoing a disinfection or treatment process were selected from the Utah PDWS database. Because of the longer monitoring

period for chloroform, bromoform, bromodichloromethane, and chlorodibromomethane, data from 1990-98 for these compounds were included in the PDWS data set.

The NWIS VOC data set for Utah was collected at a regional scale in 1989 and includes 31 samples. The NWIS VOC data set for Idaho is part of a State-monitoring network created in cooperation with the Idaho Department of Water Resources that consists of 43 wells within the study unit. Another set of VOC data specific to the shallow unconfined aquifer and underlying confining layers in Salt Lake County, Utah (Thiros, 1992), and data collected to better understand localized areas with contaminated ground water, were not included in this retrospective analysis.

The PDWS data set mostly contains nitrate concentrations, whereas most analyses in the NWIS data set are for nitrite plus nitrate. Because nitrite concentrations are typically low compared with nitrate concentrations, nitrate plus nitrite will be referred to as nitrate so that comparisons can be made between the NWIS and PDWS data sets. Although different preservation methods and holding times were used for the nitrate and nitrate plus nitrite analyses stored in the databases, they are thought to be suitable for comparison.

The minimum reporting limit for nitrate data gathered from the Utah PDWS database ranged from 0.01 to 0.1 mg/L. The minimum reporting limit for nitrate plus nitrite as nitrogen from the NWIS database ranged from 0.05 to 0.1 mg/L. The minimum reporting limit for selected VOC data retrieved from the PDWS databases generally was 0.5 µg/L, although other limits were listed depending on the compound and the database (table 1). The minimum reporting limits for VOCs in the NWIS data set were 0.2 µg/L for samples from Salt Lake Valley in Utah, 0.5 µg/L for samples from Idaho, and 3.0 µg/L for samples from the rest of the study unit in Utah.

Nitrate data from the NWIS data set were grouped by well depth. Wells with depths less than or equal to 150 ft were placed into a shallow ground-water group and those with depths greater than 150 ft were placed into a deeper ground-water group. The basis for this arbitrary grouping is that the shallower ground water is more susceptible to contamination from land-surface activities, and the deeper ground water should be more representative of a water composition influenced by natural processes. Well-depth information was not readily available electronically from the PDWS database. Volatile organic compound data from the NWIS data set were not grouped by well depth because

some sampled wells lacked depth information and because of a limited number of analyses and detections. Nitrate and VOC data from the NWIS and PDWS data sets also were divided into groups on the basis of overlying land use: agricultural, urban/residential, and rangeland. The areal distribution of nitrate and VOC sample locations in the study unit also is presented in this report.

ANALYSIS OF NITRATE DATA

The NWIS data set contained nitrate analyses for water from 480 wells in the study unit (fig. 3). Nitrate was not reported in 92 ground-water samples (fig. 4). Concentration ranged from 0.01 to 86 mg/L with mean and median values of 2.71 and 1.30 mg/L, respectively, for the 388 values above minimum reporting limits. The MCL for nitrate was exceeded in water from 13 wells and water from 40 wells had concentrations equal to or greater than 5 mg/L in the study unit.

The PDWS data set contained nitrate analyses for water from 587 wells in the study unit (fig. 3). Nitrate analyses were included in the Utah PDWS data set if the site description indicated that the sample was collected near the well source. Samples collected from taps in the distribution system were not used because of the possibility of mixing with other sources. Nitrate concentrations were less than minimum reporting limits in 39 samples (fig. 4). Concentrations ranged from 0.01 to 13 mg/L with mean and median values of 1.57 and 1.12 mg/L, respectively, for the 548 values above minimum reporting limits (table 2). The MCL for nitrate was exceeded at 1 site in Utah County, Utah, and 22 sites had concentrations equal to or greater than 5 mg/L in the study unit.

The NWIS nitrate data set was divided into two groups: (1) water from wells greater than 150 ft deep, and (2) water from wells less than or equal to 150 ft deep. The MCL for nitrate was exceeded in water from 3 of 280 wells greater than 150 ft deep in the NWIS data set. The maximum concentration in the data set was 26 mg/L in water from a well in Box Elder County, Utah. Water from 13 wells had nitrate concentrations equal to or greater than 5 mg/L. The mean and median nitrate concentrations were 1.84 and 1.20 mg/L, respectively, for the 220 values above minimum reporting limits (table 2).

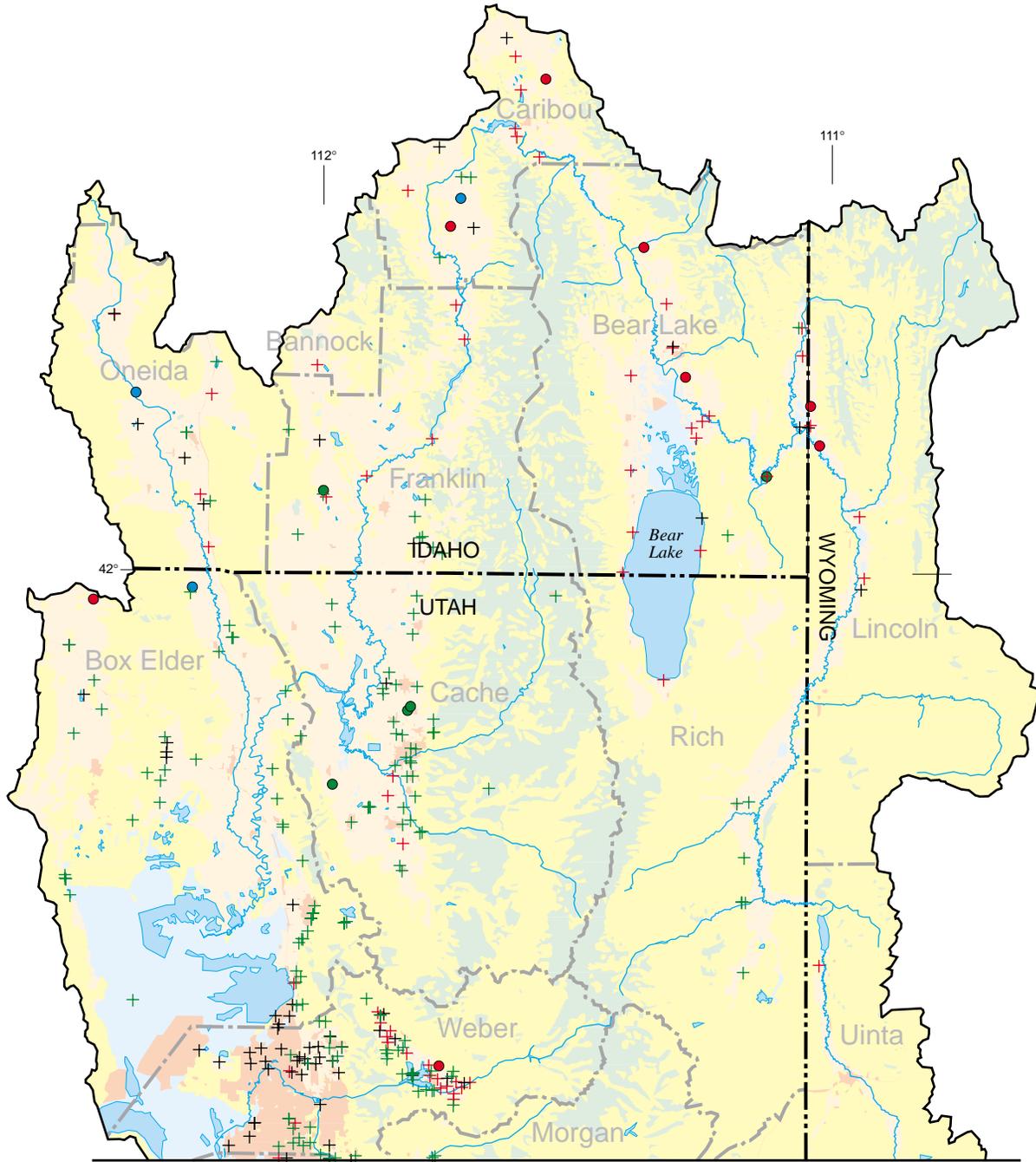
The MCL for nitrate was exceeded in water from 10 of the 200 wells less than or equal to 150 ft deep in the NWIS data set. The maximum concentration in water from wells less than or equal to 150 ft deep was

86 mg/L from a well in the northwestern part of Salt Lake County, Utah. Water from 27 wells had nitrate concentrations equal to or greater than 5 mg/L. The mean and median nitrate concentrations were 3.84 and 1.40 mg/L, respectively, for the 168 values above minimum reporting limits (table 2).

Most of the wells in the PDWS data set are assumed to be greater than 150 ft deep because of completion rules for public-supply wells. A comparison between wells greater than and less than or equal to 150 ft deep indicates that mean measured nitrate concentrations in water are greater for the shallower wells (3.84 mg/L) than for the deeper wells (1.57 mg/L for water from wells in the PDWS data set and 1.84 mg/L for water from wells greater than 150 ft deep in the NWIS data set). The median concentration was similar for the three data sets (fig. 5).

The type of land use in the area surrounding a well and the well depth were related to measured nitrate concentrations in the sampled ground water (table 2). Land use in the study unit was grouped into four categories: agricultural, rangeland, urban/residential, and other. Overall, water sampled from wells in rangeland areas had a lower median measured nitrate concentration (0.76 mg/L) than ground water from areas with an agricultural or urban/residential land use (1.41 and 1.20 mg/L, respectively). The median measured nitrate concentration for water from wells in agricultural areas did not vary substantially with well depth or data set (fig. 6), but the MCL for nitrate was exceeded in 6 of 98 water samples from wells less than or equal to 150 ft deep in the NWIS data set (6 percent). Conversely, 3 of 121 water samples from wells greater than 150 ft deep in the NWIS data set and only 1 of 153 water samples from wells in the PDWS data set had nitrate concentrations greater than 10 mg/L in agricultural areas.

The median measured nitrate concentration for water sampled from wells at all depths was more variable in urban/residential areas (table 2). The median measured concentration in water from urban/residential areas varied from a low of 1.00 mg/L for wells greater than 150 ft deep to a high of 1.84 mg/L for wells less than or equal to 150 ft deep in the NWIS data set. Twelve of the 63 water samples from wells less than or equal to 150 ft deep in urban/residential areas had concentrations equal to or greater than 5 mg/L and 2 samples had concentrations that exceeded the MCL for nitrate. Slightly more than 50 percent of the water samples above reporting limits (259) in the PDWS data set are located in urban/residential areas with a median measured nitrate concentration of 1.26 mg/L. This is



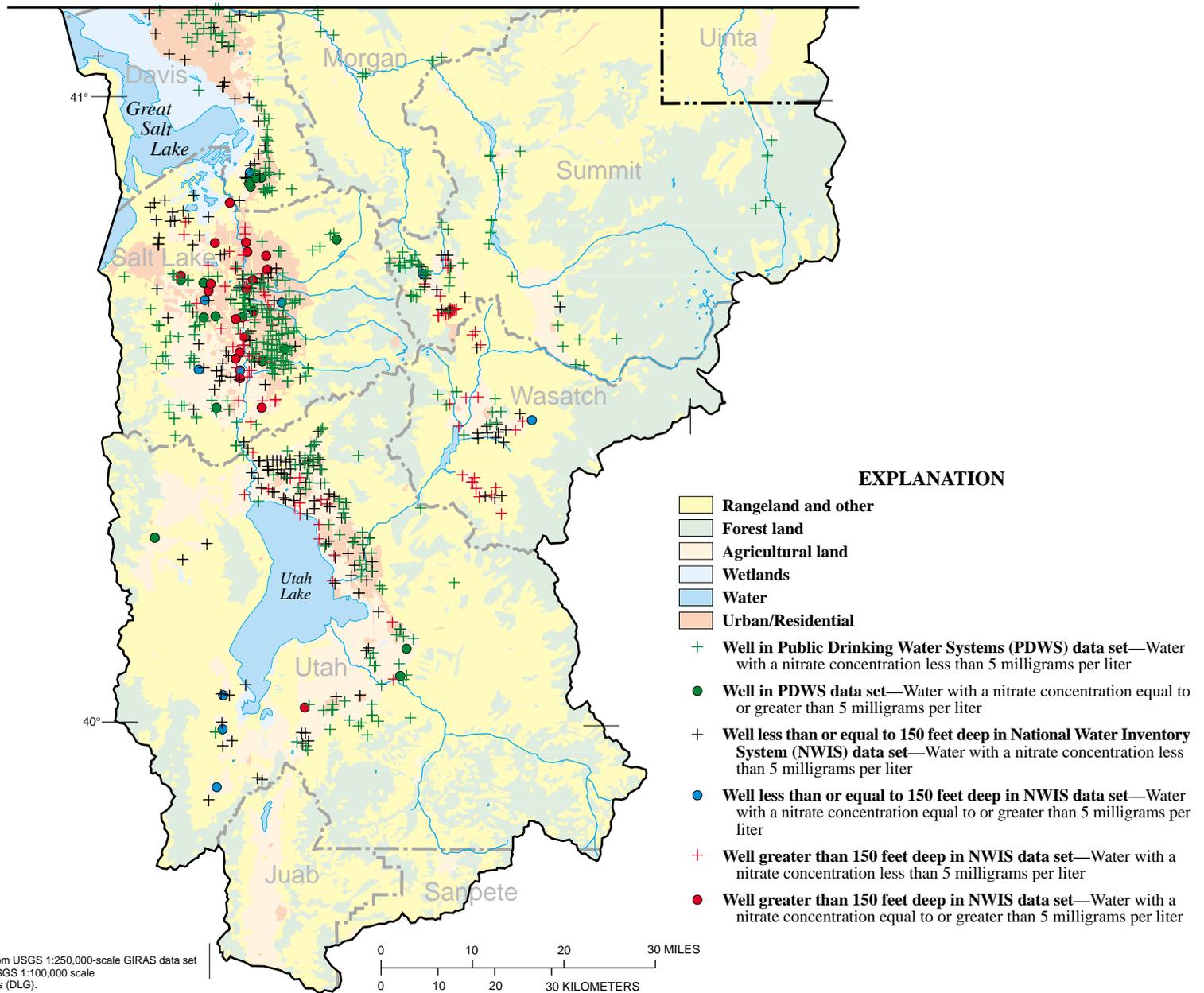


Figure 3. Land use and location of wells in the Public Drinking Water Systems and National Water Inventory System data sets where water was analyzed for nitrate and nitrate concentration was less than, equal to, or greater than 5 mg/L, Great Salt Lake Basins study unit.

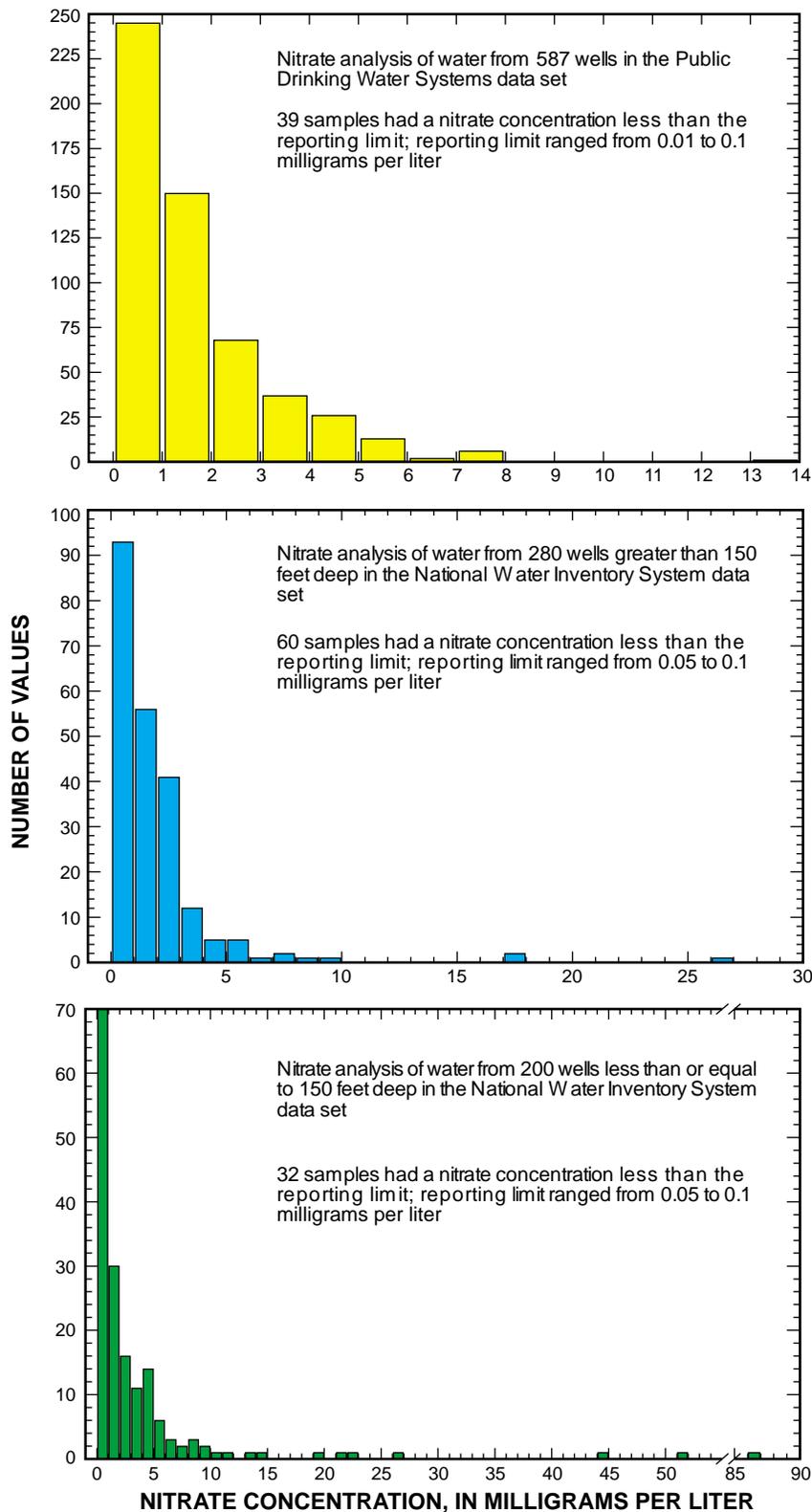


Figure 4. Nitrate concentration in water from wells in the Public Drinking Water Systems data set, and from wells greater than, and less than or equal to 150 feet deep in the National Water Information System data set, Great Salt Lake Basins study unit.

Table 2. Summary statistics for nitrate concentration in ground-water samples, Great Salt Lake Basins study unit, 1980-98

[mg/L, milligrams per liter]

National Water Information System (NWIS) data set										
Generalized land use	Wells greater than 150 feet deep					Wells less than or equal to 150 feet deep				
	Number of samples greater than reporting limit	Concentration			Number of samples less than reporting limit	Number of samples greater than reporting limit	Concentration			Number of samples less than reporting limit
		Mean (mg/L)	Maximum (mg/L)	Median (mg/L)			Mean (mg/L)	Maximum (mg/L)	Median (mg/L)	
Agricultural	109	2.38	26	1.60	12	84	3.64	44.7	1.45	14
Rangeland	23	1.15	5.5	.91	13	18	4.39	51	.44	10
Urban/Residential	80	1.43	7.5	1.00	30	63	4.11	86	1.84	8
Other	8	.68	2.1	.53	5	3	.39	.87	.29	0
Total	220	1.84	26	1.20	60	168	3.84	86	1.40	32

Public Drinking Water Systems (PDWS) data set						Combined NWIS and PDWS data sets				
Generalized land use	Number of samples greater than reporting limit	Concentration			Number of samples less than reporting limit	Number of samples greater than reporting limit	Concentration			Number of samples less than reporting limit
		Mean (mg/L)	Maximum (mg/L)	Median (mg/L)			Mean (mg/L)	Maximum (mg/L)	Median (mg/L)	
Agricultural	144	1.82	13.14	1.30	9	337	2.46	44.7	1.41	35
Rangeland	113	1.34	7.32	.78	12	154	1.67	51	.76	35
Urban/Residential	259	1.59	7.39	1.26	14	402	1.95	86	1.20	52
Other	32	1.01	4.00	.61	4	43	.91	4.00	.60	9
Total	548	1.57	13.14	1.12	39	936	2.04	86	1.18	131

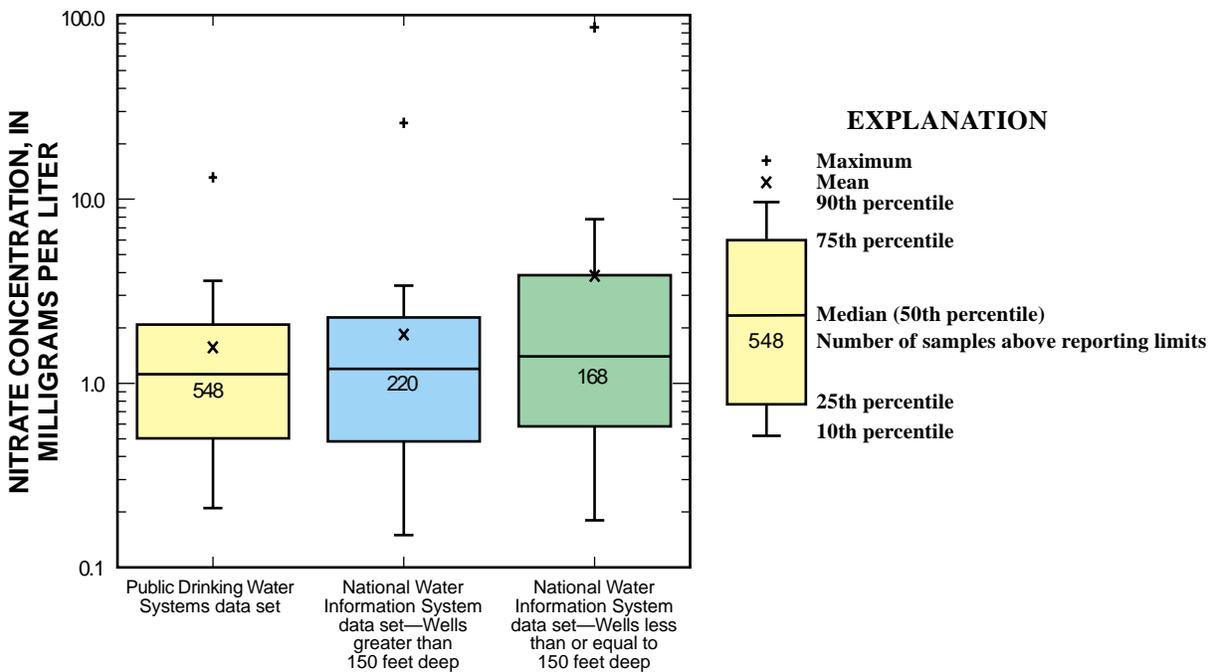
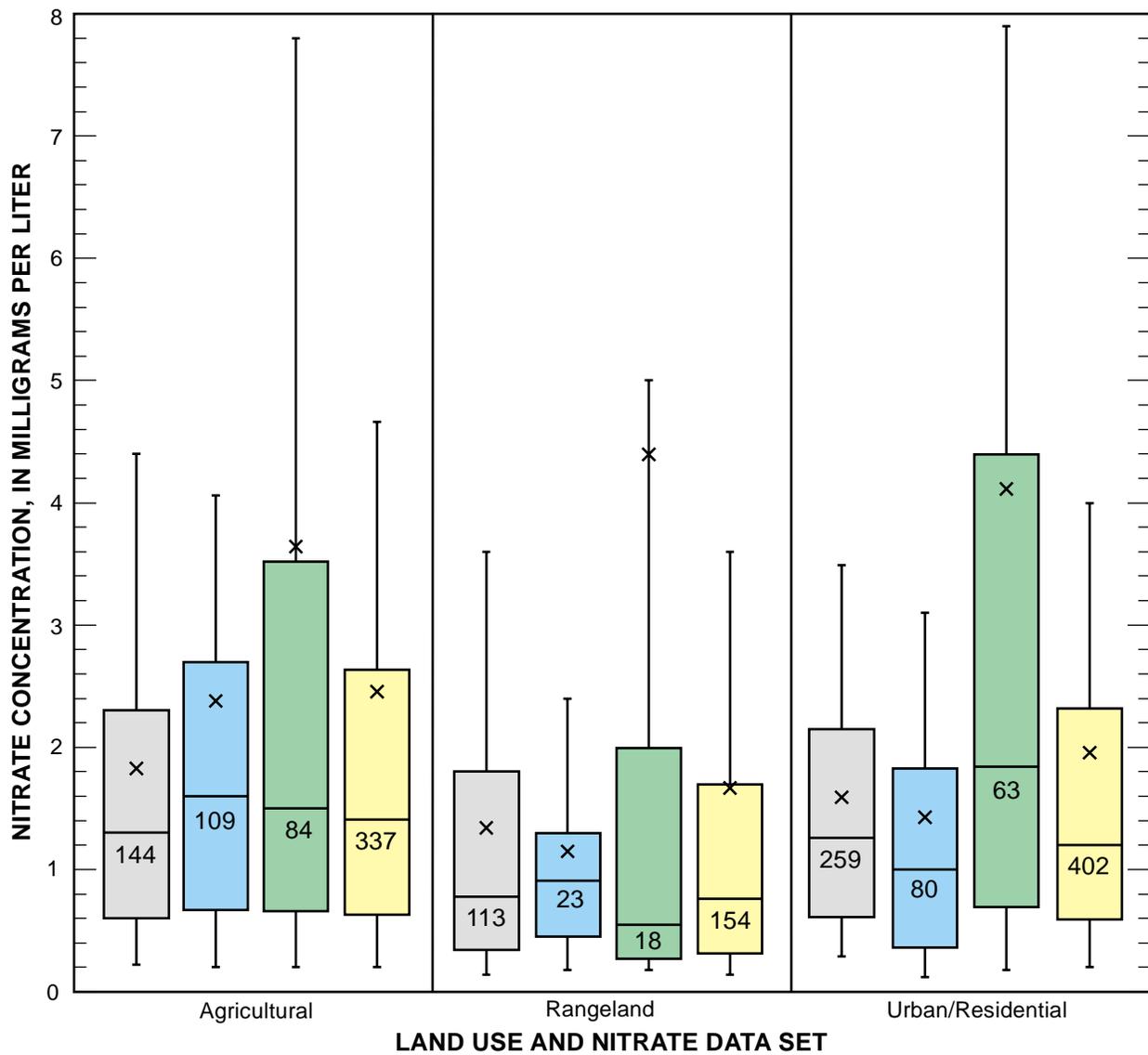


Figure 5. Range and distribution of measured nitrate concentration in water from wells in the Public Drinking Water Systems data set, and from wells greater than, and less than or equal to 150 feet deep in the National Water Information System data set, Great Salt Lake Basins study unit.



EXPLANATION

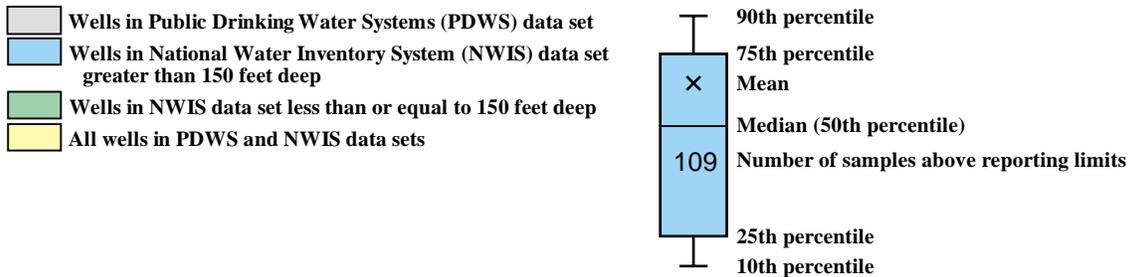


Figure 6. Range and distribution of measured nitrate concentration in water from wells by land use, Great Salt Lake Basins study unit.

comparable to the median measured nitrate concentrations for water from wells in the NWIS data set because it includes both depth ranges. Although nine samples in the PDWS data set had concentrations equal to or greater than 5 mg/L, none were above the MCL for nitrate.

ANALYSIS OF VOLATILE ORGANIC COMPOUND DATA

PDWS and NWIS data sets contained analyses for most of the State and Federally regulated and unregulated VOCs in water from about 368 and 74 wells, respectively. Fifteen different VOCs were detected at least once in ground water sampled from the GSLB study unit (table 3). Water sampled from 21 wells in the study unit contained at least 1 VOC at detectable concentrations (table 4). Site number 8 listed VOCs detected in both the NWIS and PDWS data sets (table 4).

Land use and location of wells with water in which VOCs were detected are shown in figure 7. Most of the wells sampled were in urban areas, particularly in Salt Lake County, Utah. This is a function of where ground water is used for public consumption. About 68 percent of the VOCs detected were in water sampled from wells in Salt Lake County.

Tetrachloroethylene (PCE) was the most commonly detected VOC in ground water sampled from the study unit and was measured in 8 out of 442 samples (less than 2 percent) (table 3). Tetrachloroethylene was detected in ground water from seven wells in Salt Lake and Davis Counties.

Maximum contaminant levels for tetrachloroethylene and 1,1-dichloroethylene were exceeded in water from one well each. Water suppliers are aware of these concentrations because the wells were sampled to determine if the water quality complies with State and Federal requirements.

Six VOCs were detected in water from site number 13 in the PDWS data set (table 4). This well is located in a rangeland area. The VOCs 1,1-dichloroethylene and 1,2-dichloroethane were detected exclusively in water from this well, in addition to trichloroethylene, 1,1,1-trichloroethane, ethylbenzene, and total xylenes. All six detected VOCs are used as metal degreasers or solvents; 1,1-dichloroethylene is a degradation by-product of trichloroethylene and 1,1,1-trichloroethane. The VOCs may have been introduced to water in the well by cleaned metal parts of the pump. The presence of VOCs at this site has not been verified with additional sampling.

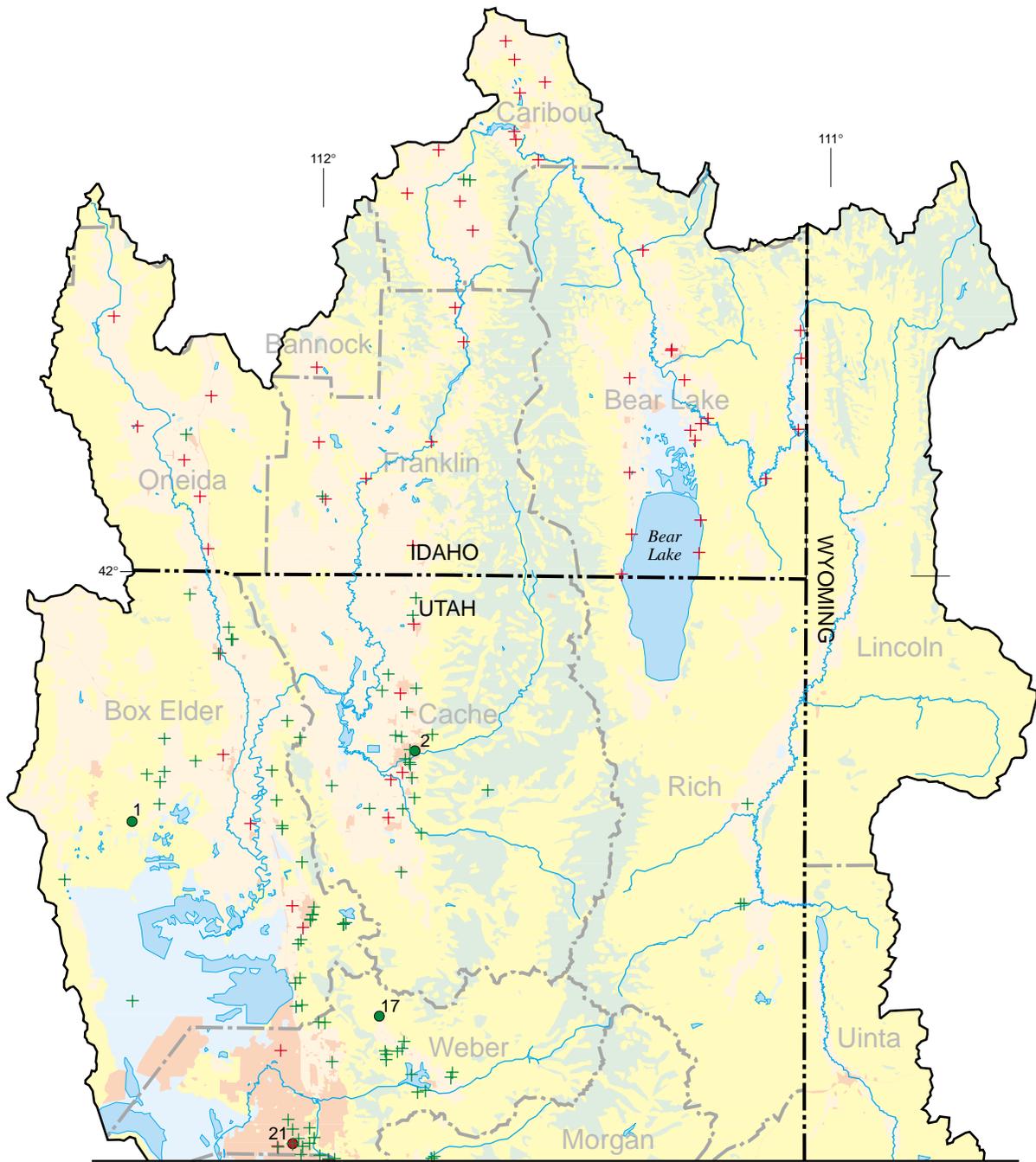
The occurrence of VOCs in ground water was correlated with the overlying land use in the GSLB

Table 3. Summary statistics for volatile organic compounds detected in ground water, Great Salt Lake Basins study unit

[µg/L, micrograms per liter; —, not applicable]

Detected volatile organic compound (VOC)	Total number of sites with detections	National Water Information System data set			Public Drinking Water Systems data set		
		Number of sites sampled	Number of sites with detections	Maximum concentration (µg/L)	Number of sites sampled	Number of sites with detections	Maximum concentration (µg/L)
Tetrachloroethylene	8	74	1	5.4	368	7	6.9
1,1,1-Trichloroethane	5	74	1	.3	368	4	26
Chloroform	3	74	3	19	¹ 68	0	—
Xylenes, total	3	31	0	—	369	3	1.0
Bromodichloromethane	2	74	2	10	¹ 67	0	—
Ethylbenzene	2	74	0	—	369	2	.2
Trichloroethylene	2	74	0	—	368	2	4.2
Toluene	2	74	1	.2	369	1	1.3
Chlorodibromomethane	1	74	1	4.8	¹ 66	0	—
1,2-Dichloroethane	1	74	0	—	368	1	.8
1,1-Dichloroethylene	1	74	0	—	368	1	18
Dichloromethane	1	74	1	.2	368	0	—
Hexachlorobenzene	1	0	—	—	88	1	.1
Chlorobenzene	1	74	0	—	368	1	.1
Styrene	1	74	0	—	368	1	.6

¹Samples analyzed for chloroform, bromodichloromethane, and chlorodibromomethane included in the Public Drinking Water Systems data set for Utah were collected from wells undergoing no water treatment.



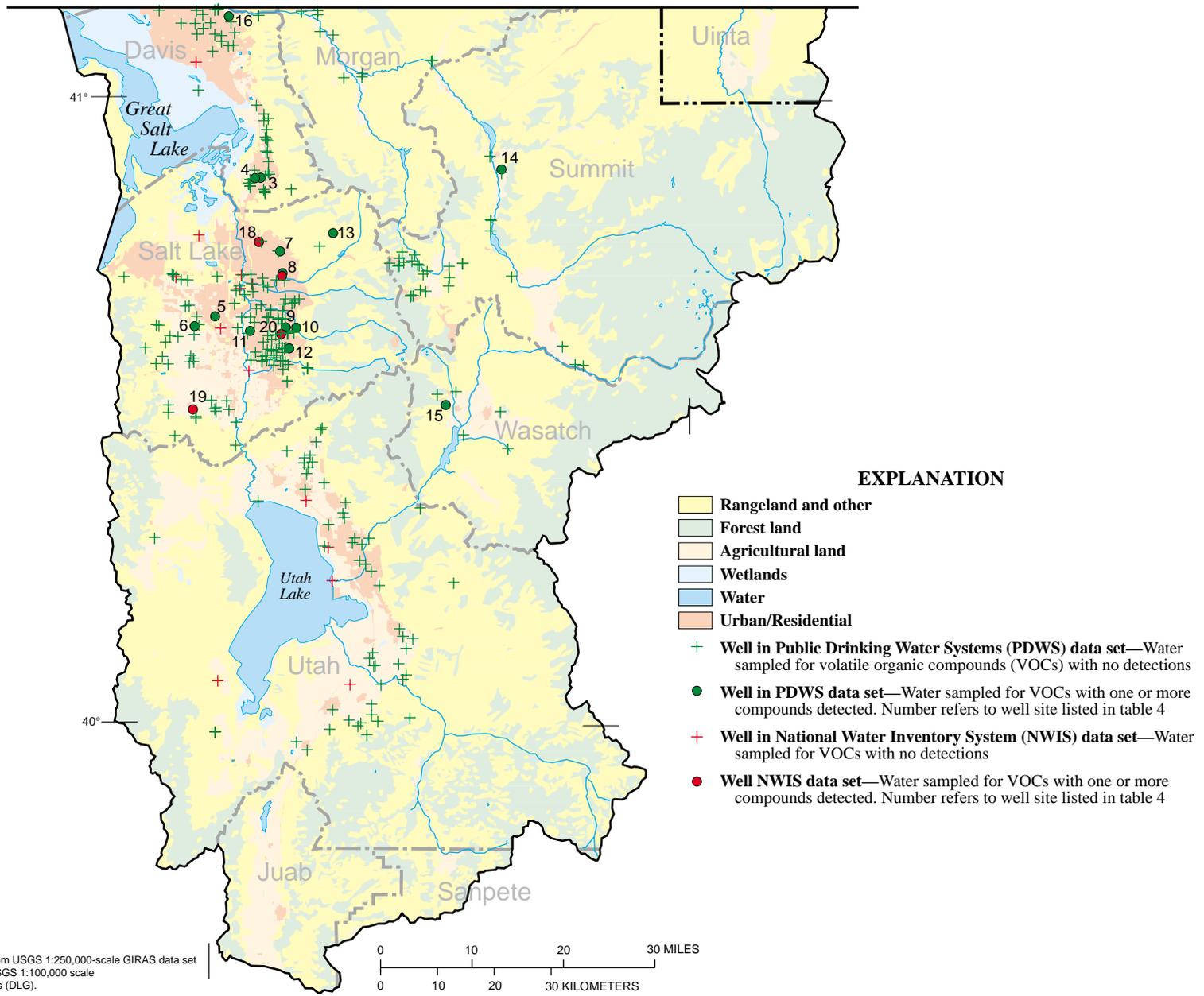


Figure 7. Land use and location of wells in the Public Drinking Water Systems and National Water Information System data sets where water was sampled for selected volatile organic compounds and where volatile organic compounds were detected, Great Salt Lake Basins study unit.

Table 4. Concentration of selected volatile organic compounds detected in ground water, Great Salt Lake Basins study unit

[See fig. 7 for location of well sites; concentration in micrograms per liter; —, not detected]

Well site	Date collected	County, State	Chloroform	Bromodichloromethane	Chlorodibromomethane	Tetrachloroethylene	1,1,1-Trichloroethane	Ethylbenzene	Trichloroethylene	Xylenes, total	1,2-Dichloroethane	1,1-Dichloroethylene	Dichloromethane	Hexachlorobenzene	Chlorobenzene	Styrene	Toluene
Public Drinking Water Systems data set																	
1	6/9/98	Box Elder, Utah	—	—	—	—	—	—	4.2	—	—	—	—	—	—	—	—
2	9/21/98	Cache, Utah	—	—	—	—	—	—	—	—	—	—	—	.1	—	—	—
3	10/28/98	Davis, Utah	—	—	—	1.3	—	—	—	—	—	—	—	—	—	—	—
4	10/28/98	Davis, Utah	—	—	—	1.5	—	—	—	—	—	—	—	—	—	—	—
5	6/22/98	Salt Lake, Utah	—	—	—	.7	—	—	—	—	—	—	—	—	—	—	—
6	7/29/97	Salt Lake, Utah	—	—	—	—	—	.1	—	.5	—	—	—	—	.1	—	—
7	7/8/97	Salt Lake, Utah	—	—	—	.6	—	—	—	—	—	—	—	—	—	—	—
8	9/11/96	Salt Lake, Utah	—	—	—	6.9	—	—	—	—	—	—	—	—	—	—	—
9	8/19/97	Salt Lake, Utah	—	—	—	2.7	—	—	—	—	—	—	—	—	—	—	—
10	3/14/96	Salt Lake, Utah	—	—	—	—	.8	—	—	—	—	—	—	—	—	—	—
11	8/3/94	Salt Lake, Utah	—	—	—	—	1.1	—	—	—	—	—	—	—	—	—	—
12	7/1/98	Salt Lake, Utah	—	—	—	3.9	—	—	—	—	—	—	—	—	—	—	—
13	2/25/94	Salt Lake, Utah	—	—	—	—	26	.2	1.3	1.0	.8	18	—	—	—	—	—
14	5/20/97	Summit, Utah	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.3
15	2/16/96	Wasatch, Utah	—	—	—	—	—	—	—	.7	—	—	—	—	—	—	—
16	8/28/95	Davis, Utah	—	—	—	—	—	—	—	—	—	—	—	—	—	.6	—
17	1/27/94	Weber, Utah	—	—	—	—	1.0	—	—	—	—	—	—	—	—	—	—
National Water Information System data set																	
18	6/19/89	Salt Lake, Utah	1.3	.2	—	—	—	—	—	—	—	—	—	—	—	—	—
19	6/6/89	Salt Lake, Utah	—	—	—	—	—	—	—	—	—	—	—	—	—	—	.2
8	6/28/89	Salt Lake, Utah	.4	—	—	5.4	—	—	—	—	—	—	—	—	—	—	—
20	6/7/89	Salt Lake, Utah	—	—	—	—	.3	—	—	—	—	—	.2	—	—	—	—
21	7/18/89	Weber, Utah	19	10	4.8	—	—	—	—	—	—	—	—	—	—	—	—

study unit. Water from three wells in agricultural areas and six wells in rangeland areas contained at least one VOC at detectable concentrations. The presence of chlorobenzene, ethylbenzene, toluene, and total xylenes in water samples from agricultural areas may be related to the use of these VOCs in pesticides and fuels. Trichloroethylene and 1,1,1-trichloroethane were detected in water sampled from two and three wells, respectively, in rangeland areas (fig. 8). The presence of these VOCs may result from the use of metal degreasers and solvents in the area of the wells.

Most VOCs detected in water from the GSLB study unit were from wells located in urban/residential land use areas (fig. 8). Eight different compounds were detected at least once in water sampled from 12 wells. Tetrachloroethylene was the most commonly detected VOC, accounting for 7 of the 18 detections in water from urban/residential areas. This may be related to the

presence of dry cleaners and other industries that use solvents in urban areas.

Chloroform was detected in water sampled from three wells in urban/residential areas. Chloroform, along with bromoform, bromodichloromethane, and chlorodibromomethane, are a group of VOCs known as trihalomethanes (THMs). Trihalomethanes consist of a central carbon atom to which any three halogen atoms (chlorine, bromine, or fluorine) are bonded and can form as a consequence of disinfecting drinking-water supplies. Generally, chlorine added for disinfection reacts with naturally occurring organic material in the water to produce THMs. Together they are regulated by the USEPA as total THMs with a proposed cumulative MCL of 80 mg/L (U.S. Environmental Protection Agency, 1996).

The detection of THMs in water pumped from wells may indicate relatively recent recharge to the ground-water system, such as from infiltration of chlo-

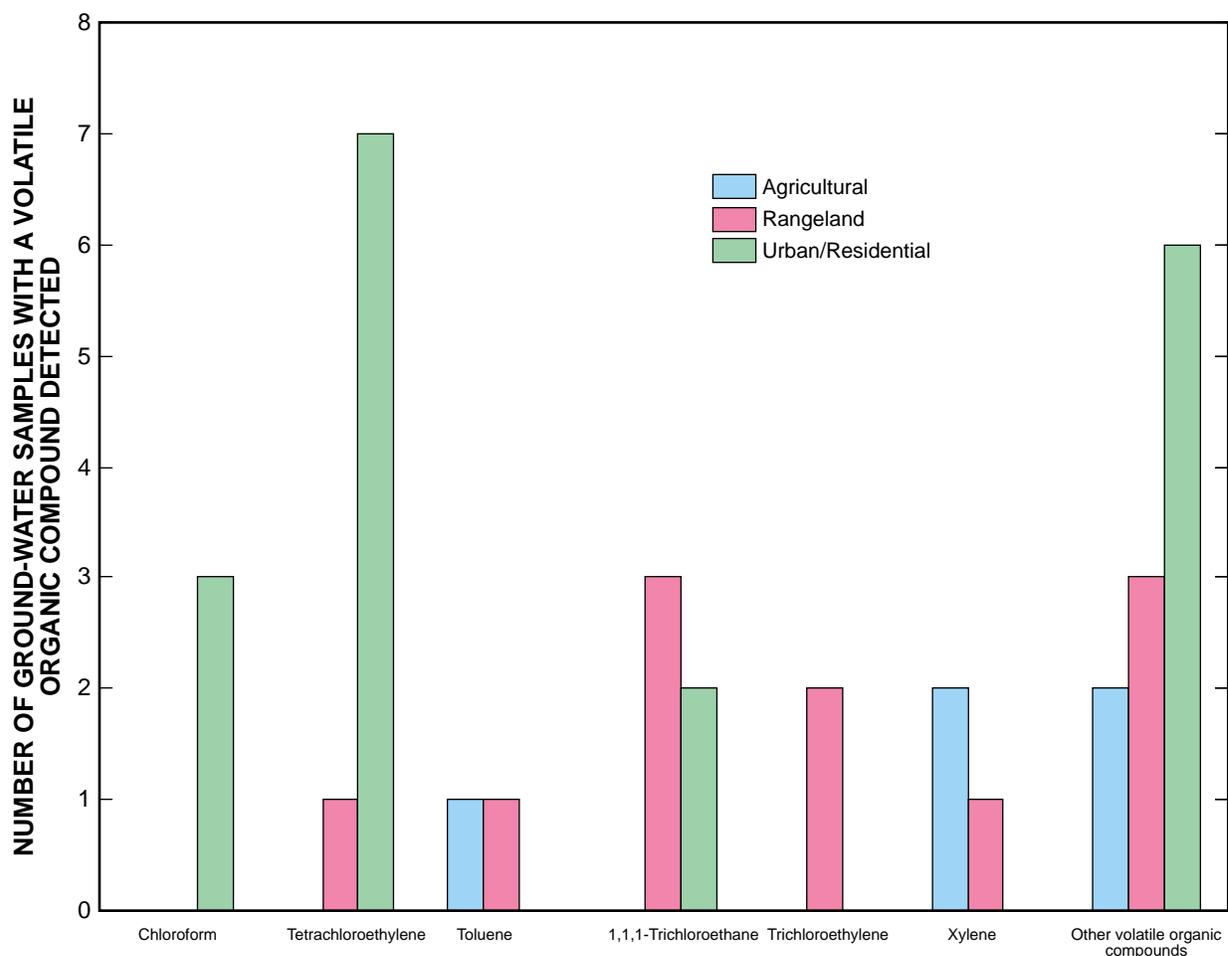


Figure 8. Number of volatile organic compounds detected in ground-water samples by land use, Great Salt Lake Basins study unit.

rinated water applied to lawns and gardens, leaking water pipes, septic tank drainfields, contamination occurring at chlorinated wells, or a combination of sources. Although check valves that prevent the movement of chlorinated water into public-supply wells are required, the possibility exists for some to leak or fail resulting in the addition of THMs to the aquifers. Additional data and study are needed to determine the sources of THMs in the ground-water system. No trihalomethanes were measured in agricultural or rangeland areas.

SUMMARY

Nitrate and volatile organic compound data for ground-water samples collected in the Great Salt Lake Basins study unit were compiled and summarized as part of the National Water-Quality Assessment Program's objective to describe water-quality conditions in

the Nation's aquifers. Ground-water data collected during 1980-98 and stored in the U.S. Geological Survey National Water Information System and the Idaho and Utah Public Drinking Water Systems databases were reviewed.

The National Water Information System data set contained nitrate analyses for water from 480 wells. The median concentration of nitrate was 1.30 milligrams per liter (mg/L) for the 388 values above minimum reporting limits. The maximum contaminant level for nitrate was exceeded in water from 10 of the 200 wells less than or equal to 150 feet deep and in water from 3 of 280 wells greater than 150 feet deep. The Public Drinking Water Systems data set contained nitrate analyses for water from 587 wells. The median concentration of nitrate was 1.12 mg/L for the 548 values above minimum reporting limits. The maximum contaminant level for nitrate was exceeded at 1 site and

22 sites had concentrations equal to or greater than 5 mg/L.

The types of land use in the area surrounding a well and the well depth were related to nitrate concentrations in the sampled ground water. Overall, water sampled from wells in rangeland areas had a lower median measured nitrate concentration (0.76 mg/L) than ground water from areas with an agricultural or urban/residential land use (1.41 and 1.20 mg/L, respectively). In the National Water Information System data set, the median nitrate concentration in water from urban/residential areas varied from 1.00 mg/L for wells greater than 150 feet deep to 1.84 mg/L for wells less than or equal to 150 feet deep.

The Public Drinking Water Systems and the National Water Information System data sets contained analyses for most of the regulated volatile organic compounds in water from about 368 and 74 wells, respectively. Fifteen different volatile organic compounds were detected at least once in ground water sampled from the Great Salt Lake Basins study unit. Water sampled from 21 wells contained at least 1 volatile organic compound at detectable concentrations. About 68 percent of the volatile organic compounds detected were in water sampled from wells in Salt Lake County, Utah. Tetrachloroethylene was the most commonly detected volatile organic compound in ground water sampled from the study unit, present in 8 out of 442 samples. Maximum contaminant levels for tetrachloroethylene and 1,1-dichloroethylene as established by the U.S.

Environmental Protection Agency were exceeded in water from one well each from these two data sets.

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