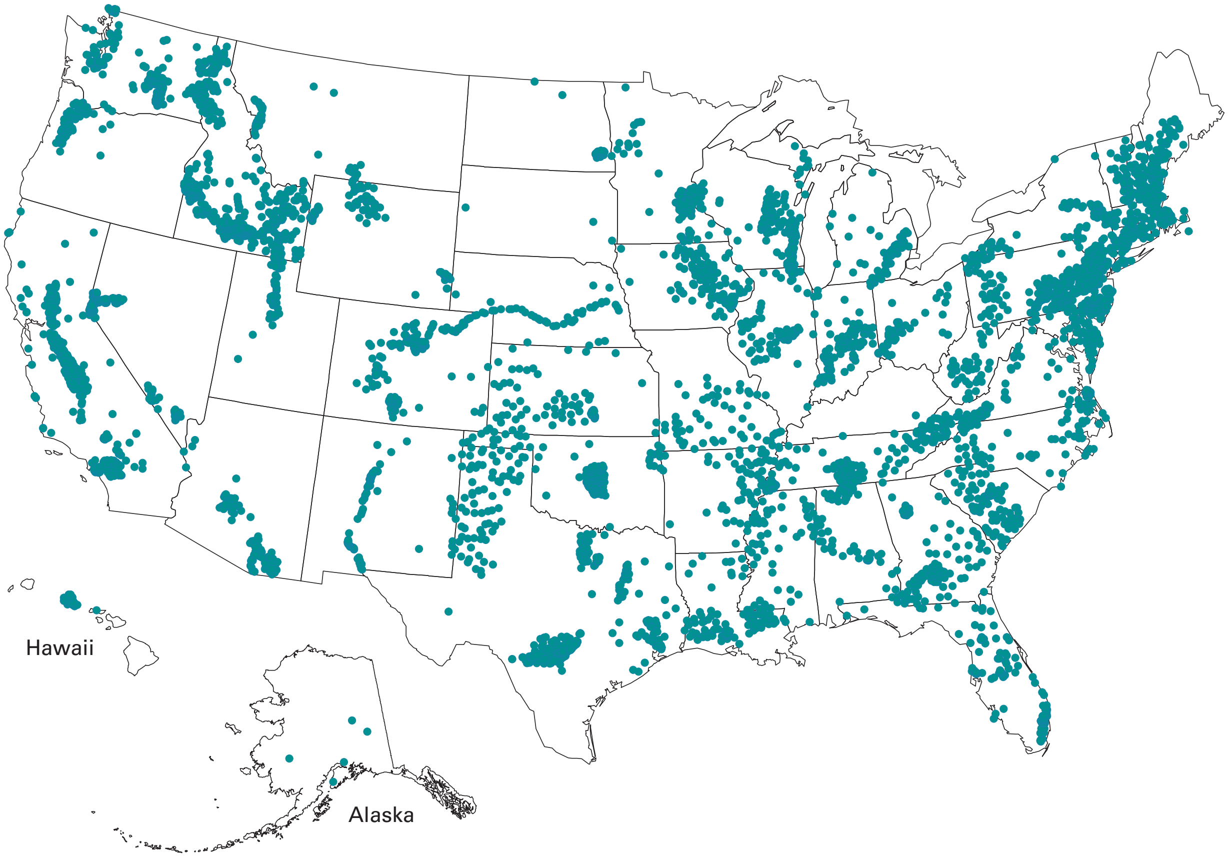
NATIONAL WATER-QUALITY ASSESSMENT PROGRAM
NATIONAL SYNTHESIS ON VOLATILE ORGANIC COMPOUNDS

Occurrence of Trihalomethanes in the Nation's Ground Water and Drinking-Water Supply Wells, 1985–2002



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

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By Bryan D. Schaap and John S. Zogorski

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Study Unit Abbreviations, Other Abbreviations and Acronyms:

ACAD	Acadian–Pontchartrain Drainages
ACFB	Apalachicola–Chattahoochee–Flint River Basins
ALBE	Albemarle–Pamlico Drainage Basin
ALMN	Allegheny–Monongahela River Basins
CAZB	Central Arizona Basins
CCPT	Central Columbia Plateau
CNBR	Central Nebraska Basins
CONN	Connecticut, Housatonic, and Thames River Basins
COOK	Cook Inlet Basin
DELR	Delaware River Basin
EIWA	Eastern Iowa Basins
GAFL	Georgia–Florida Coastal Plain
GRSL	Great Salt Lake Basins
HDSN	Hudson River Basin
HPGW	High Plains Regional Ground Water Study
KANA	Kanawha–New River Basins
LERI	Lake Erie–Lake St. Clair Drainages
LINJ	Long Island–New Jersey Coastal Drainages
LIRB	Lower Illinois River Basin
LSUS	Lower Susquehanna River Basin
LTEN	Lower Tennessee River Basin
MIAM	Great and Little Miami River Basins
MISE	Mississippi Embayment
MOBL	Mobile River Basin

NECB	New England Coastal Basins
NROK	Northern Rockies Intermontane Basins
NVBR	Nevada Basin and Range
OAHU	Oahu
OZRK	Ozark Plateaus
POTO	Potomac River Basin
PUGT	Puget Sound Basin
REDN	Red River of the North Basin
RIOG	Rio Grande Valley
SACR	Sacramento River Basin
SANA	Santa Ana Basin
SANJ	San Joaquin–Tulare Basins
SANT	Santee River Basin and Coastal Drainages
SCTX	South-Central Texas
SOFL	Southern Florida
SPLT	South Platte River Basin
TRIN	Trinity River Basin
UCOL	Upper Colorado River Basin
UIRB	Upper Illinois River Basin
UMIS	Upper Mississippi River Basin
USNK	Upper Snake River Basin
UTEN	Upper Tennessee River Basin
WHIT	White River Basin
WILL	Willamette Basin
WMIC	Western Lake Michigan Drainages
YELL	Yellowstone River Basin
µg/L	microgram per liter
AWWARF	American Water Works Association Research Foundation
CAS	Chemical Abstract Service
CFC-11	trichlorofluoromethane
CFC-12	dichlorodifluoromethane
CFC-113	trichlorotrifluoroethane
EDB	ethylene dibromide
IUPAC	International Union of Pure and Applied Chemistry
MCL	Maximum Contaminant Level
MTBE	methyl *tert*-butyl ether
NAWQA	U.S. Geological Survey National Water-Quality Assessment Program
NWQL	U.S. Geological Survey National Water Quality Laboratory
PCE	perchloroethene
RETRO	retrospective data
TCA	1,1,1-trichloroethane
TCE	trichloroethene
THM	trihalomethane
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
VOC	volatile organic compound

Occurrence of Trihalomethanes in the Nation’s Ground Water and Drinking-Water Supply Wells, 1985–2002

By Bryan D. Schaap and John S. Zogorski

Abstract

This report describes the occurrence of trihalomethanes (THMs) in the Nation’s ground water and drinking-water supply wells based on analysis of 5,642 samples of untreated ground water and source water collected or compiled during 1985–2002 by the U.S. Geological Survey National Water-Quality Assessment (NAWQA) Program. THMs are a group of volatile organic compounds (VOCs) with natural and anthropogenic sources that are of interest because they are associated with acute and chronic health problems in humans. THMs occur in water primarily from chlorination and are classified as disinfection by-products. In this report, the four THMs are discussed in the order of chloroform, bromodichloromethane, dibromochloromethane, and then bromoform; this sequence corresponds to largest to smallest chlorine content and smallest to largest bromine content.

Four trihalomethanes were detected in less than 20 percent of samples from studies of (1) aquifers, (2) shallow ground water in agricultural areas, (3) shallow ground water in urban areas, (4) domestic wells, and (5) public wells. Detection frequencies for individual THMs in the five studies ranged from zero for shallow ground water in agricultural areas to 19.5 percent for shallow ground water in urban areas. None of the samples from aquifer studies, domestic wells, or public wells had total THM concentrations (the sum of the concentrations of chloroform, bromodichloromethane, dibromochloromethane, and bromoform) greater than or equal to the U.S. Environmental Protection Agency Maximum Contaminant Level of 80 micrograms per liter (μg/L).

Comparisons of results among studies of aquifers, shallow ground water in agricultural areas, and shallow ground water in urban areas were used to describe the occurrence of the four THMs in ground water for three different land-use settings—mixed, agricultural, and urban, respectively. At the 0.2-μg/L assessment level, one or more of the four THMs were detected in 7.9 percent of the samples from aquifer studies, 2.2 percent of the samples from shallow ground water in agricultural areas, and 19.5 percent of the samples from shallow ground water in urban areas. In general, detection frequencies and concentrations of the four THMs were greater in shallow ground water in urban areas compared to aquifer studies and to shallow ground water in agricultural areas. For all three of these studies, the most common two-THM mixture at the 0.2-μg/L assessment level was chloroform–bromodichloromethane, and this was the only two-THM mixture found in samples of shallow ground water in agricultural areas.

Comparisons of results between studies of domestic wells and public wells were used to describe the occurrence of the four THMs in two different supplies of ground water used for drinking water. At the 0.2-μg/L assessment level, one or more of the four THMs were detected in 5.2 percent of the domestic well samples and in 14.7 percent of the public well samples. In general, detection frequencies and THM concentrations were greater in samples from public wells than from domestic wells. At the 0.2-μg/L assessment level, the six possible two-THM mixtures occurred about six times more frequently in samples from public wells than from domestic wells. One of the most common two-THM mixtures in samples from domestic and public wells was bromodichloromethane–dibromochloromethane.

Detection frequency is associated with the chlorine content of the THM compound. In general, for each of the five studies, as the chlorine content of the THM compound decreased, the detection frequency at the 0.2-μg/L assessment level also decreased. The exception was the study of public wells in which the detection frequency of the THMs decreased in the following order: chloroform, bromoform, dibromochloromethane, and bromodichloromethane.

At the 0.2-μg/L assessment level, the median concentration for one or more of the four THMs ranged from 0.3 μg/L (shallow ground water in agricultural areas) to 0.6 μg/L (shallow ground water in urban areas). For the other three studies (aquifers, domestic wells, and public wells), the median concentration was 0.5 μg/L. Generally, as the chlorine content of the THM compound decreased, the maximum concentration of the THM also decreased.

At both the 0.2-µg/L and the 0.02-µg/L assessment levels, the most common finding was that most samples did not have any detected THMs. Furthermore, the number of samples with no THMs was much greater than the number of samples with 2, 3, or 4 THMs combined. At the 0.2-µg/L assessment level, one THM was detected in 6.7 percent of the samples from aquifer studies (mixed land use), 2.1 percent of the samples from shallow ground water in agricultural areas, and 17.7 percent of the samples from shallow ground water in urban areas. For the same studies at the same assessment level, two or more THMs were detected in 1.3, 0.1, and 1.8 percent of the samples, respectively. At the 0.2-µg/L assessment level, one THM was detected in 4.6 percent of the domestic well samples and 9.4 percent of the public well samples. For the same studies at the same assessment level, two or more THMs were detected in 0.6 and 5.3 percent of the samples, respectively. For all five of the studies, chloroform was the most frequently detected individual THM, and if only one THM was detected in a sample, the THM was most likely to be chloroform.

Analyses of mixtures were performed using the 0.2-µg/L assessment level for shallow ground water in agricultural areas, shallow ground water in urban areas, and public wells and using the 0.02-µg/L assessment level for aquifer studies and domestic wells. No mixtures occurred in 1 percent or more of the samples collected from shallow ground water in agricultural areas. Comparing the results for the other four studies was difficult because of the different assessment levels, but some mixtures were more prevalent in all four studies. Generally, the most common mixtures included chloroform. Chloroform–bromodichloromethane was the most frequently detected or one of the most frequently detected two-THM mixtures in the four studies, and the mixtures of chloroform–perchloroethene and chloroform–methyl *tert*-butyl ether were the most frequently detected or one of the most frequently detected THM and non-THM mixtures in the four studies. For bromodichloromethane, dibromochloromethane, and bromoform, the most common mixtures were with other THMs. In samples collected from shallow ground water in urban areas and in samples collected from domestic wells, these three THMs were only detected when one or more of the other THMs were detected.

Introduction

The primary goals of the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) are to describe the status and trends in the quality of the Nation's ground- and surface-water resources and to identify the primary factors affecting the quality of these resources. A major component of the NAWQA Program includes the National Synthesis Investigations, for which occurrence information is compiled, interpreted, and reported for specific groups of contaminants, such as volatile organic compounds (VOCs), on a national scale.

Trihalomethanes (THMs) are a subgroup of VOCs that were included in water-quality analyses by the NAWQA Program during its first decade of assessments. Some general information about THMs, such as formal names, predominant use (origin), and chemical formulas, is presented in table 1. Detailed information about the chemical and physical properties of these four THMs can be found in Ivahnenko and Barbash (2004, p. 14).

THMs were selected for study because they are associated with acute and chronic health problems in humans. Three of the THMs (chloroform, bromodichloromethane, and bromoform) are suspected human carcinogens (Ivahnenko and Barbash, 2004). There is evidence that dibromochloromethane is carcinogenic, but that evidence is insufficient to assess human carcinogenic potential (U.S. Environmental Protection Agency, 2004). Ivahnenko and Barbash (2004) cited many different studies showing that exposure and ingestion of chloroform are associated with liver and kidney problems and adverse effects on unborn children. In addition, the four THMs are detected in surface water and ground water and in drinking-water supplies (Squillace, Moran, and others, 1999; Grady and Casey, 2001; Moran and others, 2002; Grady, 2003). The total concentration of THMs in drinking water has been regulated by the U.S. Environmental Protection Agency (USEPA) since 1979. The USEPA Maximum Contaminant Level (MCL) for total THMs is 80 µg/L (micrograms per liter).

THMs have natural and anthropogenic sources. A thorough description of chloroform sources can be found in Ivahnenko and Barbash (2004), who reported that natural sources account for 90 percent of the total global input of chloroform into the

Table 1. Properties of trihalomethanes.

[Modified from Bender and others, 1999. IUPAC, International Union of Pure and Applied Chemistry; CAS, Chemical Abstract Service]

Name used in report	IUPAC name	CAS number	Predominant use (origin)	Chemical formula	Molecular weight (gram/mole)
Chloroform	Trichloromethane	67-66-3	Disinfection by-product	$CHCl_3$	119.39
Bromodichloromethane	Bromodichloromethane	75-27-4	Disinfection by-product	$CHBrCl_2$	163.83
Dibromochloromethane	Chlorodibromomethane	124-48-1	Disinfection by-product	$CHBr_2Cl$	208.28
Bromoform	Tribromomethane	75-25-2	Disinfection by-product	$CHBr_3$	252.77

hydrologic system. Natural sources of chloroform are associated with volcanic gases, biomass burning, marine algae, and soil microorganisms (Ivahnenko and Barbash, 2004). Marine algae also have been identified as a natural source of the other three THMs (bromodichloromethane, dibromochloromethane, and bromoform) (Gribble, 1994).

Chloroform and other THMs commonly are produced during the chlorination of water and wastewater. Thus, THMs are a group of VOCs classified as disinfection by-products (table 1).

Chloroform was discovered in 1831 and has been used for many purposes since then, from an anesthetic to production of refrigerants. The major industrial use of chloroform is in the production of a refrigerant for home air conditioners and large commercial freezers. However, the largest releases of industrial chloroform were reported by the paper industry. In addition, chloroform is used for a variety of other commercial purposes. The widespread occurrence of chloroform in the hydrologic system was attributed to the chlorination of drinking water and wastewater and the natural and anthropogenic recycling of these waters containing THMs in the hydrologic cycle (Ivahnenko and Barbash, 2004). Disinfection by-products, including THMs, are produced when chlorine is added to water and interacts with organic material dissolved in the water (Rook, 1975). If bromide is present, one or more of the three brominated THMs (bromodichloromethane, dibromochloromethane, and bromoform) may be generated (Weinberg and others, 2002). The presence of brominated THMs with chloroform might be used as a criterion for distinguishing chlorinated waters from other potential sources of chloroform in the hydrologic system (Ivahnenko and Barbash, 2004).

THMs are relatively water soluble, have relatively low affinity for organic carbon, and are persistent under oxic conditions in ground water. Because of these properties, THMs that are not volatilized in near-surface soils or taken up by plants are expected to migrate substantial distances through the subsurface, especially in aquifers with small amounts of organic carbon (McCarty and others, 1981).

Purpose and Scope

The primary purpose of this report is to describe the occurrence of the four THMs (chloroform, bromodichloromethane, dibromochloromethane, and bromoform) in the Nation's ground water and drinking-water supply wells. The samples used in this assessment were of untreated ground water and source water that were collected or compiled by the NAWQA Program during 1985–2002. A secondary purpose is to compare reported concentrations with the USEPA MCL for total THMs (80 µg/L).

This report summarizes information assembled by the VOC National Synthesis team, including, in part, NAWQA water-quality data collected from 1993 to 2002. This report describes the occurrence of the four THMs in the following five studies: (1) aquifers, (2) shallow ground water in agricultural areas, (3) shallow ground water in urban areas, (4) domestic well samples, and (5) public well samples. Each of the five studies are presented separately for readers with different areas of interest (ground-water managers, urban planners, public health officials, water utilities, homeowners, and so forth). The occurrence of individual THMs and total THMs is characterized in terms of locations of detections, detection frequencies, concentrations, and their occurrence as mixtures. In addition, occurrence comparisons are made for (1) ground water (aquifer studies and shallow ground water in agricultural and urban areas), and (2) drinking-water supply wells (domestic well samples and public well samples). Two assessment levels, 0.2 and 0.02 µg/L, are used in the report. The basis for the two assessment levels is provided in Moran and others (2006).

In this report, the four THMs generally are discussed in the order of chloroform, bromodichloromethane, dibromochloromethane, and bromoform; this sequence corresponds to largest to smallest chlorine content and smallest to largest bromine content. This sequence is used when describing mixtures as well. For a two-THM mixture, the THM with the largest chlorine content is listed as the first of the pair. The order of discussion for two-THM mixtures is based on the chlorine content of the first THM and then on the second THM of the pair.

Previous Investigations

Several studies have described the occurrence of VOCs, including THMs, in untreated ground water, source water, and drinking water in the United States. Five of these studies are of particular relevance to this report, and some of these studies used part of the same water-quality data that were used for this study. The five studies are summarized briefly in this section of the report.

Squillace, Moran, and others (1999) studied the occurrence of VOCs, including THMs, in ambient ground water in rural and urban areas of the United States during 1985–1995 using some of the same water-quality data that were used for this study. At a 0.2-µg/L assessment level, chloroform was the most frequently detected VOC in urban areas, followed by methyl *tert*-butyl ether (MTBE), perchloroethene (also known as tetrachloroethylene, perc, or PCE), and trichloroethene (TCE). These four VOCs commonly were found together, but Squillace, Moran, and others (1999) concluded that this was because of their widespread distribution and not necessarily because they were used together.

Grady and Casey (2001) studied the distribution of VOCs, including THMs, in drinking water in 12 New England and Mid-Atlantic States during 1993–1998. Typically, the samples were collected after any water-treatment processes and before distribution to customers of the community water systems. Many of the samples had been chlorinated during treatment. At a 1.0-µg/L assessment level, the four most frequently detected VOCs in decreasing order were chloroform, bromodichloromethane, dibromochloromethane, and bromoform. In that same order, THMs were found in 26, 20, 19, and 12 percent, respectively, of systems with ground-water sources.

Moran and others (2002) studied the occurrence of VOCs in ground water from rural, untreated, self-supplied domestic well samples in the United States during 1986–1999 using some of the same water-quality data that were used for this study. At a 0.2-µg/L assessment level, at least one VOC was detected in 12 percent of the samples. At the same assessment level, chloroform was the most frequently detected VOC, found in 4.3 percent of well samples, and MTBE was the second most frequently detected VOC, found in 2.2 percent of well samples. Using no assessment level, 8 of the top 10 most frequently occurring mixtures of VOCs had chloroform as a component, including the four most frequently detected VOC mixtures.

Grady (2003) studied the distribution of VOCs, including THMs, in drinking-water sources of community water systems in the United States and Puerto Rico during 1999–2000 using some of the same water-quality data that were used for this study. The analytical results used by Grady (2003) for untreated ground-water sources included 575 ground-water samples that are described later in this report. The most frequently detected VOC was chloroform, and 4 of the 5 most frequently detected VOCs were THMs. One or more of the THMs were detected in 16 percent of ground-water sources. An analysis of the detection frequency of THMs by community water-system size showed that, in ground-water sources, the smallest systems had the largest detection frequency (18 percent) and the largest systems had the next largest detection frequency (17 percent). No seasonal variation in THM concentrations was observed in the ground-water sources studied. None of the samples from the ground-water sources had total THMs greater than the USEPA MCL of 80 µg/L.

Ivahnenko and Barbash (2004) provided a comprehensive literature review of information about chloroform in the hydrologic system that was based on information from more than 150 other studies conducted in the United States and many other countries. This included information about chloroform sources, fate in the hydrologic system, health effects, and the chemical reactions associated with the formation and degradation of chloroform.

Approach

Water-quality data collected or compiled by NAWQA were used to characterize the occurrence of the four THMs in representative data sets for each of the five studies—aquifer studies, shallow ground water in agricultural areas, shallow ground water in urban areas, domestic wells, and public wells. The use of different assessment levels affects these characterizations. The occurrence of the four THMs is described in terms of the locations of detections and nondetections, detection frequencies, concentrations, mixtures, and comparisons to the MCL.

The samples in this report generally were analyzed for 55 VOCs, which included the four THMs. For some samples, analytical results for one or more of the VOCs may not be available because of analytical and (or) field quality-control limitations. The missing results may affect the interpretation of the data, especially for the comparisons of various mixtures.

Data Sets

Analytical results for VOCs in samples from 5,642 wells were assembled to characterize the occurrence of these compounds in ground water and drinking-water supply wells of the United States. Typically, one sample was collected from each well, and as such, "samples" and "wells" have the same meaning herein. These samples are believed to be from untreated ground-water sources, and every effort was made to exclude any samples that might have included treated water, surface-water sources, or water from sites known or suspected of being contaminated. The 5,642 samples included 3,882 samples collected by NAWQA, 575 samples collected as part of an American Water Works Association Research Foundation (AWWARF) research project, and 1,185 retrospective (RETRO) samples that were assembled from historical data from a variety of sources (Lapham and Tadayon, 1996; Lapham and others, 1997). The 5,642 samples were assigned to one or more of five data sets to characterize aquifer studies, shallow ground water in agricultural areas, shallow ground water in urban areas, domestic wells, and public wells (table 2).

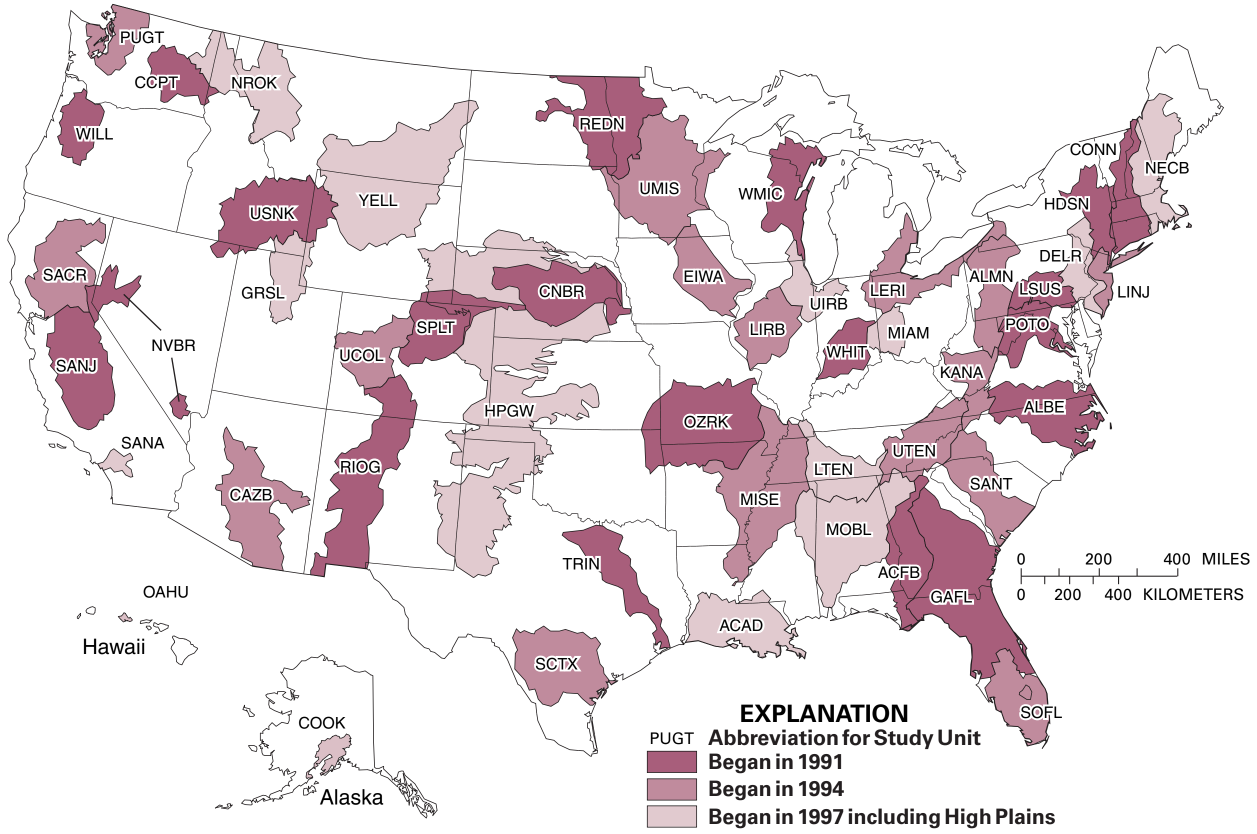
Samples collected by NAWQA are known to be samples of untreated ground water, and the samples were analyzed by the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado. These samples were characterized as "aquifer study," "agricultural," or "urban," and some of these samples are included in each of the five data sets. A 0.2-µg/L assessment level can be used for all 3,882 samples collected by 50 NAWQA Study Units from 1993 through 2002 (fig. 1). A 0.02-µg/L assessment level also can be used for the 2,332 samples collected during 1996–2002 by the NAWQA Study Units that began in 1994 and 1997 (fig. 1). These latter samples were analyzed using the USGS's new low-level VOC method (Connor and others, 1998). For samples not collected or analyzed by the USGS, laboratory certification and use of gas chromatography/mass spectrometry were required for inclusion in this study (Zogorski and others, 2006).

Table 2 includes information about how many samples from each of the data sources are in the five data sets and the years that the samples were collected. Additional details are provided in Section A in the Supplemental Information section

Table 2. Sources of volatile organic compound (VOC) information used in this study.

[NAWQA, National Water-Quality Assessment; AWWARF, American Water Works Association Research Foundation; RETRO, retrospective]

Data set	Number of samples by source of VOC data			Total number of samples
	NAWQA	AWWARF	RETRO	
Assessment level of 0.2 microgram per liter				
All samples	3,882	575	1,185	5,642
(Years)	(1993–2002)	(1999–2000)	(1985–1995)	(1985–2002)
Aquifer studies	2,312	0	1,185	3,497
(Years)	(1993–2001)	(None)	(1985–1995)	(1985–2001)
Shallow ground water in agricultural areas	723	0	0	723
(Years)	(1988–1998)	(None)	(None)	(1988–1998)
Shallow ground water in urban areas	847	0	0	847
(Years)	(1993–2002)	(None)	(None)	(1993–2002)
Domestic wells	1,883	0	517	2,400
(Years)	(1993–2001)	(None)	(1986–1995)	(1986–2001)
Public wells	329	575	192	1,096
(Years)	(1993–2001)	(1999–2000)	(1986–1995)	(1986–2001)
Assessment level of 0.02 microgram per liter				
All samples	2,332	0	0	2,332
(Years)	(1996–2001)	(None)	(None)	(1996–2001)
Aquifer studies	1,686	0	0	1,686
(Years)	(1996–2001)	(None)	(None)	(1996–2001)
Domestic wells	1,207	0	0	1,207
(Years)	(1996–2001)	(None)	(None)	(1996–2001)



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure 1. Location and implementation dates of National Water-Quality Assessment Program Study Units.

at the end of the report regarding the three sources of information (NAWQA, AWWARF, and RETRO) and the five data sets. Figure A1 in the Supplemental Information section shows the location of the samples from the three data sources. This information is included to provide a more complete description of the water-quality data, but no interpretation in this report is based on the source of the data or when the samples were collected.

Assessment Levels

An assessment level is a fixed concentration established by a scientist for the interpretation of water-quality data for different compounds, different data sets, and different time periods. A uniform assessment level was needed because varied laboratory reporting levels were used and the interpretation of water-quality data may be affected by different laboratory reporting levels (Lapham and others, 2000). Differences in laboratory reporting levels may arise because of differences in instrument sensitivity, analytical resolution, and (or) laboratory censoring procedures. All computations in this report were performed using a 0.2- or 0.02-μg/L assessment level.

The 0.2-μg/L assessment level was chosen to represent the occurrence of VOCs at a historical reporting value for USGS and some other agencies. Using the 0.2-μg/L assessment level allowed for the inclusion of data from other sources, such as AWWARF and RETRO data, which increased the overall number of samples for analysis and the spatial coverage of occurrence information. The 0.2-μg/L assessment level was considered to be appropriate for all of the 5,642 samples in the overall data set, regardless of the data source or when the samples were collected. Although a smaller percentage of samples had detections of the four THMs using a 0.2-μg/L assessment level compared to 0.02 μg/L, the concentration of 0.2 μg/L is substantially less than the MCL of 80 μg/L for total THMs.

A 0.02-μg/L assessment level also was used to describe the occurrence of VOCs and was used only for the 2,332 samples analyzed using the new low-level analytical method of the NWQL (Connor and others, 1998) starting in April 1996. These samples were collected by NAWQA Study Units that began in 1994 and 1997 (fig. 1). The use of the smaller assessment value provides a more complete description of THM occurrence and may be especially valuable in determining decadal trends and factors associated with THM occurrence. Additional information on the selection of the 0.02-μg/L assessment level is reported by Moran and others (2006).

For this study, the specified assessment level, 0.2 or 0.02 μg/L, was used for all VOCs within a data set or samples collected during a specified time period. When concentrations equal to or greater than the assessment level were reported, the THM was considered to be detected in the sample even for concentrations reported by the laboratory as estimated. When a concentration was reported to be less than a minimum detection level or the reported concentration was less than the assessment level, the THM was not considered to be detected, even if a smaller concentration was reported. For example, a 1994 NAWQA Study Unit may have collected a sample with reported concentrations of 0.30 μg/L for chloroform, 0.20 μg/L for bromodichloromethane, 0.02 μg/L for dibromochloromethane, and less than (<) 0.02 μg/L for bromoform. At the 0.2-μg/L assessment level, the detections would include chloroform and bromodichloromethane, and the nondetections would include dibromochloromethane and bromoform. At the 0.02-μg/L assessment level, the detections would include the first three THMs, but not bromoform.

Locations of Detections

Maps showing the location of all samples for each data set are presented in this report. The maps for each of the five studies within the main part of the report show the location of the samples with detections of one or more of the four THMs and the location of samples with no detections of any of the four THMs. In the respective supplemental sections, selected maps show the location of the samples with the detections and nondetections of selected individual THMs.

In these maps, the detections were presented in two categories for aquifer studies and domestic wells, and the nondetections were presented in one category for all five studies. The categories were defined in such a way as to produce a limited number of divisions that could be used to effectively represent thousands of wells on a national map and also to include each sample only once in each category. For all five studies, detections with concentrations greater than or equal to 0.2 μg/L were included in one category. For aquifer studies and domestic wells, detections with concentrations greater than or equal to 0.02 μg/L but less than 0.2 μg/L were included in another category. Nondetections included those samples with analytical results that were reported as "less than" concentrations and those with concentrations less than the lower assessment level used for the study. For aquifer studies and domestic wells, samples with concentrations less than 0.02 μg/L were considered to be nondetections. For example, the nondetections included samples with concentrations reported as <0.5, <0.05, and 0.0050 μg/L. For the other studies, samples with concentrations less than 0.2 μg/L were considered to be nondetections.

Detection Frequencies

For each specified set of conditions, detections are reported in terms of the number of detections and the detection frequency. The detection frequency is reported for a specified assessment level as a percentage and is calculated as the number of detections divided by the number of samples analyzed multiplied by 100. For each of the studies, values are reported for the number of detections of any of the four THMs in a sample and for the number of detections of individual THMs in a sample. The detection frequencies for each depend on the number of detections and the number of samples analyzed.

For example, at the 0.2-µg/L assessment level, 200 of the 2,000 samples in a particular data set might have concentrations greater than or equal to 0.2 µg/L of one or more of the four THMs. For these conditions, the detection frequency would be reported as 10 percent (200 divided by 2,000 multiplied by 100). At the same assessment level, chloroform might be detected in 197 samples out of the 1,970 samples with analytical results for chloroform. For this case, the detection frequency of chloroform also would be reported as 10 percent (197 divided by 1,970 multiplied by 100).

The 5,067 samples collected by the NAWQA Study Units or as part of the RETRO data set were grouped into 161 networks with a median of 28 wells per network. For the purposes of this report, a network is defined as a group of wells of a specific study (aquifer studies, shallow ground water in agricultural areas, or shallow ground water in urban areas) within a limited geographical area from which samples were collected within a limited time period. The maps showing the location of individual samples for the various studies have hundreds to thousands of points, sometimes with many of the points clustered within relatively small areas. Presenting some information by network, with each network represented by a single point plotted at the centroid of the area represented by the network, can make any large-scale areal variations in the data easier to see. Maps showing detection frequency for networks of wells for selected studies also are presented in this report. Detection frequency (in percent) for a network is defined as the number of samples in each network with the detection of at least one of the four THMs at or above the specified assessment level divided by the total number of samples in the network and multiplied by 100.

The wells in three studies (aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas) can be organized by network. Information is provided about the networks within the Study Units in Section B in the Supplemental Information section. Information includes the type of network (aquifer study, shallow ground water in agricultural areas, shallow ground water in urban areas) and the number of analytical results and detection frequency for each THM. For the other two studies (domestic wells and public wells), the network concept is not applicable although some of the wells in these data sets may be included in the networks of the other data sets.

Concentrations

Statistics such as minimum, median, and maximum concentrations were calculated using only the concentrations in samples with detections. If the statistics were calculated for all samples, the minimum and median concentrations would always equal the assessment level because, for all five studies, the majority of samples did not have THM concentrations greater than or equal to the two assessment levels. The minimum, median, and maximum concentrations were determined for (1) any one or more of the four THMs in a sample and (2) each THM separately.

The minimum, median, and maximum concentrations for samples with detections of any one or more of the four THMs are based on the total number of detections. For example, a data set with 10 samples might have 3 samples with detections of one or more of the four THMs at the 0.2-µg/L assessment level. Chloroform might have been detected in each of the 3 samples at concentrations of 10, 5.0, and 1.0 µg/L, and bromoform might have been detected in 2 samples at 0.5 and 0.2 µg/L. These concentrations would be sorted (0.2, 0.5, 1.0, 5.0, and 10 µg/L), and the minimum would be reported as 0.2 µg/L, the median would be reported as 1.0 µg/L, and the maximum would be reported as 10 µg/L. Note that there is no attempt to distinguish between THMs in reporting the statistics for “one or more” of the four THMs in samples.

Total THM concentrations were calculated by adding together the concentrations of each of the four THMs in a sample. For each detection, the reported concentration was used for the calculation, but for each nondetection, the concentration was set to zero. This convenient way of handling nondetections did not have a substantial effect on the calculated total THM concentrations in samples with large concentrations that may have been close to the MCL (80 µg/L). Another way of handling nondetections would have been to set the concentration to one-half of the assessment level or to one-half of the laboratory’s minimum reporting level prior to summing the four THM concentrations. Neither of these two approaches, however, would have yielded a different finding for the comparison of the calculated total THM concentration to the THM MCL.

Mixtures

As used in this report, a mixture is defined as a unique combination of specified compounds in a sample, regardless of the presence of other compounds that may occur in the same sample. In most cases in this report, a VOC mixture will refer to two VOC compounds if the two compounds include one THM and one non-THM VOC. THM mixtures, however, will refer to combinations of two, three, or all four of the THMs. For each VOC or THM mixture, the number of detections are reported. The different data sets may have different mixtures, or some mixtures may be found more frequently or less frequently within some of the data sets.

The detection frequency of a two-component mixture is reported in three different ways. Detection frequency may be (1) the percentage of all samples, (2) the percentage of samples with the first component detected, and (3) the percentage of samples with the second component detected. For example, a data set of 1,000 samples might include 80 chloroform detections and 8 bromoform detections. The chloroform–bromoform mixture might be found in six samples. The detection frequency of that mixture would be reported as 0.6 percent (6 mixture occurrences/1,000 samples × 100), 7.5 percent (6 mixture occurrences/80 chloroform detections × 100), or 75.0 percent (6 mixture occurrences/8 bromoform detections × 100). The different ways of reporting the detection frequency of mixtures allow different comparisons to be made among data sets and among mixtures in the same data set and may facilitate the planning of toxicological studies of mixtures.

For some studies, information about VOC or THM mixtures is presented in two tables and a graph. The first table shows the most frequently occurring two-compound mixtures that contain at least one THM and that were detected in 1 percent or more of the samples. The second table shows the most frequently occurring two-compound mixtures for each of the four THMs that were detected in 1 percent or more of the samples. In the second table, the 10 most common mixtures for chloroform and bromodichloromethane are listed for each compound, and the 5 most common mixtures for dibromochloromethane and bromoform are listed for each compound. Mixtures consisting of two THMs are emphasized by shading the rows in the tables. The graph shows the number of samples with the specified number of THMs detected, zero through four. Each sample is only included in one category. For example, a sample with four detected THMs is only included in the four-THM category.

Trihalomethane Concentrations Compared to the Maximum Contaminant Level

THM concentrations for the selected studies are compared to the MCL for total THMs. An MCL is a legally enforceable drinking-water standard for public water systems and is defined as the maximum permissible level of a contaminant in drinking water. MCLs are based on health effects but also may consider cost and the limitations of analytical and treatment technologies. The comparisons of concentrations to the MCL are especially important for the aquifer studies, domestic well, and public well data sets, because the ground water represented in these three data sets is potentially or actually a source for drinking water. Comparisons of the MCL to the measured concentrations in the shallow ground water in agricultural areas and shallow ground water in urban areas data sets are not made because shallow ground water in those two data sets is not considered to be a potential source of drinking water for most of the sampled wells.

The USEPA MCL for total THMs is 80 μg/L in drinking water (U.S. Environmental Protection Agency, 2004). Total THMs in this report are the sum of the concentrations of chloroform, bromodichloromethane, dibromochloromethane, and bromoform. Details of how this calculation was made was described previously in the Concentrations section of the Approach.

The MCL for total THMs was not exceeded by any of the samples in the aquifer, domestic well, or public well studies. Few samples from these data sets have total THM concentrations within an order of magnitude of the MCL; that is, greater than or equal to 8 μg/L. The percentage of samples from the aquifer, domestic well, and public well studies with total THM concentrations greater than or equal to 8 μg/L was 0.5, 0.2, and 0.9 percent, respectively.

Occurrence of Trihalomethanes

The occurrence of four THMs in the Nation's ground water is described for three studies: aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas. The occurrence of four THMs in the Nation's drinking-water supply wells is described for two studies: domestic wells and public wells. The occurrence is described in terms of the locations of detections and nondetections, detection frequencies, concentrations, and mixtures of THMs (with other THMs and with other VOCs) for all five studies. Detection frequencies by network for aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas also are provided. Although some samples from the three ground-water studies also are part of the domestic well and public well data sets, the domestic and public wells do not constitute true networks; therefore, the occurrence of the four THMs is not described in terms of detection frequency by network for domestic and public wells.

Aquifer Studies

The occurrence of the four THMs in aquifer studies is described on the basis of samples collected during 1985–2001 from 3,497 wells (table 2). The occurrence of THMs is described in terms of locations of detections and nondetections, detection frequencies, concentrations, and mixtures of THMs (with THMs and with other VOCs).

Samples in the aquifer studies data set were collected from regionally extensive aquifers or from less extensive aquifer systems that are used as a source of potable water or have a potential for such use. The NAWQA samples typically were collected from the most important aquifers used for drinking water within each Study Unit. The RETRO samples were included in the data set to add information for geographical areas and aquifers that had not been sampled as part of the NAWQA Program. A detailed description of the samples used to describe the occurrence of the four THMs in aquifer studies can be found in Section A in the Supplemental Information section and in Moran and others (2006), which describes the approach to the NAWQA studies.

Locations of Detections

The locations of the 3,497 wells that comprise the aquifer studies data set are shown in figure 2. One or more of the four THMs were detected at concentrations greater than or equal to 0.02 μg/L in samples from 525 wells, including the 278 samples where one or more of the four THMs were detected at concentrations greater than or equal to 0.2 µg/L. The four THMs were detected in many areas throughout the Nation, often in relative isolation. In several locations, well samples with large THMs concentrations are in the midst of other well samples with no detected THMs, even at the smaller assessment level.

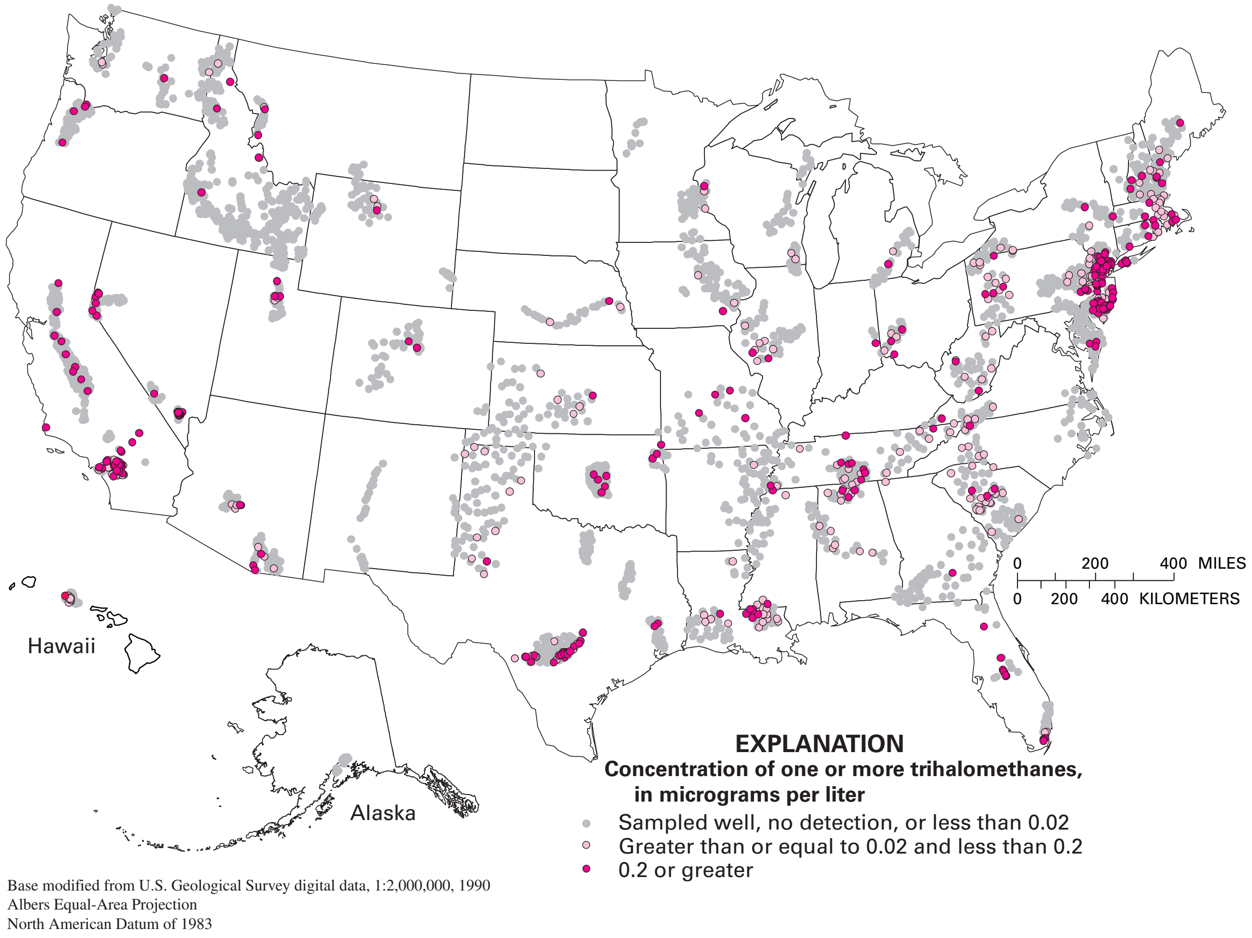
Section C in the Supplemental Information section has additional figures showing the location of sampled wells and individual THM detections in aquifer studies. Figure C1 for chloroform is very similar to figure 2 because, for most of the wells with one or more THM detections, at least one of the detected THMs was chloroform. Figures C2 (bromodichloromethane), C3 (dibromochloromethane), and C4 (bromoform) are very similar to each other. They show fewer detections than figure C1 for chloroform but about the same number of detections for each THM, and detections are found throughout the Nation, often in relative isolation. Information presented later in the report regarding mixtures in the aquifer studies data set shows that if one of these three THMs occurs with chloroform in a sample, then often all three of them occur with chloroform.

Detection Frequencies

At the 0.2-µg/L assessment level, at least one THM was detected in 7.9 percent of the samples from aquifer studies. Chloroform was detected in 7.4 percent of the samples, and the other THMs were each detected in about 1 percent of the samples (table 3).

At the 0.02-µg/L assessment level, at least one THM was detected in 21.6 percent of the samples. Chloroform was detected in 21.2 percent of the samples. For bromodichloromethane, dibromochloromethane, and bromoform, the detection frequencies were 3.7, 1.7, and 1.4 percent, respectively. As the chlorine content of the THM compound decreased, the detection frequency also decreased (table 3).

The locations of the centroids of 98 networks comprising the aquifer studies data set are shown in figure 3. In 34 of the networks, or more than one-third of the total networks, none of the THMs were detected in any of the samples in the network at the 0.2-µg/L assessment level. The 34 networks are located throughout the Nation and most of them are located in States where THMs were detected in other networks. The remaining 64 networks are represented by four classes of 16 networks



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure 2. Concentrations of trihalomethanes in aquifer studies, 1985–2001.

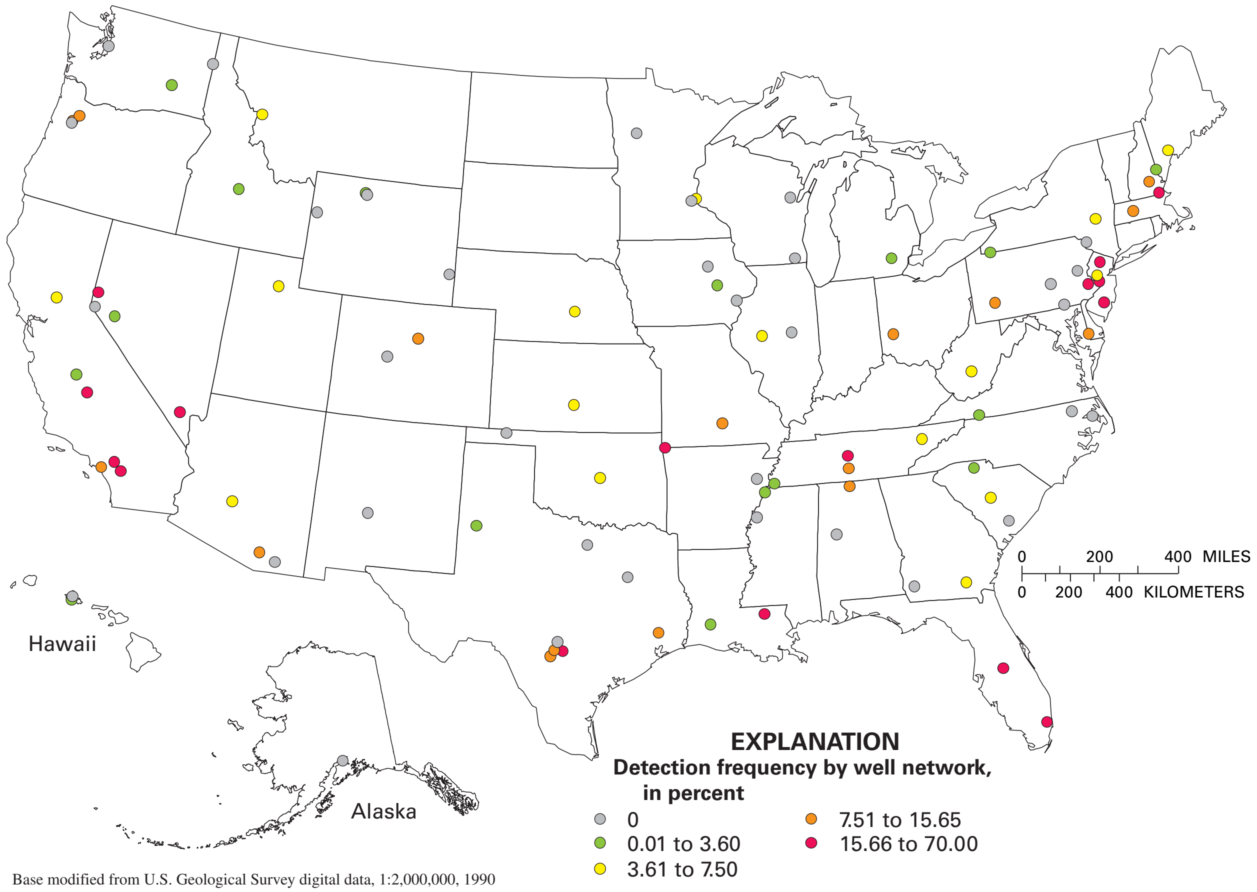
Table 3. Detection frequencies of trihalomethanes in samples from aquifer studies, 1985–2001.

Trihalomethane	Number of samples	Number of detections	Detection frequency (percent)
Assessment level of 0.2 microgram per liter			
One or more of the trihalomethanes	3,497	278	7.9
Chloroform	3,495	257	7.4
Bromodichloromethane	3,497	39	1.1
Dibromochloromethane	3,497	33	0.9
Bromoform	3,496	36	1.0
Assessment level of 0.02 microgram per liter			
One or more of the trihalomethanes	1,686	364	21.6
Chloroform	1,686	358	21.2
Bromodichloromethane	1,686	63	3.7
Dibromochloromethane	1,686	28	1.7
Bromoform	1,685	23	1.4

each, with detection frequencies of one or more THMs that ranged from 0.01 percent to almost 70 percent. Some of the networks in the highest quartile include high population density areas within parts of California, Nevada, New Jersey, and Florida. None of the networks with the highest THM detection frequencies are found in Alaska, Hawaii, or the north-central area of the contiguous United States.

Concentrations

In samples with detections of one or more THMs, chloroform usually was one, if not the only, THM detected. Therefore, for those samples, the median concentration for one or more of the THMs was very similar to the median concentration for chloroform. At the 0.2-µg/L assessment level, the median concentration of one or more of the THMs was 0.5 µg/L, which also was the median concentration for chloroform (table 4). At the 0.02-µg/L assessment level, the median concentrations also were the same (0.08 µg/L).



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure 3. Detection frequency, by well network, of one or more trihalomethanes in samples from aquifer studies at an assessment level of 0.2 microgram per liter, 1985–2001.

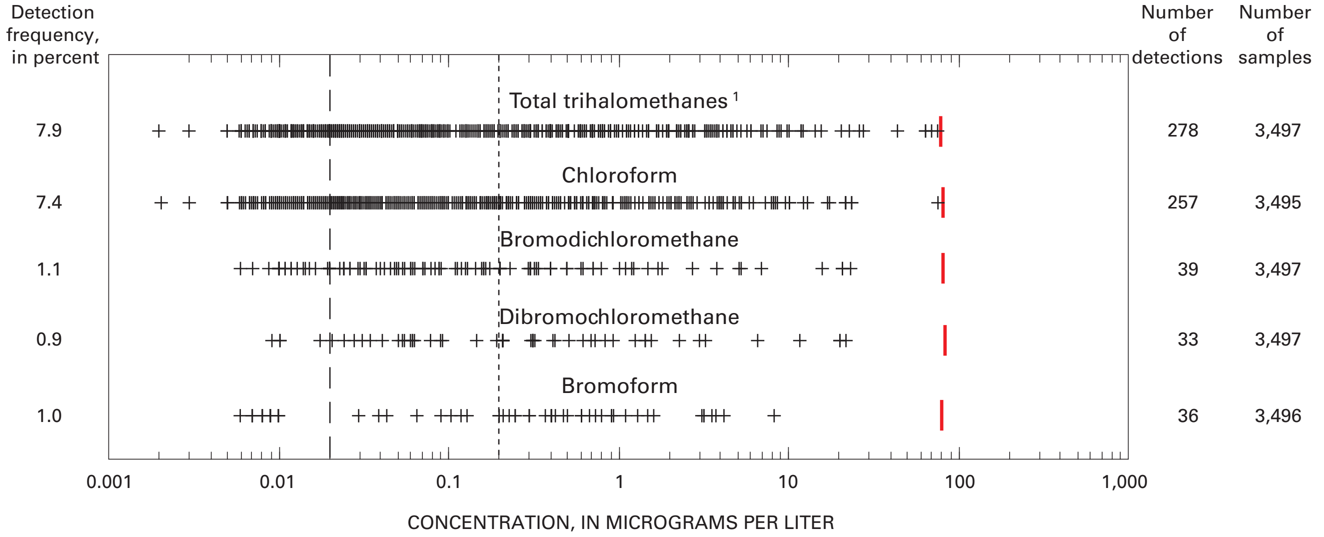
Table 4. Trihalomethane concentrations in samples from aquifer studies, 1985–2001.

[THMs, trihalomethanes; µg/L, microgram per liter]

Statistic	Concentration in samples with detections, in µg/L				
	One or more THMs	Chloroform	Bromodichloromethane	Dibromochloromethane	Bromoform
Assessment level of 0.2 µg/L					
Minimum	0.2	0.2	0.2	0.2	0.2
Median	.5	.5	.6	.6	.6
Maximum	74	74	23	21	8.2
Assessment level of 0.02 µg/L					
Minimum	0.02	0.02	0.02	0.02	0.03
Median	.08	.08	.07	.08	.25
Maximum	17	17	7.0	3.1	3.1

At the 0.2-µg/L assessment level, the median concentrations for bromodichloromethane, dibromochloromethane, and bromoform were all 0.6 µg/L (table 4). At the 0.02-µg/L assessment level, the median concentrations for bromodichloromethane, dibromochloromethane, and bromoform were 0.07, 0.08, and 0.25 µg/L, respectively (table 4).

Figure 4 shows the concentrations for total THMs and individual THMs in samples from aquifer studies. As figure 4 shows, many samples from aquifer studies had reported THM concentrations that were less than the 0.2- and 0.02-µg/L assessment levels. Chloroform especially was reported at small concentrations in many samples in which it was not considered to be detected at the assessment levels used in this report. As with detection frequency, as the chlorine content of the THM compound decreased, the maximum concentration of the THM also decreased. At



[1] The MCL of 80 micrograms per liter is for the sum of the concentrations of four trihalomethanes including chloroform, bromodichloromethane, dibromochloromethane, and bromoform (U.S. Environmental Protection Agency, 2004).

EXPLANATION

\+ **Concentration for a sample**—Several analytical methods, with differing sensitivity for a specific trihalomethane with time, as well as between THMs, were used for this study. Concentrations are shown for all samples without the application of an assessment level. Median concentrations at specific assessment levels are provided in table 4. Multiple samples of equal concentration will appear as a single symbol

7.9 **Detection frequency, in percent, at an assessment level of 0.2 microgram per liter**—For detection frequency at 0.02 assessment level refer to table 3

278 **Number of detections at an assessment level of 0.2 microgram per liter**

3,497 **Number of samples**

Assessment level

— — 0.02 microgram per liter

\- - - - - - 0.2 microgram per liter

Drinking-water standard

| U.S. Environmental Protection Agency Maximum Contaminant Level (MCL)

Figure 4. Concentrations of trihalomethanes (THMs) in samples from aquifer studies, 1985–2001.

the 0.2-µg/L assessment level, the maximum concentration decreased from 74 to 23 to 21 to 8.2 µg/L, for chloroform, bromodichloromethane, dibromochloromethane, and bromoform, respectively. At the 0.02-µg/L assessment level, the maximum concentration decreased from 17 to 7.0 to 3.1 µg/L for chloroform, bromodichloromethane, and dibromochloromethane/bromoform, respectively (table 4).

Mixtures

The distribution of samples with detections of 0, 1, 2, 3, or 4 THMs at the 0.2- and 0.02-µg/L assessment levels is shown in figure 5. The number of samples with THMs and the percentage of the whole data set that they represent for the two assessment levels are presented in table 5. At the 0.2-µg/L assessment level, 3,497 samples were considered, and at the 0.02-µg/L assessment level, a subset of 1,686 samples was considered. At both assessment levels, the most common finding was that most samples did not have any THMs. Furthermore, the number of samples with no THMs was much greater than the number of samples with 2, 3, or 4 detected THMs combined. At the 0.2-µg/L assessment level, 92.1 percent of the samples did not have any THMs, and 1.3 percent of the samples had two or more THMs. At the 0.02-µg/L assessment level, 78.4 percent of the samples did not have any THMs, and 3.9 percent of the samples had two or more THMs (table 5).

At the 0.02-µg/L assessment level, the most frequently detected mixtures with at least one THM included chloroform–PCE, which was detected in 4.9 percent of the samples, and chloroform–MTBE, which was detected in 4.2 percent of the samples (table 6). Eighteen mixtures with at least one THM were found in 1 percent or more of the samples. Six of these mixtures included two THMs. The most common two-THM mixture, chloroform–bromodichloromethane, was found in 3.6 percent of the samples, and the least common two-THM mixtures, chloroform–bromoform and dibromochloromethane–bromoform, were found in 1.0 percent of the samples. Fourteen of the 18 mixtures included chloroform (table 6).

Chloroform occurred with one or more of the other three THMs in 61 samples, which is 3.6 percent of the 1,686 samples and 17.0 percent of the 358 samples in which chloroform was detected. Chloroform occurred with two or more of the other three THMs in 27 samples and with all three of the other THMs in 13 samples, which is 7.5 percent and 3.6 percent, respectively, of the 358 samples in which chloroform was detected.

For the other three THMs, if they were detected, they almost always occurred with another THM. Bromodichloromethane occurred with another THM in 63 samples, which is 3.7 percent of the 1,686 samples and 100 percent of the 63 samples in which bromodichloromethane was detected. Dibromochloromethane occurred with another THM in

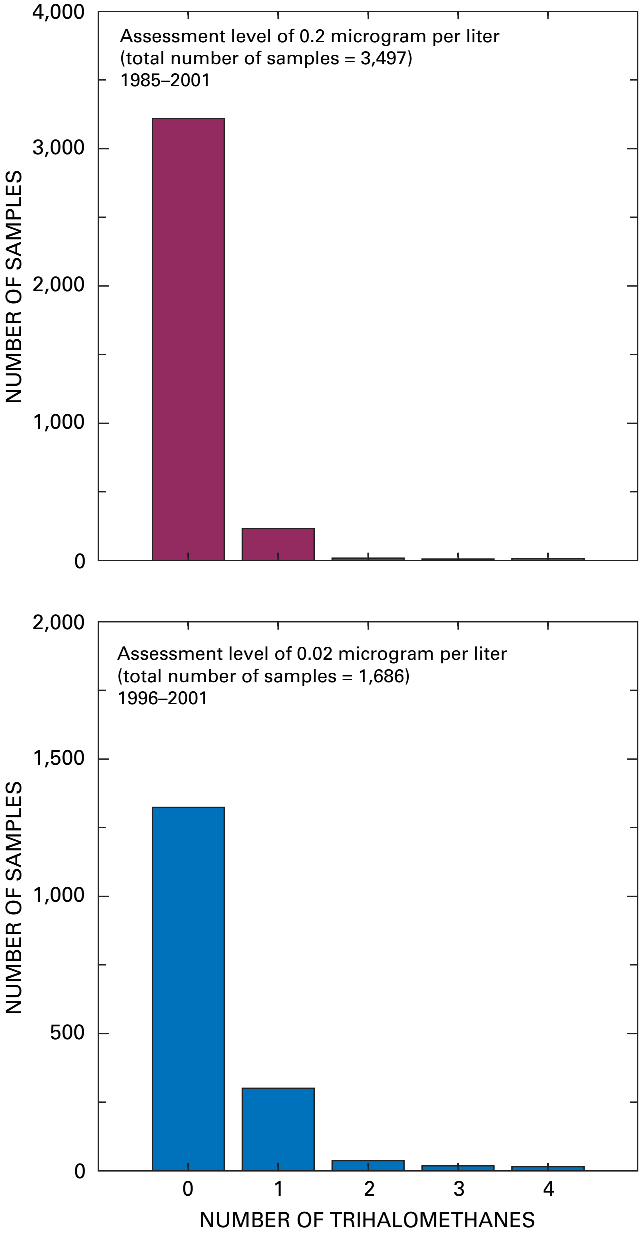


Figure 5. Number of trihalomethanes in samples from aquifer studies, 1985–2001.

Table 5. Number of trihalomethanes detected and percentage of detections in samples from aquifer studies, 1985–2001.

	Number of trihalomethanes detected					
	None	One	Two	Three	Four	Two or more
Assessment level of 0.2 microgram per liter						
Number of samples	3,219	233	18	12	15	45
Percentage of samples	92.1	6.7	.5	.3	.4	1.3
Assessment level of 0.02 microgram per liter						
Number of samples	1,322	299	35	17	13	65
Percentage of samples	78.4	17.7	2.1	1.0	.8	3.9

Table 6. Most frequently detected two-compound mixtures in samples from aquifer studies that contain at least one trihalomethane and that were detected in 1 percent or more of samples at an assessment level of 0.02 microgram per liter, 1985–2001.

[THM, trihalomethane; VOC, volatile organic compound; shaded rows indicate two-THM mixtures; t, tied]

Rank	Mixture		Number of THM samples	Number of detections	Detection frequency (percent)
	THM	Other[1] VOC			
1	Chloroform	Perchloroethene (PCE)	1,686	82	4.9
2	Chloroform	Methyl *tert*-butyl ether (MTBE)	1,686	71	4.2
3	Chloroform	Bromodichloromethane	1,686	60	3.6
4	Chloroform	1,1,1-Trichloroethane (TCA)	1,686	49	2.9
5	Chloroform	Trichloroethene (TCE)	1,686	41	2.4
6	Chloroform	Toluene	1,686	29	1.7
7	Bromodichloromethane	Dibromochloromethane	1,686	27	1.6
8	Chloroform	1,1-Dichloroethane	1,686	26	1.5
9	Chloroform	Dibromochloromethane	1,686	24	1.4
10	Chloroform	Dichlorodifluoromethane (CFC-12)	1,686	21	1.2
t11	Chloroform	1,1-Dichloroethene	1,686	20	1.2
t11	Bromodichloromethane	Perchloroethene (PCE)	1,686	20	1.2
13	Bromodichloromethane	Bromoform	1,686	19	1.1
t14	Chloroform	Chloromethane	1,686	18	1.1
t14	Chloroform	Methylene chloride	1,686	18	1.1
t16	Chloroform	Bromoform	1,686	17	1.0
t16	Dibromochloromethane	Bromoform	1,686	17	1.0
t16	Chloroform	1,2,4-Trimethylbenzene	1,686	17	1.0

[1] The word “other” refers to the second compound of the specified mixture.

28 samples or 100 percent of the 28 samples in which it was detected. Bromoform occurred with another THM in 21 samples or 91.3 percent of the samples in which it was detected.

The most common mixture of two THMs was chloroform–bromodichloromethane, which occurred in 60 samples. This mixture occurred in 3.6 percent of the 1,686 samples (table 6), 16.8 percent of the 358 samples in which chloroform was detected (table 7), and 95.2 percent of the 63 samples in which bromodichloromethane was detected (table 7).

Additional information on mixtures for aquifer studies is presented in table 7. Mixtures are listed separately for chloroform, bromodichloromethane, dibromochloromethane, and bromoform in table 7. For three of the four THMs, the most common mixtures were those with other THMs. The exception was chloroform, for which the most common mixtures were with PCE and MTBE. For all four THMs, the most common mixture of the specified THM and a non-THM VOC was with PCE. The chloroform–PCE mixture occurred in 22.9 percent of the samples in which chloroform was detected, the bromodichloromethane–PCE mixture occurred in 31.7 percent of the samples in which bromodichloromethane was detected, the dibromochloromethane–PCE mixture occurred in 35.7 percent of the samples in which dibromochloromethane was detected, and the bromoform–PCE mixture occurred in 26.1 percent of the samples with bromoform detected. PCE has a long history of use in industry, commerce, and household products, and its occurrence in samples from aquifer studies has been shown to be associated with shallow depth to the top of well screen, oxic ground water, and urban land use and septic systems near the sampled well (Zogorski and others, 2006).

Shallow Ground Water in Agricultural Areas

The occurrence of the four THMs in shallow ground water in agricultural areas is described on the basis of samples collected during 1988–1998 from 723 wells (table 2). The occurrence of THMs is described in terms of locations of detections and nondetections, detection frequencies, concentrations, and mixtures of THMs.

All samples in the study of shallow ground water in agricultural areas data set were collected by NAWQA Study Units. These samples were collected from wells not considered to be likely sources of potable water. Most of the wells were installed by NAWQA for the purpose of collecting water-quality samples and were not intended to serve as sources of drinking water. A detailed description of the samples used to describe the occurrence of trihalomethanes in shallow ground water in agricultural areas can be found in Section A in the Supplemental Information section.

Table 7. Most frequently detected two-compound mixtures in samples from aquifer studies for each trihalomethane at an assessment level of 0.02 microgram per liter, 1985–2001.

[THM, trihalomethane; VOC, volatile organic compound; shaded rows indicate two-THM mixtures; t, tied]

Rank	Other[1] VOC	Predominant use of other[1] VOC	Number of THM detections	Number of mixture detections	Detection frequency (percent)[2]
		Chloroform			
1	Perchloroethene (PCE)	Solvent	358	82	22.9
2	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	358	71	19.8
3	Bromodichloromethane	Disinfection by-product	358	60	16.8
4	1,1,1-Trichloroethane (TCA)	Solvent	358	49	13.7
5	Trichloroethene (TCE)	Solvent	358	41	11.5
6	Toluene	Gasoline aromatic hydrocarbon	358	29	8.1
7	1,1-Dichloroethane	Solvent	358	26	7.3
8	Dibromochloromethane	Disinfection by-product	358	24	6.7
9	Dichlorodifluoromethane (CFC-12)	Refrigerant	358	21	5.9
10	1,1-Dichloroethene	Organic synthesis	358	20	5.6
		Bromodichloromethane			
1	Chloroform	Disinfection by-product	63	60	95.2
2	Dibromochloromethane	Disinfection by-product	63	27	42.9
3	Perchloroethene (PCE)	Solvent	63	20	31.7
4	Bromoform	Disinfection by-product	63	19	30.2
5	Trichloroethene (TCE)	Solvent	63	13	20.6
t6	Trichlorofluoromethane (CFC-11)	Refrigerant	63	11	17.5
t6	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	63	11	17.5
8	1,1,1-Trichloroethane (TCA)	Solvent	63	10	15.9
t9	1,1-Dichloroethene	Organic synthesis	63	9	14.3
t9	Dichlorodifluoromethane (CFC-12)	Refrigerant	63	9	14.3
		Dibromochloromethane			
1	Bromodichloromethane	Disinfection by-product	28	27	96.4
2	Chloroform	Disinfection by-product	28	24	85.7
3	Bromoform	Disinfection by-product	28	17	60.7
4	Perchloroethene (PCE)	Solvent	28	10	35.7
5	Trichloroethene (TCE)	Solvent	28	7	25.0
		Bromoform			
1	Bromodichloromethane	Disinfection by-product	23	19	82.6
t2	Chloroform	Disinfection by-product	23	17	73.9
t2	Dibromochloromethane	Disinfection by-product	23	17	73.9
t4	Perchloroethene (PCE)	Solvent	23	6	26.1
t4	Trichloroethene (TCE)	Solvent	23	6	26.1

[1] The word "other" refers to the second compound of the specified mixture.

[2] This detection frequency is based on the subset of samples containing the indicated THM.

Locations of Detections

The locations of the 723 wells sampled to describe THMs in shallow ground water in agricultural areas are shown in figure 6. One or more of the THMs were detected at concentrations greater than or equal to 0.2 µg/L in samples from 16 wells (table 8). THMs were detected in several areas throughout the Nation, often in isolation, with THMs detected in the midst of many other wells with no THMs detected. Chloroform was detected in all 16 of these wells. The only other THM detected was bromodichloromethane, which occurred with chloroform in a sample from an agricultural well in Wisconsin.

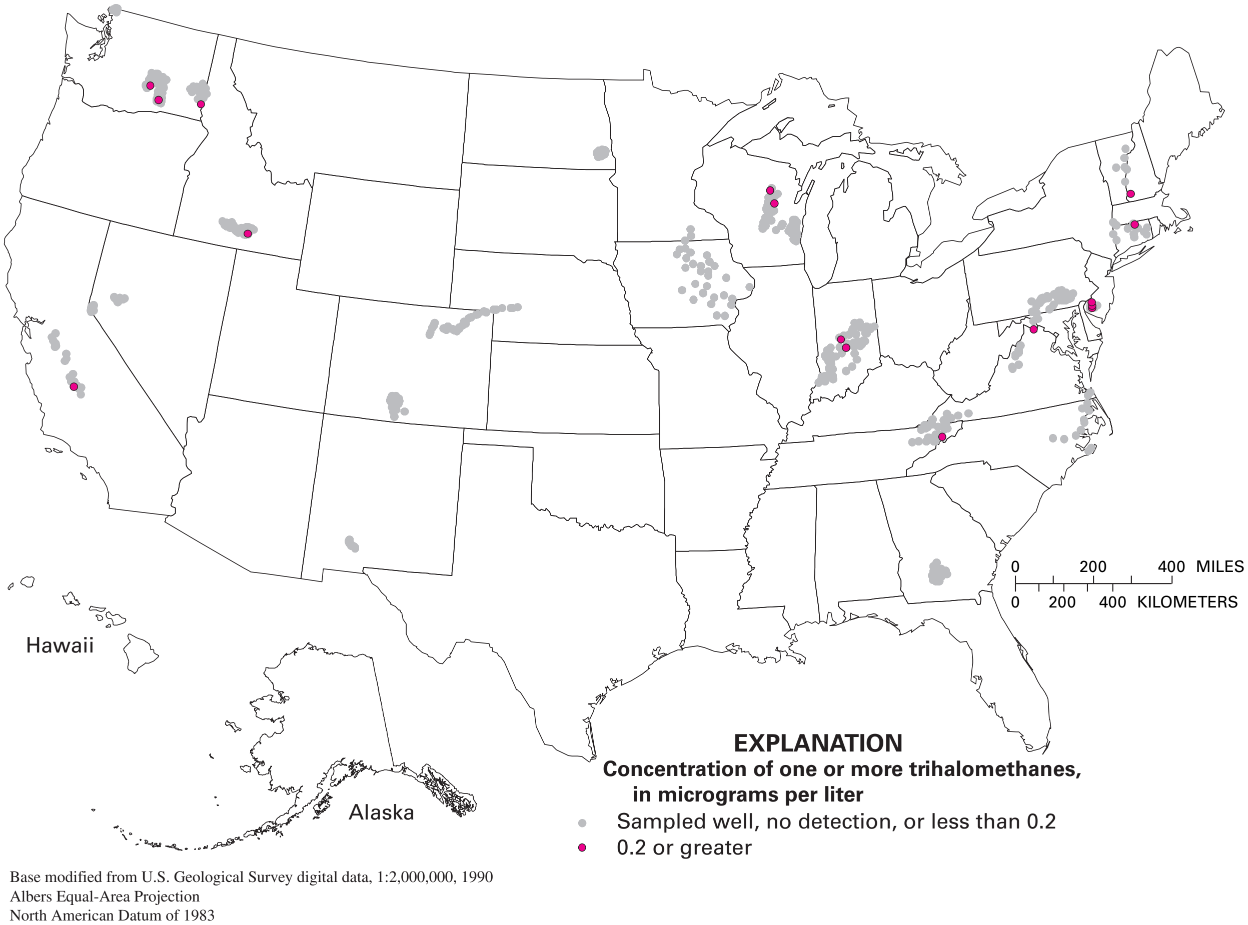


Figure 6. Concentrations of trihalomethanes in samples from shallow ground water in agricultural areas, 1988–1998.

Detection Frequencies

At the 0.2-µg/L assessment level, at least one THM was detected in 2.2 percent of the samples. At this assessment level, chloroform was detected in 2.2 percent of the samples, bromodichloromethane was detected in 0.1 percent of the samples, and neither dibromochloromethane nor bromoform was detected in any of the samples (table 8).

The location of the centroid of the 30 networks in the study of shallow ground water in agricultural areas is shown in figure 7. In 19 of the networks, or almost two-thirds of the total networks, none of the THMs were detected in any of the samples in the network at the 0.2-µg/L assessment level. The 19 networks with no THM detections are located throughout the United States. Eleven of these 19 networks are located in eight States (Nevada, Colorado, New Mexico, North Dakota, Iowa, Georgia, North Carolina, and Pennsylvania) that do not have any THM detections. The other eight networks with no THM detections are located in four States (Washington, Idaho, Wisconsin, and Indiana).

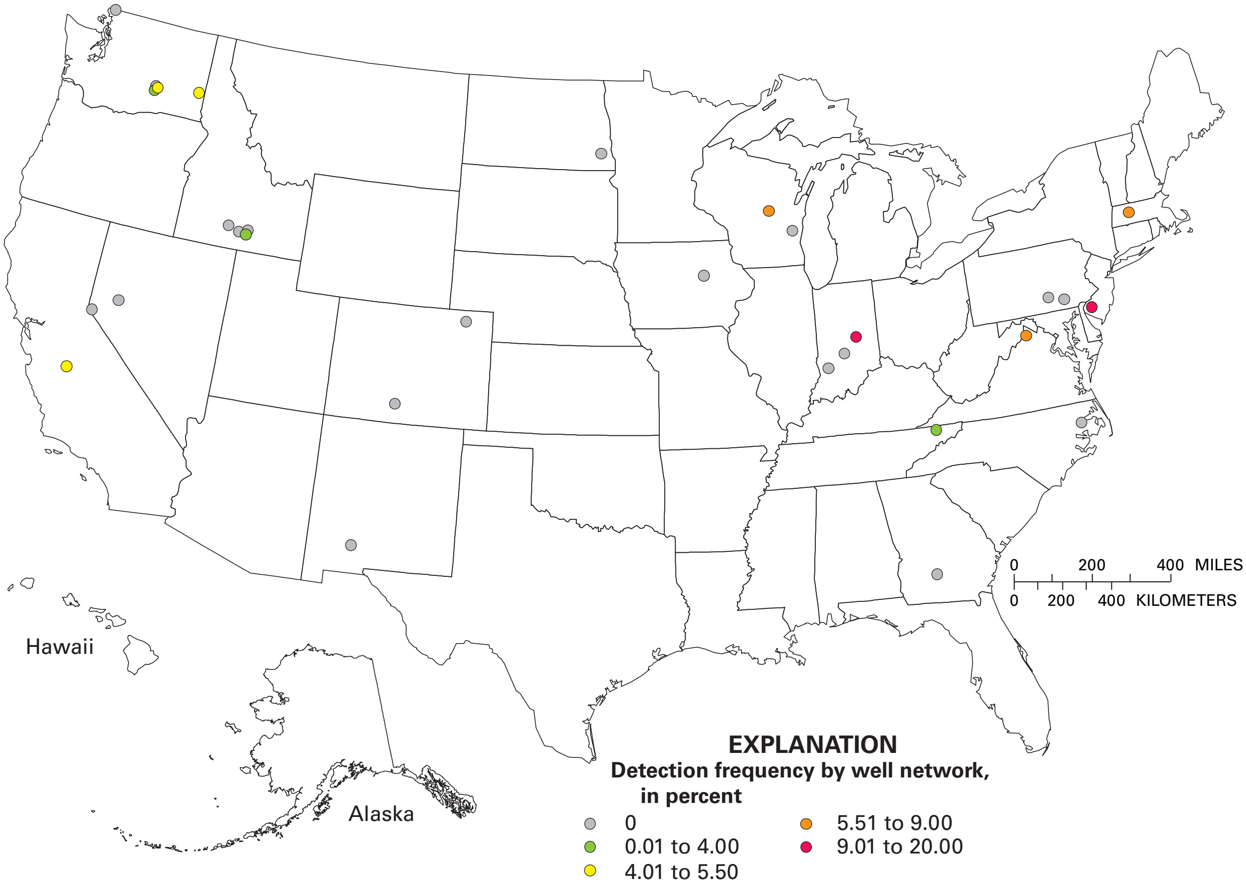
The remaining 11 networks are represented by four classes of two or three networks each, with detection frequencies that ranged from 0.01 to 20.0 percent. Those two networks in the highest quartile are located in Indiana and New Jersey. The three networks in the next highest quartile are located in Connecticut, West Virginia, and Wisconsin. None of the networks in these two quartiles are found west of the Mississippi River.

Table 8. Detection frequencies of trihalomethanes in samples from shallow ground water in agricultural areas, 1988–1998.

Trihalomethane	Number of samples	Number of detections	Detection frequency (percent)
Assessment level of 0.2 microgram per liter			
One or more of the trihalomethanes	723	16	2.2
Chloroform	723	16	2.2
Bromodichloromethane	723	1	.1
Dibromochloromethane	723	0	.0
Bromoform	723	0	.0

Concentrations

In samples with detections of one or more THMs, chloroform always was one of the detected THMs. Therefore, for those samples, the median concentration for one or more



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure 7. Detection frequency, by well network, of one or more trihalomethanes in samples from shallow ground water in agricultural areas at an assessment level of 0.2 microgram per liter, 1988–1998.

of the THMs was affected substantially by the chloroform concentrations. Consequently, the median concentration for one or more of the THMs was very similar to the median for chloroform. At the 0.2-µg/L assessment level, the median concentration of one or more of the THMs was 0.3 µg/L, which also was the median concentration for chloroform and for bromodichloromethane (table 9).

Table 9. Trihalomethane concentrations in samples from shallow ground water in agricultural areas, 1988–1998.

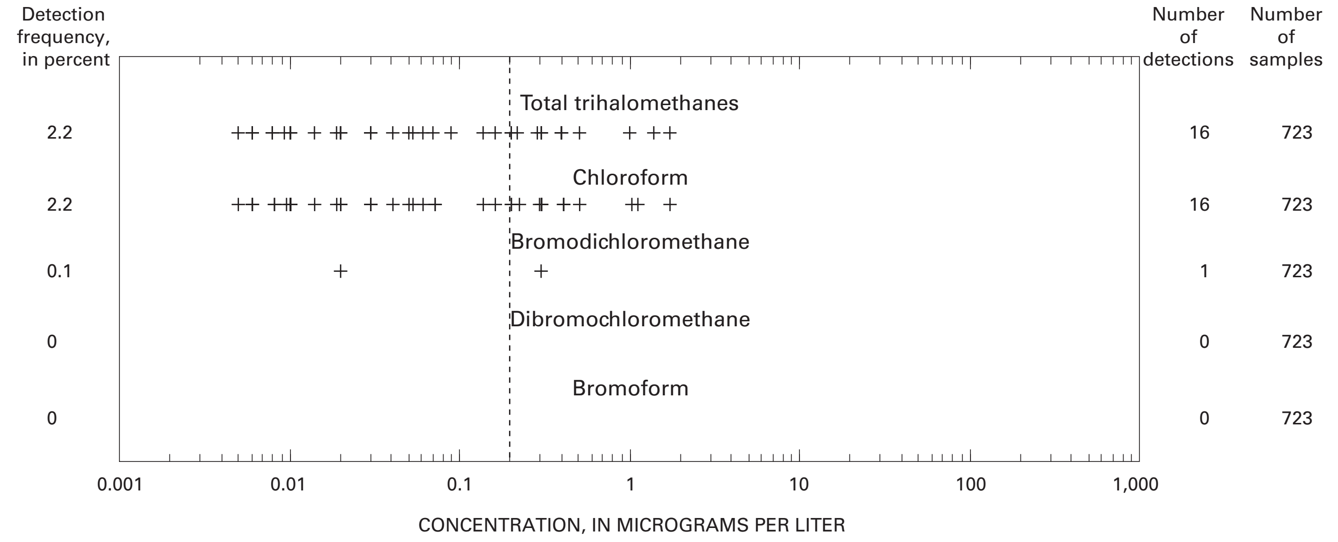
[THMs, trihalomethanes; µg/L, microgram per liter; NA, not available because there were no detections of the specified THM]

Statistic	Concentration in samples with detections, in µg/L				
	One or more THMs	Chloroform	Bromodichloromethane	Dibromochloromethane	Bromoform
Assessment level of 0.2 µg/L					
Minimum	0.2	0.2	0.3	NA	NA
Median	.3	.3	.3	NA	NA
Maximum	1.7	1.7	.3	NA	NA

Concentrations of total THMs and individual THMs in shallow ground water in agricultural areas are shown in figure 8. As figure 8 shows, all of the reported concentrations were for chloroform or bromodichloromethane, and none were for dibromochloromethane or bromoform, even at concentrations less than the 0.2-µg/L assessment level. For chloroform, more samples had reported concentrations less than the 0.2-µg/L assessment level than concentrations greater than or equal to the 0.2-µg/L assessment level. For bromodichloromethane, two samples had reported concentrations, one of which was greater than the 0.2-µg/L assessment level. As with detection frequency, as the chlorine content of the THM compound decreased, the maximum concentration of the THM decreased from 1.7 µg/L for chloroform to 0.3 µg/L for bromodichloromethane (table 9).

Mixtures

The number of samples with detections of 0, 1, 2, 3, or 4 THMs at the 0.2-µg/L assessment level is shown in figure 9. The number of samples with THMs and the percentage of the



EXPLANATION

+	**Concentration for a sample**—Several analytical methods, with differing sensitivity for a specific trihalomethane with time, as well as between THMs, are shown in the bar concentration charts. Median concentrations at an assessment level of 0.2 microgram per liter are provided in table 9. Multiple samples of equal concentration will appear as a single symbol
2.2	**Detection frequency, in percent, at an assessment level of 0.2 microgram per liter**
16	**Number of detections at an assessment level of 0.2 microgram per liter**
723	**Number of samples**
------	**Assessment level of 0.2 microgram per liter**

Figure 8. Concentrations of trihalomethanes (THMs) in samples from shallow ground water in agricultural areas, 1988–1998.

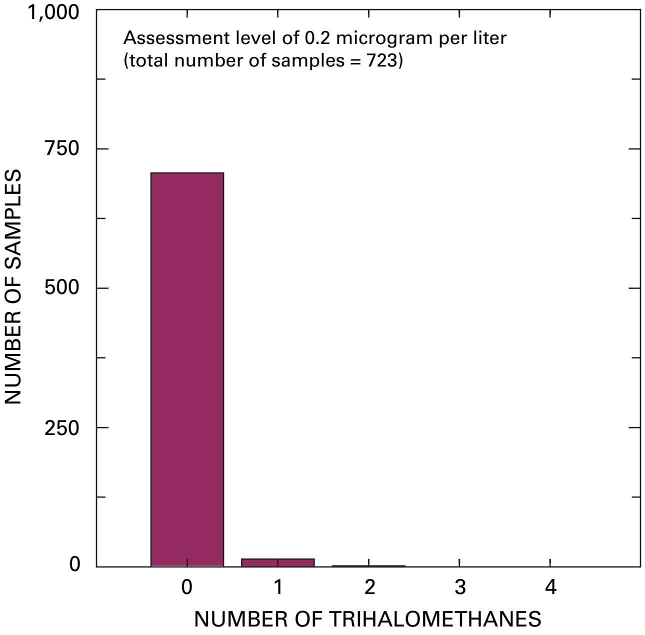


Figure 9. Number of trihalomethanes in samples from shallow ground water in agricultural areas, 1988–1998.

whole data set (723 samples) that they represent are shown in table 10. Most samples did not have any THMs, and the number of samples with no THMs was much greater than the number of samples with 2, 3, or 4 THMs combined. Almost 98 percent of the samples did not have any THMs, and only 0.1 percent of the samples had a mixture of THMs.

At the 0.2-μg/L assessment level, the only two-THM mixture found, chloroform–bromodichloromethane, occurred in one sample or 0.1 percent of all samples. Chloroform occurred in 16 samples (table 8), so the chloroform–bromodichloromethane mixture occurred in 6.2 percent of the samples in which chloroform was detected. Bromodichloromethane was found

Table 10. Number of trihalomethanes detected and percentage of detections in samples from shallow ground water in agricultural areas, 1988–1998.

	Number of trihalomethanes detected					
	None	One	Two	Three	Four	Two or more
Assessment level of 0.2 microgram per liter						
Number of samples	707	15	1	0	0	1
Percentage of samples	97.8	2.1	0.1	0.0	0.0	0.1

in one sample, so the chloroform–bromodichloromethane mixture occurred in 100.0 percent of the samples in which bromodichloromethane was detected. No two-compound mixtures occurred in 1 percent or more of the samples from shallow ground water in agricultural areas.

Shallow Ground Water in Urban Areas

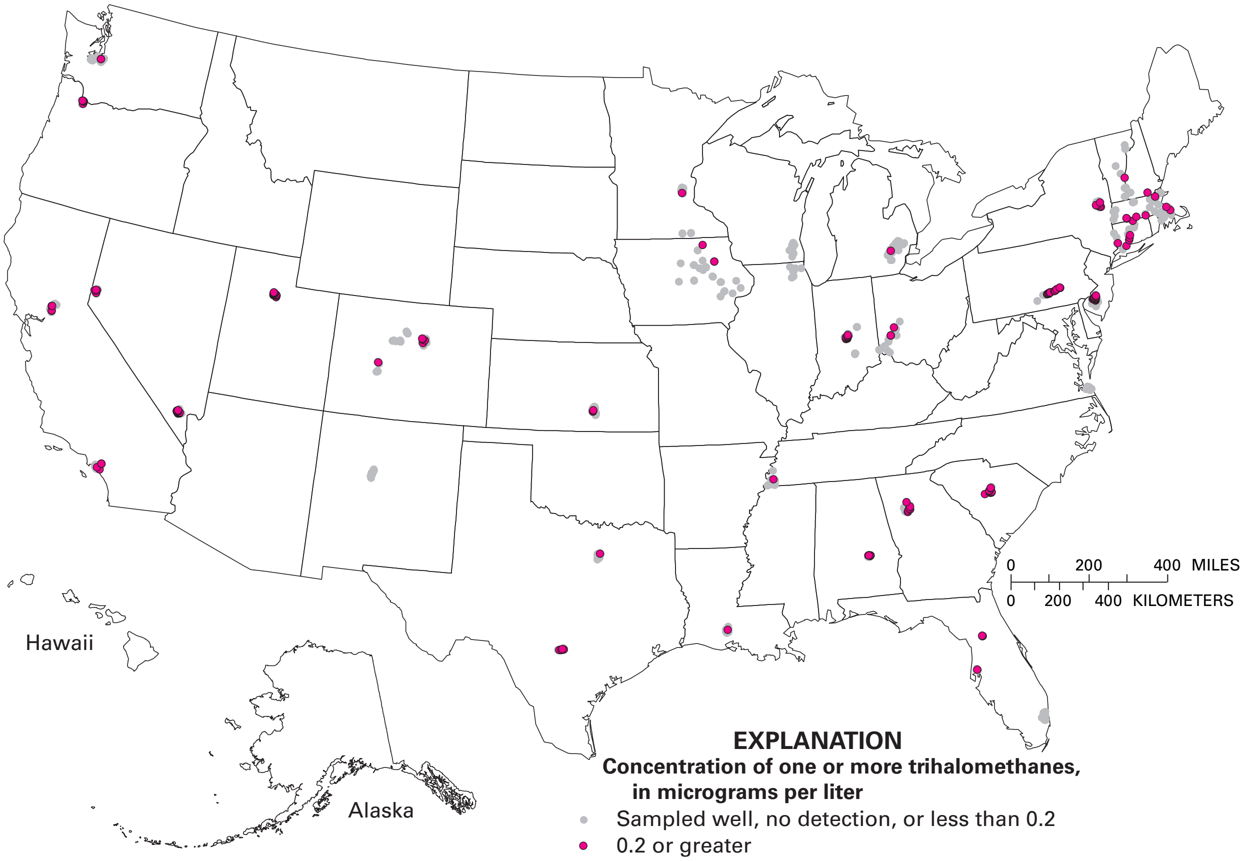
The occurrence of the four THMs in shallow ground water in urban areas is described on the basis of samples collected during 1993–2002 from 847 wells (table 2). The occurrence of THMs is described in terms of locations of detections and nondetections, detection frequencies, concentrations, and mixtures of THMs (with other THMs and with other VOCs).

All samples in the study of shallow ground water in urban areas were collected by NAWQA Study Units. Most of the samples were collected from wells installed by NAWQA for the purpose of collecting water-quality samples and were not intended to serve as sources of drinking water. A detailed description of the samples used to describe the occurrence of trihalomethanes in shallow ground water in urban areas can be found in Section A in the Supplemental Information section.

Locations of Detections

The locations of the 847 wells that were sampled to describe THMs in shallow ground water in urban areas are shown in figure 10. One or more of the four THMs were detected at concentrations greater than or equal to 0.2 μg/L in samples from 165 wells (table 11). The samples were collected in many urban areas throughout the Nation, and nearly every area had one or more samples with a THM detection.

Section D in the Supplemental Information section has additional figures showing the locations of sampled wells and individual THM detections in shallow ground water in urban areas. Figure D1 for chloroform is the same as figure 10 because, for all of the wells with one or more THM detections, at least one of the detected THMs was chloroform. Figure D2 shows the location of the 14 samples in which bromodichloromethane was detected. Bromodichloromethane was detected in seven States—Tacoma, Washington; Los Angeles, California; Las Vegas, Nevada; Salt Lake City, Utah; Oelwein, Iowa; Dayton, Ohio; and Harrisburg, Pennsylvania. The three samples in which dibromochloromethane was detected were located in urban areas in three States—Las Vegas, Nevada; Dayton, Ohio; and Harrisburg, Pennsylvania. The one sample in which bromoform was detected was collected in the San Antonio, Texas, area.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure 10. Concentrations of trihalomethanes in samples from shallow ground water in urban areas, 1993–2002.

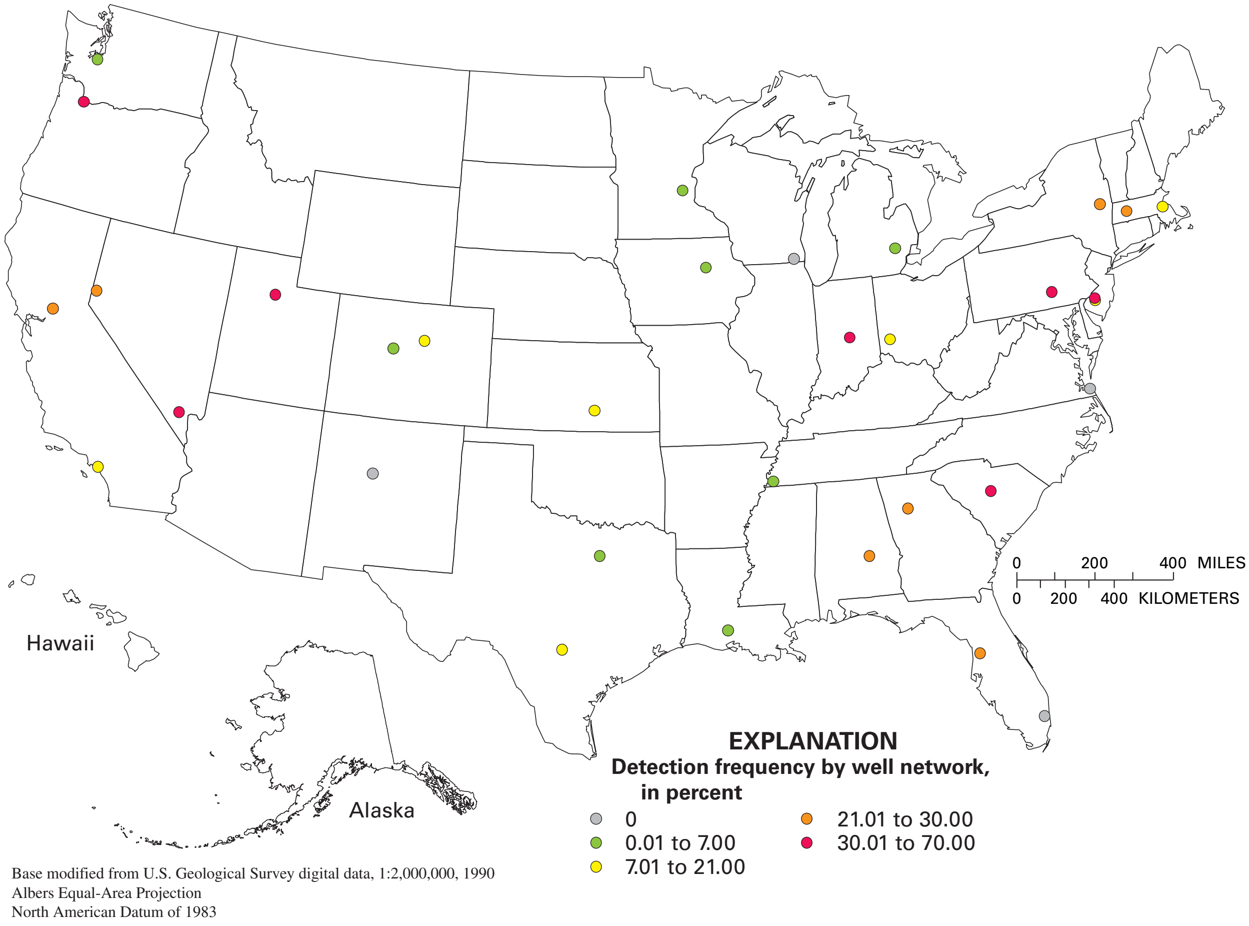
Table 11. Detection frequencies of trihalomethanes in samples from shallow ground water in urban areas, 1993–2002.

Trihalomethane	Number of samples	Number of detections	Detection frequency (percent)
Assessment level of 0.2 microgram per liter			
One or more of the trihalomethanes	847	165	19.5
Chloroform	847	165	19.5
Bromodichloromethane	847	14	1.7
Dibromochloromethane	847	3	.4
Bromoform	847	1	.1

Detection Frequencies

At the 0.2-µg/L assessment level, at least one THM was detected in 19.5 percent of the samples of shallow ground water in urban areas, and chloroform was detected in each of these samples. Bromodichloromethane was detected in 1.7 percent of the samples, dibromochloromethane was detected in 0.4 percent of the samples, and bromoform was detected in 0.1 percent of the samples (table 11). The detection frequency of the four THMs decreased with increased bromide content of individual THMs, and this pattern is typical of most findings from previous investigations (Ivahnenko and Barbash, 2004).

The locations of the centroid of 33 networks where THMs in shallow ground water in urban areas were investigated are shown in figure 11. None of the THMs were detected in any of the samples in four networks at the 0.2-µg/L assessment level. These four networks are located in Albuquerque, New Mexico; Milwaukee, Wisconsin/Chicago, Illinois; Fort Lauderdale, Florida; and Virginia Beach, Virginia. These are the only networks of shallow ground water in urban areas in New Mexico, Wisconsin/Illinois, and Virginia, but Florida has another such network in Tampa/Ocala with a detection frequency of 25.0 percent. The 29 networks with detections of THMs are represented by four classes of 7 or 8 networks each, with detection frequencies that ranged from 0.01 to almost 70 percent. The seven networks with the highest detection frequencies are located in urban areas of seven States—Portland, Oregon; Las Vegas, Nevada; Salt Lake City, Utah; Indianapolis, Indiana; Columbia, South Carolina; Harrisburg, Pennsylvania; and Glassboro, New Jersey.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure 11. Detection frequency, by well network, of one or more trihalomethanes in samples from shallow ground water in urban areas at an assessment level of 0.2 microgram per liter, 1993–2002.

Concentrations

In samples with detections of one or more THMs, chloroform always was detected; therefore, the median concentration for one or more of the four THMs is very similar to the median concentration for chloroform. At the 0.2-µg/L assessment level, the median concentration of one or more of the four THMs was 0.6 µg/L, which also was the median concentration for chloroform. At the 0.2-µg/L assessment level, median concentrations for bromodichloromethane, dibromochloromethane, and bromoform in samples with detections were 0.4, 0.7, and 0.2 µg/L, respectively (table 12).

Table 12. Trihalomethane concentrations in samples from shallow ground water in urban areas, 1993–2002.

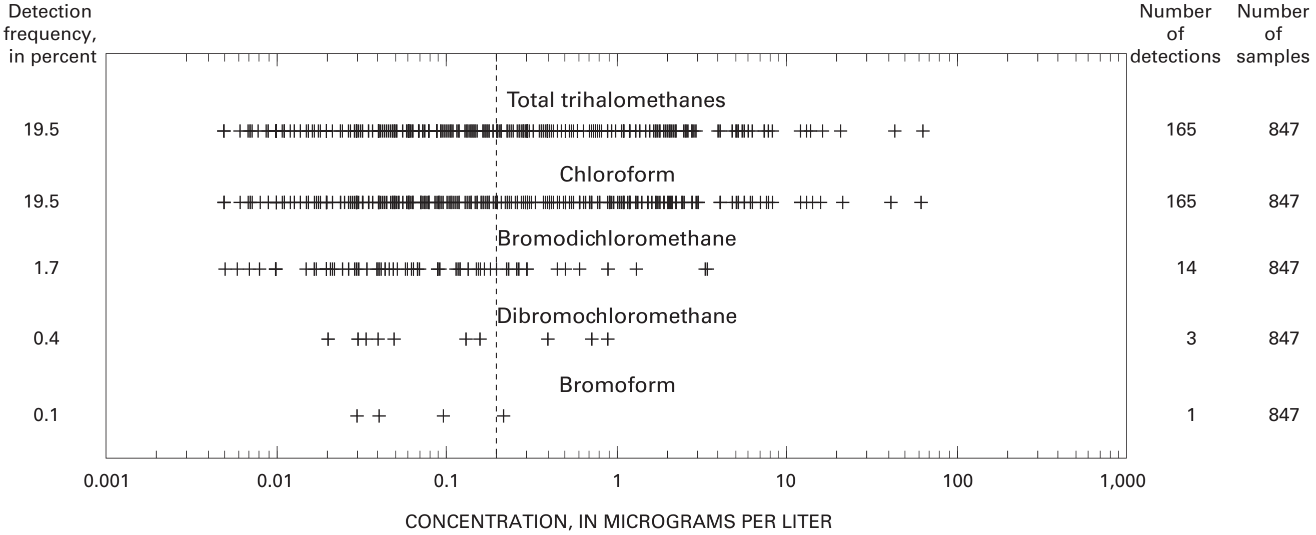
[THMs, trihalomethanes; µg/L, micrograms per liter]

Statistic	Concentration in samples with detections, in µg/L				
	One or more THMs	Chloroform	Bromodichloromethane	Dibromochloromethane	Bromoform
Assessment level of 0.2 µg/L					
Minimum	0.2	0.2	0.2	0.4	0.2
Median	.6	.6	.4	.7	.2
Maximum	61.0	61.0	3.5	.9	.2

Concentrations for total THMs and individual THMs in shallow ground water in urban areas are shown in figure 12. Many of the samples of shallow ground water in urban areas had THM concentrations, especially for chloroform and bromodichloromethane, reported that were less than the 0.2-µg/L assessment level (fig. 12). The number of samples with THMs reported at small concentrations, such that the reported THMs were not considered to be detected at the assessment level used in this report, was directly related to the detection frequency for the individual THMs. Chloroform was the THM with the most samples with concentrations greater than or equal to the assessment level and with the most samples with concentrations less than the assessment level. Bromoform was the THM with the fewest samples with concentrations greater than or equal to the assessment level and with the fewest samples with concentrations less than the assessment level. As with detection frequency, as the chlorine content of the THM compound decreased, the maximum concentration of the THM decreased also, from 61 to 3.5 to 0.9 to 0.2 µg/L (table 12).

Mixtures

The number of samples of shallow urban ground water with detections of 0, 1, 2, 3, or 4 THMs at the 0.2-µg/L assessment level is shown in figure 13. The number of



EXPLANATION

+ **Concentration for a sample**—Several analytical methods, with differing sensitivity for a specific trihalomethane with time, as well as between THMs, are shown in the bar concentration charts. Median concentrations at an assessment level of 0.2 microgram per liter are provided in table 12. Multiple samples of equal concentration will appear as a single symbol

19.5 **Detection frequency, in percent, at an assessment level of 0.2 microgram per liter**

165 **Number of detections at an assessment level of 0.2 microgram per liter**

847 **Number of samples**

------ **Assessment level of 0.2 microgram per liter**

Figure 12. Concentrations of trihalomethanes (THMs) in samples from shallow ground water in urban areas, 1993–2002.

samples with THMs and the percentage of the whole data set (847 samples) that they represent are shown in table 13. The number of samples with no THMs (682 samples or 80.5 percent) was much greater than the number of samples with 2, 3, or 4 THMs combined (15 samples or 1.8 percent).

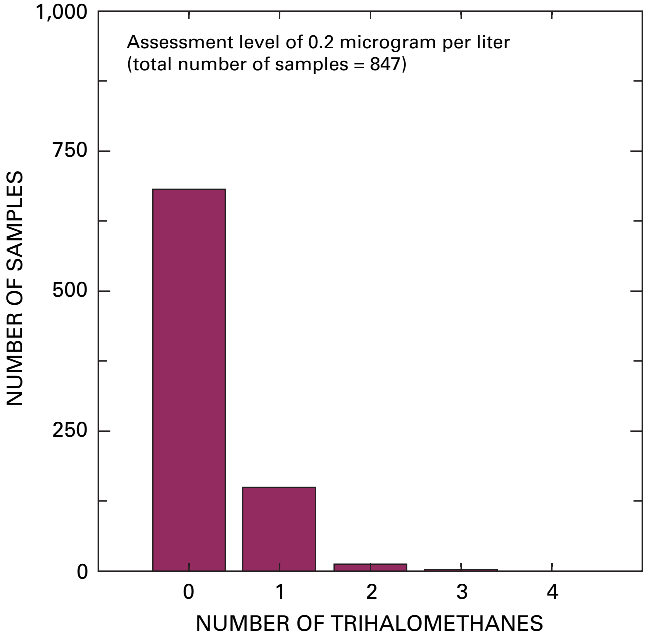


Figure 13. Number of trihalomethanes in samples from shallow ground water in urban areas, 1993–2002.

Table 13. Number of trihalomethanes detected and percentage of detections in samples from shallow ground water in urban areas, 1993–2002.

	Number of trihalomethanes detected					
	None	**One**	**Two**	**Three**	**Four**	**Two or more**
Assessment level of 0.2 microgram per liter						
Number of samples	682	150	12	3	0	15
Percentage of samples	80.5	17.7	1.4	0.4	0	1.8

At the 0.2-µg/L assessment level, the most frequently detected two-THM mixture of chloroform–bromodichloromethane was detected in 1.7 percent of the samples (table 14). The two-THM mixtures, chloroform–dibromochloromethane and bromodichloromethane–dibromochloromethane, were detected in only 3 of the 847 samples or 0.4 percent of the samples. The mixture of chloroform–bromoform occurred in one sample or 0.1 percent of the samples. The other THM mixtures were not found in any of the samples.

Of the 165 samples in which chloroform was detected, the chloroform–bromodichloromethane mixture occurred in 8.5 percent of the samples, the chloroform–dibromochloromethane mixture occurred in 1.8 percent of the samples (table 15), and the chloroform–bromoform mixture occurred in 0.6 percent of the samples.

Of the 14 samples in which bromodichloromethane was detected, the chloroform–bromodichloromethane mixture occurred in 100 percent of the samples, the bromodichloromethane–dibromochloromethane mixture occurred in 21.4 percent of the samples (table 15), and the bromodichloromethane–bromoform mixture was not found in any of the samples.

Of the three samples in which dibromochloromethane was detected, the chloroform–dibromochloromethane and the bromodichloromethane–dibromochloromethane mixtures were found in 100 percent of the samples (table 15), and the dibromochloromethane–bromoform mixture was not found in any of the samples.

The one sample in which bromoform was detected also contained chloroform, so the chloroform–bromoform mixture was found in the single sample in which bromoform was detected. Neither bromodichloromethane nor dibromochloromethane was detected in this sample, and as such, bromoform was not detected with either of these two THMs.

Table 14. Most frequently detected two-compound mixtures in samples from shallow ground water in urban areas that contain at least one trihalomethane and that were detected in 1 percent or more of samples at an assessment level of 0.2 microgram per liter, 1993–2002.

[THM, trihalomethane; VOC, volatile organic compound; shaded row indicates a two-THM mixture]

Rank	Mixture		Number of THM samples	Number of detections	Detection frequency (percent)
	THM	**Other[1] VOC**			
1	Chloroform	Perchloroethene (PCE)	847	40	4.7
2	Chloroform	Methyl *tert*-butyl ether (MTBE)	847	27	3.2
3	Chloroform	1,1,1-Trichloroethane (TCA)	847	21	2.5
4	Chloroform	Trichloroethene (TCE)	847	20	2.4
5	Chloroform	Bromodichloromethane	847	14	1.7
6	Chloroform	Trichlorofluoromethane (CFC-11)	847	10	1.2

[1] The word “other” refers to the second compound of the specified mixture.

Table 15. Most frequently detected two-compound mixtures in samples from shallow ground water in urban areas for each trihalomethane and that were detected in 1 percent or more of samples at an assessment level of 0.2 microgram per liter, 1993–2002.

[VOC, volatile organic compound; THM, trihalomethane; shaded rows indicate two-THM mixtures]

Rank	Other[1] VOC	Predominant use of other[1] VOC	Number of THM detections	Number of mixture detections	Detection frequency (percent)
		Chloroform			
1	Perchloroethene (PCE)	Solvent	165	40	24.2
2	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	165	27	16.4
3	1,1,1-Trichloroethane (TCA)	Solvent	165	21	12.7
4	Trichloroethene (TCE)	Solvent	165	20	12.1
5	Bromodichloromethane	Disinfection by-product	165	14	8.5
6	Trichlorofluoromethane (CFC-11)	Refrigerant	165	10	6.1
7	Dibromochloromethane	Disinfection by-product	165	3	1.8
		Bromodichloromethane			
1	Chloroform	Disinfection by-product	14	14	100.0
2	Dibromochloromethane	Disinfection by-product	14	3	21.4
		Dibromochloromethane			
1	Chloroform	Disinfection by-product	3	3	100.0
2	Bromodichloromethane	Disinfection by-product	3	3	100.0
		Bromoform			
1	Chloroform	Disinfection by-product	1	1	100.0

[1] The word "other" refers to the second compound of the specified mixture.

Domestic Well Samples

The occurrence of the four THMs in domestic well samples is described on the basis of samples collected during 1986–2001 from 2,400 wells (table 2). The occurrence of THMs is described in terms of locations of detections and non-detections, detection frequencies, concentrations, and mixtures of THMs (with other THMs and with other VOCs).

Most of the samples in the domestic well data set were collected as part of NAWQA's aquifer studies. The data set also includes some samples collected as part of NAWQA's studies of shallow ground water in agricultural and urban areas. Also, almost one-half of the RETRO samples were collected from domestic wells and are included in the domestic well data set. A detailed description of the samples used to describe the occurrence of trihalomethanes in domestic well samples can be found in Section A in the Supplemental Information section and in Moran and others (2006), which describes the approach of the NAWQA studies.

Locations of Detections

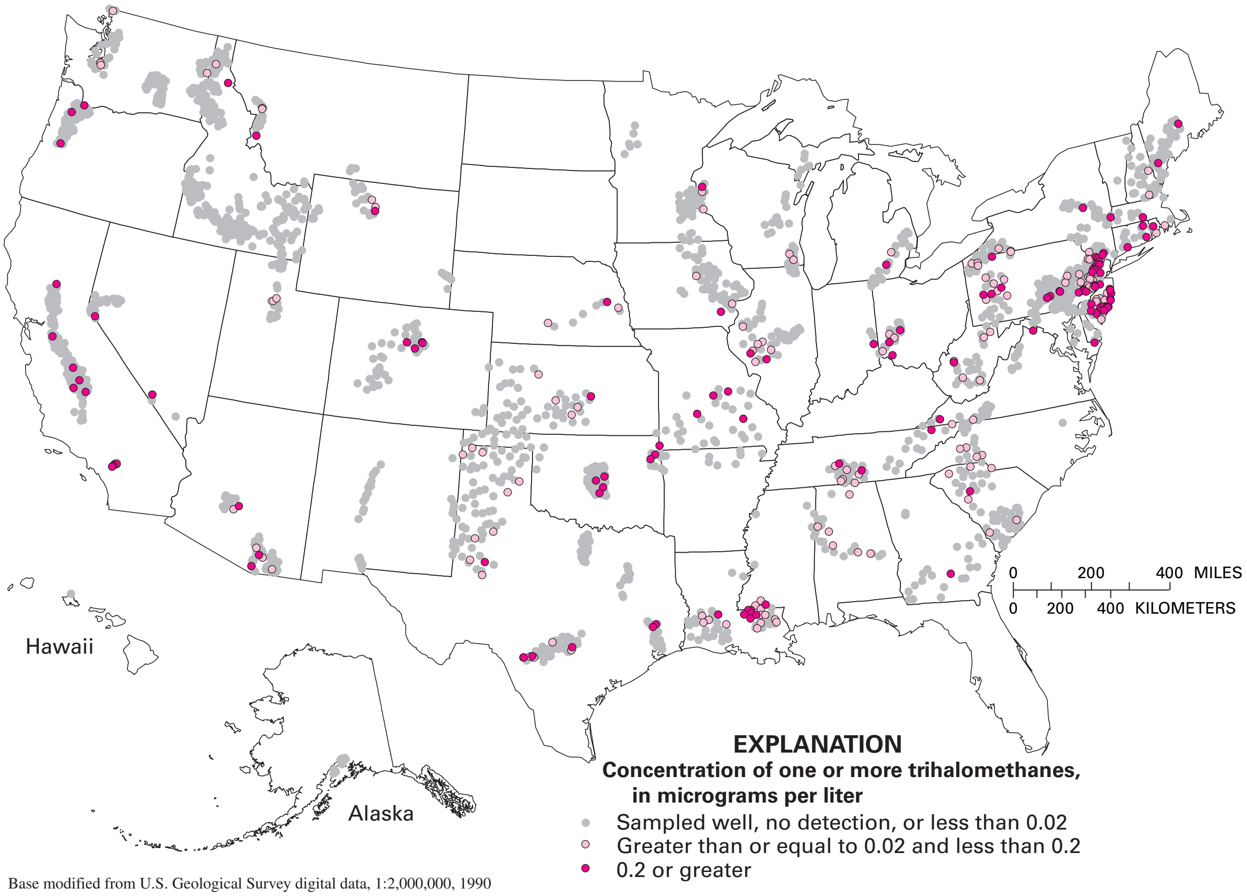
The locations of the 2,400 wells that were sampled to describe THMs in domestic wells are shown in figure 14. One or more of the four THMs were detected at concentrations greater than or equal to 0.2 µg/L in samples from 126 wells. Of the 1,207 samples to which the 0.02-µg/L assessment level could be applied, a total of 217 samples had detections of one or more THMs, including 143 samples with none of the individual THM concentrations greater than 0.2 µg/L. THMs were detected in domestic well samples throughout the Nation and in most cases, if samples were collected in an area, at least some of the samples had detectable concentrations of THMs (fig. 14).

Section E in the Supplemental Information section has additional figures showing the locations of sampled wells and individual THM detections in domestic well samples. Figure E1 for chloroform is very similar to figure 14 because, for most of the wells with one or more THM detections, at least one of the THMs was chloroform. Figure E2 shows that the bromodichloromethane detections, both the larger and smaller concentrations, occurred throughout the Nation. Figure E3 shows that the dibromochloromethane was detected throughout the Nation, and it also shows that when dibromochloromethane was detected, it generally was detected at larger concentrations rather than smaller concentrations. Figure E4 shows that bromoform was detected infrequently and that when bromoform was detected, it had an even greater tendency than dibromochloromethane to be found at larger concentrations.

Detection Frequencies

At the 0.2-µg/L assessment level, one or more THMs were detected in 5.2 percent of the domestic well samples. Chloroform was detected in every sample that contained a THM (5.2 percent of the samples), and the other THMs each were detected in less than 1 percent of the samples (table 16).

At the 0.02-µg/L assessment level, one or more THMs were detected in 18.0 percent of the samples. Again, chloroform was detected in every sample that contained THMs (18.0 percent of the samples). For bromodichloromethane,



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure 14. Concentrations of trihalomethanes in samples from domestic wells, 1986–2001.

dibromochloromethane, and bromoform, the detection frequencies were 2.3, 1.1, and 0.7 percent, respectively. At the 0.02-µg/L assessment level, the decrease in detection frequencies with increasing THM-bromide content is even more pronounced than the pattern at the 0.2-µg/L assessment level (table 16).

Concentrations

In samples with detections of one or more THMs, chloroform was usually one, if not the only, compound detected. Therefore, for those samples, the median concentration for one or more of the THMs is affected substantially by the chloroform concentrations. Consequently, the median concentration for one or more of the THMs is very similar to the median for chloroform. At the 0.2-µg/L assessment level, the median concentration of one or more of the THMs was 0.5 µg/L, which also was the median concentration for chloroform. At the 0.02-µg/L assessment level, the median concentrations also were the same (0.08 µg/L) (table 17).

At the 0.2-µg/L assessment level, and again for those samples with a detection, the median concentrations for bromodichloromethane, dibromochloromethane, and bromoform were 0.6, 0.6, and 0.8 µg/L, respectively (table 17). At the 0.02-µg/L assessment level, the median concentrations for bromodichloromethane, dibromochloromethane, and bromoform were 0.07, 0.06, and 0.19 µg/L, respectively (table 17).

Table 16. Detection frequencies of trihalomethanes in samples from domestic wells, 1986–2001.

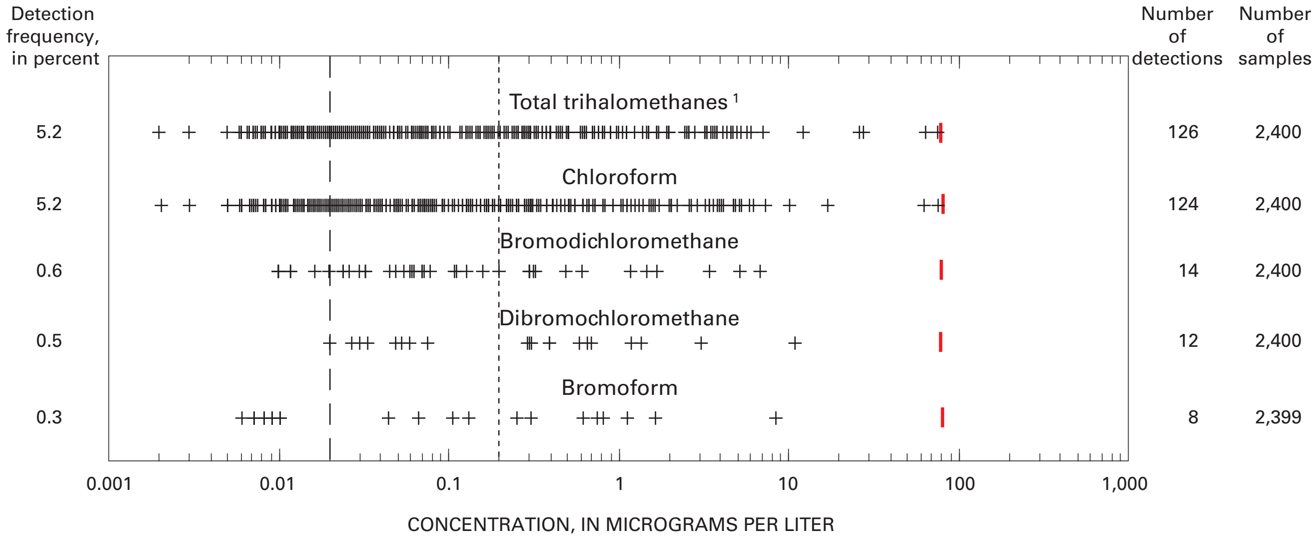
Trihalomethane	Number of samples	Number of detections	Detection frequency (percent)
Assessment level of 0.2 microgram per liter			
One or more of the trihalomethanes	2,400	126	5.2
Chloroform	2,400	124	5.2
Bromodichloromethane	2,400	14	.6
Dibromochloromethane	2,400	12	.5
Bromoform	2,399	8	.3
Assessment level of 0.02 microgram per liter			
One or more of the trihalomethanes	1,207	217	18.0
Chloroform	1,207	217	18.0
Bromodichloromethane	1,207	28	2.3
Dibromochloromethane	1,207	13	1.1
Bromoform	1,206	8	.7

Table 17. Trihalomethane concentrations in samples from domestic wells, 1986–2001.

[THMs, trihalomethanes; µg/L, microgram per liter]

Statistic	Concentration in samples with detections, in µg/L				
	One or more THMs	Chloroform	Bromodichloromethane	Dibromochloromethane	Bromoform
Assessment level of 0.2 µg/L					
Minimum	0.2	0.2	0.2	0.3	0.2
Median	.5	.5	.6	.6	.8
Maximum	74	74	7.0	11	8.2
Assessment level 0.02 µg/L					
Minimum	0.02	0.02	0.02	0.02	0.04
Median	.08	.08	.07	.06	.19
Maximum	17	17	7.0	3.1	1.6

Concentrations for total THMs and individual THMs in samples from domestic wells are shown in figure 15. Many samples from domestic wells had reported THM concentrations that were less than the assessment levels of 0.2 and 0.02 µg/L (fig. 15). Chloroform especially was reported at small concentrations in many samples in which it was not considered to be detected at the assessment levels used in this report. In general, as the chlorine content of the THM compound decreased, the maximum concentration of the THM decreased also, with the exception of bromodichloromethane at the 0.2-µg/L assessment level. At the 0.2-µg/L assessment level, maximum concentrations decreased from 74 to 11 to 8.2 to 7.0 µg/L, for chloroform, dibromochloromethane, bromoform, and bromodichloromethane, respectively. At the 0.02-µg/L assessment level, the trend in maximum



[1] The MCL of 80 micrograms per liter is for the sum of the concentrations of four trihalomethanes including chloroform, bromodichloromethane, dibromochloromethane, and bromoform (U.S. Environmental Protection Agency, 2004).

EXPLANATION

+	**Concentration for a sample**—Several analytical methods, with differing sensitivity for a specific trihalomethane with time, as well as between THMs, are shown in the bar concentration charts. Median concentrations at specific assessment levels are provided in table 17. Multiple samples of equal concentration will appear as a single symbol
5.2	**Detection frequency, in percent, at an assessment level of 0.2 microgram per liter**—For detection frequency levels at 0.02 microgram per liter refer to table 16
126	**Number of detections at an assessment level of 0.2 microgram per liter**
2,400	**Number of samples**
	Assessment level
— —	0.02 microgram per liter
- - - - - -	0.2 microgram per liter
	Drinking-water standard
|	U.S. Environmental Protection Agency Maximum Contaminant Level (MCL)

Figure 15. Concentrations of trihalomethanes (THMs) in samples from domestic wells, 1986–2001.

concentrations followed that of detection frequencies as it decreased from 17 to 7.0 to 3.1 to 1.6 µg/L for chloroform, bromodichloromethane, dibromochloromethane, and bromoform, respectively.

Mixtures

The number of samples with detections of 0, 1, 2, 3, or 4 THMs at the 0.2- and 0.02-µg/L assessment levels is shown in figure 16. Table 18 shows the number of samples with numbers of THMs and the percentage of the whole data set that they represent. At the 0.2-µg/L assessment level, 2,400 samples were considered, and at the 0.02-µg/L assessment level, 1,207 samples were considered. At both assessment levels, the most common finding was that most samples did not have any THMs. Furthermore, the number of samples with no THMs was much greater than the number of samples with 2, 3, or 4 THMs combined. At the 0.2-µg/L assessment level, about 95 percent of the samples did not have any THMs, and less than 0.7 percent of the samples had 2, 3, or 4 THMs. At the 0.02-µg/L assessment level, 82.0 percent of the samples did not have any THMs, and 2.3 percent of the samples had two or more THMs (table 18).

At the 0.02-µg/L assessment level, 11 mixtures with at least one THM occurred in 1 percent or more of the samples (table 19). Ten of the 11 mixtures included chloroform. The most frequently detected mixtures with at least one THM included chloroform–MTBE, which was detected in 3.0 percent of the samples, and chloroform–PCE, which was detected in 2.9 percent of the samples. Three of the 11 mixtures included two THMs. The most common two-THM mixture, chloroform–bromodichloromethane, occurred in 2.3 percent of the samples, and the two-THM mixtures of chloroform–dibromochloromethane and bromodichloromethane–dibromochloromethane occurred in 1.1 percent of the samples (table 19).

Chloroform occurred with one or more of the other three THMs in 28 samples, which is 2.3 percent of the 1,207 samples and 12.9 percent of the 217 samples in which chloroform was detected. Chloroform occurred with two or more of the other three THMs in 14 samples and with all three of the other THMs in 7 samples, which is 6.5 and 3.2 percent, respectively, of the 217 samples in which chloroform was detected.

For the other three THMs, if they were detected, they always occurred with another THM. Bromodichloromethane occurred with another THM in 28 samples, which is 2.3 percent of the 1,207 samples and 100 percent of the 28 samples in which bromodichloromethane was detected. Dibromochloromethane occurred with another THM in 13 samples or 100 percent of the 13 samples in which it was detected. Bromoform occurred with another THM in 8 samples or 100 percent of the samples in which it was detected.

As noted previously, the most common mixture of two THMs was chloroform–bromodichloromethane, which was found in 28 samples or 2.3 percent of the 1,207 samples at the

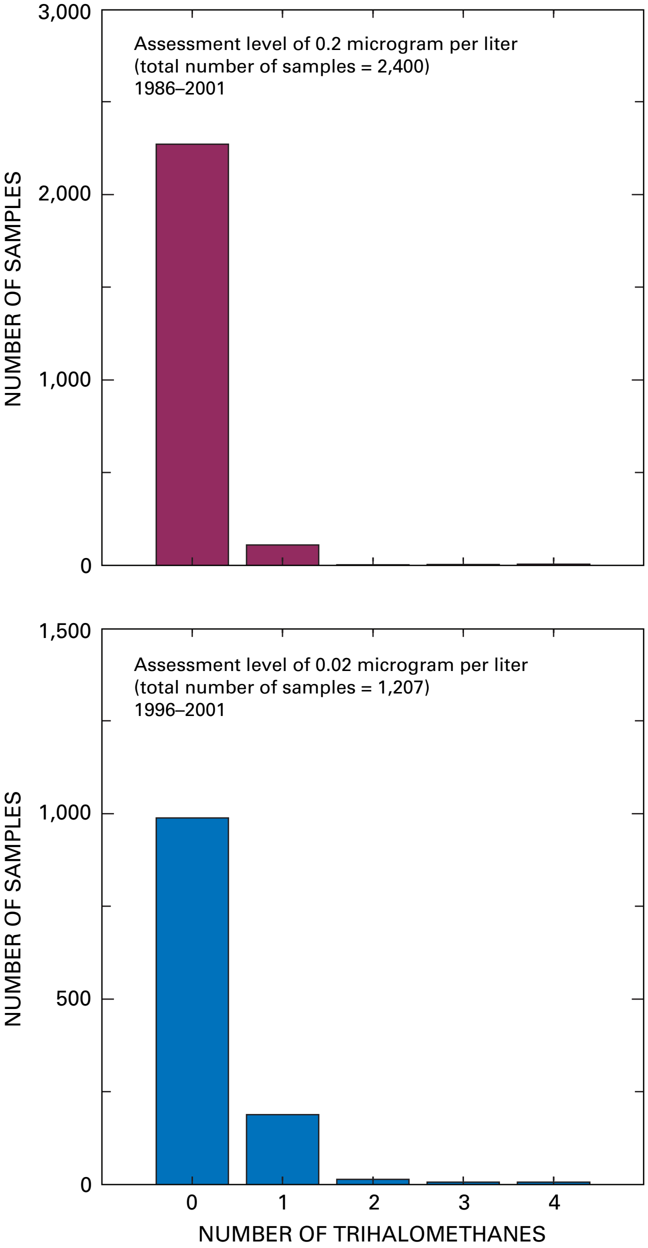


Figure 16. Number of trihalomethanes in samples from domestic wells, 1986–2001.

Table 18. Number of trihalomethanes detected and percentage of detections in samples from domestic wells, 1986–2001.

	Number of trihalomethanes detected					
	None	One	Two	Three	Four	Two or more
Assessment level of 0.2 microgram per liter						
Number of samples	2,274	111	4	5	6	15
Percentage of samples	94.8	4.6	.2	.2	.2	.6
Assessment level of 0.02 microgram per liter						
Number of samples	990	189	14	7	7	28
Percentage of samples	82.0	15.7	1.2	.6	.6	2.3

Table 19. Most frequently detected two-compound mixtures in samples from domestic wells that contain at least one trihalomethane and that were detected in 1 percent or more of samples at an assessment level of 0.02 microgram per liter, 1986–2001.

[THM, trihalomethane; VOC, volatile organic compound; shaded rows indicate 2-THM mixtures; t, tied]

Rank	Mixture		Number of THM samples	Number of detections	Detection frequency (percent)
	THM	Other[1] VOC			
1	Chloroform	Methyl *tert*-butyl ether (MTBE)	1,207	36	3.0
2	Chloroform	Perchloroethene (PCE)	1,207	35	2.9
3	Chloroform	1,1,1-Trichloroethane (TCA)	1,207	31	2.6
4	Chloroform	Bromodichloromethane	1,207	28	2.3
5	Chloroform	Toluene	1,207	21	1.7
t6	Chloroform	Chloromethane	1,207	16	1.3
t6	Chloroform	Trichloroethene (TCE)	1,207	16	1.3
t8	Chloroform	Methylene chloride	1,207	15	1.2
t8	Chloroform	1,1-Dichloroethane	1,207	15	1.2
t10	Chloroform	Dibromochloromethane	1,207	13	1.1
t10	Bromodichloromethane	Dibromochloromethane	1,207	13	1.1

[1] The word "other" refers to the second compound of the specified mixture.

0.02-μg/L assessment level. Chloroform–bromodichloromethane was detected in 12.9 percent of the 217 samples in which chloroform was detected and in 100 percent of the 28 samples in which bromodichloromethane was detected.

The most frequently detected two-compound mixtures in domestic well samples for chloroform, bromodichloromethane, dibromochloromethane, and bromoform are listed in table 20. For three of the four THMs, the most common mixtures are those with other THMs. The exception is chloroform, for which the most common mixture was chloroform–MTBE. For the other three THMs, the most common mixtures of the specified THM and a non-THM VOC was with PCE. The chloroform–PCE mixture occurred in 16.1 percent of the samples in which chloroform was detected, the bromodichloromethane–PCE mixture occurred in 17.9 percent of the samples in which bromodichloromethane was detected, the dibromochloromethane–PCE mixture occurred in 23.1 percent of the samples in which dibromochloromethane was detected, and the bromoform–PCE mixture occurred in 25.0 percent of the samples in which bromoform was detected.

Public Well Samples

The occurrence of the four THMs in public well samples is described on the basis of samples collected during 1986–2001 from 1,096 wells (table 2). The occurrence of THMs is described in terms of locations of detections and nondetections, detection frequencies, concentrations, and mixtures of THMs (with other THMs and with other VOCs). A detailed description of the samples used to describe the occurrence of trihalomethanes in public well samples can be found in Section A in the Supplemental Information section and in Moran and others (2006), which describes the approach of the NAWQA studies.

Locations of Detections

The locations of the 1,096 wells that were sampled to describe THMs in samples from public wells are shown in figure 17. One or more of the THMs were detected at concentrations greater than or equal to 0.2 μg/L in samples from 161 wells (table 21). Some States, such as California, Texas, New Jersey, and Pennsylvania, had multiple samples with detected THMs, but THMs were found in public well samples throughout the Nation.

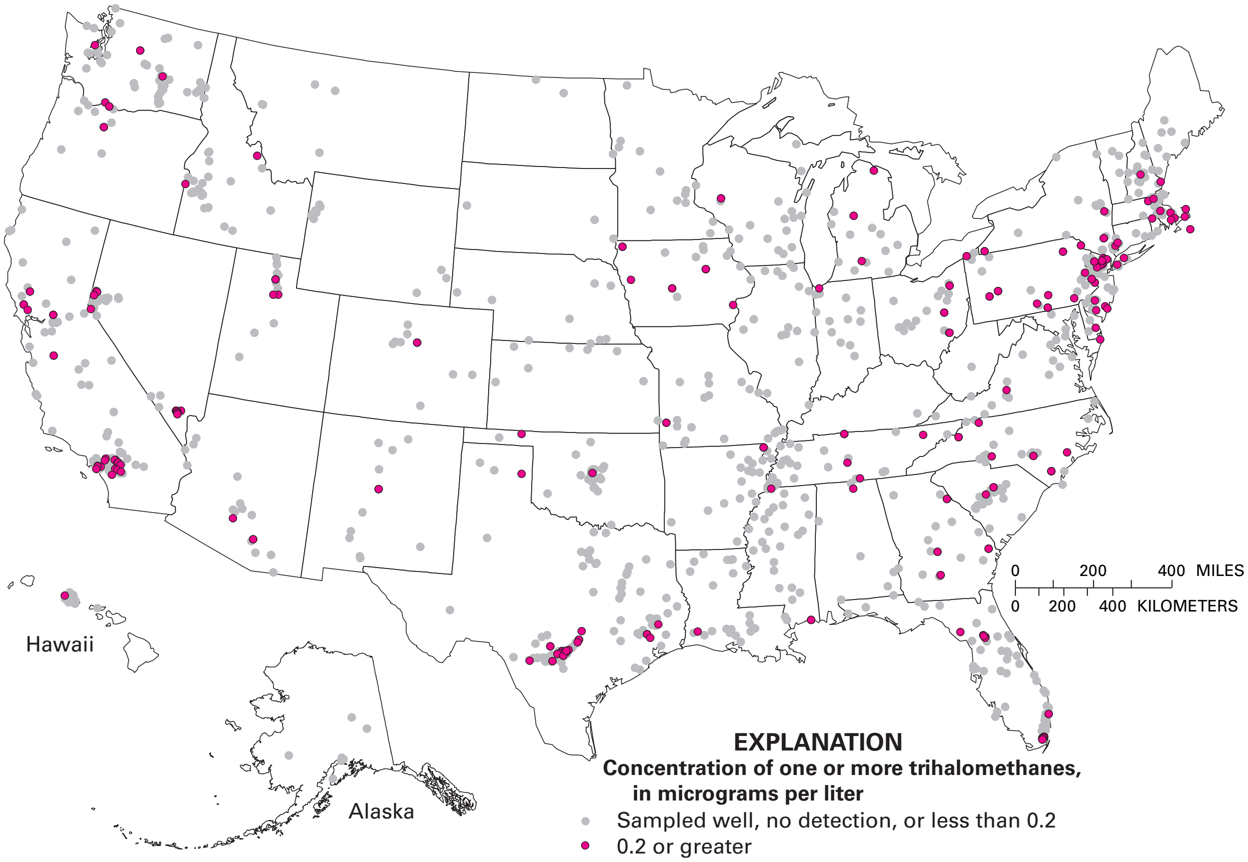
Section F in the Supplemental Information section has additional figures showing individual THM detections in public well samples. Figure F1 for chloroform is very similar to figure 17 because, for most of the wells with one or more THM detections, chloroform was one of the detected THMs. Chloroform was detected in samples from public wells in many States throughout the Nation. Of the samples in which one or more THMs were detected, but chloroform was not, many were from States such as California, Texas, and Pennsylvania, which also have many samples from public wells in which chloroform was detected. The occurrence patterns in figure F2 (bromodichloromethane), figure F3 (dibromochloromethane), and figure F4 (bromoform) are very similar to each other. In general, bromodichloromethane, dibromochloromethane, and bromoform occurred in samples from most of the same States as chloroform, but in fewer samples per State. However, in Missouri and Hawaii, chloroform was not detected in any of

Table 20. Most frequently detected two-compound mixtures in samples from domestic wells for each trihalomethane at an assessment level of 0.02 microgram per liter, 1986–2001.

[THM, trihalomethane; VOC, volatile organic compound; shaded rows indicate two-THM mixtures; t, tied]

Rank	Other[1] VOC	Predominant use of other[1] VOC	Number of THM detections	Number of mixture detections	Detection frequency (percent)
		Chloroform			
1	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	217	36	16.6
2	Perchloroethene (PCE)	Solvent	217	35	16.1
3	1,1,1-Trichloroethane (TCA)	Solvent	217	31	14.3
4	Bromodichloromethane	Disinfection by-product	217	28	12.9
5	Toluene	Gasoline aromatic hydrocarbon	217	21	9.7
t6	Chloromethane	Solvent	217	16	7.4
t6	Trichloroethene (TCE)	Solvent	217	16	7.4
t8	Methylene chloride	Solvent	217	15	6.9
t8	1,1-Dichloroethane	Solvent	217	15	6.9
10	Dibromochloromethane	Disinfection by-product	217	13	6.0
		Bromodichloromethane			
1	Chloroform	Disinfection by-product	28	28	100.0
2	Dibromochloromethane	Disinfection by-product	28	13	46.4
3	Bromoform	Disinfection by-product	28	8	28.6
t4	Perchloroethene (PCE)	Solvent	28	5	17.9
t4	1,1,1-Trichloroethane (TCA)	Solvent	28	5	17.9
t6	Toluene	Gasoline aromatic hydrocarbon	28	4	14.3
t6	Methylene chloride	Solvent	28	4	14.3
t6	Trichlorofluoromethane (CFC-11)	Refrigerant	28	4	14.3
t6	1,1-Dichloroethene	Organic synthesis	28	4	14.3
t6	Dichlorodifluoromethane (CFC-12)	Refrigerant	28	4	14.3
t6	Trichloroethene (TCE)	Solvent	28	4	14.3
		Dibromochloromethane			
t1	Chloroform	Disinfection by-product	13	13	100.0
t1	Bromodichloromethane	Disinfection by-product	13	13	100.0
3	Bromoform	Disinfection by-product	13	7	53.8
t4	Perchloroethene (PCE)	Solvent	13	3	23.1
t4	Trichlorofluoromethane (CFC-11)	Refrigerant	13	3	23.1
t4	Trichloroethene (TCE)	Solvent	13	3	23.1
		Bromoform			
t1	Chloroform	Disinfection by-product	8	8	100.0
t1	Bromodichloromethane	Disinfection by-product	8	8	100.0
3	Dibromochloromethane	Disinfection by-product	8	7	87.5
t4	Perchloroethene (PCE)	Solvent	8	2	25.0
t4	Trichlorofluoromethane (CFC-11)	Refrigerant	8	2	25.0
t4	Trichloroethene (TCE)	Solvent	8	2	25.0
t4	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	8	2	25.0

[1] The word “other” refers to the second compound of the specified mixture.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure 17. Concentrations of trihalomethanes in samples from public wells, 1986–2001.

Table 21. Detection frequencies of trihalomethanes in samples from public wells, 1986–2001.

Trihalomethane	Number of samples	Number of detections	Detection frequency (percent)
Assessment level of 0.2 microgram per liter			
One or more of the trihalomethanes	1,096	161	14.7
Chloroform	1,092	125	11.4
Bromodichloromethane	1,095	46	4.2
Dibromochloromethane	1,095	48	4.4
Bromoform	1,096	49	4.5

the samples, but one or more of the other three THMs were detected (bromodichloromethane and dibromochloromethane in Missouri and bromoform in Hawaii).

Detection Frequencies

At the 0.2-µg/L assessment level, at least one THM was detected in 14.7 percent of the public well samples. Chloroform was detected in 11.4 percent of the samples, and the other THMs were each detected in about 4 percent of the samples (table 21).

Concentrations

At the 0.2-µg/L assessment level, the median concentration for one or more of the THMs in samples with detections was 0.5 µg/L. The median concentrations for chloroform, dibromochloromethane, and bromoform were 0.6 µg/L, and the median concentration for bromodichloromethane was 0.4 µg/L (table 22).

Concentrations for total THMs and individual THMs in public well samples are shown in figure 18. Many samples from public wells had THM concentrations reported

Table 22. Trihalomethane concentrations in samples from public wells, 1986–2001.

[THMs, trihalomethanes; µg/L, microgram per liter]

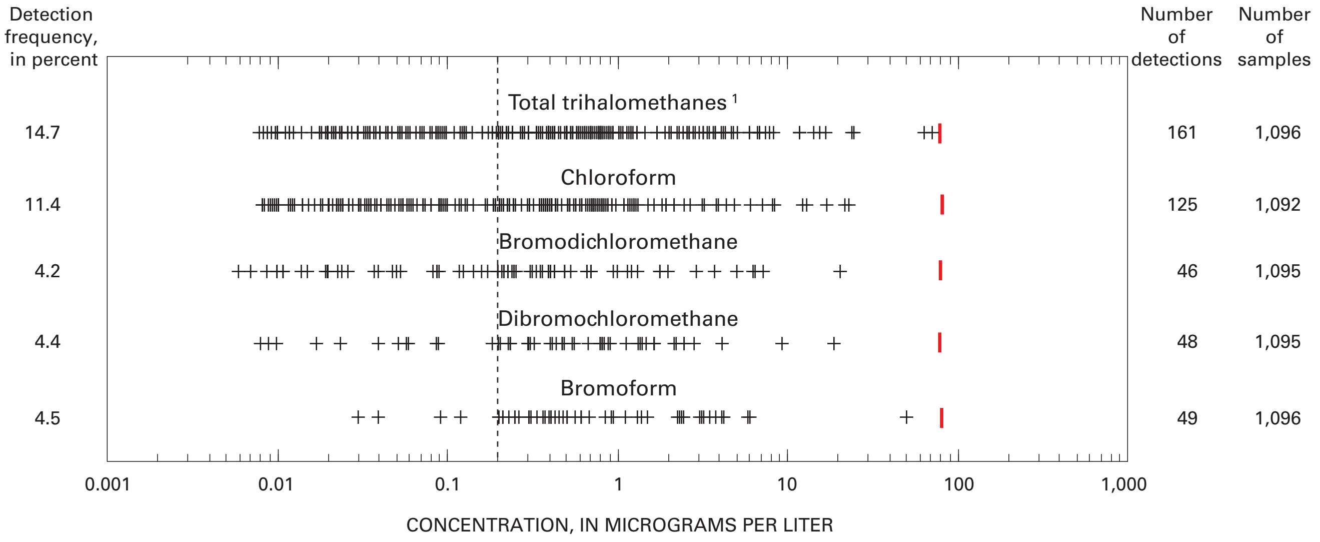
Statistic	Concentration in samples with detections, in µg/L				
	One or more THMs	Chloroform	Bromodichloromethane	Dibromochloromethane	Bromoform
Assessment level of 0.2 µg/L					
Minimum	0.2	0.2	0.2	0.2	0.2
Median	.5	.6	.4	.6	.6
Maximum	49	22	21	19	49

that were less than the 0.2-µg/L assessment level (fig. 18). Chloroform especially was reported at small concentrations in many samples in which it was not considered to be detected at the 0.2-µg/L assessment level used in this report for public well samples. The maximum concentration of any THM was 49 µg/L for bromoform. This was the largest bromoform concentration of any sample from any of the five studies considered in this report and much larger than the second largest bromoform concentration of 5.8 µg/L for a public well sample. For the other three THMs, a decrease in chlorine content corresponded with a small maximum concentration decrease from 22 to 21 to 19 µg/L for chloroform, bromodichloromethane, and dibromochloromethane, respectively (table 22).

Mixtures

The number of samples with detections of 0, 1, 2, 3, or 4 THMs at the 0.2-µg/L assessment level is shown in figure 19. The number of samples with THMs and the percentage of the whole data set (1,096 samples) that they represent are presented in table 23. Most samples did not have any THMs, and the number of samples with no THMs was much greater than the number of samples with 2, 3, or 4 THMs combined. A mixture of THMs occurred in 5.3 percent of the public well samples.

At the 0.2-µg/L assessment level, 11 mixtures with at least one THM occurred in 1 percent or more of the samples (table 24). The six most common of these mixtures include two THMs. The most common two-THM mixture, bromodichloromethane–dibromochloromethane, occurred in 3.4 percent of the samples, and the least common two-THM mixture, chloroform–bromoform, occurred in 1.7 percent of the samples. Eight of the 11 mixtures included chloroform. The most frequently detected mixture with one THM and one non-THM VOC was chloroform–TCE, which was detected in 1.6 percent of the samples (table 24). Of the five mixtures that included one non-THM VOC, all five of the mixtures included chloroform, and in four of the mixtures, the non-THM VOC was a solvent.



[1] The MCL of 80 micrograms per liter is for the sum of the concentrations of four trihalomethanes including chloroform, bromodichloromethane, dibromochloromethane, and bromoform (U.S. Environmental Protection Agency, 2004).

EXPLANATION

+	**Concentration for a sample**—Several analytical methods, with differing sensitivity for a specific trihalomethanes with time, as well as between THMs, are shown in the bar concentration charts. Median concentrations at an assessment level of 0.2 microgram per liter are provided in table 22. Multiple samples of equal concentration will appear as a single symbol
14.7	**Detection frequency, in percent, at an assessment level of 0.2 microgram per liter**
161	**Number of detections at an assessment level of 0.2 microgram per liter**
1,096	**Number of samples**
	Assessment level
------	0.2 microgram per liter
	Drinking-water standard
|	U.S. Environmental Protection Agency Maximum Contaminant Level (MCL)

Figure 18. Concentrations of trihalomethanes (THMs) in samples from public wells, 1986–2001.

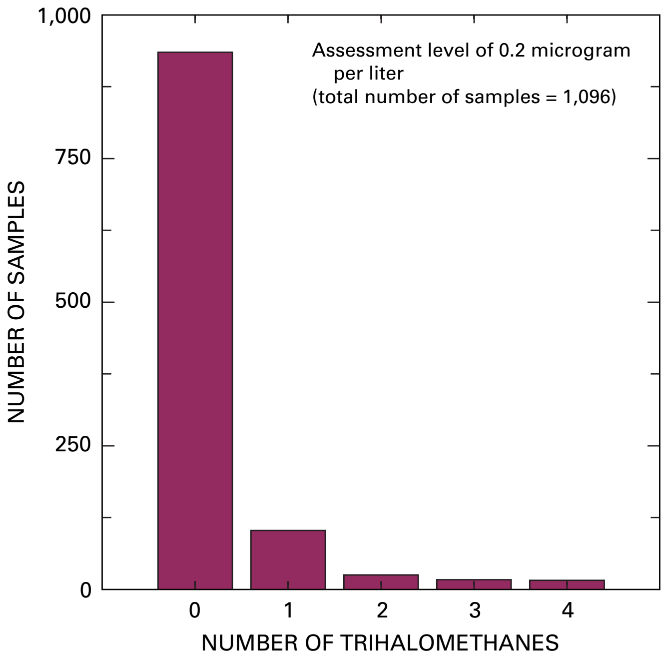


Figure 19. Number of trihalomethanes in samples from public wells, 1986–2001.

Table 23. Number of trihalomethanes detected and percentage of detections in samples from public wells, 1986–2001.

	Number of trihalomethanes detected					
	None	One	Two	Three	Four	Two or more
Assessment level of 0.2 microgram per liter						
Number of samples	935	103	25	17	16	58
Percentage of samples	85.3	9.4	2.3	1.6	1.5	5.3

Chloroform occurred with one or more of the other three THMs in 38 samples, which is 3.5 percent of the 1,096 samples and 30.4 percent of the 125 samples in which chloroform was detected. Chloroform occurred with two or more of the other three THMs in 27 samples and with all three of the other THMs in 16 samples, which is 21.6 and 12.8 percent, respectively, of the 125 samples in which chloroform was detected.

Bromodichloromethane occurred with one or more of the other three THMs in 46 samples, which is 4.2 percent of the 1,096 samples and 100 percent of the 46 samples in which bromodichloromethane was detected. Bromodichloromethane occurred with two or more of the other three THMs in 32 samples and with all three of the other THMs in 16 samples, which is 69.6 and 34.8 percent, respectively, of the 46 samples in which bromodichloromethane was detected.

Dibromochloromethane occurred with one or more of the other three THMs in 47 samples, which is 4.3 percent of the 1,096 samples and 97.9 percent of the 48 samples in which dibromochloromethane was detected. Dibromochloromethane occurred with two or more of the other three THMs in 33 samples and with all three of the other THMs in 16 samples, which is 68.8 and 33.3 percent, respectively, of the 48 samples in which dibromochloromethane was detected.

Bromoform occurred with one or more of the other three THMs in 34 samples, which is 3.1 percent of the 1,096 samples and 69.4 percent of the 49 samples in which bromoform was detected. Bromoform occurred with two or more of the other three THMs in 23 samples and with all three of the other THMs in 16 samples, which is 46.9 and 32.7 percent, respectively, of the 49 samples in which bromoform was detected.

The most common mixture of two THMs was bromodichloromethane–dibromochloromethane, which occurred in 37 samples (table 25). This represents 3.4 percent of the 1,096 samples from public wells, 80.4 percent of the

Table 24. Most frequently detected two-compound mixtures in samples from public wells that contain at least one trihalomethane and that were detected in 1 percent or more of samples at an assessment level of 0.2 microgram per liter, 1986–2001.

[THM, trihalomethane; VOC, volatile organic compound; shaded rows indicate two-THM mixtures; t, tied]

Rank	Mixture		Predominant use of other[1] VOC	Number of THM samples	Number of detections	Detection frequency (percent)
	THM	Other[1] VOC				
1	Bromodichloromethane	Dibromochloromethane	Disinfection by-product	1,096	37	3.4
2	Chloroform	Bromodichloromethane	Disinfection by-product	1,096	35	3.2
3	Dibromochloromethane	Bromoform	Disinfection by-product	1,096	32	2.9
4	Chloroform	Dibromochloromethane	Disinfection by-product	1,096	27	2.5
5	Bromodichloromethane	Bromoform	Disinfection by-product	1,096	22	2.0
6	Chloroform	Bromoform	Disinfection by-product	1,096	19	1.7
7	Chloroform	Trichloroethene (TCE)	Solvent	1,096	17	1.6
8	Chloroform	Perchloroethene (PCE)	Solvent	1,096	15	1.4
9	Chloroform	1,1,1-Trichloroethane (TCA)	Solvent	1,096	14	1.3
t10	Chloroform	1,1-Dichloroethane	Solvent	1,096	13	1.2
t10	Chloroform	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	1,096	13	1.2

[1] The word “other” refers to the second compound of the specified mixture.

Table 25. Most frequently detected two-compound mixtures in samples from public wells for each trihalomethane at an assessment level of 0.2 microgram per liter, 1986–2001.

[THM, trihalomethane; VOC, volatile organic compound; shaded rows indicate two-THM mixtures; t, tied]

Rank	Other[1] VOC	Predominant use of other[1] VOC	Number of THM detections	Number of mixture detections	Detection frequency (percent)
		Chloroform			
1	Bromodichloromethane	Disinfection by-product	125	35	28.0
2	Dibromochloromethane	Disinfection by-product	125	27	21.6
3	Bromoform	Disinfection by-product	125	19	15.2
4	Trichloroethene (TCE)	Solvent	125	17	13.6
5	Perchloroethene (PCE)	Solvent	125	15	12.0
6	1,1,1-Trichloroethane (TCA)	Solvent	125	14	11.2
t7	1,1-Dichloroethane	Solvent	125	13	10.4
t7	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	125	13	10.4
9	Dichlorodifluoromethane (CFC-12)	Refrigerant	125	8	6.4
10	1,1-Dichloroethene	Organic synthesis	125	7	5.6
		Bromodichloromethane			
1	Dibromochloromethane	Disinfection by-product	46	37	80.4
2	Chloroform	Disinfection by-product	46	35	76.1
3	Bromoform	Disinfection by-product	46	22	47.8
t4	Perchloroethene (PCE)	Solvent	46	3	6.5
t4	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	46	3	6.5
t6	Trichloroethene (TCE)	Solvent	46	2	4.3
t6	Ethylene dibromide (EDB)	Fumigant	46	2	4.3
t8	Carbon tetrachloride	Solvent	46	1	2.2
t8	Chloroethane	Solvent	46	1	2.2
t8	Bromomethane	Fumigant	46	1	2.2
t8	Chloromethane	Solvent	46	1	2.2
t8	1,1-Dichloroethane	Solvent	46	1	2.2
t8	1,1,1-Trichloroethane (TCA)	Solvent	46	1	2.2
t8	Dichlorodifluoromethane (CFC-12)	Refrigerant	46	1	2.2
t8	*cis*-1,2-Dichloroethene	Solvent	46	1	2.2
t8	*n*-Butylbenzene	Gasoline aromatic hydrocarbon	46	1	2.2
t8	Trichlorotrifluoroethane (CFC-113)	Refrigerant	46	1	2.2
		Dibromochloromethane			
1	Bromodichloromethane	Disinfection by-product	48	37	77.1
2	Bromoform	Disinfection by-product	48	32	66.7
3	Chloroform	Disinfection by-product	48	27	56.2
t4	Perchloroethene (PCE)	Solvent	48	3	6.2
t4	Methyl *tert*-butyl ether (MTBE)	Gasoline oxygenate	48	3	6.2
		Bromoform			
1	Dibromochloromethane	Disinfection by-product	49	32	65.3
2	Bromodichloromethane	Disinfection by-product	49	22	44.9
3	Chloroform	Disinfection by-product	49	19	38.8
4	Perchloroethene (PCE)	Solvent	49	7	14.3
t5	Trichloroethene (TCE)	Solvent	49	3	6.1
t5	Methyl *tert*-butyl ether (MTBE)	Oxygenate	49	3	6.1

[1] The word "other" refers to the second compound of the specified mixture.

46 samples in which bromodichloromethane was detected, and 77.1 percent of the 48 samples in which dibromochloromethane was detected.

The most frequently detected two-compound mixtures in public well samples that contained at least one THM are listed in table 25. Mixtures are listed separately for chloroform, bromodichloromethane, dibromochloromethane, and bromoform. For all four THMs, the three most common mixtures are those with the other three THMs. For all four THMs, some of the most common mixtures with the specified THM and a non-THM VOC are with the solvents TCE and PCE, and the gasoline oxygenate MTBE.

Comparisons of Occurrence Findings

In this section, the occurrence of the four THMs in (1) ground water (aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas) and (2) drinking-water supply wells (domestic wells and public wells) are compared. The comparisons are made using a 0.2-µg/L assessment level for all studies.

The comparisons are based on similarities and differences in the locations of detections, detection frequencies, concentrations, and mixtures. For aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas, comparisons also are made of the detection frequencies by network.

Ground Water

The data sets for aquifer studies and shallow ground water in agricultural and urban areas account for a total of 5,067 samples or almost 90 percent of the total number of samples (5,642) used to characterize the occurrence of THMs in ground water of the United States (table 2). There are 3,497 samples in the aquifer studies data set, 723 samples in the data set for shallow ground water in agricultural areas, and 847 samples in the data set for the shallow ground water in urban areas (table 26).

Comparison of these three data sets is for the purpose of providing initial insights on the occurrence of THMs in ground water for three different land uses—mixed, agricultural, and urban. Wells sampled for aquifer studies were not targeted to a specific land use and, as such, these wells are associated with a mix of land uses. Wells sampled for the shallow ground water in agricultural and urban studies were targeted to a specific land use around each well. Samples from all three studies were collected in varied hydrogeologic and climatic environments across the Nation and provide an initial characterization of THMs in ground water in mixed, agricultural, and urban land-use settings.

Locations of Detections

Samples for aquifer studies were collected in 47 States including Alaska and Hawaii (fig. 2). The minimum number of samples collected in any of the 47 States was three (Indiana). The maximum number of samples collected in any of the 47 States was 404 (Idaho). The median number of samples collected in the 47 States was 49. One or more THMs were detected in 41 of the 47 States (table 26).

Samples from shallow ground water in agricultural and urban areas also were collected throughout the Nation, but there were large areas from which no samples were collected (figs. 6 and 10). The distribution of samples for these studies is not as extensive as that for the aquifer studies.

Samples from shallow ground water in agricultural areas were collected in 25 States. The minimum, maximum, and median number of samples collected in those 25 States were 1 (New York), 128 (Washington), and 20, respectively. One or more THMs were detected in 10 of the 25 States (table 26).

Samples from shallow ground water in urban areas were collected in 30 States. The minimum, maximum, and median number of samples collected in those 30 States were 3 (New Hampshire), 60 (Nevada), and 27.5, respectively. One or more THMs were detected in 26 of the 30 States (table 26).

Detection Frequencies

At the 0.2-µg/L assessment level, one or more THMs were detected in 7.9 percent of the samples from aquifer studies, 2.2 percent of the samples from shallow ground water in agricultural areas, and 19.5 percent of the samples from shallow ground water in urban areas. For chloroform and bromodichloromethane, detection frequencies for samples from aquifer studies were higher than those for samples from shallow ground water in agricultural areas and lower than those for samples from shallow ground water in urban areas. For dibromochloromethane and bromoform, the detection frequencies for samples from aquifer studies were higher than the detections frequencies for samples from shallow ground water in urban areas, which were higher than the detection frequencies for samples from shallow ground water in agricultural areas (table 26).

Concentrations

The distribution of concentrations of total THMs for the three data sets is shown in figure 20. For all three data sets, most samples did not have any detected THMs, and most detections were at small concentrations.

The three data sets have similar concentration distributions, and it is only in the area of the larger concentrations that differences were observed. Figure 20 shows that, in general, total THMs in samples from shallow ground water in urban areas were detected more often and at larger concentrations than total THMs in samples from aquifer studies. Of the three studies, total THMs were detected least often and at the smallest concentrations in shallow ground water in agricultural areas.

For chloroform, the same relation as total THMs was observed, with detection frequencies and concentrations from largest to smallest in samples from shallow ground water in urban areas, then aquifer studies, and then shallow ground water in agricultural areas. For bromodichloromethane, the same pattern in detection frequency was observed, but the largest concentrations occurred in aquifer studies rather than in shallow ground water in urban areas, and the smallest concentrations occurred in shallow ground water in agricultural areas. Dibromochloromethane and bromoform were not found in samples from shallow ground water in agricultural areas. Both of these THMs occurred more frequently and at larger concentrations in samples from aquifer studies than in samples from shallow ground water in urban areas.

Table 26. Comparison of trihalomethane occurrence in ground water at an assessment level of 0.2 microgram per liter.

[THM, trihalomethane; µg/L, microgram per liter; NA, not applicable]

Occurrence information	Study		
	Aquifer studies (1985–2001)	Shallow ground water in agricultural areas (1988–1998)	Shallow ground water in urban areas (1993–2002)
Samples			
Total	3,497	723	847
Minimum number of samples in a State in which samples were collected	3 (Indiana)	1 (New York)	3 (New Hampshire)
Median number of samples per State in which samples were collected	49	20	27.5
Maximum number of samples in a State in which samples were collected	404 (Idaho)	128 (Washington)	60 (Nevada)
Location of detections			
Number of States in which samples were collected	47	25	30
Number of States in which one or more THMs were detected	41	10	26
Detection frequency for all samples			
Frequency of one or more THMs, in percent	7.9	2.2	19.5
Frequency of individual THMs, in percent	Chloroform, 7.4 Bromodichloromethane, 1.1 Dibromochloromethane, 0.9 Bromoform, 1.0	Chloroform, 2.2 Bromodichloromethane, 0.1 Dibromochloromethane, 0.0 Bromoform, 0.0	Chloroform, 19.5 Bromodichloromethane, 1.7 Dibromochloromethane, 0.4 Bromoform, 0.1
Networks			
Percentage of networks with detections of one or more THMs	65.3	36.7	87.9
Percentage of networks with detections of individual THMs	Chloroform, 63.3 Bromodichloromethane, 22.4 Dibromochloromethane, 17.3 Bromoform, 4.1	Chloroform, 36.7 Bromodichloromethane, 3.3 Dibromochloromethane, 0.0 Bromoform, 0.0	Chloroform, 87.9 Bromodichloromethane, 21.2 Dibromochloromethane, 9.1 Bromoform, 3.0
Concentrations			
Total THM concentrations less less than 1 µg/L, in percent	97.3	99.6	92.4
Total THM concentrations from 1 to 10 µg/L, in percent	2.3	0.4	6.7
Total THM concentrations greater than 10 µg/L, in percent	0.4	0.0	0.9
Median concentration in samples with detections for individual THMs, in µg/L	Chloroform, 0.5 Bromodichloromethane, 0.6 Dibromochloromethane, 0.6 Bromoform, 0.6	Chloroform, 0.3 Bromodichloromethane, 0.3 Dibromochloromethane, NA Bromoform, NA	Chloroform, 0.6 Bromodichloromethane, 0.4 Dibromochloromethane, 0.7 Bromoform, 0.2
Number of THMs per sample			
Zero, in percent	92.1	97.8	80.5
One, in percent	6.7	2.1	17.7
Two, in percent	0.5	0.1	1.4
Three, in percent	0.3	0.0	0.4
Four, in percent	0.4	0.0	0.0

Table 26. Comparison of trihalomethane occurrence in ground water at an assessment level of 0.2 microgram per liter.—Continued

[THM, trihalomethane; µg/L, microgram per liter; NA, not applicable]

Occurrence information	Study Aquifer studies (1985–2001)	 Shallow ground water in agricultural areas (1988–1998)	 Shallow ground water in urban areas (1993–2002)
THM mixtures			
Frequency of two-THM mixtures, in percent of samples with analytical results for both THMs	Chloroform–bromodichloromethane, 1.0 Chloroform–dibromochloromethane, 0.7 Chloroform–bromoform, 0.5 Bromodichloromethane–dibromochloromethane, 0.8 Bromodichloromethane–bromoform, 0.5 Dibromochloromethane–bromoform, 0.6	Chloroform–bromodichloromethane, 0.1 Chloroform–dibromochloromethane, 0.0 Chloroform–bromoform, 0.0 Bromodichloromethane–dibromochloromethane, 0.0 Bromodichloromethane–bromoform, 0.0 Dibromochloromethane–bromoform, 0.0	Chloroform–bromodichloromethane, 1.7 Chloroform–dibromochloromethane, 0.4 Chloroform–bromoform, 0.1 Bromodichloromethane–dibromochloromethane, 0.4 Bromodichloromethane–bromoform, 0.0 Dibromochloromethane–bromoform, 0.0

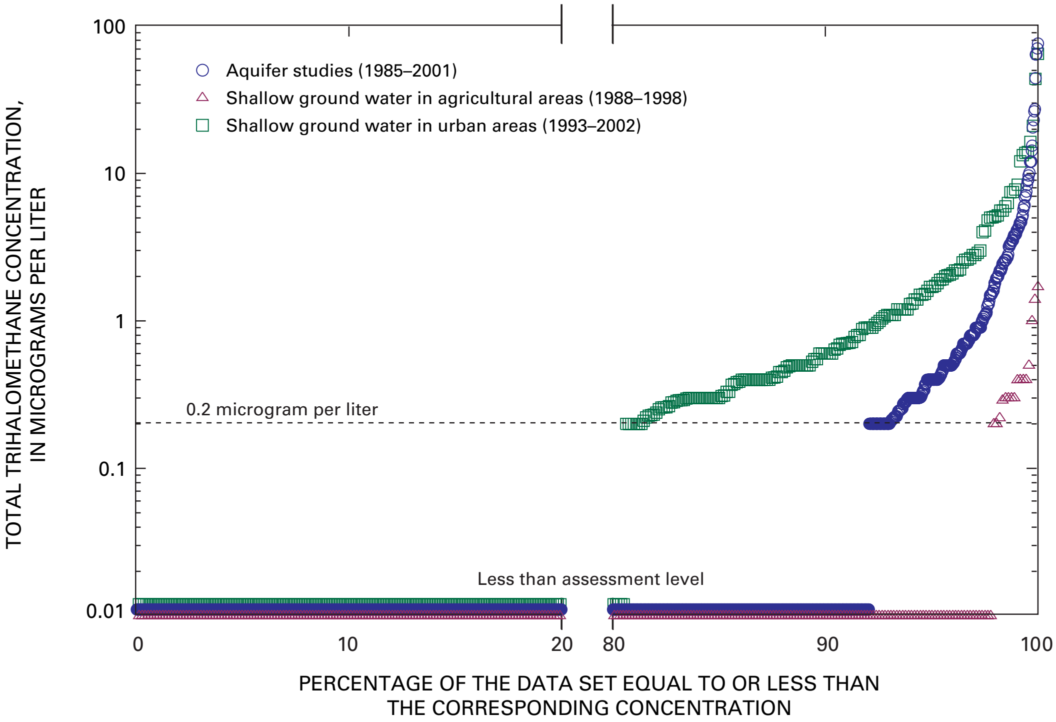


Figure 20. Comparison of total trihalomethane concentrations in ground water at an assessment level of 0.2 microgram per liter.

Mixtures

Comparison of mixtures among the three studies is difficult because the mixtures analysis for the aquifer studies (tables 6 and 7) was done using the 0.02-µg/L assessment level and the mixtures analysis for shallow ground water in agricultural and urban (tables 14 and 15) areas was done using the 0.2-µg/L assessment level. Therefore, the analysis of the two-THM mixtures for aquifer studies was re-done at the 0.2-µg/L assessment level (table 26) for the comparison of the three studies.

For all three studies, the most common two-THM mixture was chloroform–bromodichloromethane, and this was the only two-THM mixture found in the samples from shallow ground water in agricultural areas. For this mixture, the detection frequency in samples from shallow ground water in urban areas (1.7 percent) is higher than that for samples from aquifer studies (1.0 percent) and shallow ground water in agricultural areas (0.1 percent). For the other five two-THM mixtures, the detection frequencies in samples from aquifer studies are higher than for samples from shallow ground water in urban areas, but none of the mixtures were found in more than 1.0 percent of the samples from either study (table 26).

Samples from Drinking-Water Supply Wells

There are 2,400 samples from domestic wells and 1,096 samples from public wells in data sets used to characterize the occurrence of THMs in drinking-water supply wells of the United States (table 27). Samples were collected from domestic wells and public wells throughout the Nation, but the domestic wells (fig. 14) are not as evenly distributed as the public wells (fig. 17).

Comparison of the two data sets provides some insights on the occurrence of THMs in two different supplies of ground water used for drinking water. Domestic wells tend to be used in rural areas where public water supplies are not available and in areas where ground water does not need extensive treatment before use. Public wells are more likely located in more populated areas than domestic wells and tend to have larger capacities and generally are deeper than domestic wells.

Locations of Detections

Samples in the domestic well data set were collected in 46 States (fig. 14). The minimum number of samples collected in any of the 46 States was one (Hawaii). The maximum number of samples collected in any of the 46 States was 365 (Idaho). The median number of samples collected from domestic wells in the 46 States was 32. One or more THMs were detected in 34 of the 46 States (table 27).

Samples in the public wells data set were collected in 50 States (fig. 17). The minimum number of samples collected in any of the 50 States was two (Kentucky, North Dakota, Rhode Island, and West Virginia). The maximum number of samples collected in any of the 50 States was 115 (California). The median number of samples collected in the 50 States was 16. One or more THMs were detected in 37 of the 50 States (table 27).

Detection Frequencies

At the 0.2-µg/L assessment level, one or more THMs were detected in 5.2 percent of the domestic well samples and in 14.7 percent of the public well samples. For each of the individual trihalomethanes, the detection frequencies for the domestic well samples also were less than the detection frequencies for the public well samples (table 27). For chloroform, the detection frequency for samples from domestic wells was about one-half that for samples from public wells. For the other THMs, the detection frequencies for samples from domestic wells were even lower, relative to the detection frequencies for samples from public wells.

Concentrations

The distribution of concentrations of total THMs for drinking-water supply wells is shown in figure 21. Most of the samples did not have any detected THMs, and most detections were at small concentrations. THMs occurred less frequently and generally at smaller concentrations in domestic well samples than public wells samples.

For each of the four individual THMs, the same relation was observed, with lower detection frequencies and smaller concentrations in domestic well samples than in public well samples. The difference between domestic and public well samples was most pronounced for chloroform but also was observed for the other three THMs.

Mixtures

Comparison of THM mixtures for samples from domestic and public wells is difficult because the mixtures analysis for samples from domestic wells was done using the 0.02-µg/L assessment level (tables 19 and 20) and the mixtures analysis for samples from public wells was done using the 0.2-µg/L assessment level (tables 24 and 25). Therefore, the analysis of the two-THM mixtures for samples from domestic wells was re-done using the 0.2-µg/L assessment level (table 27) for comparison of the two studies.

For domestic wells, individual two-THM mixtures occurred in 0.3 to 0.5 percent of the samples. For public wells, individual two-THM mixtures occurred in 1.7 to 3.4 percent of the samples. The detection frequencies for all six of the two-THM mixtures were less for domestic well samples than for public well samples, and individual two-THM mixtures occurred at about one-sixth the frequency in domestic well samples as they did in public well samples. For both domestic and public well samples, one of the most common two-THM mixtures was bromodichloromethane–dibromochloromethane. Both this mixture and chloroform–bromodichloromethane occurred in 0.5 percent of the domestic well samples. The bromodichloromethane–dibromochloromethane mixture occurred in 3.4 percent of the public well samples (table 27).

Table 27. Comparison of trihalomethane occurrence in samples from drinking-water supply wells at an assessment level of 0.2 microgram per liter, 1986–2001.

[THM, trihalomethane; µg/L, microgram per liter]

Occurrence information	Study	
	Domestic wells	Public wells
Samples		
Total	2,400	1,096
Minimum number of samples in a State in which samples were collected	1 (Hawaii)	2 (Kentucky, North Dakota, Rhode Island, and West Virginia)
Median number of samples per State in which samples were collected	32	16
Maximum number of samples in a State in which samples were collected	365 (Idaho)	115 (California)
Location of detections		
Number of States in which samples were collected	46	50
Number of States in which one or more THMs were detected	34	37
Detection frequency for all samples		
Frequency of one or more THMs, in percent	5.2	14.7
Frequency of individual THMs, in percent	Chloroform, 5.2 Bromodichloromethane, 0.6 Dibromochloromethane, 0.5 Bromoform, 0.3	Chloroform, 11.4 Bromodichloromethane, 4.2 Dibromochloromethane, 4.4 Bromoform, 4.5
Concentrations		
Total THM concentrations less than 1 µg/L, in percent	98.1	94.7
Total THM concentrations from 1 to 10 µg/L, in percent	1.7	4.5
Total THM concentrations greater than 10 µg/L, in percent	0.2	0.8
Median concentration in samples with detections for individual THMs, in µg/L	Chloroform, 0.5 Bromodichloromethane, 0.6 Dibromochloromethane, 0.6 Bromoform, 0.8	Chloroform, 0.6 Bromodichloromethane, 0.4 Dibromochloromethane, 0.6 Bromoform, 0.6
Number of THMs per sample		
Zero, in percent	94.8	85.3
One, in percent	4.6	9.4
Two, in percent	0.2	2.3
Three, in percent	0.2	1.6
Four, in percent	0.2	1.5
THM mixtures		
Frequency of two-THM mixtures, in percent of samples with analytical results for both THMs	Chloroform—bromodichloromethane, 0.5 Chloroform—dibromochloromethane, 0.4 Chloroform—bromoform, 0.3 Bromodichloromethane—dibromochloromethane, 0.5 Bromodichloromethane—bromoform, 0.3 Dibromochloromethane—bromoform, 0.3	Chloroform—bromodichloromethane, 3.2 Chloroform—dibromochloromethane, 2.5 Chloroform—bromoform, 1.7 Bromodichloromethane—dibromochloromethane, 3.4 Bromodichloromethane—bromoform, 2.0 Dibromochloromethane—bromoform, 2.9

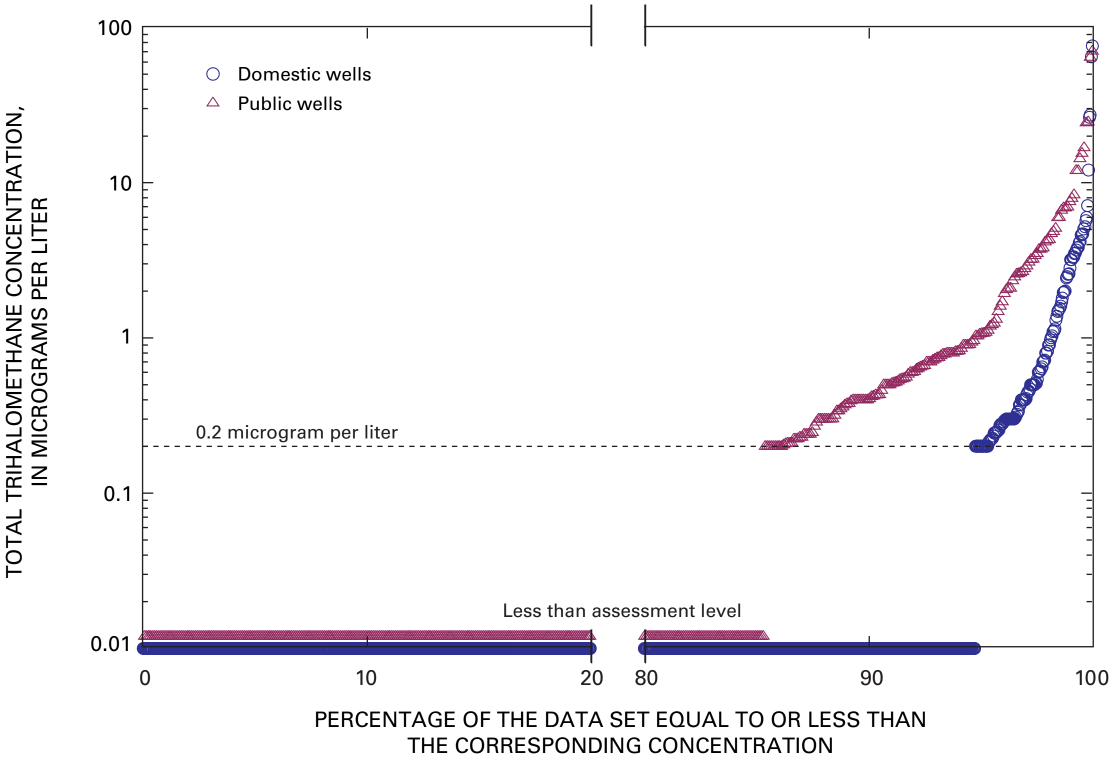


Figure 21. Comparison of total trihalomethane concentrations in samples from drinking-water supply wells at an assessment level of 0.2 microgram per liter, 1986–2001.

Summary and Conclusions

Trihalomethanes (THMs) are a group of volatile organic compounds (VOCs) with natural and anthropogenic sources. THMs are of interest because they are associated with acute and chronic health problems in humans.

Analytical results for VOCs in samples from a total of 5,642 wells were assembled to characterize the occurrence of the four THMs (chloroform, bromodichloromethane, dibromochloromethane, and bromoform) in aquifer studies, shallow ground water in agricultural areas, shallow ground water in urban areas, domestic well samples, and public well samples. The occurrence of individual THMs and total THMs was characterized in terms of locations of detections, detection frequencies, concentrations, and mixtures. In addition, occurrence comparisons were made for (1) ground water (aquifer studies and shallow ground water in agricultural and urban areas), and (2) drinking-water supply wells (domestic wells and public wells).

Two assessment levels, 0.2 and 0.02 microgram per liter (µg/L), were used in the report. The 0.2-µg/L assessment level was considered to be appropriate for all of the 5,642 samples, regardless of the data source or when the samples were collected. A 0.02-µg/L assessment level was used to characterize the occurrence of THMs in samples collected from aquifer studies and domestic wells by personnel of 1994 and 1997 Study-Units of the U.S. Geological Survey's National Water-Quality Assessment (NAWQA) Program. VOC samples collected by these Study Units were analyzed by a new low-level analytical method that facilitated reporting of results at the lower assessment level.

One or more of four THMs were detected in less than 20 percent of samples collected from (1) aquifer studies, (2) shallow ground water in agricultural areas, (3) shallow ground water in urban areas, (4) domestic wells, and (5) public wells. Detection frequencies for individual THMs in the five studies ranged from zero for shallow ground water in agricultural areas (for dibromochloromethane and bromoform) to 19.5 percent for shallow ground water in urban areas (for chloroform). None of the samples from aquifer studies, domestic wells, or public wells had total THM concentrations (the sum of the concentrations of chloroform, bromodichloromethane, dibromochloromethane, and bromoform) greater than or equal to the U.S. Environmental Protection Agency Maximum Contaminant Level (MCL) of 80 µg/L. Few samples from these data sets have total THM concentrations within an order of magnitude of the MCL. The percentages of samples from the aquifer, domestic well, and public well studies with total THM concentrations greater than or equal to one-tenth of the MCL (8 µg/L) were 0.5, 0.2, and 0.9 percent, respectively.

Detection frequency mimics the chlorine content of the THM compound. In general, for each of the studies, as the chlorine content of the THM compound decreased, the detection frequency at the 0.2-µg/L assessment level also decreased. The exception was for public well samples, in which bromoform did not have the lowest detection frequency. At the 0.2-µg/L assessment level, the fraction of well networks that did not have any THM detections was about one-third for the aquifer studies, about two-thirds for shallow ground-water studies in agricultural areas, and about one-eighth for the shallow ground-water studies in urban areas.

At the 0.2-µg/L assessment level, the median concentration for one or more of the THMs ranged from 0.3 µg/L (shallow ground water in agricultural areas) to 0.6 µg/L (shallow ground water in urban areas). For the other three studies (aquifer studies, domestic wells, public wells), the median concentration was 0.5 µg/L. At the 0.02-µg/L assessment level, the median concentration for one or more of the THMs in samples from aquifer studies and domestic wells was 0.08 µg/L. Generally, as the chlorine content of the THM compound decreased, the maximum concentration of the THM also decreased.

At both assessment levels, the most common finding was that most samples did not have any detected THMs. Furthermore, the number of samples with no THMs was much greater than the number of samples with 2, 3, or 4 THMs combined. At the 0.2-µg/L assessment level, one THM was detected in 6.7 percent of the samples from aquifer studies (mixed land use), 2.1 percent of the samples from shallow ground water in agricultural areas, and 17.7 percent of the samples from shallow ground water in urban areas. For the same studies at the same assessment level, two or more THMs were detected in 1.3, 0.1, and 1.8 percent of the samples, respectively. At the 0.2-µg/L assessment level, one THM was detected in 4.6 percent of the domestic well samples and in 9.4 percent of the public well samples. For the same studies at the same assessment level, two or more THMs were detected in 0.6 and 5.3 percent of the samples, respectively. For all five of the studies, chloroform was the most frequently detected individual THM and if only one THM was detected in a sample, the THM was most likely to be chloroform.

Analyses of mixtures were performed using the 0.2-µg/L assessment level for shallow ground water in agricultural areas, shallow ground water in urban areas, and public wells and using the 0.02-µg/L assessment level for aquifer studies and domestic wells. No VOC mixtures occurred in 1 percent or more of the samples collected from shallow ground water in agricultural areas. Comparing the results for the other studies was difficult because of the different assessment levels, but chloroform mixtures were among the most common for all four studies. Chloroform–bromodichloromethane was the most frequently detected or one of the most frequently detected two-THM mixtures at the 0.2-µg/L assessment level, and mixtures of chloroform–perchloroethene and chloroform–methyl *tert*-butyl ether were the most frequently detected or one of the most frequently detected THM and non-THM mixtures. For bromodichloromethane, dibromochloromethane, and bromoform, the most common mixtures were with other THMs. In samples collected from shallow ground water in urban areas and in samples collected from domestic wells, these three THMs were detected only when one or more of the other THMs were detected.

Comparison of the occurrence findings for ground water (aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas) was used to help further characterize the occurrence patterns for three different land-use settings—mixed, agricultural, and urban. At the 0.2-µg/L assessment level, one or more THMs were detected in 7.9 percent of the samples from aquifer studies (mixed land use), 2.2 percent of the samples from shallow ground water in agricultural areas, and 19.5 percent of the samples from shallow ground water in urban areas. In general, detection frequencies and concentrations of THMs ranged from larger to smaller in shallow ground water in urban areas to aquifer studies to shallow ground water in agricultural areas. For all three ground-water studies, the most common two-THM mixture at the 0.2-µg/L assessment level was chloroform–bromodichloromethane, and this was the only two-THM mixture found in the samples of shallow ground water in agricultural areas.

Comparison of results from samples from drinking-water supply wells (domestic wells and public wells) was used to help characterize the occurrence of THMs in two different supplies of ground water used for drinking water. At the 0.2-µg/L assessment level, one or more THMs were detected in 5.2 percent of the domestic well samples and in 14.7 percent of the public well samples. In general, detection frequencies and THM concentrations were larger in public well samples than in domestic well samples. At the 0.2-µg/L assessment level, the six two-THM mixtures analyzed occurred about six times more frequently in public well samples than in domestic well samples. One of the most common two-THM mixtures in domestic and public well samples was bromodichloromethane–dibromochloromethane.

Selected References

Bender, D.A., Zogorski, J.S., Halde, M.J., and Rowe, B.L., 1999, Selection procedure and salient information for volatile organic compounds emphasized in the National Water-Quality Assessment Program: U.S. Geological Survey Open-File Report 99–182, 32 p.

Connor, B.F., Rose, D.L., Noriega, M.C., Murtagh, L.K., and Abney, S.R., 1998, Methods of analysis by the U.S. Geological Survey National Water Quality Laboratory—Determination of 86 volatile organic compounds in water by gas chromatography/mass spectrometry, including detections less than reporting limits: U.S. Geological Survey Open-File Report 97–829, 78 p.

Grady, S.J., 2003, A national survey of methyl *tert*-butyl ether and other volatile organic compounds in drinking-water sources—Results of the random survey: U.S. Geological Survey Water-Resources Investigations Report 02–4079, 85 p.

Grady, S.J., and Casey, G.D., 2001, Occurrence and distribution of methyl *tert*-butyl ether and other volatile organic compounds in drinking water in the Northeast and Mid-Atlantic regions of the United States, 1993–98: U.S. Geological Survey Water-Resources Investigations Report 00–4228, 123 p.

Gribble, G.W., 1994, The natural production of chlorinated compounds: Environmental Science & Technology, v. 28, no. 7, p. 310A–319A.

Ivahnenko, Tamara, and Barbash, J.E., 2004, Chloroform in the hydrologic system—sources, transport, fate, occurrence, and effects on human health and aquatic organisms: U.S. Geological Survey Scientific Investigations Report 2004–5137, 34 p.

Lapham, W.W., Moran, M.J., and Zogorski, J.S., 2000, Enhancements of nonpoint source monitoring of volatile organic compounds in ground water: Journal of the American Water Resources Association, v. 36, no. 6, p. 1321–1334.

Lapham, W.W., Neitzert, K.M., Moran, M.J., and Zogorski, J.S., 1997, USGS compiles data set for national assessment of VOCs in ground water: Ground Water Monitoring and Remediation, v. 17, no. 4, p. 147–157.

Lapham, W.W., and Tadayon, Saeid, 1996, Plan for assessment of the occurrence, status, and distribution of volatile organic compounds in aquifer of the United States: U.S. Geological Survey Open-File Report 96–199, 44 p.

McCarty, P.L., Reinhard, M., and Rittman, B.E., 1981, Trace organics in groundwater: Environmental Science & Technology, v. 15, no. 1, p. 40–51.

Moran, M.J., Lapham, W.W., Rowe, B.L., and Zogorski, J.S., 2002, Occurrence and status of volatile organic compounds in ground water from rural, untreated, self-supplied domestic wells in the United States, 1986–99: U.S. Geological Survey Water-Resources Investigations Report 02–4085, 51 p.

Moran, M.J., Zogorski, J.S., and Rowe, B.L., 2006, Approach to an assessment of volatile organic compounds in the Nation’s ground water and drinking-water supply wells: U.S. Geological Survey Open-File Report 2005–1452, 36 p.

Rook, J.J., 1975, Formation and occurrence of haloforms in drinking water: Proceedings of the 95th Annual American Water Works Association Conference, June 1975, Paper 32–4.

Squillace, P.J., Moran, M.J., Lapham, W.W., Price, C.V., Clawges, R.M., and Zogorski, J.S., 1999, Volatile organic compounds in untreated ambient groundwater of the United States, 1985–1995: Environmental Science & Technology, v. 33, no. 23, p. 4176–4187.

Squillace, P.J., Pankow, J.F., Barbash, J.E., Price, C.V., and Zogorski, J.S., 1999, Preserving ground water samples with hydrochloric acid does not result in the formation of chloroform: Ground Water Monitoring and Review, Winter, p. 67–74.

Squillace, P.J., Scott, J.C., Moran, M.J., Nolan, B.T., and Kolpin, D.W., 2002, VOCs, pesticides, nitrate, and their mixtures in ground water used for drinking water in the United States: Environmental Science & Technology, v. 36, no. 9, p. 1923–1930.

U.S. Environmental Protection Agency, 1988, Draft guide to drinking water health advisories: Washington, D.C., U.S. Environmental Protection Agency, Office of Drinking Water, Criteria and Standards Division, Health Effects Branch, August 25, 1988 [variously paged].

U.S. Environmental Protection Agency, 1993, Health advisories for drinking water contaminants: Boca Raton, Fla., Lewis Publishers, 260 p.

U.S. Environmental Protection Agency, 2000, Federal Register Document 40 CFR, Part 141: U.S. Environmental Protection Agency, v. 65, no. 104, p. 34404–34405.

U.S. Environmental Protection Agency, 2004, 2004 Edition of the drinking water standards and health advisories: U.S. Environmental Protection Agency, Office of Water, EPA 822–R–04–005, 12 p.

Weinberg, H.S., Krasner, S.W., Richardson, S.D., and Thruston, A.D., Jr., 2002, The occurrence of disinfection by-products (DBPs) of health concern in drinking water–results of a nationwide DBP occurrence study: National Exposure Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Athens, Ga., EPA/600/R–02/068 (September 2002).

Zogorski, J.S., Carter, J.M., Ivahnenko, Tamara, Lapham, W.W., Moran, M.J., Rowe, B.L, Squillace, P.J., and Toccalino, P.L., 2006, The quality of our Nation’s waters—volatile organic compounds in the Nation’s ground water and drinking-water supply wells: U.S. Geological Survey Circular 1292, 101 p.

Supplemental Information

Section A. Data Sets

Section A provides information about the samples used in this report to describe the occurrence of trihalomethanes in the Nation's ground water and drinking-water supply wells. This is in addition to the general information provided in the Approach section of the report. The following sections provide additional details regarding the three sources of information (NAWQA, AWWARF, and RETRO) and the data sets compiled for aquifer studies, shallow ground water in agricultural areas, shallow ground water in urban areas, domestic wells, and public wells.

Sources of VOC Occurrence Information

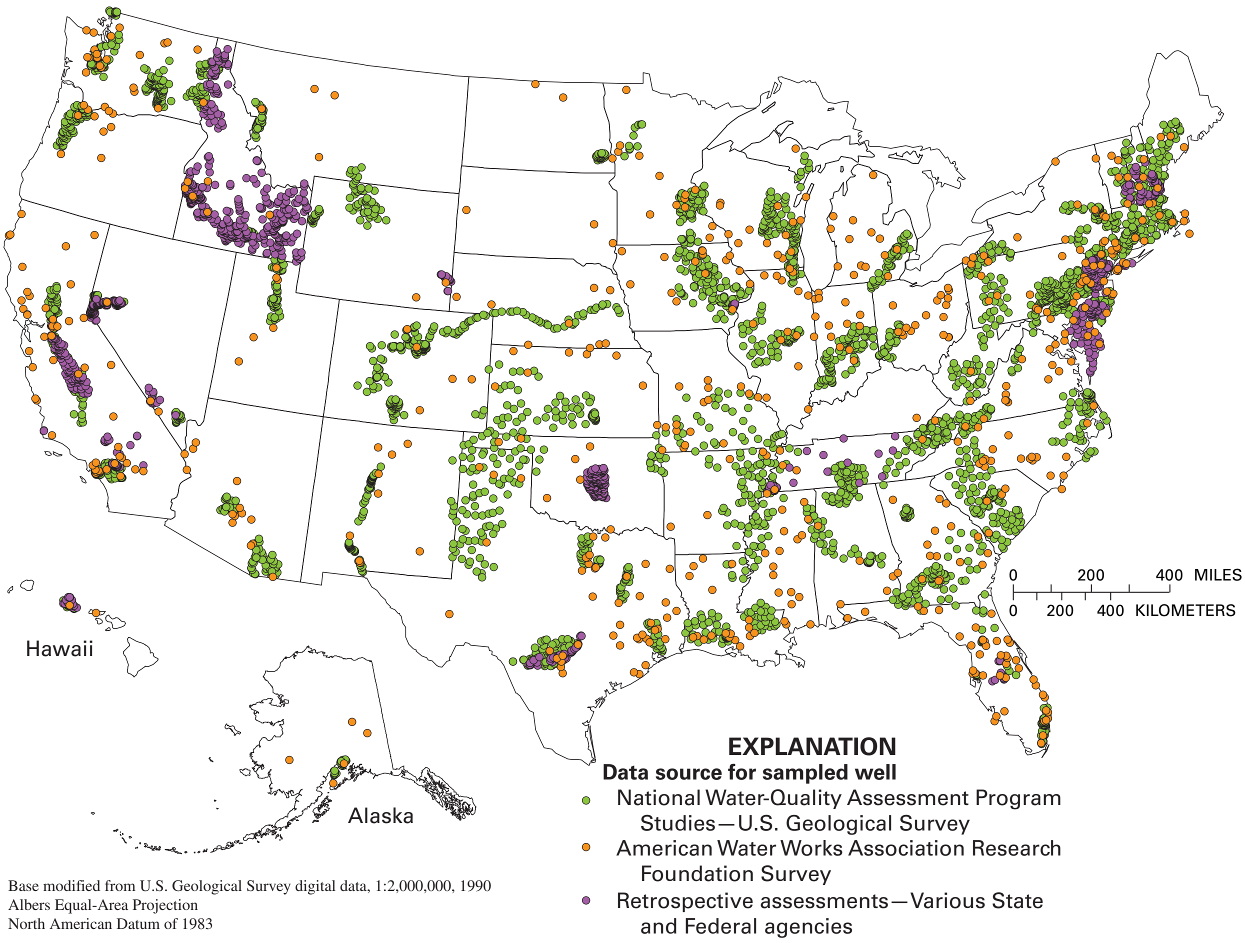
Most of the water-quality information for this report came from samples collected nationwide by the USGS NAWQA Program (fig. A1). Some additional water-quality data were compiled by NAWQA staff from an AWWARF survey and from a variety of other monitoring programs collectively termed RETRO (retrospective) data (fig. A1). Each of the sources of the VOC data are described in the following paragraphs.

NAWQA Program Studies

NAWQA samples for VOCs are identified by the year that the Study Unit responsible for their collection was started. The numbers of Study Units started in the years 1991, 1994, and 1997, were 20, 16, and 14, respectively. A total of 3,882 samples were collected by the NAWQA Study Units—1,550 samples by the 1991 Study Units, 1,314 samples by the 1994 Study Units, and 1,018 samples by the 1997 Study Units.

1991 NAWQA Study Units

Of the 1,550 samples collected by the 1991 NAWQA Study Units, 762 samples were included in more than one of the five data sets. Of these 762 samples, 496 were included in the aquifer studies data set, 94 were included in the data set for shallow ground water in agricultural areas, 331 were included in the data set for shallow ground water in urban areas, 676 were included in the data set for domestic wells, and 86 were included in the data set for public wells. Of the remaining 788 samples, 130 were included only in the data set for



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure A1. Location of samples from three data sources.

aquifer studies, 381 were included only in the data set for shallow ground water in agricultural areas, and 277 were included only in the data set for shallow ground water in urban areas.

1994 NAWQA Study Units

Of the 1,314 samples collected by the 1994 NAWQA Study Units, 763 samples were included in more than one data set. Of these 763 samples, 758 were included in the data set for aquifer studies, 4 were included in the data set for shallow ground water in agricultural areas, 1 was included in the data set for shallow ground water in urban areas, 642 were included in the data set for domestic wells, and 121 were included in the data set for public wells. Of the remaining 551 samples, 126 were included only in the data set for aquifer studies, 94 were included only in the data set for shallow ground water in agricultural areas, and 331 were included only in the data set for shallow ground water in urban areas.

1997 NAWQA Study Units

Of the 1,018 samples collected by the 1997 Study Units, 687 samples were included in more than one data set. All 687 of these samples were included in the data set for aquifer studies, 565 of these samples were included in the data set for domestic wells, and 122 of these samples were included in the data set for public wells. Of the remaining 331 samples, 115 were included only in the data set for aquifer studies, and 216 were included only in the data set for shallow ground water in urban areas.

AWWARF Survey

AWWARF samples were collected from May 1999 through October 2000 (Grady, 2003). Only a 0.2-μg/L assessment level was used for these data because detections less than this concentration were not reviewed for field-quality assurance. The 575 AWWARF samples were a part of the public wells data set.

RETRO Samples

RETRO samples were collected from 1985 through 1995 by various State and Federal agencies (Lapham and Tadayon, 1996; Lapham and others, 1997). The 0.2-μg/L assessment level was used for these data. All 1,185 of the RETRO samples were included in the data set for aquifer studies, 192 RETRO samples were included in the data set for public wells, and 517 RETRO samples were included in the data set for domestic wells.

Data Sets

Selected samples from the three sources were used to form data sets for different areas of interest including (1) ground water (aquifer studies, shallow ground water in agricultural areas, shallow ground water in urban areas) and (2) drinking-water supply wells (domestic wells and public wells). At the 0.2-μg/L assessment level, the data sets were composed of samples from one or more sources. At the 0.02-μg/L assessment level, the data sets were composed of selected NAWQA samples only.

Aquifer Studies

The aquifer studies data set consisted of 3,497 samples (2,312 NAWQA samples and 1,185 RETRO samples). For this data set, the 1991 NAWQA Study Units collected 626 samples during 1993–1997, the 1994 NAWQA Study Units collected 884 samples during 1996–1999, and the 1997 NAWQA Study Units collected 802 samples during 1998–2001.

Shallow Ground Water in Agricultural Areas

The data set for shallow ground water in agricultural areas consisted of 723 samples. The 1991 NAWQA Study Units collected 625 samples during 1988–1995 for this data set, and the 1994 NAWQA Study Units collected 98 samples during 1996–1998 for this data set. The 1997 NAWQA Study Units did not collect any samples for this data set. None of the AWWARF or RETRO samples were included in this data set.

Shallow Ground Water in Urban Areas

The data set for shallow ground water in urban areas consisted of 847 samples. For this data set, the 1991 NAWQA Study Units collected 299 samples during 1993–1997, the 1994 NAWQA Study Units collected 332 samples during 1996–1998, and the 1997 NAWQA Study Units collected 216 samples during 1999–2002. None of the AWWARF or RETRO samples were included in this data set.

Domestic Wells

The data set for domestic wells consisted of 2,400 samples (1,883 NAWQA samples and 517 RETRO samples). The NAWQA samples consisted of 247 agricultural samples, 1,620 samples from aquifer studies, and 16 urban samples. For this data set, the 1991 NAWQA Study Units collected 676 samples during 1993–1997, the 1994 NAWQA Study Units collected 642 samples during 1996–1999, and the 1997 NAWQA Study Units collected 565 samples during 1998–2001.

Public Wells

The data set for public wells consisted of 1,096 samples (329 NAWQA samples, 575 AWWARF samples, and 192 RETRO samples). NAWQA samples consisted of 1 agricultural sample, 321 aquifer studies samples, and 7 urban samples. The 1991 NAWQA Study Units collected 86 samples during 1993–1995, the 1994 NAWQA Study Units collected 121 samples during 1996–1999, and the 1997 NAWQA Study Units collected 122 samples during 1998–2001.

Section B. Detection Frequencies of Trihalomethanes by Network

This report is not intended to characterize the occurrence of THMs in ground water on a State-by-State basis, but it is recognized that many readers may be interested in comparing local ground-water samples to national characteristics for the studies of aquifers, shallow ground water in agricultural areas, and shallow ground water in urban areas.

The NAWQA information was collected by the individual NAWQA Study Units, which are identified by a four-letter code (fig. 1 and Study Unit Abbreviations following Contents), and the Study Units collected the samples for the studies of aquifers, shallow ground water in agricultural areas, and shallow ground water in urban areas from groups of wells known as networks. For the purposes of this report, a network is defined as a group of wells of a specific type (aquifer studies, shallow ground water in agricultural areas, or shallow ground water in urban areas) within a limited geographical area from which samples were collected within a limited time period. These networks typically included about 30 wells, but the number varied from as few as 10 to as many as 74, as shown in table B1. All of NAWQA Study Units have published reports describing the ground-water aspects of their study areas. Information about NAWQA Study Units and publications can be obtained at the NAWQA Web site (http://water.usgs.gov/nawqa/).

This section provides information about the networks within the Study Units. Information includes the type of network (aquifer studies, shallow ground water in agricultural areas, shallow ground water in urban areas) and the number of analytical results and detection frequency for each THM. The AWWARF and RETRO samples did not come from NAWQA Study Units or networks. For the purposes of table B1, all of the 575 AWWARF samples were considered as one study area and in the AWWARF network of the type “public.” The 1,185 RETRO samples were considered to be in 14 Study Units with networks of the same name and all were of the type “aquifer studies.” The startup year for the 50 NAWQA Study Units was specified along with the network type (“aquifer studies,” “agricultural,” or “urban”) for the 147 different networks.

Table B1. Detection frequency of trihalomethanes in samples from well networks in aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas at an assessment level of 0.2 microgram per liter.

[NAWQA, National Water-Quality Assessment; AWWARF, American Water Works Association Research Foundation; PUB, public; UR, shallow ground water in urban areas; AS, aquifer studies; AG, shallow ground water in agricultural areas. Shaded cells indicate detection frequency is 10 percent or greater. Information about NAWQA Study Units can be obtained at the NAWQA Web site (http://water.usgs.gov/nawqa/)]

NAWQA Study Unit code or other identifier	Source of data (year)[1]	Network	Network type	Chloroform		Bromodichloro-methane		Dibromochloro-methane		Bromoform	
				Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)
AWWARF	AWWARF	AWWARF	PUB	571	11.6	574	5.7	574	5.9	575	4.5
ACAD	NAWQA (1997)	acadlusrc1	UR	28	3.6	28	.0	28	.0	28	.0
ACAD	NAWQA (1997)	acadsus1	AS	29	3.4	29	.0	29	.0	29	.0
ACAD	NAWQA (1997)	acadsus2	AS	28	25.0	28	.0	28	.0	28	.0
ACFB	NAWQA (1991)	acfblusur1	UR	21	28.6	21	.0	21	.0	21	.0
ACFB	NAWQA (1991)	acfbsus1	AS	26	.0	26	.0	26	.0	26	.0
ALBE	NAWQA (1991)	albelusag1	AG	14	.0	14	.0	14	.0	14	.0
ALBE	NAWQA (1991)	albelusur1	UR	15	.0	15	.0	15	.0	15	.0
ALBE	NAWQA (1991)	albesus1	AS	10	.0	11	.0	11	.0	11	.0
ALBE	NAWQA (1991)	albesus2	AS	14	.0	15	.0	15	.0	15	.0
ALMN	NAWQA (1994)	almnsus1	AS	30	10.0	30	.0	30	.0	30	.0
ALMN	NAWQA (1994)	almnsus2	AS	30	3.3	30	.0	30	.0	30	.0
CARSON	RETRO	CARSON	AS	148	3.4	148	.7	148	.7	148	.7
CAZB	NAWQA (1994)	cazbsus1a	AS	30	6.7	30	3.3	30	.0	30	.0
CAZB	NAWQA (1994)	cazbsus2	AS	27	11.1	27	.0	27	.0	26	.0
CAZB	NAWQA (1994)	cazbsus3	AS	18	.0	18	.0	18	.0	18	.0
CCPT	NAWQA (1991)	ccptlusag1a	AG	19	5.3	19	.0	19	.0	19	.0
CCPT	NAWQA (1991)	ccptlusag2a	AG	30	.0	30	.0	30	.0	30	.0
CCPT	NAWQA (1991)	ccptlusag2b	AG	19	5.3	19	.0	19	.0	19	.0
CCPT	NAWQA (1991)	ccptlusor1	AG	40	2.5	40	.0	40	.0	40	.0
CCPT	NAWQA (1991)	ccptsus1	AS	32	3.1	32	.0	32	.0	32	.0
CNBR	NAWQA (1991)	cnbrsus2	AS	27	3.7	27	.0	27	.0	27	.0
CONN	NAWQA (1991)	connlusag1	AG	24	8.3	24	.0	24	.0	24	.0
CONN	NAWQA (1991)	connlusur1	UR	39	28.2	39	.0	39	.0	39	.0
CONN	NAWQA (1991)	connsus1	AS	30	13.3	30	.0	30	.0	30	.0
COOK	NAWQA (1997)	cooksus1a	AS	28	.0	28	.0	28	.0	28	.0
DELM	RETRO	DELMARVA	AS	34	8.8	34	.0	34	.0	34	.0
DELR	NAWQA (1997)	delrsus1	AS	30	20.0	30	.0	30	.0	30	3.3
DELR	NAWQA (1997)	delrsus2	AS	30	.0	30	.0	30	.0	30	.0
DELR	NAWQA (1997)	delrsus3	AS	16	.0	16	.0	16	.0	16	.0
EIWA	RETRO	EIWA03	AS	16	.0	16	.0	16	.0	16	.0
EIWA	NAWQA (1994)	eiwaluscr1	AG	31	.0	31	.0	31	.0	31	.0
EIWA	NAWQA (1994)	eiwalusrc1	UR	30	6.7	30	3.3	30	.0	30	.0

Table B1. Detection frequency of trihalomethanes in samples from well networks in aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas at an assessment level of 0.2 microgram per liter.—Continued

[NAWQA, National Water-Quality Assessment; AWWARF, American Water Works Association Research Foundation; PUB, public; UR, shallow ground water in urban areas; AS, aquifer studies; AG, shallow ground water in agricultural areas. Shaded cells indicate detection frequency is 10 percent or greater. Information about NAWQA Study Units can be obtained at the NAWQA Web site (http://water.usgs.gov/nawqa/)]

NAWQA Study Unit code or other identifier	Source of data (year)[1]	Network	Network type	Chloroform		Bromodichloro-methane		Dibromochloro-methane		Bromoform	
				Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)
EIWA	NAWQA (1994)	eiwasus1	AS	33	0.0	33	0.0	33	0.0	33	0.0
EIWA	NAWQA (1994)	eiwasus2	AS	32	3.1	32	3.1	32	3.1	32	3.1
GAFL	NAWQA (1991)	gaflluscr1	AG	23	.0	23	.0	23	.0	23	.0
GAFL	NAWQA (1991)	gafllusur3a	UR	16	25.0	16	.0	16	.0	16	.0
GAFL	NAWQA (1991)	gaflsus1	AS	36	5.6	36	.0	36	.0	36	.0
GRSL	NAWQA (1997)	grsllusrc1	UR	30	56.7	30	16.7	30	.0	30	.0
GRSL	NAWQA (1997)	grslsus1	AS	52	5.8	52	1.9	52	1.9	52	1.9
HDSN	NAWQA (1991)	hdsnlusur1	UR	21	23.8	21	.0	21	.0	21	.0
HDSN	NAWQA (1991)	hdsnsus1	AS	35	5.7	35	.0	35	.0	35	.0
HPGW	NAWQA (1997)	hpgwlusur1	UR	30	10.0	30	.0	30	.0	30	.0
HPGW	NAWQA (1997)	hpgwsus1a	AS	74	.0	74	.0	74	.0	74	.0
HPGW	NAWQA (1997)	hpgwsus1b	AS	47	2.1	47	.0	47	.0	47	.0
HPGW	NAWQA (1997)	hpgwsus2	AS	20	5.0	20	.0	20	.0	20	.0
ID01	RETRO	ID01	AS	385	1.0	385	.0	385	.0	385	.0
KANA	NAWQA (1994)	kanasus1	AS	30	3.3	30	.0	30	.0	30	3.3
KANA	NAWQA (1994)	kanasus2	AS	30	3.3	30	.0	30	.0	30	.0
LERI	NAWQA (1994)	lerilusrc1	UR	30	3.3	30	.0	30	.0	30	.0
LERI	NAWQA (1994)	lerisus1	AS	28	3.6	28	.0	28	.0	28	.0
LINJ	RETRO	LINJ01	AS	130	36.2	130	.8	130	1.5	130	.8
LINJ	NAWQA (1994)	linjluscr1	AG	15	20.0	15	.0	15	.0	15	.0
LINJ	NAWQA (1994)	linjlusrc1	UR	30	36.7	30	.0	30	.0	30	.0
LINJ	NAWQA (1994)	linjlusur1	UR	20	20.0	20	.0	20	.0	20	.0
LINJ	NAWQA (1994)	linjsus1	AS	30	33.3	30	3.3	30	.0	30	.0
LINJ	NAWQA (1994)	linjsus2	AS	30	50.0	30	.0	30	.0	30	.0
LINJ	NAWQA (1994)	linjsus3	AS	20	5.0	20	.0	20	.0	20	.0
LIRB	NAWQA (1994)	lirbsus1	AS	30	.0	30	.0	30	.0	30	.0
LIRB	NAWQA (1994)	lirbsus2	AS	29	6.9	29	.0	29	.0	29	.0
LSUS	NAWQA (1991)	lsuslusag1	AG	30	.0	30	.0	30	.0	30	.0
LSUS	NAWQA (1991)	lsuslusag3	AG	20	.0	20	.0	20	.0	20	.0
LSUS	NAWQA (1991)	lsuslusur1	UR	20	55.0	20	15.0	20	5.0	20	.0
LSUS	NAWQA (1991)	lsussus1	AS	29	.0	29	.0	29	.0	29	.0
LSUS	NAWQA (1991)	lsussus2	AS	10	.0	10	.0	10	.0	10	.0
LTEN	NAWQA (1997)	ltensus1	AS	32	15.6	32	.0	32	.0	32	.0

Table B1. Detection frequency of trihalomethanes in samples from well networks in aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas at an assessment level of 0.2 microgram per liter.—Continued

[NAWQA, National Water-Quality Assessment; AWWARF, American Water Works Association Research Foundation; PUB, public; UR, shallow ground water in urban areas; AS, aquifer studies; AG, shallow ground water in agricultural areas. Shaded cells indicate detection frequency is 10 percent or greater. Information about NAWQA Study Units can be obtained at the NAWQA Web site (http://water.usgs.gov/nawqa/)]

NAWQA Study Unit code or other identifier	Source of data (year)[1]	Network	Network type	Chloroform		Bromodichloro-methane		Dibromochloro-methane		Bromoform	
				Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)
LTEN	NAWQA (1997)	ltensus2	AS	31	9.7	31	0.0	31	0.0	31	0.0
MIAM	NAWQA (1997)	miamlusrc1	UR	25	8.0	25	4.0	25	4.0	25	.0
MIAM	NAWQA (1997)	miamsus1	AS	30	13.3	30	6.7	30	6.7	30	3.3
MISE	RETRO	MISE07	AS	30	3.3	30	.0	30	.0	30	.0
MISE	NAWQA (1994)	miselusrc1	UR	31	3.2	31	.0	31	.0	31	.0
MISE	NAWQA (1994)	misesus1	AS	29	.0	29	.0	29	.0	29	.0
MISE	NAWQA (1994)	misesus2	AS	30	3.3	30	.0	30	.0	30	.0
MISE	NAWQA (1994)	misesus3	AS	25	.0	25	.0	25	.0	25	.0
MOBL	NAWQA (1997)	mobllusrc1	UR	30	23.3	30	.0	30	.0	30	.0
MOBL	NAWQA (1997)	moblsus1	AS	30	.0	30	.0	30	.0	30	.0
NECB	NAWQA (1997)	necblusrc1	UR	28	14.3	28	.0	28	.0	28	.0
NECB	NAWQA (1997)	necbsus1	AS	28	7.1	28	.0	28	.0	28	.0
NECB	NAWQA (1997)	necbsus2	AS	30	3.3	30	.0	30	.0	30	.0
NECB	NAWQA (1997)	necbsus3	AS	30	16.7	30	3.3	30	.0	30	.0
NNEB05	RETRO	NNEB05	AS	69	8.7	69	.0	69	.0	69	.0
NROK	NAWQA (1997)	nroksus1	AS	31	.0	31	.0	31	.0	31	.0
NROK	NAWQA (1997)	nroksus2	AS	30	6.7	30	.0	30	.0	30	.0
NVBR	NAWQA (1991)	nvbrlusag1	AG	20	.0	20	.0	20	.0	20	.0
NVBR	NAWQA (1991)	nvbrlusag2	AG	10	.0	10	.0	10	.0	10	.0
NVBR	NAWQA (1991)	nvbrlusur1	UR	33	69.7	33	6.1	33	3.0	33	.0
NVBR	NAWQA (1991)	nvbrlusur2	UR	27	22.2	27	.0	27	.0	27	.0
NVBR	NAWQA (1991)	nvbrsus1	AS	21	52.4	21	19.0	21	14.3	21	14.3
NVBR	NAWQA (1991)	nvbrsus2	AS	16	18.8	16	.0	16	.0	16	6.2
NVBR	NAWQA (1991)	nvbrsus3	AS	16	.0	16	.0	16	.0	16	.0
OAHU	RETRO	OAHU02	AS	15	.0	15	.0	15	.0	15	.0
OAHU	NAWQA (1997)	oahusus1	AS	28	.0	28	.0	28	.0	28	3.6
OKLAHOMA	RETRO	OKLAHOMA	AS	120	3.3	120	1.7	120	1.7	120	.8
OZRK	NAWQA (1991)	ozrksus2a	AS	33	12.1	33	3.0	33	3.0	33	3.0
OZRK	NAWQA (1991)	ozrksus3a	AS	16	18.8	16	.0	16	.0	16	.0
POTO	NAWQA (1991)	potolusag1	AG	17	5.9	17	.0	17	.0	17	.0
PUGT	NAWQA (1994)	pugtluscr1	AG	22	.0	22	.0	22	.0	22	.0
PUGT	NAWQA (1994)	pugtlusrs1	UR	27	3.7	27	3.7	27	.0	27	.0

Table B1. Detection frequency of trihalomethanes in samples from well networks in aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas at an assessment level of 0.2 microgram per liter.—Continued

[NAWQA, National Water-Quality Assessment; AWWARF, American Water Works Association Research Foundation; PUB, public; UR, shallow ground water in urban areas; AS, aquifer studies; AG, shallow ground water in agricultural areas. Shaded cells indicate detection frequency is 10 percent or greater. Information about NAWQA Study Units can be obtained at the NAWQA Web site (http://water.usgs.gov/nawqa/)]

NAWQA Study Unit code or other identifier	Source of data (year)[1]	Network	Network type	Chloroform		Bromodichloro-methane		Dibromochloro-methane		Bromoform	
				Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)
PUGT	NAWQA (1994)	pugtsus1	AS	30	0.0	30	0.0	30	0.0	30	0.0
REDN	NAWQA (1991)	rednlusag2	AG	28	.0	28	.0	28	.0	28	.0
REDN	NAWQA (1991)	rednsus2	AS	10	.0	10	.0	10	.0	10	.0
RIOG	NAWQA (1991)	rioglusag1	AG	20	.0	20	.0	20	.0	20	.0
RIOG	NAWQA (1991)	riogluscr1	AG	35	.0	35	.0	35	.0	35	.0
RIOG	NAWQA (1991)	rioglusur1	UR	24	.0	24	.0	24	.0	24	.0
RIOG	NAWQA (1991)	riogsus1	AS	28	.0	28	.0	28	.0	28	.0
SACR	RETRO	SACR04	AS	142	16.2	142	1.4	142	1.4	142	2.1
SACR	NAWQA (1994)	sacrlusrc1	UR	19	21.1	19	.0	19	.0	19	.0
SACR	NAWQA (1994)	sacrsus1	AS	30	6.7	30	.0	30	.0	30	.0
SANA	NAWQA (1997)	sanalusrc1	UR	26	11.5	26	3.8	26	.0	26	.0
SANA	NAWQA (1997)	sanasus1	AS	27	22.2	27	3.7	27	3.7	27	7.4
SANA	NAWQA (1997)	sanasus2	AS	20	15.0	20	.0	20	.0	20	.0
SANA	NAWQA (1997)	sanasus3	AS	22	9.1	22	.0	22	.0	22	9.1
SANJ	NAWQA (1991)	sanjluscr1a	AG	20	5.0	20	.0	20	.0	20	.0
SANJ	NAWQA (1991)	sanjsus1	AS	28	3.6	28	.0	28	.0	28	.0
SANT	NAWQA (1994)	santlusrc1	UR	30	33.3	30	.0	30	.0	30	.0
SANT	NAWQA (1994)	santsus1	AS	27	7.4	27	3.7	27	.0	27	.0
SANT	NAWQA (1994)	santsus2	AS	30	.0	30	.0	30	.0	30	.0
SANT	NAWQA (1994)	santsus3	AS	30	3.3	30	.0	30	.0	30	.0
SCTX	RETRO	SCTX01	AS	52	5.8	52	7.7	52	9.6	52	19.2
SCTX	NAWQA (1994)	sctxlusrc1	UR	30	16.7	30	.0	30	.0	30	3.3
SCTX	NAWQA (1994)	sctxsus1	AS	28	10.7	28	.0	28	.0	28	.0
SCTX	NAWQA (1994)	sctxsus2	AS	31	.0	31	.0	31	.0	31	.0
SCTX	NAWQA (1994)	sctxsus3	AS	29	3.4	29	3.4	29	6.9	29	10.3
SOFL	RETRO	SOFL03	AS	13	69.2	13	61.5	13	30.8	13	.0
SOFL	NAWQA (1994)	sofllusrc1a	UR	30	.0	30	.0	30	.0	30	.0
SOFL	NAWQA (1994)	soflsus1	AS	29	13.8	29	3.4	29	6.9	29	6.9
SPLT	NAWQA (1991)	spltluscr1	AG	30	.0	30	.0	30	.0	30	.0
SPLT	NAWQA (1991)	spltlusur1	UR	29	13.8	29	.0	29	.0	29	.0
SPLT	NAWQA (1991)	spltsus1	AS	26	7.7	26	7.7	26	7.7	26	.0
TRIN	NAWQA (1991)	trinlusur1	UR	18	5.6	18	.0	18	.0	18	.0
TRIN	NAWQA (1991)	trinsus1	AS	24	.0	24	.0	24	.0	24	.0

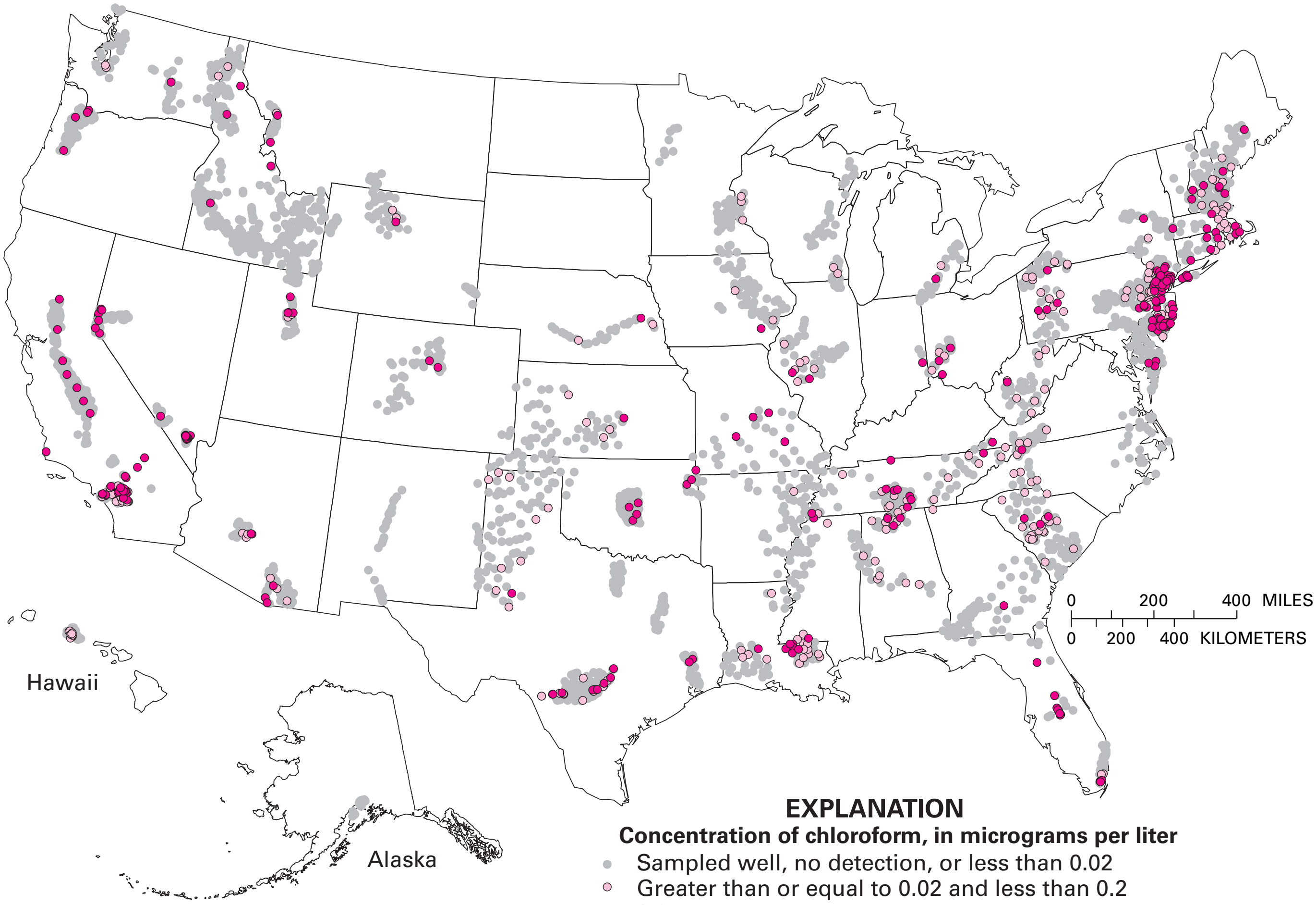
Table B1. Detection frequency of trihalomethanes in samples from well networks in aquifer studies, shallow ground water in agricultural areas, and shallow ground water in urban areas at an assessment level of 0.2 microgram per liter.—Continued

[NAWQA, National Water-Quality Assessment; AWWARF, American Water Works Association Research Foundation; PUB, public; UR, shallow ground water in urban areas; AS, aquifer studies; AG, shallow ground water in agricultural areas. Shaded cells indicate detection frequency is 10 percent or greater. Information about NAWQA Study Units can be obtained at the NAWQA Web site (http://water.usgs.gov/nawqa/)]

NAWQA Study Unit code or other identifier	Source of data (year)[1]	Network	Network type	Chloroform		Bromodichloro-methane		Dibromochloro-methane		Bromoform	
				Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)	Number of samples	Detection frequency (percent)
TRIN	NAWQA (1991)	trinsus2	AS	22	0.0	22	0.0	22	0.0	22	0.0
TRIN	NAWQA (1991)	trinsus3	AS	24	8.3	24	.0	24	.0	24	.0
UCOL	NAWQA (1994)	ucollusrc1	UR	25	4.0	25	.0	25	.0	25	.0
UCOL	NAWQA (1994)	ucolsus1	AS	29	.0	29	.0	29	.0	29	.0
UIRB	NAWQA (1997)	uirblusrc1	UR	19	.0	19	.0	19	.0	19	.0
UIRB	NAWQA (1997)	uirbsus1	AS	27	.0	27	.0	27	.0	27	.0
UMIS	NAWQA (1994)	umislusrc1	UR	30	3.3	30	.0	30	.0	30	.0
UMIS	NAWQA (1994)	umissus3	AS	25	.0	25	4.0	25	4.0	25	.0
UMIS	NAWQA (1994)	umissus4	AS	25	.0	25	.0	25	.0	25	.0
USNK	NAWQA (1991)	usnkluscr1	AG	28	3.6	28	.0	28	.0	28	.0
USNK	NAWQA (1991)	usnkluscr2	AG	31	.0	31	.0	31	.0	31	.0
USNK	NAWQA (1991)	usnkluscr3	AG	30	.0	30	.0	30	.0	30	.0
USNK	NAWQA (1991)	usnkluscr4	AG	15	.0	15	.0	15	.0	15	.0
USNK	NAWQA (1991)	usnksus3	AS	20	.0	20	.0	20	.0	20	.0
UTEN	RETRO	UTEN02	AS	12	16.7	12	8.3	12	8.3	12	.0
UTEN	NAWQA (1994)	utenluscr1	AG	30	3.3	30	.0	30	.0	30	.0
UTEN	NAWQA (1994)	utensus1	AS	30	6.7	30	.0	30	.0	30	.0
WHIT	NAWQA (1991)	whitluscr1	AG	20	10.0	20	.0	20	.0	20	.0
WHIT	NAWQA (1991)	whitluscr2	AG	22	.0	22	.0	22	.0	22	.0
WHIT	NAWQA (1991)	whitluscr3a	AG	24	.0	24	.0	24	.0	24	.0
WHIT	NAWQA (1991)	whitlusur1a	UR	25	40.0	25	.0	25	.0	25	.0
WILL	NAWQA (1991)	willlusag1	AS	15	.0	15	.0	15	.0	15	.0
WILL	NAWQA (1991)	willlusag2	AS	25	8.0	25	.0	25	.0	25	.0
WILL	NAWQA (1991)	willlusur1	UR	11	54.6	11	.0	11	.0	11	.0
WILL	NAWQA (1991)	willsus1	AS	25	8.0	25	.0	25	.0	25	.0
WMIC	NAWQA (1991)	wmiclusag1a	AG	26	.0	26	.0	26	.0	26	.0
WMIC	NAWQA (1991)	wmiclusag2	AG	30	6.7	30	3.3	30	.0	30	.0
WMIC	NAWQA (1991)	wmicsus1	AS	26	.0	26	.0	26	.0	26	.0
YELL	RETRO	YELL01	AS	19	.0	19	.0	19	.0	19	.0
YELL	NAWQA (1997)	yellsus1	AS	24	.0	24	.0	24	.0	24	.0
YELL	NAWQA (1997)	yellsus2	AS	28	3.6	28	3.6	28	.0	28	.0

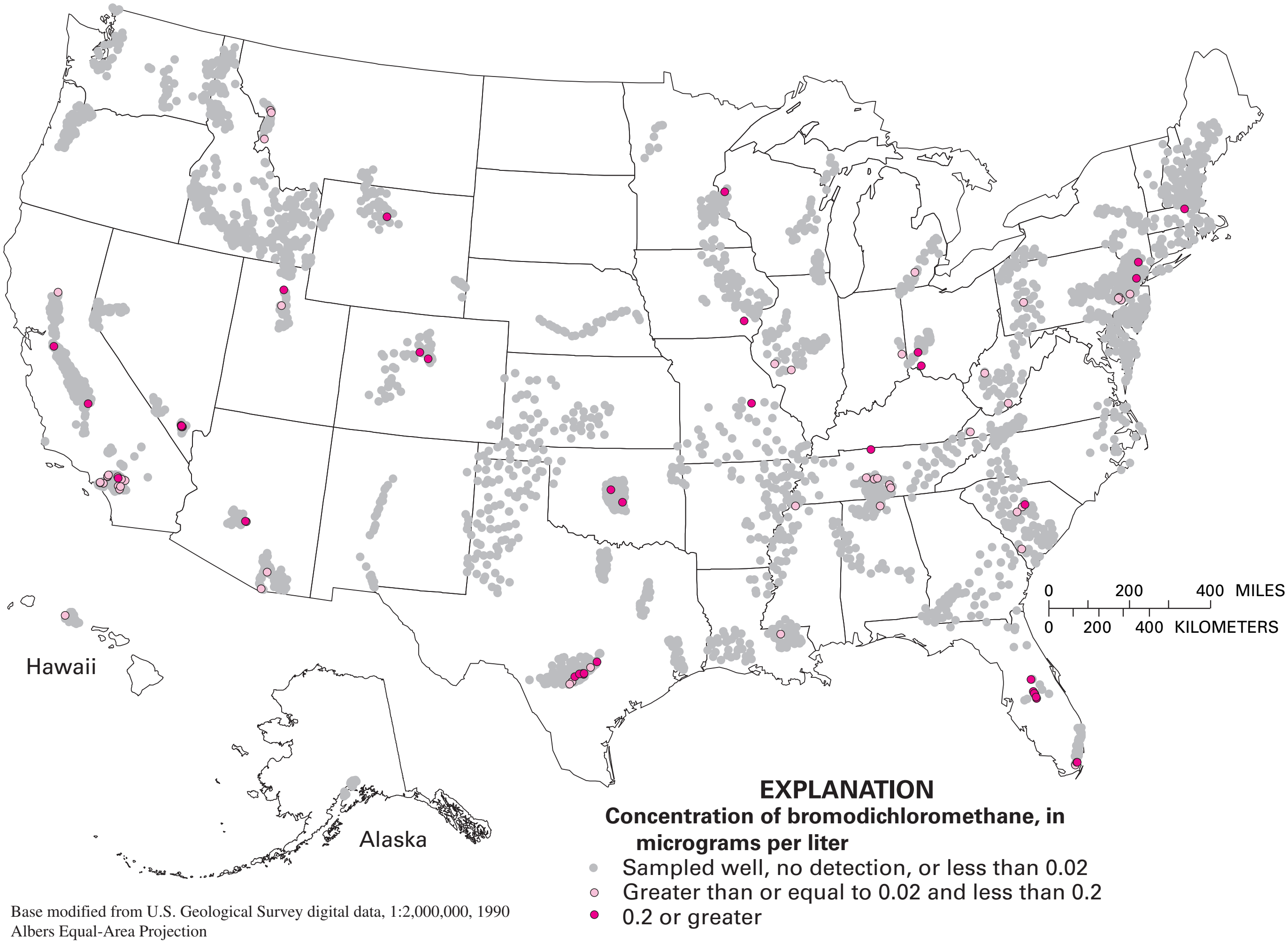
[1] Year in which the study unit investigation commenced.

Section C. Aquifer Studies



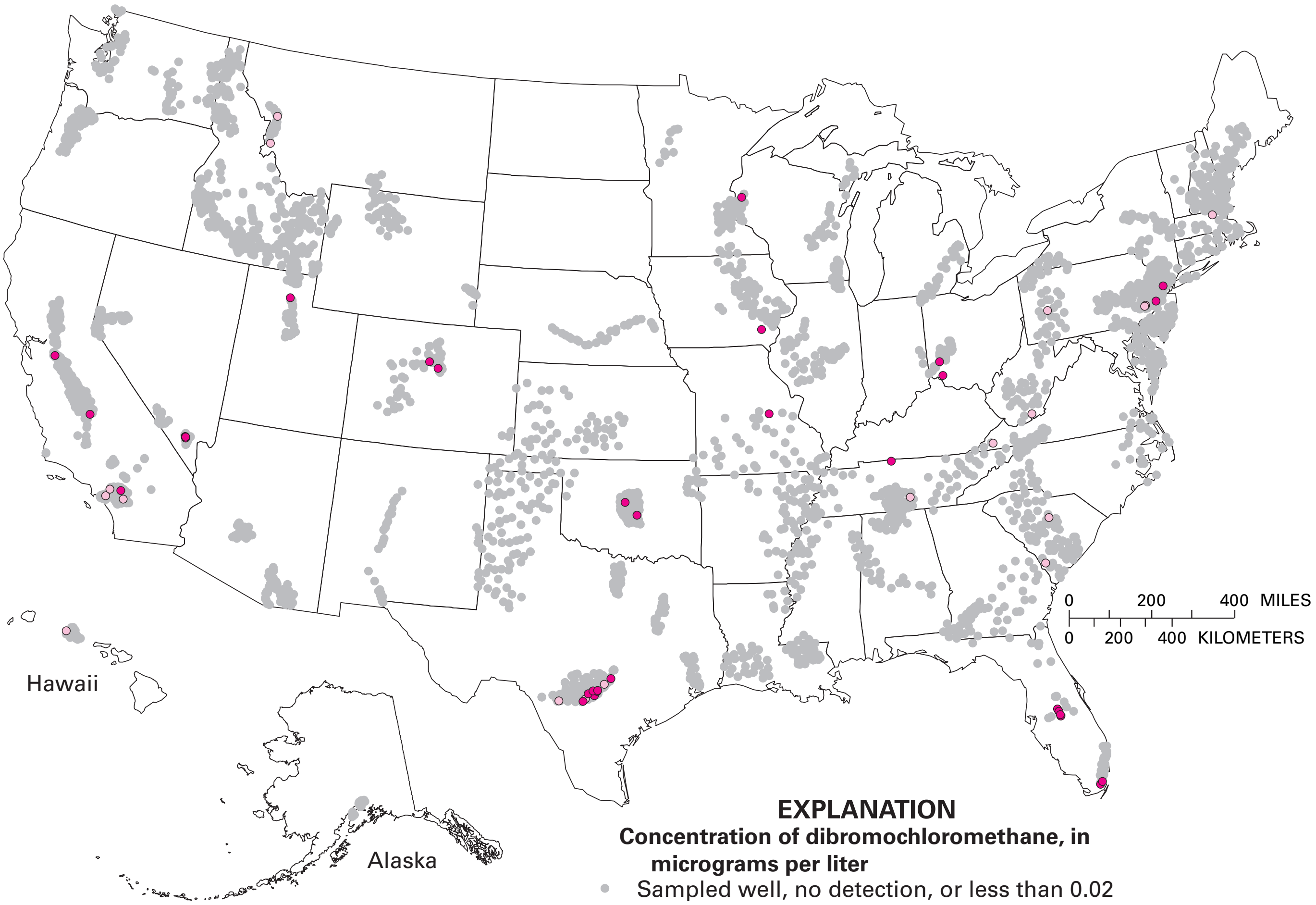
Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure C1. Concentrations of chloroform in aquifer studies, 1985–2001.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure C2. Concentrations bromodichloromethane in aquifer studies, 1985–2001.



EXPLANATION

Concentration of dibromochloromethane, in micrograms per liter

- ● Sampled well, no detection, or less than 0.02
- ○ Greater than or equal to 0.02 and less than 0.2
- ● 0.2 or greater

Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure C3. Concentrations of dibromochloromethane in aquifer studies, 1985–2001.

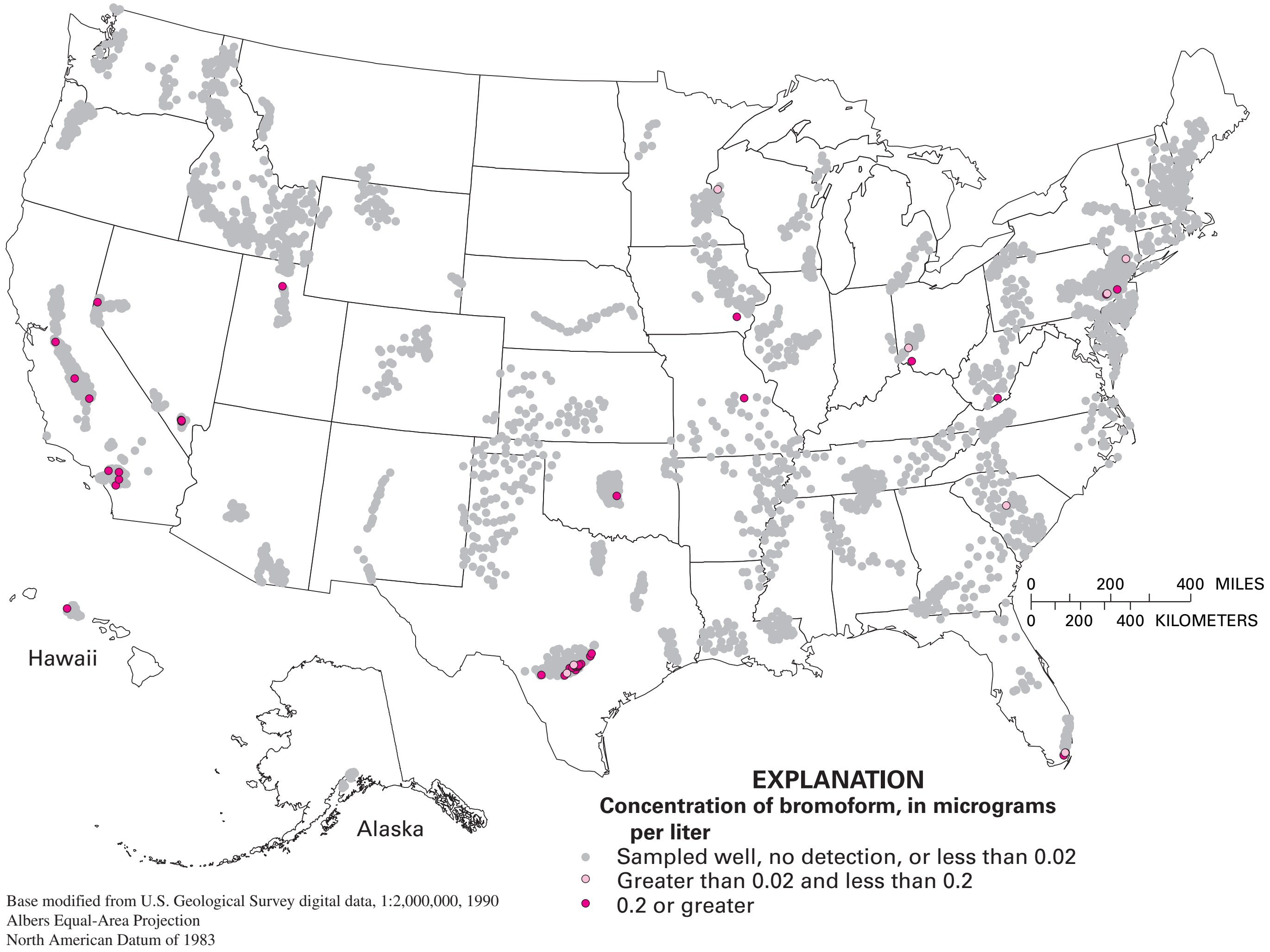
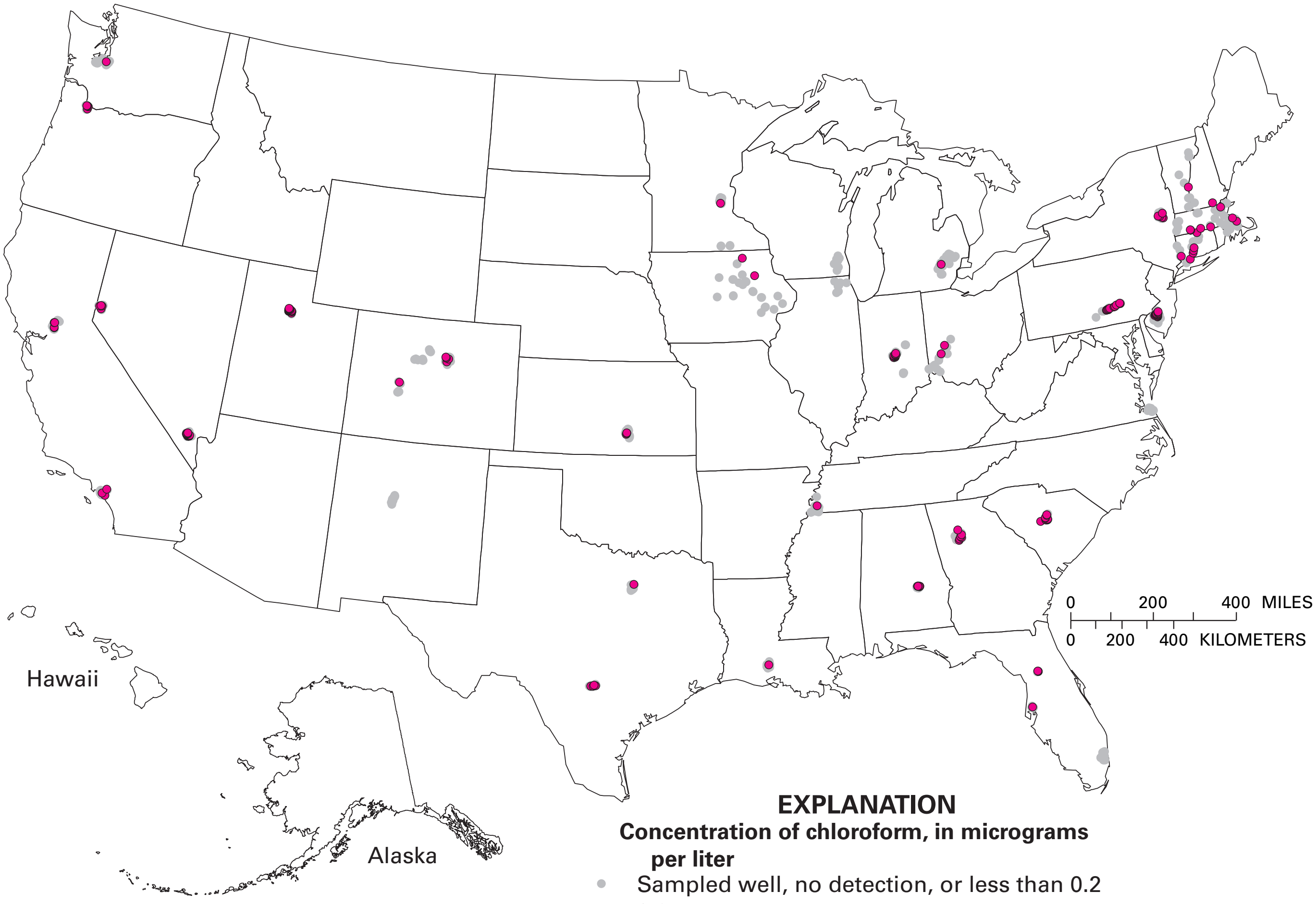


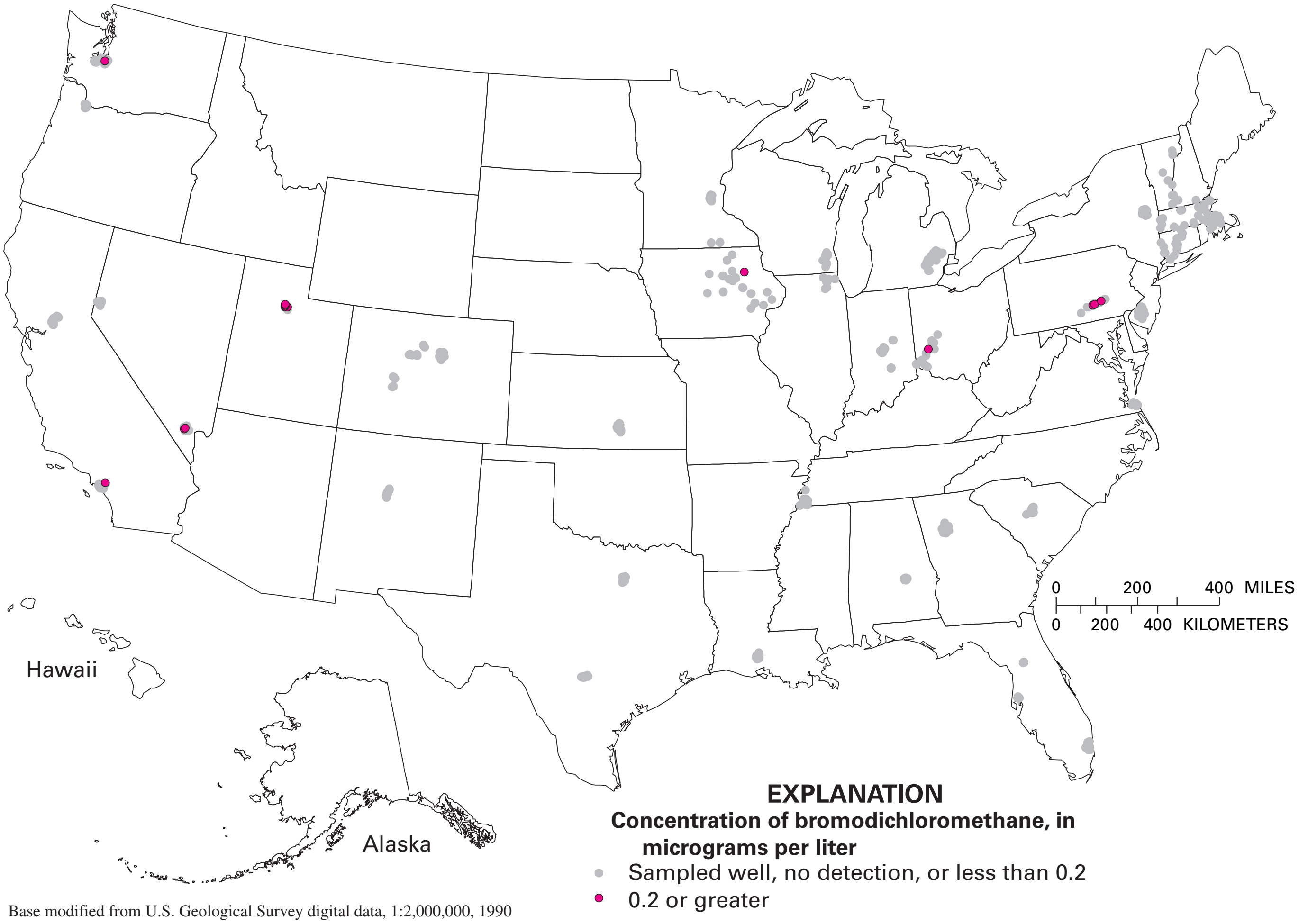
Figure C4. Concentrations of bromoform in aquifer studies, 1985–2001.

Section D. Shallow Ground Water in Urban Areas



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

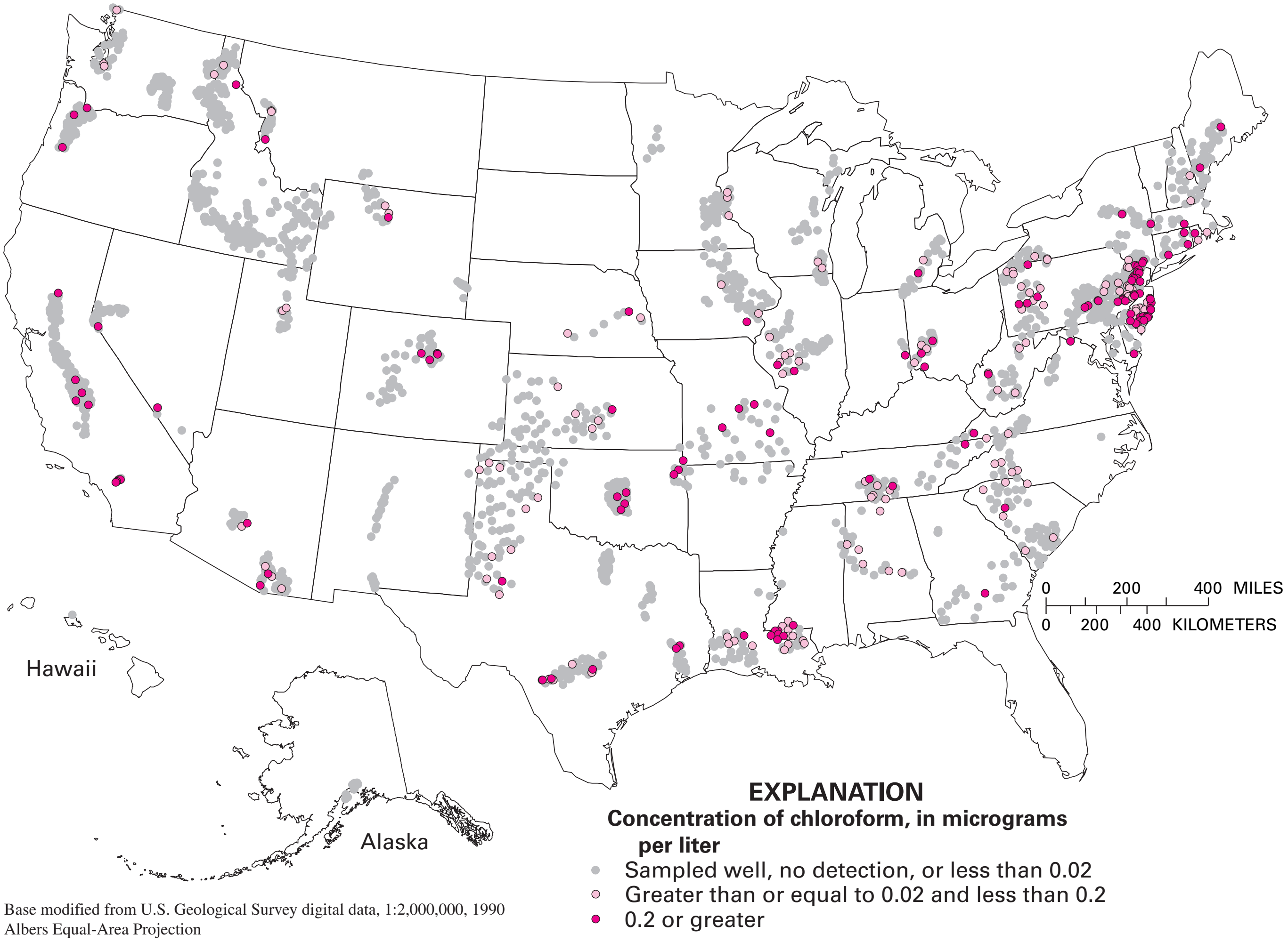
Figure D1. Concentrations of chloroform in shallow ground water in urban areas, 1993–2002.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

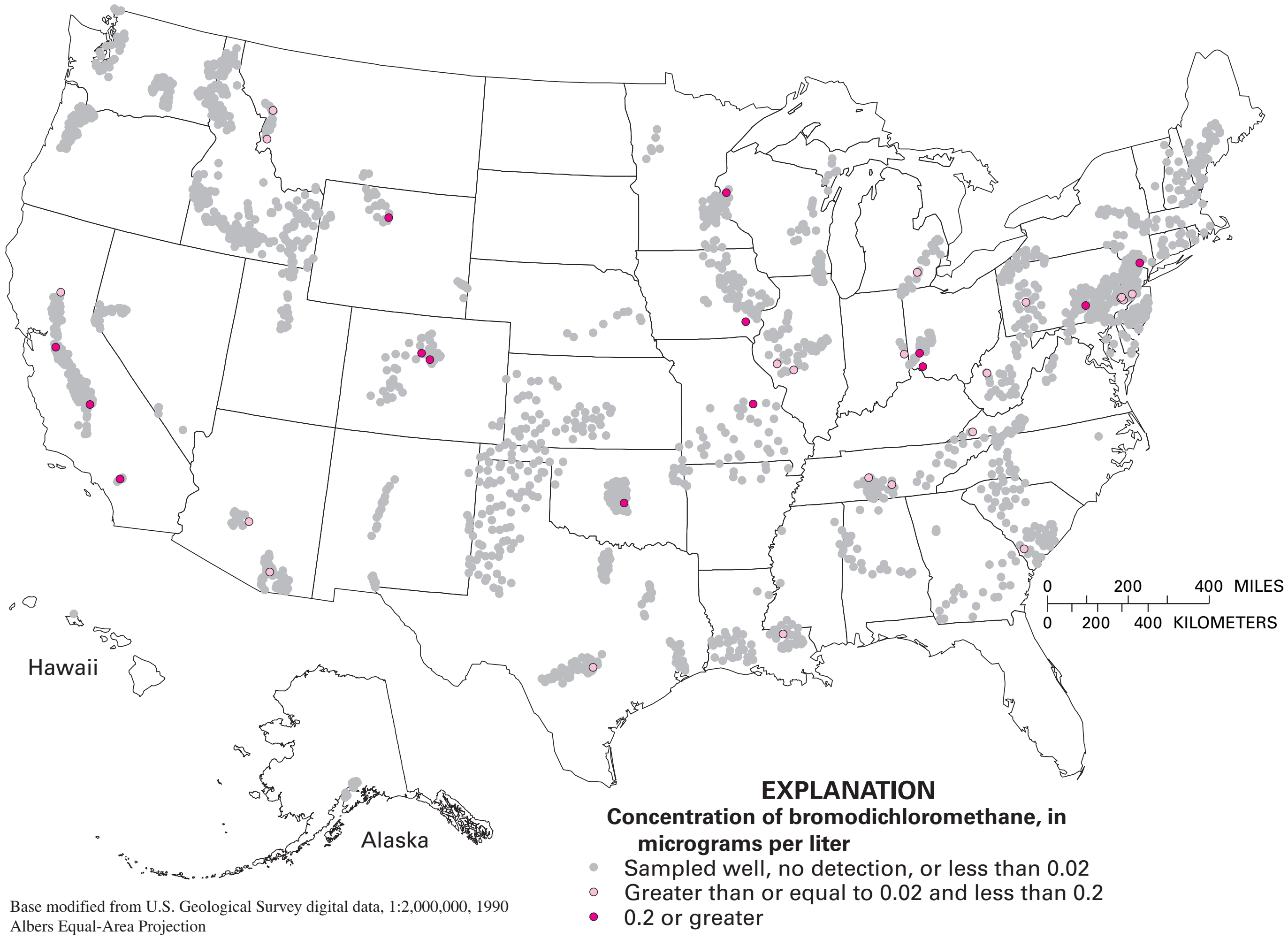
Figure D2. Concentrations of bromodichloromethane in shallow ground water in urban areas, 1993–2002.

Section E. Domestic Well Samples



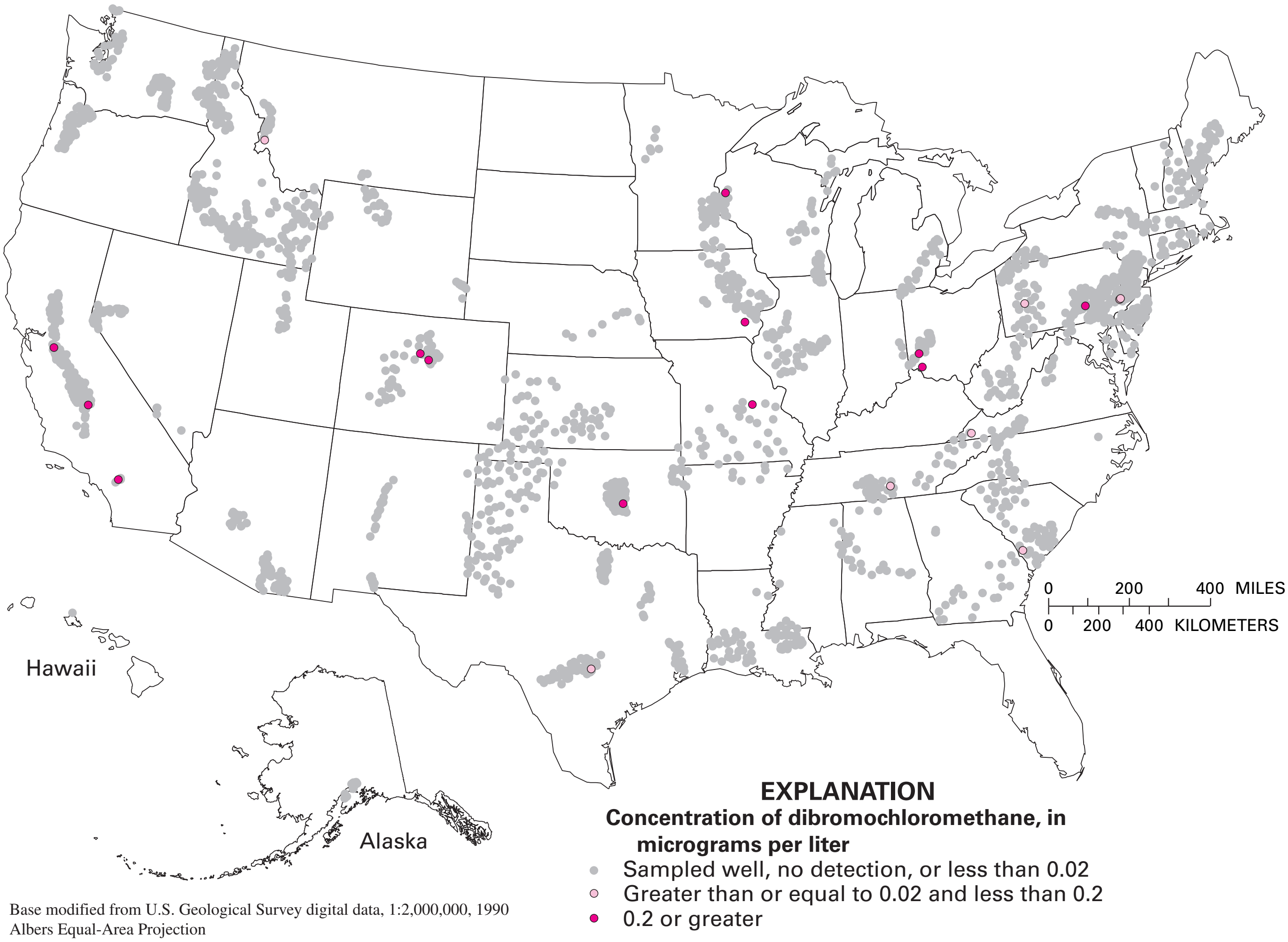
Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure E1. Concentrations of chloroform in domestic well samples, 1986–2001.



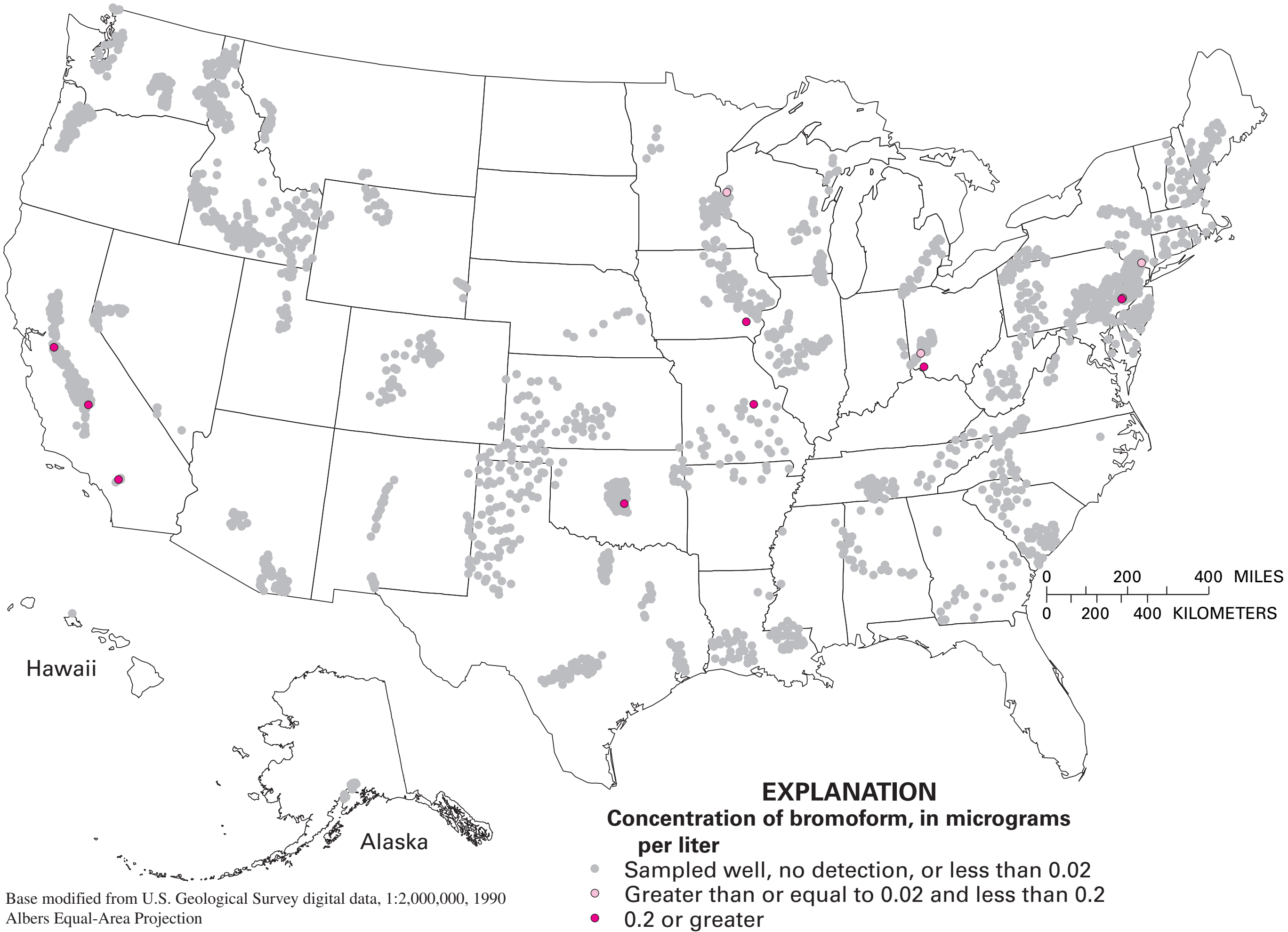
Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure E2. Concentrations of bromodichloromethane in domestic well samples, 1986–2001.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

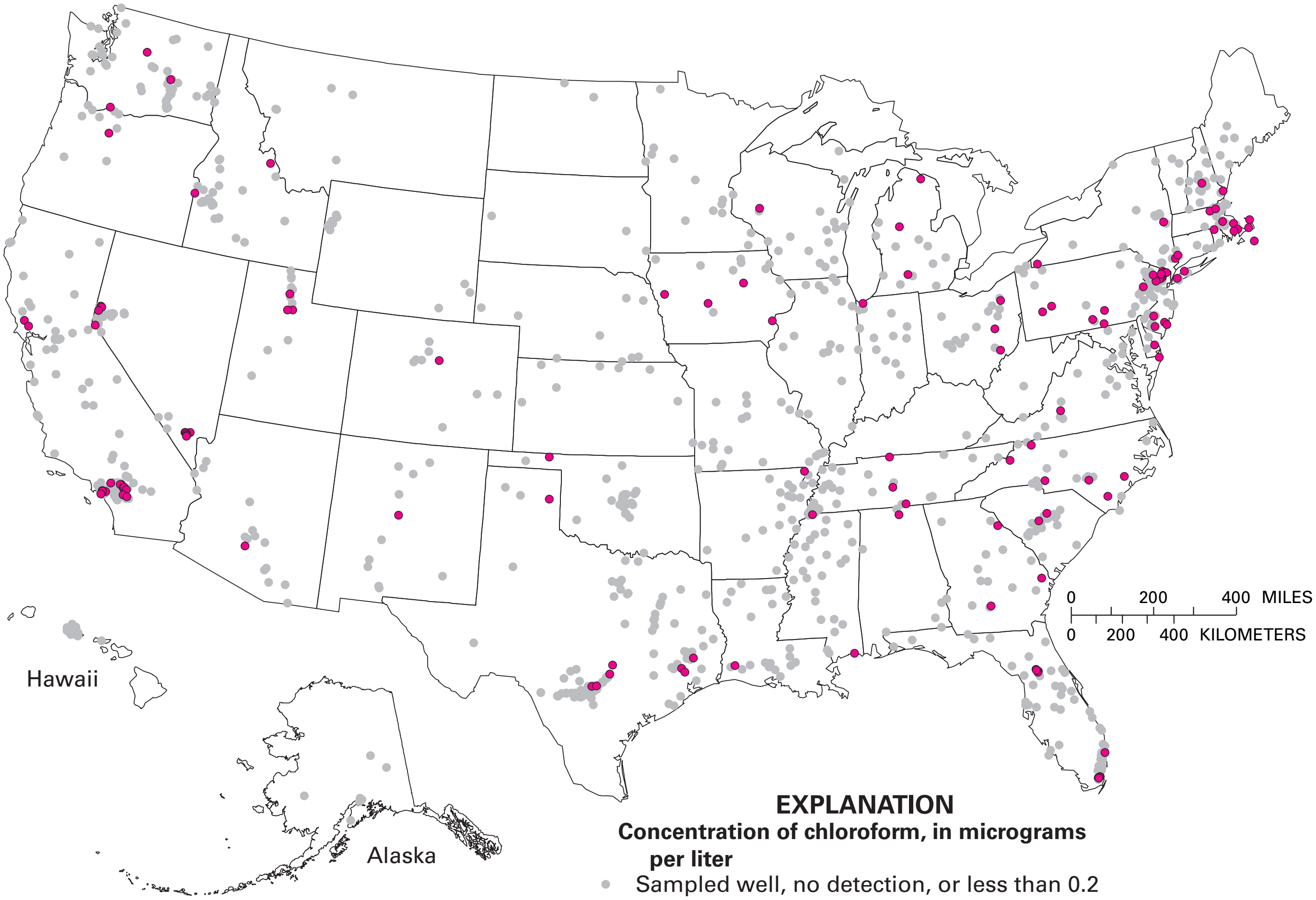
Figure E3. Concentrations of dibromochloromethane in domestic well samples, 1986–2001.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure E4. Concentrations of bromoform in domestic well samples, 1986–2001.

Section F. Public Well Samples



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
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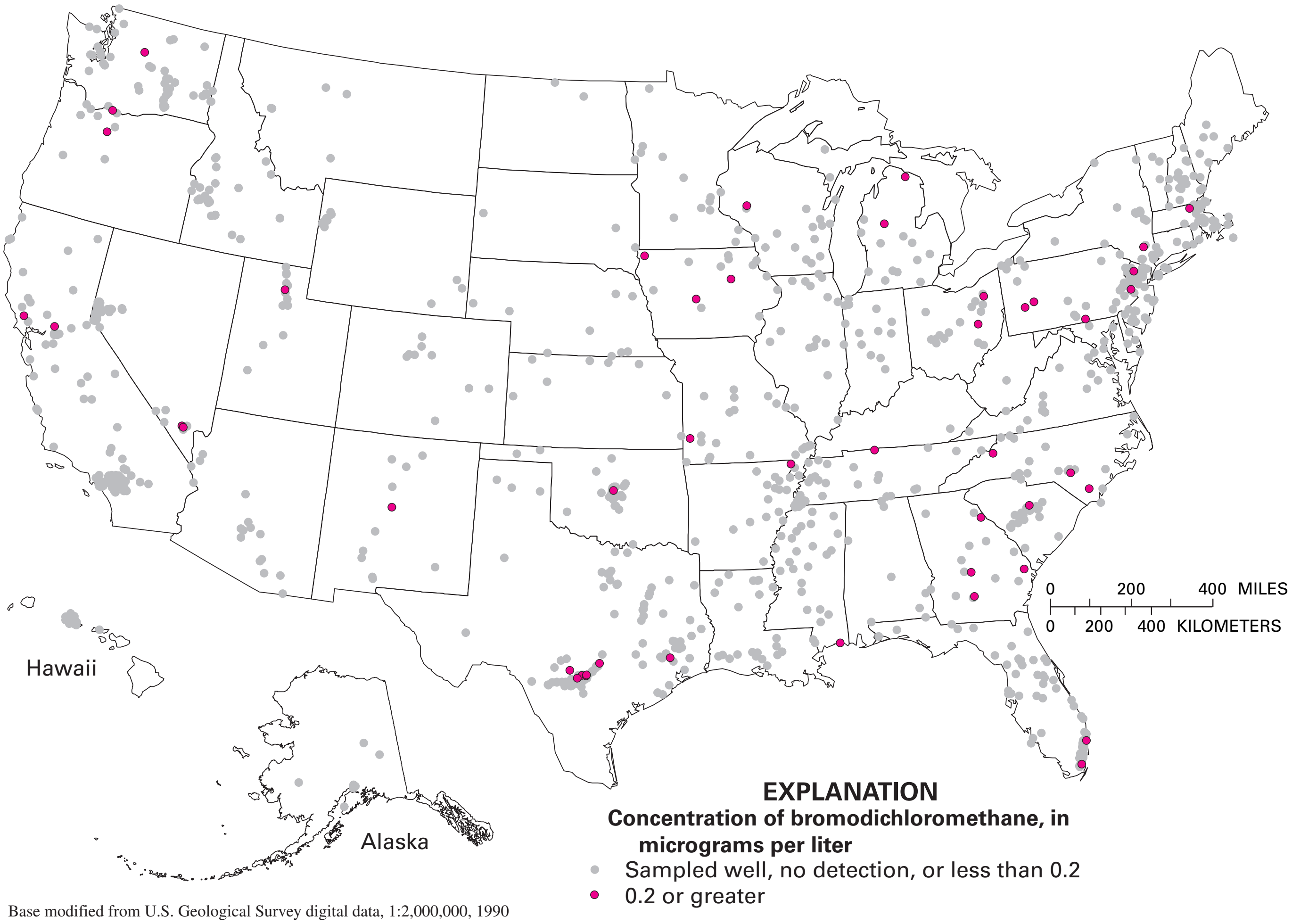
Figure F1. Concentrations of chloroform in public well samples, 1986–2001.



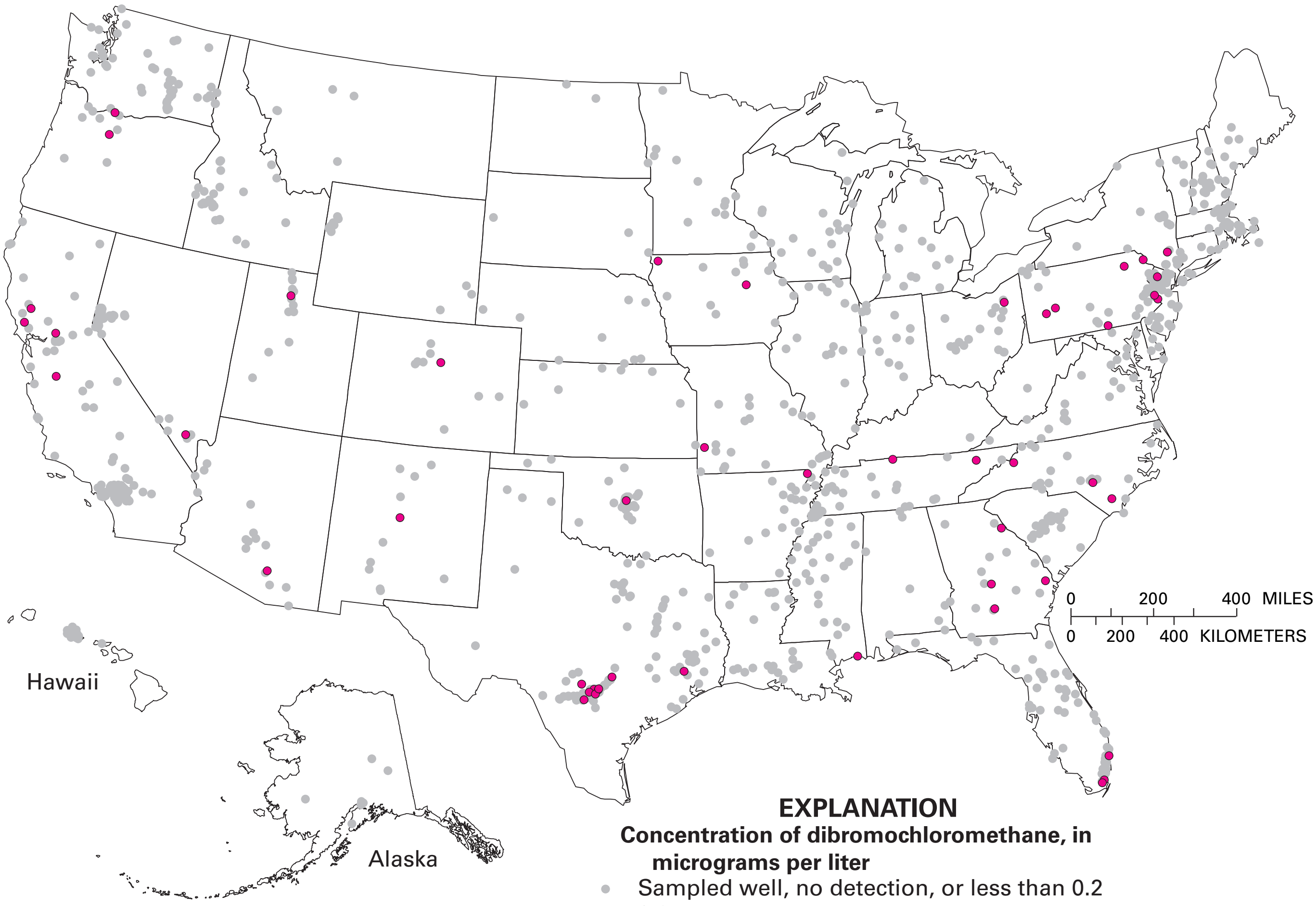
EXPLANATION

Concentration of bromodichloromethane, in micrograms per liter

- ● Sampled well, no detection, or less than 0.2
- ● 0.2 or greater

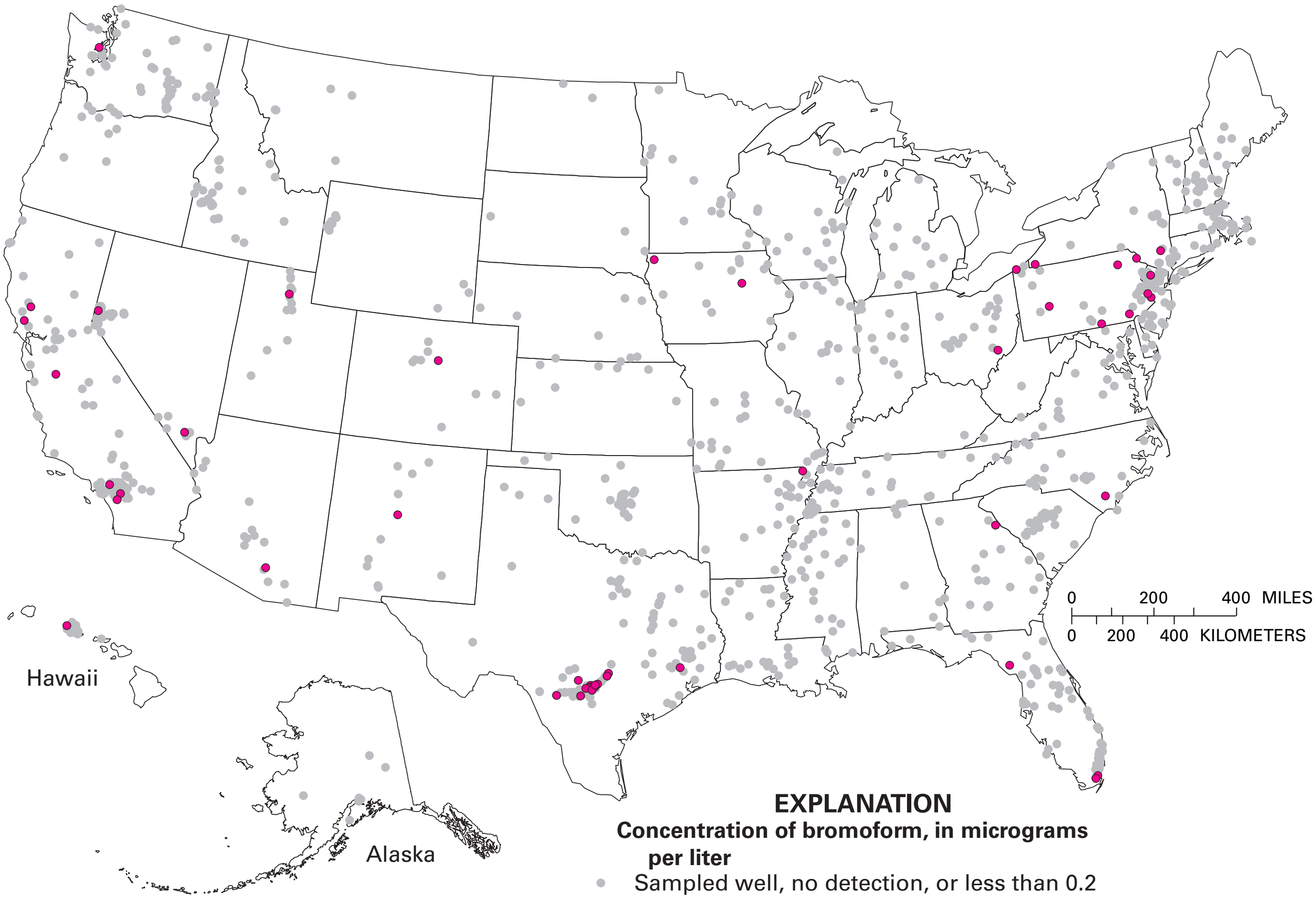
Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure F2. Concentrations of bromodichloromethane in public well samples, 1986–2001.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure F3. Concentrations of dibromochloromethane in public well samples, 1986–2001.



Base modified from U.S. Geological Survey digital data, 1:2,000,000, 1990
Albers Equal-Area Projection
North American Datum of 1983

Figure F4. Concentrations of bromoform in public well samples, 1986–2001.

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