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

A Plan for Assessing the Occurrence and Distribution of Methyl *tert*-Butyl Ether and Other Volatile Organic Compounds in Drinking Water and Ambient Ground Water in the Northeast and Mid-Atlantic Regions of the United States

By Stephen J. Grady and George D. Casey

Open-File Report 99-207

Prepared in cooperation with the U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water

East Hartford, Connecticut
1999

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
inch (in.)	2.54	centimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
gallon per minute (gal/min)	0.06309	liter per second
million gallons (Mgal)	3,785	cubic meter

Sea level, as used in this report, refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Altitude, as used in this report, refers to distance above or below sea level.

Concentrations of chemical constituents in water are given in micrograms per liter (µg/L).

Other abbreviation used is billion gallons per day (Bgal/d).

A PLAN FOR ASSESSING THE OCCURRENCE AND DISTRIBUTION OF METHYL *TERT*-BUTYL ETHER AND OTHER VOLATILE ORGANIC COMPOUNDS IN DRINKING WATER AND AMBIENT GROUND WATER IN THE NORTHEAST AND MID-ATLANTIC REGIONS OF THE UNITED STATES

by Stephen J. Grady and George D. Casey

ABSTRACT

A plan to assess the occurrence and distribution of methyl *tert*-butyl ether (MTBE) and other volatile organic compounds (VOCs) in drinking water and ambient ground water in the Northeast and Mid-Atlantic regions of the United States was designed to meet two primary objectives. This study will provide the U.S. Environmental Protection Agency with information on potential human exposure to MTBE and other VOCs from drinking water. In addition, the study will further the goals of the U.S. Geological Survey's (USGS) National Water Quality Assessment Program (NAWQA) by providing additional information on the occurrence and distribution of VOCs in ambient ground water beneath a large, highly urbanized part of the Nation. The study will proceed in two phases—a drinking-water assessment (phase 1) and an ambient ground-water assessment (phase 2). The drinking-water assessment will involve compilation, review, and analysis of available water-quality and ancillary data for approximately 20 percent of the community water systems in 12 States in the Northeast and Mid-Atlantic regions. This effort will summarize the occurrence and distribution of MTBE and other VOCs in drinking water supplied by 2,110 community water systems. The ambient ground-water assessment will involve compilation, review, and analysis of data on MTBE and other VOCs from previous USGS studies in the 12-State area, including regional water-quality assessments conducted for the USGS's NAWQA, plus other available State or local datasets. These data will be related, to the extent allowed by the completeness and quality of the data, to land-use patterns, population density, and other anthropogenic and natural factors using statistical tests. The occurrence and distribution of MTBE and other VOCs in ambient ground water and, to the extent possible, drinking water in relation to such factors, will be evaluated.

INTRODUCTION

Methyl *tert*-butyl ether (MTBE) is a chemical compound that is added to gasoline principally for the purpose of controlling air pollution. MTBE also has been used since 1979 at low concentrations (about 1 to 2 percent by volume) in conventional gasoline to enhance octane. The Clean Air Act Amendments of 1990, however, mandated that oxygenates (oxygen-containing compounds) be added to gasoline in areas where concentrations of ozone in the summer and carbon monoxide in the winter exceed established air-quality standards. Although the Clean Air Act does not stipulate which specific oxygenates among a number of ether and alcohol compounds must be added to gasoline, MTBE is the most widely used oxygenate. When MTBE is used in oxygenated gasoline (OXY) the MTBE concentration is approximately 15 percent by volume. Several of the urban areas currently or formerly included in the wintertime OXY fuel program that began in 1992 are located in Northeast or Mid-Atlantic States. Large-scale use of MTBE in parts of the Nation, including much of the Northeast and Mid-Atlantic regions, began in 1995 with the introduction of reformulated gasoline (RFG). RFG has 11 percent MTBE by volume and is currently used year-round in a large part of the region. Annual domestic production of MTBE has increased from less than 10 billion liters in 1980 to about 350 billion liters in 1997 (Chemical Manufacturers Association, 1997).

MTBE may be released into the environment from point sources such as leaks or spills that occur during the refining, distribution, storage, and use of gasoline, and some of these have resulted in the abandonment of domestic and public water-supply sources (Office of Science and Technology Policy, 1997; Hitzig and others, 1998). Furthermore, the release of MTBE to the atmosphere and the hydrosphere from nonpoint sources such as automobile emissions and evaporative losses may result in low concentrations of MTBE in water in urban areas (Pankow and others, 1997).

The presence of MTBE, a possible human carcinogen, in drinking water is a human health concern, and at concentrations as low as 15 μg/L, MTBE may adversely affect the taste and odor of drinking water, causing it to be nonpotable (Young and others, 1996; Malcome Pirnie, Inc., 1998). However, the report of the Interagency Assessment of Oxygenated Fuels was unable to adequately describe the occurrence of MTBE in the Nations's drinking water from the limited data available in 1997 (Zogorski and others, 1997), and consequently has recommended that additional data on MTBE in drinking water be collected. Although analysis of drinking-water samples for MTBE is not currently required under the Safe Drinking Water Act (SDWA), some States and/or public drinking-water suppliers have included MTBE in chemical analyses of drinking-water samples in recent years.

MTBE is an example of the class of volatile organic compounds (VOCs), natural and manmade chemicals that are typically characterized by high vapor pressures, high solubilities in water, and low octanol-water partition coefficients. They include hydrocarbons, halocarbons, aldehydes, ketones, alcohols, ethers, acids, and methyl-sulfur compounds. VOCs are used and produced in the manufacture of paints, adhesives, petroleum products, pharmaceuticals, and refrigerants. They are components of a number of products such as fuels, solvents, hydraulic fluids, paint, and dry-cleaning agents commonly used in urban settings as well as active and inert components of some pesticides (particularly fumigants) used in agricultural settings. Contamination of drinking-water supplies by VOCs is also a human health concern, because many are toxic and are known or suspected human carcinogens (U.S. Environmental Protection Agency, 1996). Twenty-one VOCs (plus EDB and DBCP: see appendix 1) are currently regulated in drinking water under the SDWA and the U.S. Environmental Protection Agency (USEPA) has established maximum contaminant levels (MCLs) for these compounds. Additionally, monitoring for 21 unregulated VOCs is required under the SDWA and monitoring for 14 other VOCs can be required at the discretion of the individual States.

Specific questions and concerns that have been raised about MTBE and VOCs in drinking water and ambient ground water include:

• Has the widespread use of the gasoline additive MTBE resulted in contamination of drinking water and ambient ground water? If so, are point or nonpoint sources (land and air) primarily associated with most detections of MTBE? Does the occurrence of MTBE in drinking water or ambient ground water reflect different use patterns?

• What other VOCs have been detected in drinking water and ambient ground water? How frequently have regulated VOCs been detected at concentrations below MCLs? How frequently have unregulated VOCs been detected in drinking water at any concentration? How often does MTBE co-occur with other VOCs? Also, if MTBE and other VOCs occur widely in drinking water, can estimates be made of how many people have been exposed to VOCs through consumption of affected drinking water?

• Does the frequency of VOC detections differ among States? If so, do differences in VOC detections in drinking water or ambient ground water relate to land use, population density, areas of required MTBE use, proximity to known point sources or releases of contaminants, or other human factors? Also, if VOCs occur frequently in ambient ground water beneath urban or other areas, are they found in aquifers being developed for public or private drinking-water supplies?

• Does the type, concentration, and frequency of VOC detections differ among major aquifer systems? If so, does it relate to well depth, water-table conditions, ground-water withdrawals, or regional flow patterns?

• Are VOCs detected more frequently in drinking water obtained from ground-water sources than from surface-water sources? Does the type and frequency of VOCs detected differ substantially between source waters and finished (treated) waters? If so, can the occurrence of VOCs in drinking water be related to the size of public water systems and level of water treatment they provide?

To answer these questions, the U.S. Geological Survey (USGS), in cooperation with the USEPA, will conduct a multi-year assessment of the occurrence and distribution of MTBE and other VOCs in drinking water and ambient ground water in the Northeast and Mid-Atlantic regions of the United States. This study will compile, evaluate, and analyze existing information on drinking-water quality and public water-supply systems, ambient ground-water quality, and other ancillary data collected by or for various State and local health or environmental agencies, the USEPA, and the USGS.

Purpose and Scope

This report presents a plan for the assessment of the occurrence and distribution of MTBE and other VOCs in drinking water and ambient ground water in 12 States in the Northeast and Mid-Atlantic regions of the United States (fig. 1). The assessment can be divided into two phases. The first phase will provide information on the frequency of detection, concentration, and distribution of MTBE and other VOCs in drinking water; this information will be used by the USEPA to evaluate the extent of human exposure to these compounds from drinking-water sources and to implement monitoring requirements of the SDWA Amendments of 1996. The second phase will provide information on the occurrence and distribution of MTBE and other VOCs in ambient ground water and relate their areal and temporal distribution to human or natural factors. Ambient ground water refers to ground water where there are no known point sources of contamination. This information will help accomplish goals of USGS's NAWQA Program.

The drinking-water assessment will focus on obtaining water-quality and ancillary data for public water systems (PWSs) and, when possible, on private drinking-water supplies. The ambient ground-water assessment will focus on water quality and ancillary data for domestic or other supply and monitoring wells in aquifers used for water supplies collected for NAWQA studies, other USGS studies, and State, county, or local sampling programs. Both assessments will complement other planned or ongoing studies, including a national assessment of the occurrence and distribution of VOCs in ground water (Lapham and Tadayon, 1996) and studies focused on the effects of urban land use on shallow ground water (Squillace and Price, 1996) and streams (Lopes and Price, 1997).

Need for This Assessment

Why Target VOCs in Drinking Water and Ambient Ground Water?

Information on the occurrence and distribution of at least 60 VOCs (appendix 1) was collected during 1993-97 as part of the National Water-Quality Assessment (NAWQA) Program during 1993-97. VOCs were widely detected in shallow ground water across the Nation but were most closely associated with urban land use. Nearly one-fifth of 1,650 wells sampled through 1997 contained one or more VOCs; more than half of 304 wells sampled in urban areas contained VOCs (M.J. Moran, U.S. Geological Survey, 1999, oral commun.). At least 36 different VOCs were detected in shallow, ambient ground water; most detections were at concentrations below current or proposed MCLs or health advisories (HAs) issued by the USEPA. Chloroform, the most frequently detected VOC (in approximately 9 percent of all wells), may be present in ground water partly as a by-product of the disinfection of drinking-water supplies with chlorine. The gasoline additive MTBE was the second most frequently detected VOC (in approximately 6 percent of all wells), but it was present in nearly one-quarter (67) of 304 wells sampled in urban areas. If chloroform, MTBE, and other VOCs are present in public and private ground-water supplies at similar concentrations and frequencies, millions of people may potentially be exposed to VOCs in drinking water.

Westrick and others (1984) reported that 23 VOCs were detected in finished drinking water supplied by nearly one-fourth (230 of 945) of water systems sampled during 1981 and 1982. The "ground-water supply survey" included 34 VOC analytes. Overall, detection frequencies varied from about 17 percent of samples from small, randomly selected public water systems, to a high of 37 percent of

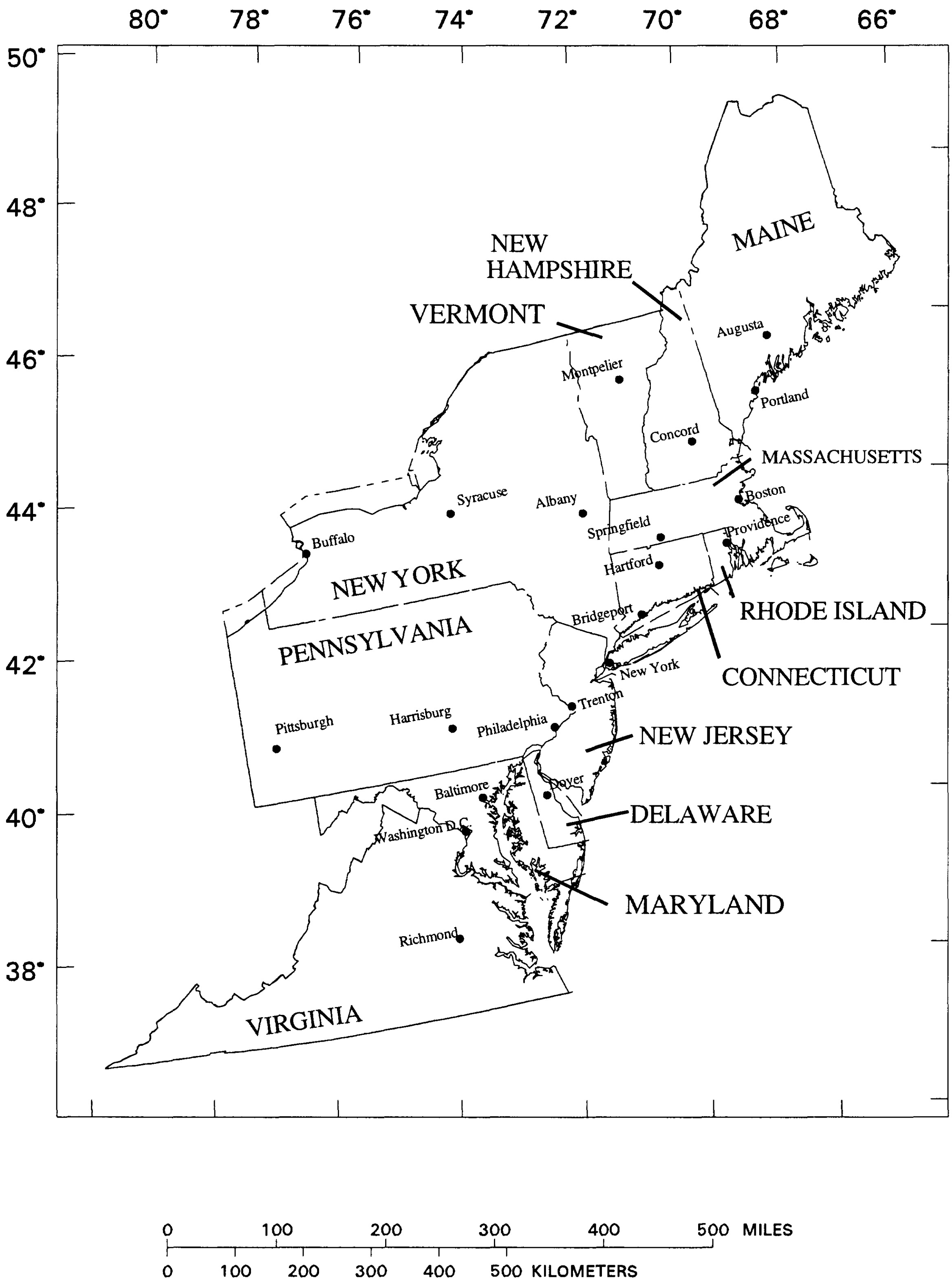

Figure 1. Twelve Northeast and Mid-Atlantic States in the study area.

samples from larger systems selected for sampling because they had been identified as "problem systems." The most frequently detected VOCs were trihalomethanes--chloroform, bromodichloromethane, chlorodibromomethane, and bromoform--present in 45-, 43-, 39-, and 22-percent of the systems sampled, respectively. They were detected more often from larger systems (serving more than 10,000 people) than from smaller systems that were less likely to chlorinate their source water. After the trihalomethanes, four commonly used solvents—tetrachloroethylene, trichloroethylene, 1,1,1-trichloroethane, and 1,1-dichloroethane—were the next most frequently detected compounds, present in 4 to 7 percent of the systems sampled. Fifty-three percent of the samples with VOC detections contained more than one VOC. The relatively high detection frequencies, the age of the data, and limited analytical coverage point out the need for a current and comprehensive picture of VOCs in drinking water.

The SDWA Amendments of 1996 require the USEPA to identify contaminants that are not presently subject to any proposed or promulgated National Primary Drinking Water Regulation (NPDWR) but are known or anticipated to occur in drinking-water supplies, and to determine whether or not to regulate these contaminants or require monitoring by the States. These new contaminants are known as the Contaminant Candidate List (CCL), and presently it identifies 10 microbiological and 50 chemical contaminants, including MTBE and 12 other VOCs (USEPA, 1998a). The SDWA requires the USEPA to make a determination of whether or not to regulate not less than five contaminants from the CCL by 2001. The CCL is divided into two categories: (1) contaminants for which sufficient information exists to begin to make regulatory determinations by 2001, and (2) contaminants for which additional research and occurrence information are necessary before regulatory determinations can be made. MTBE falls into the latter category because there is a significant need for additional research in the areas of health effects and a more complete occurrence database (USEPA, 1998a). Consequently, the USEPA has proposed including MTBE in revised monitoring for unregulated contaminants beginning in 2001 (USEPA, 1999). Information collected during this assessment will help provide the occurrence data needed for MTBE and other VOCs on the CCL.

Why Target the Northeast and Mid-Atlantic Regions?

The Northeast and Mid-Atlantic regions of the United States have large populations, extensive urban and industrial development, and widespread use and release of many VOCs. The Northeast and Mid-Atlantic regions make up the largest contiguous region outside of California (fig. 2) where MTBE is added to gasoline to meet the requirements of the USEPA's oxygenated and (or) reformulated gasoline program. Although all of Vermont and some parts of six other States are not required to use oxygenated or reformulated gasoline, they were included in the study area because gasoline containing MTBE may be distributed beyond oxygenated or reformulated gasoline-use areas.

During 1993-96, between 17.7 and 19 billion gallons of reformulated and oxygenated gasoline were used annually in the 12-State region (table 1). Because RFG contains MTBE at about 11 percent by volume (or more for oxygenated gasoline), at least 2 billion gallons of MTBE are used annually in those parts of the study area where RFG and oxygenated gasoline use is required. MTBE also has been used in lesser amounts to increase the octane rating in gasoline since the mid-1970's, but the volume of MTBE added and the distribution patterns are poorly documented and are more variable than with reformulated or oxygenated gasoline.

Detections of MTBE have been reported previously (Squillace and others, 1996; Grady, 1997; Lindsey and others, 1997; Stackelberg and others, 1997; Zogorski and others, 1997) in ambient ground water in at least eight eastern States (Connecticut, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia). MTBE also was reported in private or public drinking-water supplies (Grady, 1997; Lindsey and others, 1997; Zogorski and others, 1997) in at least five of these States (Connecticut, Massachusetts, New Jersey, Pennsylvania, and Rhode Island). Although reported MTBE concentrations were generally low and most were below the 20- to 40-μg/L range recommended by the USEPA drinking water advisory (U.S. Environmental Protection Agency, 1997), the National Research Council (1996) concluded that "if USEPA's recommended health-advisory concentrations were reduced considerably, substantial concerns would arise about the potential hazards of MTBE in drinking water."

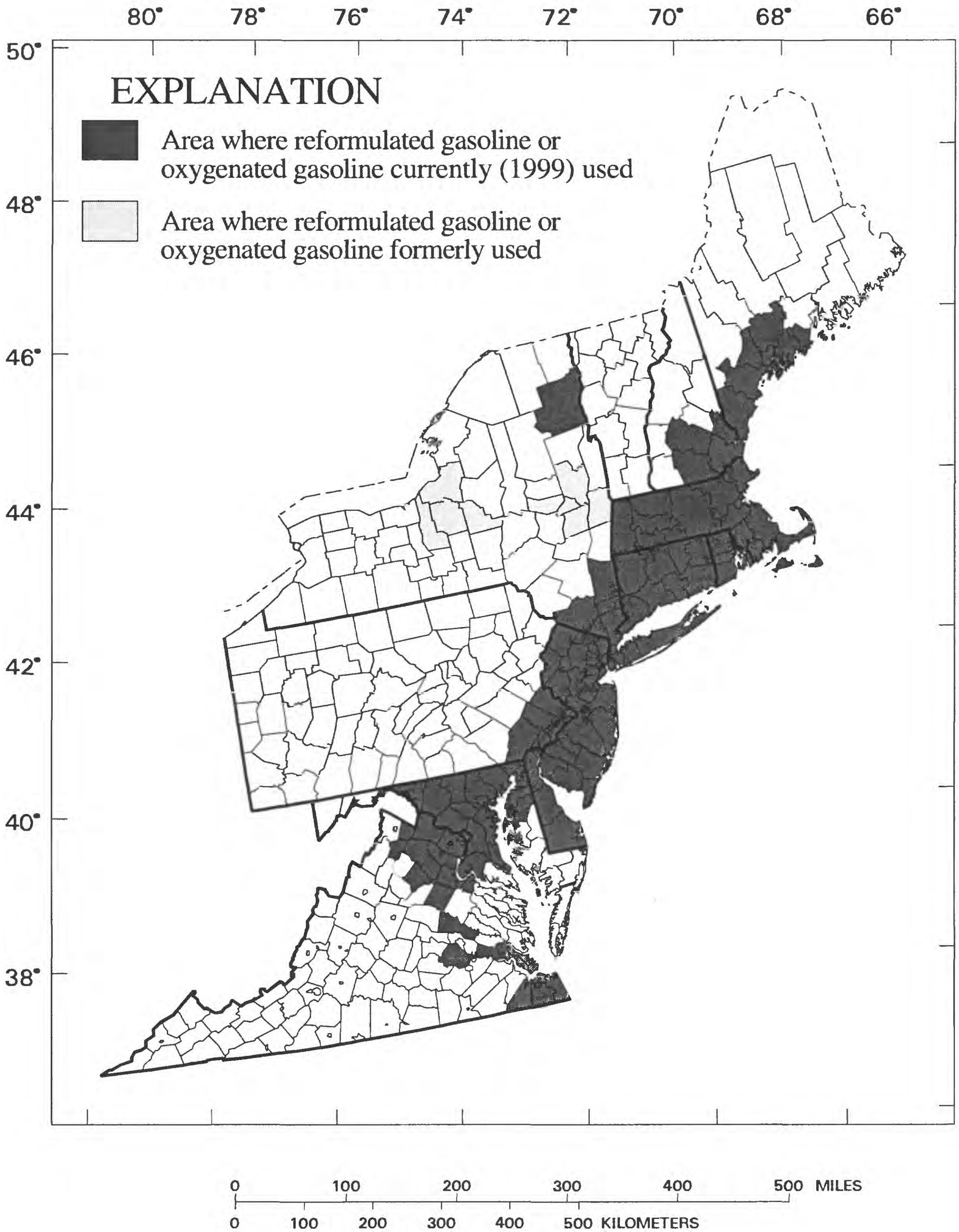

Figure 2. Counties where reformulated or oxygenated gasoline is currently or was formerly used. (Data from U.S. Environmental Protection Agency, 1998 b, c.)

Table 1. Total estimated reformulated or oxygenated gasoline use in the 12-State study area, 1993-96

[Volume of gasoline used in each State is based on the population within reformulated or oxygenated fuel use areas multiplied by the yearly average usage of gasoline per person in the State. Data from Population Estimates and Population Distribution Branches, Population Division, U.S. Bureau of the Census; and Energy Information Administration, Office of Oil and Gas, U.S. Department of Energy]

State	Total estimated reformulated or oxygenated gasoline use, in billion gallons			
	1993	1994	1995	1996
Connecticut	1.362	1.416	1.465	1.342
Delaware	0.403	0.414	0.381	0.349
Maine	0.448	0.486	0.540	0.542
Maryland	1.748	1.792	1.798	1.802
Massachusetts	2.400	2.561	2.517	2.540
New Hampshire	0.306	0.291	0.299	0.334
New Jersey	3.393	3.978	4.061	3.979
New York	3.468	3.482	3.645	3.562
Pennsylvania	1.531	1.554	1.579	1.581
Rhode Island	0.564	0.517	0.539	0.556
Vermont[1]	--	--	--	--
Virginia[2]	2.076	2.127	2.202	2.234
Total	17.699	18.618	19.026	18.821

[1]No areas in the reformulated or oxygenated fuels program.
[2]Includes the District of Columbia.

Why Target Public Water Systems?

In 1995, PWSs provided approximately 4.6 Bgal/d or about 85 percent of the total domestic water use (fig. 3) to approximately 64 million people living in the 12-State area (including the District of Columbia) (Solley and others, 1998). Surface water provided about 80 percent of total public water-supply deliveries; however, ground water was the dominant source for large parts of the study area (fig. 4), particularly where highly productive surficial and coastal-plain aquifers are present. Private residential wells provided virtually all of the self-supplied domestic water use, about 800 Mgal/d for the study area in 1995 (fig. 5).

Federal and State drinking-water programs require that the quality of public drinking water be monitored. Under the SDWA, PWSs are subject to specific monitoring requirements, including sample locations, sampling frequency, and analytical coverage (U.S. Environmental Protection Agency, 1990), although States can exempt some PWSs from certain monitoring requirements or may require others. PWSs must sample at the point-of-entry of water into their distribution system, and most PWSs report data on "finished water" (filtered and/or treated) for contaminants with established drinking-water regulations or are required by the SDWA or State statutes. Some PWSs, however, particularly small, ground-water supplied systems, do not filter or treat their water before distribution, and data for these systems may represent the water quality of the source.

SDWA monitoring data are reviewed only for violations and compliance and generally are not reported beyond the purview of the utility, local regulatory authority, or responsible State agency. Currently, there is no regional or national database for the drinking-water analyses and, consequently, any analysis of the spatial and temporal distribution of public drinking-water analytes is precluded. The lack of an available drinking-water database also prevents attempts to relate the occurrence and distribution of MTBE and other VOCs in drinking water to natural and human factors. The PWS data, when compiled, reviewed, and analyzed, can provide information on the target contaminants in both finished and source waters used by a large segment of the population.

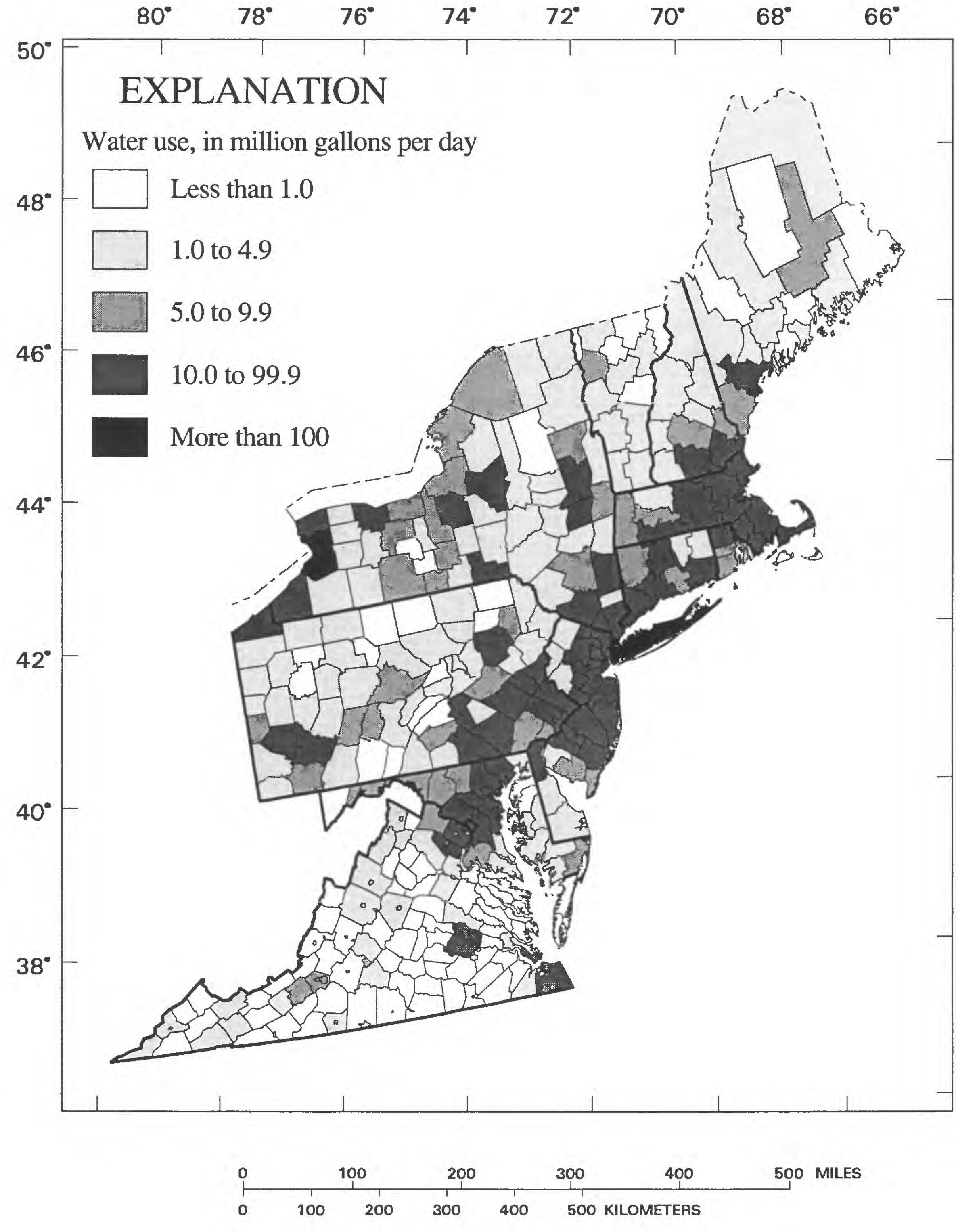

Figure 3. Public water-supply deliveries for domestic use (combined surface and ground water) by county, 1995. (Data from Price and Clawges, 1999.)

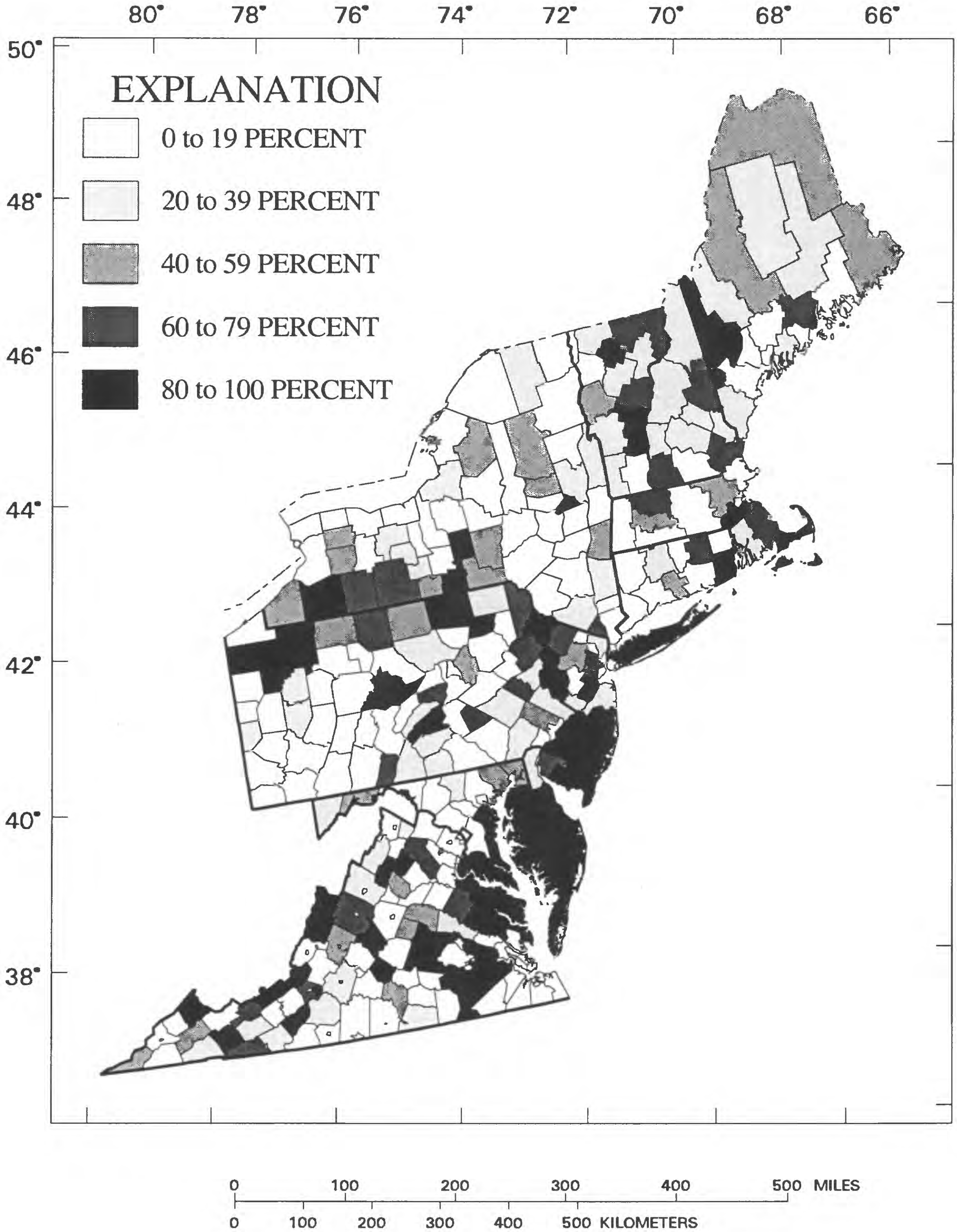

Figure 4. Percentage of total public water supplies from ground water by county, 1995. (Data from Price and Clawges, 1999.)

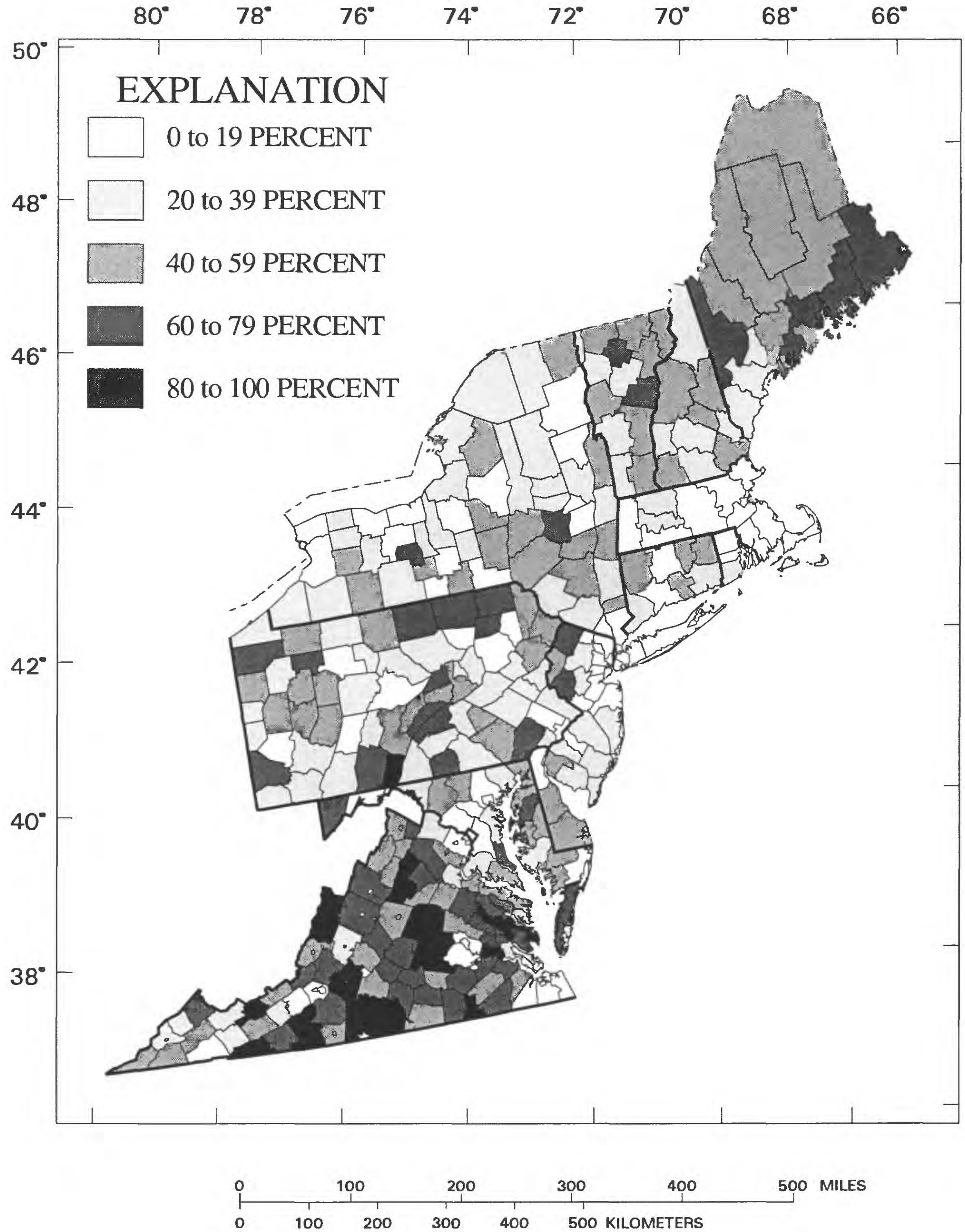

Figure 5. Percentage of total domestic water use from self-supplied ground-water sources by county, 1995. (Data from Price and Clawges, 1999.)

Description of Study Area

The study area (see fig. 1) includes the six New England States (Maine, Vermont, New Hampshire, Connecticut, Massachusetts, and Rhode Island), three Northeast States (New York, New Jersey, and Pennsylvania), and three Mid-Atlantic States (Delaware, Maryland, and Virginia) and Washington, D.C. The study area includes all or parts of 13 USGS NAWQA study units (fig. 6) that have already, or will during this assessment, collect ground-water samples for analysis of VOCs including MTBE. The 13 NAWQA study units, river basins studied, and year each study began are shown below.

The 12-State area encompasses more than 222,000 mi^2 and is extremely diverse, including parts of nine physiographic provinces: the Coastal Plain, Piedmont, Blue Ridge, New England Uplands, Valley and Ridge, Appalachian Plateaus, Adirondack Mountains, Central Lowlands, and the St. Lawrence Valley. Altitude ranges from more than 6,200 ft above sea level at Mount Washington in New Hampshire to sea level along the Atlantic seaboard. The climate is temperate and humid, with average annual precipitation between 30 and 60 in.

Bedrock in the study area ranges in age from Precambrian to early Mesozoic. Bedrock in the New England States primarily consists of folded and faulted igneous and metamorphic rocks that are present in north or northeast-trending belts (Olcott, 1995; Williams, 1978). Similar rocks comprise upland and mountainous belts of the Piedmont and Blue Ridge Provinces in eastern New York and Pennsylvania and extend south across central Virginia. Sedimentary rocks (sandstone, shale, and limestone) predominate in western New York, Pennsylvania, and Virginia. Mostly unconsolidated Coastal Plain sediments (Jurassic to Holocene) underlie southern New Jersey, much of Delaware and Maryland, and eastern Virginia (Trapp and Horn, 1997). Pleistocene glacial deposits mantle the bedrock and Coastal Plain sediments and partially fill valleys in New York, all of New England, and parts of northern New Jersey and Pennsylvania.

The five major types of aquifers in the study area reflect the lithologic composition and the degree of consolidation of the rocks and sediments that compose the aquifers (Trapp and Horn, 1997). Three of these are consolidated, bedrock aquifers with different lithologies—carbonate-rock (limestone and marble) aquifers, crystalline-rock (mostly igneous and metamorphic) aquifers, and sandstone aquifers; two consist of unconsolidated sediments—the North Atlantic Coastal Plain aquifers and the aquifers composed of glacial sand and gravel deposits. The most productive aquifers in the study area are those that underlie Long Island and the North Atlantic Coastal Plain from New Jersey to Virginia. This wedge of mostly unconsolidated sand aquifers separated by clay confining units, which dips and thickens to the east towards the Atlantic Ocean, supplies much of the total public water supplies in this part of the study area (see fig. 4). Surficial glacial aquifers composed of sand and gravel are the most productive aquifers in much of New York, northern New Jersey, and New England. Consolidated bedrock aquifers consist of carbonate rocks, sandstone, and crystalline rocks distributed throughout most of New England, Northern New Jersey, New York, Pennsylvania, and Virginia. Bedrock aquifers are the principal sources for self-supplied, domestic water use in the study area (see fig. 5).

Study unit:	River basins studied:	Year study began:
ALBE	Albemarle-Pamlico Drainages	1991
ALMN	Allegheny and Monongahela River Basins	1994
CONN	Connecticut, Housatonic, and Thames River Basins	1991
DELR	Delaware River Basin	1997
DLMV	Delmarva Peninsula	1986 (pilot study)
HDSN	Hudson River Basin	1991
KANA	Kanawha River Basin	1994
LERI	Lake Erie-Lake St. Clair Drainages	1994
LINJ	Long Island & New Jersey Coastal Drainages	1994
LSUS	Lower Susquehanna River Basin	1991
NECB	New England Coastal River Basins	1997
POTO	Potomac River Basin	1991
UTEN	Upper Tennessee River Basin	1994

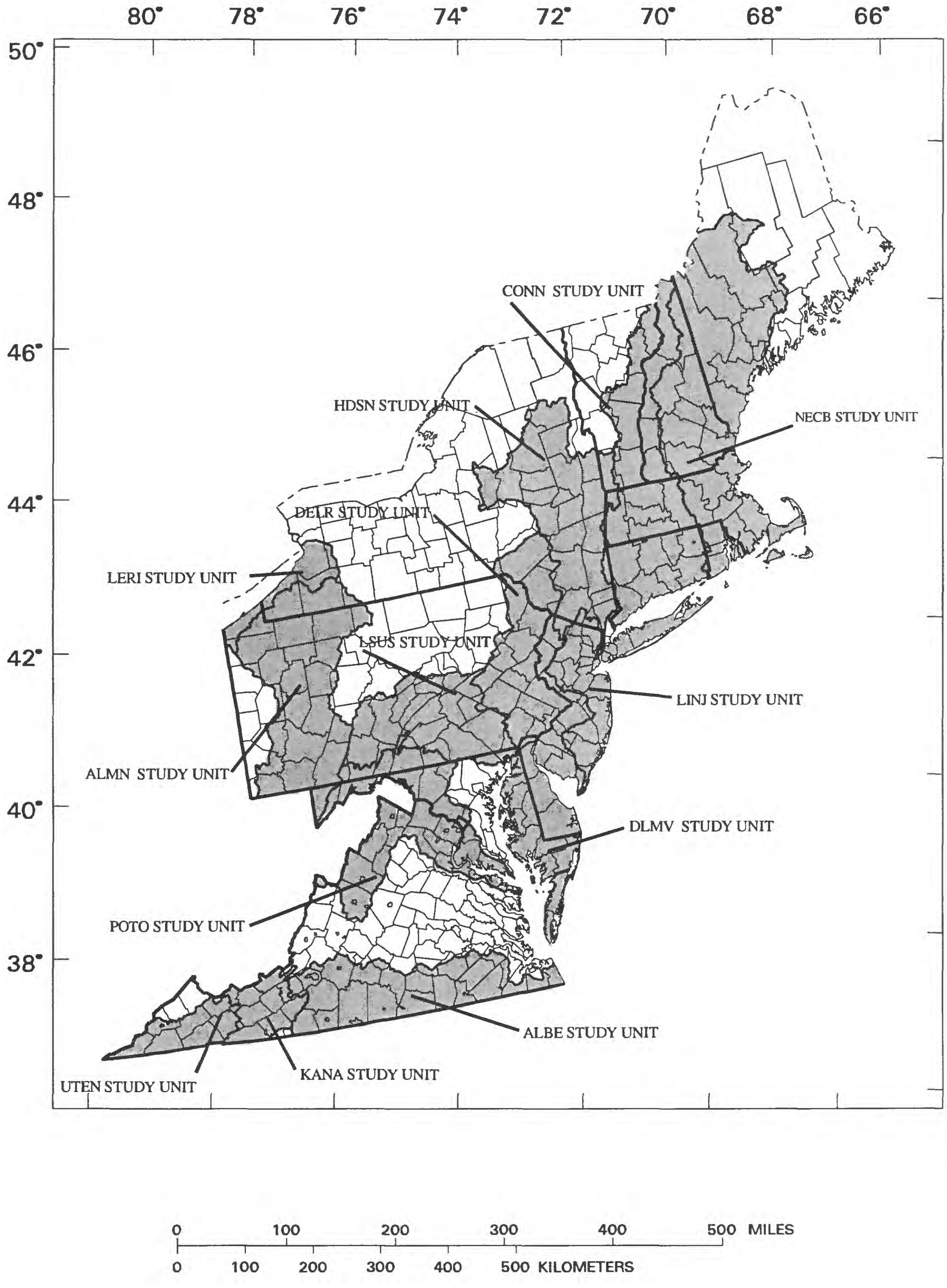

Figure 6. Distribution of U.S. Geological Survey National Water-Quality Assessment Program study units in the 12-State study area.

In 1995, about 64 million people or nearly one-quarter of the Nation's population lived in the 12-State study area (table 2) and most (about 85 percent) resided within the 44 metropolitan areas with populations exceeding 50,000 that are wholly or partially within the study area (U.S. Bureau of the Census, 1996). The population of 40 of these metropolitan areas exceeded 100,000 and 10 of these exceeded 1,000,000. Eight of the 12 States are among the 10 most densely populated States in the Nation (table 2) and contain extensive areas where population density equals or exceeds 1,000 people per square mile (fig. 7). The average population density of the 12-State region was 269 people per square mile in 1995, which was about 4 times the National average.

Overall, only about 11 percent of the 12-State area was urban land use in 1992 (table 3), but the distribution varied greatly among the States. Urban areas extended over nearly 40 percent of New Jersey in 1992 and more than 20 percent of Connecticut, Maryland, Massachusetts, and Rhode Island. The distribution of urban lands resembles the pattern of high-population-density areas (see fig. 7) as they are most concentrated along the coastal plain extending from the Boston, Massachusetts area to Washington, D.C. More than 80 percent of Maine, New Hampshire, and Vermont, however, remained undeveloped in 1992, with less than 10 percent urban lands in each of the three States.

Among the numerous potential sources for the release of VOCs to the environment in the Northeast and Mid-Atlantic regions are more than 221,000 active underground storage tanks (table 4), most of which contain petroleum products, principally gasoline. As of June 1, 1998 there had been 67,768 confirmed releases from tanks in the 12-State study area. A recent survey of State Leaking Underground Storage Tank (LUST) programs reported that MTBE was detected at LUST sites in at least 30 States, and detected at more than 60 percent of LUST sites in 18 of the States responding to the survey (Hitzig and others, 1998). Ten of the 12 States in the study area were among those reporting frequent MTBE detections at LUST sites and 7 States (see table 4), including Vermont, reported MTBE detections at 80 to 100 percent of LUSTs. The high frequency of MTBE detections at LUST sites in Vermont is notable as Vermont does not participate in either the reformulated or oxygenated gasoline programs.

Table 2. Population of the 12-State study area, 1995

[Source: Solley and others, 1998, p. 9; numbers may not add to total because of rounding]

State	Population, in thousands	Population density, people per square mile	Rank of population density
Connecticut	3,275	591	4
Delaware	717	288	7
Maine	1,241	35	36
Maryland	5,042	406	5
Massachusetts	6,074	575	3
New Hampshire	1,148	123	18
New Jersey	7,945	911	1
New York	18,136	333	6
Pennsylvania	12,072	262	8
Rhode Island	990	641	2
Vermont	585	61	30
Virginia[1]	7,172	167	15
Total	64,397	269	

[1]Includes 554,000 in the District of Columbia.

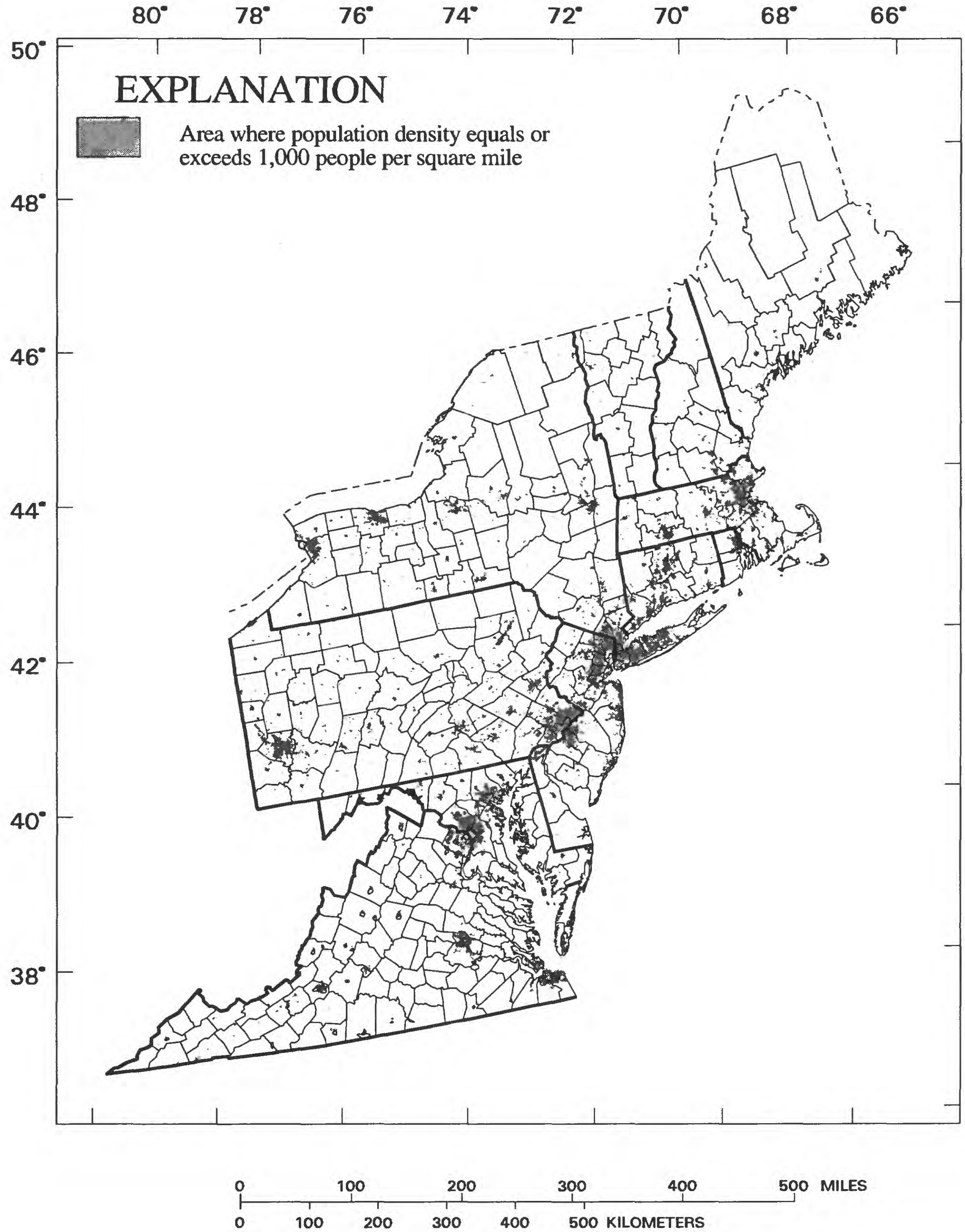

Figure 7. Areas where population density equals or exceeds 1,000 people per square mile. (Data from Price and Clawges, 1999.)

Table 3. Percentages of land use in the 12-State study area, 1992

[Data from U.S. Department of Agriculture, Economic Research Service web page http://usds.mannlib.cornell.edu/data-sets/land/89003]

State	Area, square miles	Land use[1], percent of area		
		Urban	Agricultural	Undeveloped
Connecticut	5,018	29.8	7.4	62.8
Delaware	2,044	13.9	40.4	45.7
Maine	33,265	3.4	3.3	93.4
Maryland	10,460	20.6	31.7	47.6
Massachusetts	8,284	31.1	5.5	63.4
New Hampshire	9,279	7.4	3.4	89.2
New Jersey	7,787	37.2	13.8	49.0
New York	49,108	9.6	19.7	70.7
Pennsylvania	45,308	9.3	22.1	68.6
Rhode Island	1,212	32.6	4.3	63.1
Vermont	9,614	3.1	13.3	83.6
Virginia[2]	40,767	8.2	24.7	67.1
Total	222,146	10.9	17.4	66.9

[1]Urban land use includes incorporated and unincorporated places of 2,500 population or more, defense and industrial areas, and highway, road, and railroad rights-of-way plus airport facilities; agricultural land use includes cultivated, harvested, idle, or fallow cropland and pasture, and farmsteads; and, undeveloped land use includes forest, rural parks and wildlife areas, and wetlands and bare rock.

[2]Includes the District of Columbia.

Table 4. Number of active underground storage tanks in the 12-State study area, June 1998

[Data from U.S. Environmental Protection Agency web page http://www.epa.gov/swerust1/cat/cam0698.htm] and R. Hitzig, U.S. Environmental Protection Agency, written commun., 1998]

State	Number of active tanks	Number of confirmed releases	Percent of sites reporting MTBE
Connecticut	16,777	1,712	80 - 100
Delaware	2,117	2,379	60 - 80
Maine	11,957	1,711	60 - 80
Maryland	19,261	13,522	60 - 80
Massachusetts	19,290	5,088	not reported
New Hampshire	3,777	1,795	80 - 100
New Jersey	28,646	6,768	80 -100
New York	39,110	14,531	80 -100
Pennsylvania	37,250	9,251	not reported
Rhode Island	2,422	1,079	80 - 100
Vermont	3,089	1,536	80 - 100
Virginia[1]	37,794	8,396	80 - 100
Total	221,490	67,768	

[1]Includes the District of Columbia.

APPROACH

Because this assessment will be conducted in two phases, two different but complementary study designs will be used. In general, both designs will involve a combination of two tasks—(1) inventorying and reviewing existing data on MTBE and other VOCs in public and private drinking-water supplies collected by water systems, State and local agencies, as well as data collected as part of previous or ongoing USGS, other Federal, or State water-quality sampling programs conducted in the 12-State area, and (2) analyzing and interpreting the water-quality data with available ancillary data.

A principal difference between the two efforts is the extent to which accurate locational data are needed to accomplish the objectives. The drinking-water assessment (phase 1) will assemble and statistically summarize data on the occurrence and distribution of MTBE and other VOCs in drinking water by source of water, size of system, and by State, and does not require accurate locational information on each water source to provide this information. In phase 1, available information will be used to the extent possible to characterize the occurrence and distribution of MTBE and other VOCs with respect to type of aquifer, use of RFG/OXY gasoline, or other factors as feasible. However, in phase 2, explanatory data analysis will be more closely tied to available GIS data for land use, population density, proximity to point sources, or other ancillary factors and will require accurate locational information on the source of water sampled. Consequently, the available data will been screened to include only data with sufficient locational and ancillary documentation.

Phase 1—Drinking-Water Assessment

Determining the frequency of detection and the range in concentrations of MTBE and other VOCs in drinking water requires an extensive and representative inventory of available water-quality data. The number, size, source, and location (by State) of PWSs selected for this assessment need to reflect the actual distribution of PWSs in the study area. However, there are more than 43,000 PWSs in the 12-State area, and a comprehensive review of drinking-water quality for all PWSs is not feasible. About one-quarter of the active PWSs are community water systems (CWSs) that provide water year round to the same consumer base of 25 people or more or have a minimum of 15 residential service connections. The remainder of the PWSs provide non-residential water supplies to schools, factories, and hospitals; these are referred to as nontransient noncommunity water systems (NTNCWS), or to campgrounds, motels, and restaurants, which are identified as transient noncommunity water systems (TNCWS). Consequently, a smaller, more manageable subset of CWSs will be targeted. A stratified, random design for the selection of participating CWSs will allow information developed on the occurrence and distribution of VOCs in drinking water, as well as statistical comparisons by State, source of water, and size of utility, to be extrapolated to the overall population of CWSs. Information on the location, filtration and treatment, water-distribution area, actual population served, and quantity of water delivered by suppliers also will be obtained where possible and will be used to further explain and compare the frequency of detection and concentration of VOCs in drinking water.

To extend the value of the information on drinking-water quality beyond occurrence and distribution of VOCs, additional ancillary data are needed. For surface-water sources, this includes accurate locations of intakes, the number, type, and location of any discharges to receiving surface-water bodies that are source waters for CWSs; land-use patterns in source surface-water basins; and locations of upwind releases of VOCs to the atmosphere. For ground-water sources, information is needed on the location of the supply well, the producing aquifer, depth to the open interval, and other construction characteristics of the well, well yield and contributing area to the well, land use, population density, locations of known or potential VOC sources (gasoline stations, dry cleaners, other commercial and industrial users), and other cultural and demographic information. It is anticipated that some of these data will be obtained during this assessment as part of an inventory of CWSs or as part of regional GIS coverages. However, it may be difficult to obtain or confirm some critical data elements, particularly the location of wells and surface-water intakes. Data for CWSs without this supporting information may be useful only for inclusion in the aggregate detection frequencies and concentrations observed.

Work Elements

Phase 1, the drinking-water assessment, will be accomplished with the following four work elements: (1) select representative CWSs, (2) inventory water-quality data from selected community water systems, (3) analyze water-quality data, and (4) summarize findings.

(1) Select Representative Community Water Systems

CWSs obtain water from surface-water sources—streams, rivers, lakes, and reservoirs—and (or) ground-water sources, treat it (where required) to meet drinking-water standards, and deliver the finished water to households and other customers for consumption. The USEPA (1995a) classifies CWSs by the number of people served:

Very large systems	Serve more than 100,000 people
Large systems	Serve 10,001 to 100,000 people
Medium systems	Serve 3,301 to 10,000 people
Small systems	Serve 501 to 3,300 people
Very small systems	Serve 500 or fewer people

Nationally, large and very large CWSs make up only about 6 percent of all systems, but collectively serve 79 percent of all CWS customers (U.S. Environmental Protection Agency, 1995a). Surface-water sources are used by 56 percent of the large and very large systems.

Information on the number of CWSs in the 12 States in the Northeast and Mid-Atlantic regions was retrieved from the USEPA's Safe Drinking Water Information System (SDWIS) data base (U.S. Environmental Protection Agency, 1995b) on December 1, 1997. This information was compiled by State, principal source of water, and four size categories of population served (table 5). A total of 10,470 CWSs provided drinking water in the 12 Northeast and Mid-Atlantic States on December 1, 1997. Their geographic distribution reflects to some extent the size and population of each State; New York and Pennsylvania have nearly 50 percent of the CWSs, whereas Delaware and Rhode Island have just 3 percent of the total.

In table 5, CWSs were reclassified into four categories by size:

Very large systems	Serve more than 50,000 people
Large systems	Serve 3,301 to 50,000 people
Medium systems	Serve 501 to 3,300 people
Very small systems	Serve 500 or fewer people

This change was intended to allow at least 30 CWSs within each category for statistical purposes. Only about 1 percent of the water systems fall into the very large (more than 50,000 people served) category, whereas nearly two-thirds (66 percent) serve 500 or fewer people. About 80 percent of all CWSs in the study area use ground water as the principal source of water but because most of these are small systems, collectively ground water provides only about 25 percent of public water supplies.

Table 5. Distribution of community water systems by State, principal source of water, and population served in the 12-State study area, 1997

[Community water supplies are public and private water systems that furnish water year round to at least 25 people, or that have a minimum of 15 service connections. Data from U.S. Environmental Protection Agency's SDWIS data base (M.A. Horn, U.S. Geological Survey, written commun., 1997)]

State	Number of community water systems							
	Principal source of water		Population served				Total	Percent
	Surface water	Ground water	More than 50,000	3,301 to 50,000	501 to 3,300	25 to 500		
Connecticut	59	541	10	44	55	491	600	5.7
Delaware	3	226	3	9	44	173	229	2.2
Maine	81	319	1	31	93	275	400	3.8
Maryland	57	450	7	48	109	343	507	4.8
Massachusetts	168	357	24	218	80	203	525	5.0
New Hampshire	52	618	2	31	84	553	670	6.4
New Jersey	94	517	22	207	132	250	611	5.8
New York	749	1,940	29	294	602	1,764	2,689	25.7
Pennsylvania	436	1,777	32	278	508	1,395	2,213	21.1
Rhode Island	22	59	5	21	8	47	81	0.8
Vermont	73	361	1	28	84	321	434	4.1
Virginia[1]	265	1,255	18	109	261	1,132	1,520	14.5
Total (percent)	2,059 (19.6)	8,420 (80.4)	154 (1.5)	1,318 (12.6)	2,060 (19.6)	6,947 (66.3)	10,470 (100)	100

[1]Includes District of Columbia

A relatively large and representative sample of CWSs will be included in the inventory to accomplish the drinking-water assessment and provide USEPA with information on the frequency of detection and concentration of VOCs in drinking water that will help quantify the extent of human exposure. The assessment will attempt to inventory data on VOCs in drinking water for 2,110 CWSs or about 20 percent of all CWSs in the study area. A stratified random approach was used to define the number of systems to be inventoried based on geographic distribution of systems by State, source of water, and population served. The stratified random design (table 6) distributes the 2,110 CWSs among the 12 States by source and size in direct proportion to their actual distribution (see table 5). The number of CWSs to be included in Rhode Island (16), however, was augmented by 14 to obtain a total of 30 systems from that State; the extra 14 CWSs are allocated in the same proportion as the original 16 systems and were needed to have sufficient numbers for valid statistical analysis of the data.

Because there are relatively few (154) very large CWSs and they serve a large percentage of the population in the study area, some additional effort might be well spent to inventory data from a disproportionately large number of these. It is likely that these systems will have more water-quality data than smaller systems because their monitoring requirements are generally more extensive, they have the resources to collect extra samples and analyze for additional contaminants, and they may have more electronic data storage. However, data on VOCs in water from the largest suppliers may be less likely to represent water-quality conditions of all CWSs because the largest suppliers often obtain water from surface-water or mixed surface-water/ground-water sources. Consequently, if over-sampling were targeted at the largest CWSs, the results would need to be presented separately to the overall frequency of VOCs in drinking water. In addition, the largest systems often have the capacity to shift sources if contaminant problems are related to one well or intake, and they likely have more advanced or extensive filtration and treatment facilities and more complex distribution systems. Detailed information on these factors would be needed for each large utility inventoried. If additional large CWSs were included, a corresponding reduction in the number of smaller systems would be needed to balance the additional work within the available time and fiscal resources.

Table 6. Target number of community water systems to be inventoried by State, source of water, and population served

[Community water systems are public and private water systems that furnish water year round for domestic use to at least 25 people, or that have a minimum of 15 service connections. Target number of community water systems is proportional to actual distribution except for Rhode Island, where the number of systems is increased from 14 to 30 to obtain minimum number valid for statistical analysis]

State	Number of community water systems						Total	Percent
	Source of water		Population served					
	Surface water	Ground water	More than 50,000	3,301 to 50,000	501 to 3,300	25 to 500		
Connecticut	12	108	2	9	11	98	120	5.7
Delaware	1	45	1	2	9	34	46	2.2
Maine	16	64	0	6	19	55	80	3.8
Maryland	11	90	1	10	22	68	101	4.8
Massachusetts	34	71	5	44	16	40	105	5.0
New Hampshire	10	124	0	6	17	111	134	6.4
New Jersey	19	103	4	41	27	50	122	5.8
New York	150	388	6	59	120	353	538	25.5
Pennsylvania	87	356	6	56	102	279	443	21.0
Rhode Island	8	22	2	8	3	17	30	1.4
Vermont	15	72	0	6	17	64	87	4.1
Virginia	53	251	4	22	52	226	304	14.4
Total (percent of)	416 (19.7)	1,694 (80.3)	31 (1.5)	269 (12.7)	415 (19.7)	1,395 (66.1)	2,110 (100)	100

Other stratification factors that could also be considered in the design of the CWS inventory include population density, land use, the areal extent of oxygenated and reformulated gasoline use, and the type of aquifer developed for drinking-water supplies. However, accurate locational information would be needed to stratify on these factors. By obtaining a random 20 percent sample (2,110) of all CWSs the sample population may be sufficiently large to allow valid statistical inference among some of these "environmental" categories. Additional data on the extent of distribution area, number of different source(s) of water and volumes mixed, type of treatment, sampling protocols, analytical methods, and quality assurance/quality control procedure also will be collected when possible to allow a more complete analysis and to extend the findings of this assessment.

(2) Inventory water-quality data from selected CWSs

The availability of water-quality data on VOCs for PWSs in each of the 12 States in the study area is summarized in appendix 2. The information in appendix 2 is largely based on telephone surveys of State health and water-supply agencies and has not been confirmed by any review of actual data. In addition, information previously compiled by the USEPA (Gould, 1996) and for the USGS's NAWQA Program (M.J. Moran, U.S. Geological Survey, 1997, written commun.; Robinson and Horn, 1998) on the availability of water-quality data from PWSs and other sources is included in appendix 2.

Chemical analyses for 21 regulated VOCs (plus EDB and DBCP) and 21 unregulated VOCs (appendix 1) are determined routinely for most PWSs. Additional analyses for 14 other unregulated VOCs (appendix 1) may be required at the discretion of individual States. However, MTBE is not presently regulated under the SDWA, and routine monitoring for MTBE is not required. Some State or local agencies and individual water systems have collected MTBE data as part of their PWS monitoring or a specific sampling effort that targets PWSs in areas where MTBE might be expected to occur (near gasoline stations). Ten States are known to have MTBE data for at least some CWSs, while two States (Delaware and Pennsylvania) reportedly do not have any data on MTBE in drinking water.

During a preliminary inventory for this study, 7 States (Connecticut, Maine, Maryland, Massachusetts, Rhode Island, Vermont, and Virginia) reported that MTBE was detected in drinking water from at least 200 PWSs through 1997 (see appendix 2). Because a stratified random selection of CWS may exclude some available data sets on MTBE, efforts will be made to obtain data for any sites or systems with MTBE analyses that would help to define the occurrence and distribution of this compound in drinking water. These additional MTBE data, however, would not be used for statistical analyses.

(3) Analyze water-quality data

Statistical summaries of the data will be prepared that will report the frequency of detection, concentration range, and median and other quantile concentrations for all VOCs included in the water-quality data. This information will be summarized and presented relative to the total number of CWSs and the total number of drinking-water samples for the 12-State region collectively and for each individual State. The data will also be summarized to present the occurrence and distribution of MTBE and other VOCs in relation to the source of drinking water and to each population-served category. Estimates of the total number of people exposed to individual and co-occurring VOCs will be made based on data on the actual population served by those CWSs reporting VOC detections. Maps will be prepared showing the locations of drinking-water sources (wells and surface-water intakes) where MTBE and selected other VOCs have been sampled and locations of sources where these compounds have been detected.

(4) Summarize findings

The product of the drinking-water assessment (Phase 1) will be a report that will describe the location, frequency, and extent of human exposure to MTBE and other VOCs in public drinking-water supplies. The report will summarize the number, frequency, and concentration of VOCs detected in drinking water in the Northeast and Mid-Atlantic regions and will include statistical summaries (tables and graphs) and maps showing the areal distribution of sites, sources, and systems with VOC detections.

Phase 2—Ambient Ground-Water Assessment

Data on VOCs in ground water have been collected by the USGS as part of past and ongoing NAWQA study-unit investigations. Frequently, these data were purposely collected or screened to identify sites which have the necessary ancillary data to support a more complete analysis of cause and effect factors associated with water-quality conditions. Data collected by the pilot, 1991, and 1994 study units will be assembled with data previously identified for inclusion in the NAWQA National VOC ground-water retrospective data base (Lapham and Tadayon, 1996). Additional data will be sought from USGS District offices and State monitoring agencies to provide more complete areal and temporal coverage in the study area.

Work Elements

The ambient ground-water assessment will be accomplished with the following four work elements: (1) inventory data on ambient ground-water quality, (2) compile ancillary data, (3) analyze water-quality and ancillary data, and (4) summarize findings.

(1) Inventory Data on Ambient Ground-Water Quality

The inventory of data on VOCs in ambient ground water will be limited by the availability of suitable data. The well-network design criteria outlined by Lapham and Tadayon (1996) will be used to screen available data sets. Data that conform best to network criteria have been collected mostly by the USGS for NAWQA study-unit survey ground-water networks and for other USGS sampling efforts. The NAWQA and other USGS data have field-verified site locations and generally complete well construction and hydrogeologic information. Samples from these wells were analyzed for a broad suite of VOCs (60 to about 90 analytes) including MTBE and, in some analyses, other fuel oxygenates or their degradation products. Data collected by State and local agencies for SDWA requirements and other monitoring programs also may be used to evaluate ambient ground-water quality if ancillary data are sufficiently complete, and site selection was not biased to known or suspected water-quality problem areas. For example, data for NTNCWSs) and domestic wells, where unfiltered or untreated water may be sampled, may provide information that would allow this assessment to extend beyond the relatively limited data available from USGS studies.

Private domestic-water supplies are required to obtain a "potability" test prior to local issue of a certificate of occupancy. Generally, most State or local health agencies require only bacteria, nitrate, or a few additional general characteristics of the water to be determined, but VOCs were measured for some wells where evidence (odor, taste) or the risk of contamination (proximity to underground storage tanks or other known point sources) was judged to be significant. Several counties in New Jersey require homeowners to test well water for VOCs as a condition of the sale of the property.

The availability of water-quality data on VOCs in ambient ground water in each of the 12 States in the study area is summarized in appendix 3. Study staff have contacted USGS District offices and NAWQA study-unit staff, State and local health and water supply agencies, and have reviewed information previously compiled by the USEPA (Gould, 1996) and for the USGS's NAWQA Program (M.J. Moran, U.S. Geological Survey, 1997, written commun.) for data that might be useful to describe water quality from ambient ground-water sources.

(2) Compile Ancillary Information

Regionally consistent data layers for physiographic, geologic, hydrologic, and cultural information will be needed for this assessment to conduct analysis of water-quality data in relation to ancillary data, and to facilitate presentation of the retrospective data and assessment findings. A brief discussion of the type and status of each needed data layer is included below.

Hydrography. It is necessary to illustrate the distribution of surface-water sources inventoried for this assessment with respect to the major drainage features of the study area. The location of reservoirs and other surface-water-sources will be shown in relation to streams and other water bodies on 1:100,000-scale digital line graph hydrography compiled for the USGS's and the USEPA's 1:100,000-scale National Hydrography Data Set. This GIS coverage (formerly the USEPA's Reach File Version 3) contains unique stream reach identification codes for each stream segment that can be used to determine upstream/downstream relations and other stream-reach attributes that support geospatial analysis.

Hydrogeology. Regional delineation of five major aquifers or aquifer systems in the study area have been compiled using nationally consistent definitions of the hydrogeologic environment from the "National Ground-Water Atlas" series of reports (Olcott, 1995; Trapp and Horn, 1997). These include the surficial aquifer system, the Northern Atlantic coastal plain aquifer system, the carbonate-rock aquifers, sandstone aquifers, and crystalline-rock aquifers. The coverage also includes areas of New York and northern Pennsylvania underlain largely by shale and areas of the Piedmont and Blue Ridge physiographic provinces in Virginia, Maryland, and Pennsylvania underlain by crystalline bedrock, generally not considered to be major aquifers because well yields seldom exceed 15 gal/min. Water-quality data for public-supply wells and other wells included in the retrospective data base will be compared by aquifer, depth of well, depth to water, depth of the screened or open interval, yield, and other hydrogeologic variables to the extent that the ancillary data will allow.

Land Use. The occurrence and distribution of MTBE and other VOCs in ground water and stormwater runoff are reported to be strongly associated with urban land use (Delzer and others, 1996; Squillace and others, 1996; Grady, 1997). General information on the characteristics and distribution of the principal land uses in the study area, and on urban land use in particular, is a critical coverage for this assessment. Presently, the only nationally consistent geographic data base for land use is the GIRAS digital data from 1:100,000- and 1:250,000-scale maps that were developed during the 1970's to mid 1980's (U.S. Geological Survey, 1990). However, the GIRAS data have been updated to include new areas of urban growth estimated from 1990 census block-group data (Hitt, 1994) for large parts of the study area included in NAWQA study-unit investigations. Similar updates are needed for those parts of the 12-State area (a total of 50,300 mi^2) that are outside NAWQA study units to obtain a consistent and detailed land-use coverage for the study area.

Alternatively, digital land-cover information were compiled and interpreted for some NAWQA study units from Landsat thematic mapper (TM) satellite data. Although the TM data depict conditions in 1992 plus or minus 1 year, interpretations among different study units have not always been consistent. The USGS Land Cover Characterization Program (U.S. Geological Survey, 1997) is scheduled to complete a national TM coverage (National Land Cover Dataset) in 1999; this coverage includes two urban categories—high-intensity urban (a mixture of industrial, commercial, and high-density residential) and low-intensity urban (medium-density residential). However, completion of the National Land Cover Dataset is not scheduled until October 1999, and coverage of the study area may not be available for use until late in the assessment.

Population Density. The occurrence of VOCs in ground water is related to population density as well as land use (Eckhardt and others, 1989; Eckhardt and Stackelberg, 1995; Grady, 1997). A 1990 population density equal to or greater than 1,000 people per square mile (see fig. 7) was used as an "urban" indicator for updating 1970's land use coverage (Hitt, 1994). Detailed population density data are available for the entire study area from intersecting 1990 census block-group polygons with a 1-square kilometer base grid. Information on the population density of areas surrounding PWS sources and ambient ground-water-quality sites will be obtained, compared for areas with and without VOC detections, and possibly used to derive quantifiable relations between VOC concentrations or detection frequencies and population density.

Contaminant Source Data. Information on the location of PWS wells, surface-water intakes, and ambient ground-water sample sites (with respect to facilities of known or potential use and release of VOC contaminants) may provide insight as to the actual source and transport processes that affect the occurrence of VOCs in water samples from these sites. Information on the location, type, history, and volume of contaminants leaked, spilled, or released from point sources is available from a variety of local, State, USEPA, and other databases and GIS coverages. The STARVIEW Real Estate 2.5 environmental risk site data system (Vista Information Solutions, 1999) was obtained by the VOC National Synthesis Project. The STARVIEW data include location and attributes of permitted waste treatment, storage, and disposal facilities on (or under review for) the USEPA's National Priorities List, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) lists, and Resource Conservation and Recovery Act (RCRA) lists or equivalent sites identified on State lists; solid waste landfills, incinerators, and transfer stations; leaking underground storage tanks and registered above-ground and underground storage tanks; RCRA-registered large and small hazardous waste generators; Toxic Release Inventory sites and quantities released (U.S. Environmental Protection Agency, 1995c); and sites where spills have been identified by the Emergency Response Notification System. Locations of potential contaminant sources that are within 1/8-, 1/4-, 1/2- and 1-mi of any latitude and longitude coordinates can be retrieved and plotted. Information on potential VOC sources near inventoried PWSs and ambient ground-water-quality sites will be evaluated to identify factors that could explain the occurrence of contaminants.

(3) Analyze water-quality and ancillary data

The ambient ground-water-quality data will be assembled into an electronic data base with cross reference to location (latitude and longitude, if available), State, source of water, and size of utility (population served). Statistical and graphical techniques will be used to analyze and present the data. Statistical summaries, histograms, and (or) boxplots of the frequency of detection, range of concentrations, and median concentrations of VOCs will be prepared. Contingency-table tests will be used to compare the frequency of VOC detections among various stratification categories or other categorical explanatory variables (for example, MTBE used or not, aquifer type, land use) where the ancillary and analytical data allow. For data that can be evaluated with respect to a continuous explanatory variable (population density, depth of well, proximity to potential source), principal-component analysis, and logistic-regression models will be applied.

(4) Summarize findings

The product of the ambient ground-water assessment (Phase 2) will be an interpretive report that will identify human and natural factors associated with occurrence and distribution of MTBE and other VOCs in ambient ground water and, to the extent possible, drinking water. The report will compare the frequency and concentration of VOCs in ambient ground water and drinking water by factors such as land use, MTBE use, population density, or other anthropogenic variables, and by aquifer system, well type, well depth, water-table conditions, water use, or other hydrogeologic variables. This report will identify and quantify, to the extent possible, relations between VOC occurrence and distribution and human and natural factors in the Northeast and Mid-Atlantic regions.

SUMMARY

A plan was designed to assess the occurrence and distribution of MTBE and other VOCs in drinking water and ambient ground water in the Northeast and Mid-Atlantic regions of the United States. This area was selected because it has a large population, extensive urban and industrial development, and widespread use and release of many VOCs. This region comprises the largest contiguous area outside of California where use of the gasoline additive MTBE is used to meet requirements of the Clean Air Act Amendments of 1990.

MTBE and other VOCs were targeted because they were widely detected in samples of shallow ground water collected by the USGS's NAWQA Program. Nearly one-fifth of 1,650 wells sampled through 1996 contained one or more VOCs; chloroform and MTBE were the most frequently detected VOCs in the NAWQA samples. Detections of MTBE were reported in ambient ground water in at least 8 of the 12 States included in this study (Connecticut, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and Virginia). MTBE also was reported in public drinking-water supplies in at least 7 of these States (Connecticut, Maine, Maryland, Massachusetts, Rhode Island, Vermont, and Virginia). However, a regional or national drinking-water database of MTBE or other VOC occurrence does not yet exist. Consequently, information about the areal and temporal distribution of MTBE and other VOCs in drinking water and ambient ground water or their relation to natural and human factors presently cannot be determined.

The study will proceed in two phases—a drinking-water assessment (phase 1) and an ambient ground-water assessment (phase 2). The drinking-water assessment will compile, review, and analyze available water-quality data for approximately 20 percent of the community water systems in 12 States in the Northeast and Mid-Atlantic regions. The occurrence and distribution of MTBE and other VOCs in drinking water supplied by 2,110 community water systems will be evaluated. The ambient ground-water assessment will compile water-quality and ancillary data from previous USGS NAWQA studies and other available State or local datasets. These data will be related to land-use patterns, population density, and other anthropogenic and natural factors using statistical hypothesis tests. The occurrence and distribution of MTBE and other VOCs in ambient ground water and, to the extent possible, drinking water in relation to such factors, will be evaluated.

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APPENDIXES

Appendix 1. Volatile organic compounds included in U.S. Geological Survey National Water-Quality Laboratory Schedules and in analyses of public drinking-water supplies as required by the Safe Drinking Water Act

[USEPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; CAS, Chemical Abstract Services; VOC, volatile organic compound; y, yes (analyzed by USGS); yr, regulated compound required by Safe Drinking Water Act (SDWA); yur, unregulated compound required by SDWA; ysd, unregulated compound required at the discretion of the State; n, not analyzed by USGS or not required by SDWA; c, included on USEPA's Drinking Water Contaminant Candidate List (Federal Register, March 2, 1998, v. 63, no. 40, p. 10274-10287)]

USGS parameter code	CAS number	VOC compound	Common or trade name(s)	Compound class	USGS schedule number 2090	USGS schedule number 2020	SDWA
30217	74-95-3	Dibromomethane	Methylene dibromide	Halogenated Alkane	y	y	yur
32101	75-27-4	Bromodichloromethane	Dichlorobromomethane	Halogenated Alkane	y	y	yur
32102	56-23-5	Tetrachloromethane	Carbon tetrachloride	Halogenated Alkane	y	y	yr
32103	107-06-2	1,2-Dichloroethane	Ethylene dichloride	Halogenated Alkane	y	y	yr
32104	75-25-2	Tribromomethane	Bromoform	Halogenated Alkane	y	y	yur
32105	124-48-1	Chlorodibromomethane	Dibromochloromethane	Halogenated Alkane	y	y	yur
32106	67-66-3	Trichloromethane	Chloroform	Halogenated Alkane	y	y	yur
34010	108-88-3	Methylbenzene	Toluene	Alkyl Benzene	y	y	yr
34030	71-43-2	Benzene		Aromatic Hydrocarbon	y	y	yr
34210	107-02-8	2-Propenal	Acrolein	Oxy Alkene	n	y	n
34215	107-13-1	2-Propenenitrile	Acrylonitrile	Nitro Alkene	n	y	n
34301	108-90-7	Chlorobenzene	Monochlorobenzene	Halogenated Aromatic	y	y	yr
34311	75-00-3	Chloroethane	Ethyl chloride	Halogenated Alkane	y	y	yur
34371	100-41-4	Ethylbenzene	Phenylethane	Alkyl Benzene	y	y	yr
34396	67-72-1	1,1,1,2,2,2-Hexachloroethane	Hexachloroethane	Halogenated Alkane	n	y	n
34413	74-83-9	Bromomethane	Methyl bromide	Halogenated Alkane	y	y	yur, c
34418	74-87-3	Chloromethane	Methyl chloride	Halogenated Alkane	y	y	yur
34423	75-09-2	Dichloromethane	Methylene chloride	Halogenated Alkane	y	y	yr
34475	127-18-4	Tetrachloroethene	Perchloroethene	Halogenated Alkene	y	y	yr
34488	75-69-4	Trichlorofluoromethane	CFC 11, Freon 11	Halogenated Alkane	y	y	ysd
34496	75-34-3	1,1-Dichloroethane	Ethylidene dichloride	Halogenated Alkane	y	y	yur, c
34501	75-35-4	1,1-Dichloroethene	Vinylidene chloride	Halogenated Alkene	y	y	yr
34506	71-55-6	1,1,1-Trichloroethane	Methylchloroform	Halogenated Alkane	y	y	yr
34511	79-00-5	1,1,2-Trichloroethane	Vinyl trichloride	Halogenated Alkane	y	y	yr
34516	79-34-5	1,1,2,2-Tetrachloroethane	sym-Tetrachloroethane	Halogenated Alkane	y	y	yur, c
34536	95-50-1	1,2-Dichlorobenzene	*o*-Dichlorobenzene, 1,2-DCB	Halogenated Aromatic	y	y	yr
34541	78-87-5	1,2-Dichloropropane	Propylene dichloride	Halogenated Alkane	y	y	yr
34546	156-60-5	*trans*-1,2-Dichloroethene	(E)-1,2-Dichloroethene	Halogenated Alkene	y	y	yr
34551	120-82-1	1,2,4-Trichlorobenzene		Halogenated Aromatic	y	y	yr

Appendix 1. Volatile organic compounds included in U.S. Geological Survey National Water-Quality Laboratory Schedules and in analyses of public drinking-water supplies as required by the Safe Drinking Water Act--Continued

[USEPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; CAS, Chemical Abstract Services; VOC, volatile organic compound; y, yes (analyzed by USGS); yr, regulated compound required by Safe Drinking Water Act (SDWA); yur, unregulated compound required by SDWA; ysd, unregulated compound required at the discretion of the State; n, not analyzed by USGS or not required by SDWA; c, included on USEPA's Drinking Water Contaminant Candidate List (Federal Register, March 2, 1998, v. 63, no. 40, p. 10274-10287)]

USGS parameter code	CAS number	VOC compound	Common or trade name(s)	Compound class	USGS schedule number 2090	2020	SDWA
34566	541-73-1	1,3-Dichlorobenzene	*m*-Dichlorobenzene	Halogenated Aromatic	y	y	yur
34571	106-46-7	1,4-Dichlorobenzene	*p*-Dichlorobenzene, 1,4-DCB	Halogenated Aromatic	y	y	yr
34668	75-71-8	Dichlorodifluoromethane	CFC 12, Freon 12	Halogenated Alkane	y	y	ysd
34696	91-20-3	Naphthalene		Aromatic Hydrocarbon	y	y	ysd, c
34699	10061-02-6	*trans*-1,3-Dichloropropene	(E)-1,3-Dichloropropene	Halogenated Alkene	y	y	yur, c
34704	10061-01-5	*cis*-1,3-Dichloropropene	(Z)-1,3-Dichloropropene	Halogenated Alkene	y	y	yur, c
39175	75-01-4	Chloroethene	Vinyl Chloride	Halogenated Alkene	y	y	yr
39180	79-01-6	Trichloroethene	TCE	Halogenated Alkene	y	y	yr
39702	87-68-3	Hexachlorobutadiene		Halogenated Alkene	y	y	ysd, c
49991	96-33-3	Methyl acrylate	Methyl propenoate	Oxy Alkene	n	y	n
49999	488-23-3	1,2,3,4-Tetramethylbenzene	Prehnitene	Alkyl Benzene	n	y	n
50000	527-53-7	1,2,3,5-Tetramethylbenzene	Isodurene	Hydrocarbon	n	y	n
50002	593-60-2	Bromoethene	Vinyl bromide	Halogenated Alkene	n	y	n
50004	637-92-3	Ethyl *tert*-butyl ether	ETBE	Cyclic Ether	n	y	n
50005	994-05-8	*tert*-Amyl methyl ether	TAME	Cyclic Ether	n	y	n
73547	110-57-6	*trans*-1,4-Dichloro-2-butene	2-Butylene dichloride	Halogenated Alkene	n	y	n
73570	97-63-2	Ethyl methacrylate	Ethyl 2-methyl propenoate	Oxy Alkene	n	y	n
77041	75-15-0	Carbon disulfide	Carbon sulfide	Sulfur Alkane	n	y	n
77057	108-05-4	Vinyl Acetate	Ethenyl ethanoate	Oxy Alkene	n	y	n
77093	156-59-2	*cis*-1,2-Dichloroethene	(Z)-1,2-Dichloroethene	Halogenated Alkene	y	y	yr
77103	591-78-6	2-Hexanone	Butyl methyl ketone (MBK)	Ketone	n	y	n
77128	100-42-5	Ethenylbenzene	Styrene	Aromatic Hydrocarbon	y	y	yr
77135	95-47-6	1,2-Dimethylbenzene	*o*-Xylene	Alkyl Benzene	n	y	n
77168	563-58-6	1,1-Dichloropropene		Halogenated Alkene	y	y	yur, c
77170	594-20-7	2,2-Dichloropropane		Halogenated Alkane	y	y	yur, c
77173	142-28-9	1,3-Dichloropropane	Trimethylene dichloride	Halogenated Alkane	y	y	yur, c
77220	611-14-3	2-Ethyltoluene	1-Ethyl-2-methyl benzene	Alkyl Benzene	n	y	n
77221	526-73-8	1,2,3-Trimethylbenzene	Hemimellitene	Alkyl Benzene	n	y	n
77222	95-63-6	1,2,4-Trimethylbenzene	Pseudocumene	Alkyl Benzene	y	y	ysd, c
77223	98-82-8	Isopropyl(1-Methyethyl)benzene	Cumene	Alkyl Benzene	y	y	ysd

Appendix 1. Volatile organic compounds included in U.S. Geological Survey National Water-Quality Laboratory Schedules and in analyses of public drinking-water supplies as required by the Safe Drinking Water Act--Continued

[USEPA, U.S. Environmental Protection Agency; USGS, U.S. Geological Survey; CAS, Chemical Abstract Services; VOC, volatile organic compound; y, yes (analyzed by USGS); yr, regulated compound required by Safe Drinking Water Act (SDWA); yur, unregulated compound required by SDWA; ysd, unregulated compound required at the discretion of the State; n, not analyzed by USGS or not required by SDWA; c, included on USEPA's Drinking Water Contaminant Candidate List (Federal Register, March 2, 1998, v. 63, no. 40, p. 10274-10287)]

USGS parameter code	CAS number	VOC compound	Common or trade name(s)	Compound class	USGS schedule number		SDWA
					2090	2020	
77224	103-65-1	*n*-Propylbenzene	Isocumene	Alkyl Benzene	y	y	ysd
77226	108-67-8	1,3,5-Trimethylbenzene	Mesitylene	Alkyl Benzene	y	y	ysd
77275	95-49-8	1-Chloro-2-methylbenzene	*o*-Chlorotoluene	Halogenated Aromatic	y	y	yur
77277	106-43-4	1-Chloro-4-methylbenzene	*p*-Chlorotoluene	Halogenated Aromatic	y	y	yur
77297	74-97-5	Bromochloromethane	Methylene chlorobromide	Halogenated Alkane	y	y	ysd
77342	104-51-8	*n*-Butylbenzene	1-Phenylbutane	Alkyl Benzene	y	y	ysd
77350	135-98-8	(1-Methylpropyl)benzene	*sec*-Butylbenzene	Alkyl Benzene	y	y	ysd
77353	98-06-6	(1,1-Dimethylethyl)benzene	*tert*-Butylbenzene	Alkyl Benzene	y	y	ysd
77356	99-87-6	1-Isopropyl-4-methylbenzene	*p*-Cymene	Alkyl Benzene	y	y	ysd, c
77424	74-88-4	Iodomethane	Methyl iodide	Halogenated Alkane	n	y	n
77443	96-18-4	1,2,3-Trichloropropane	Allyl trichloride	Halogenated Alkane	y	y	yur
77562	630-20-6	1,1,1,2-Tetrachloroethane	1,1,1,2-TeCA	Halogenated Alkane	y	y	yur
77613	87-61-6	1,2,3-Trichlorobenzene	1,2,3-TCB	Halogenated Aromatic	y	y	ysd
77651	106-93-4	1,2-Dibromoethane	Ethylene dibromide, EDB	Halogenated Alkane	y	y	yr
77652	76-13-1	1,1,2-Trichloro-1,2,2-trifluoroethane	Freon 113, CFC 113	Halogenated Alkane	y	y	n
78032	1634-04-4	Methyl *tert*-butyl ether	MTBE	Cyclic Ether	y	y	c
78109	107-05-1	3-Chloro-1-propene	Allyl chloride	Halogenated Alkene	n	y	n
78133	108-10-1	4-Methyl-2-pentanone	Isobutyl methyl ketone (MIK)	Ketone	n	y	n
81551	1330-20-7	Xylenes, Total	Xylenes (total)	Alkyl Benzene	y	n	yr
81552	67-64-1	Acetone	2-Propanone	Oxy Alkane	n	y	c
81555	108-86-1	Bromobenzene	Phenyl bromide	Halogenated Aromatic	y	y	yur, c
81576	60-29-7	Diethyl ether	Ethyl ether	Ether	n	y	n
81577	108-20-3	Diisopropyl ether	DIPE	Cyclic Ether	n	y	n
81593	126-98-7	Methyl acrylonitrile	2-Methyl-2-propenenitrile	Nitro Alkene	n	y	n
81595	78-93-3	2-Butanone	Ethyl methyl ketone (MEK)	Ketone	n	y	n
81597	80-62-6	Methyl methacrylate		Oxy Alkene	n	y	n
81607	109-99-9	Tetrahydrofuran		Cyclic Alkane	n	y	n
82625	96-12-8	1,2-Dibromo-3-chloropropane	DBCP, Nemagon	Halogenated Alkane	y	y	yr
85795	106-42-3: 108-38-3	1,3 & 1,4-Dimethylbenzene	*m*- & *p*-Xylene	Alkyl Benzene	n	y	n

Appendix 2. Summary of the availability of public water-supply-monitoring information on MTBE and other VOCs for community water systems in 12 Northeast and Mid-Atlantic States

[Agency abbreviations: Connecticut—DPH, Dept. of Public Health; DEP, Dept. of Environmental Protection. Delaware—DOHSS DPH ODW, Department of Health and Social Services, Division of Public Health, Office of Drinking Water; DNREC, Department of Natural Resources and Environmental Control. Maine—DOHS DHE, Department of Human Services, Division of Health Engineering. Maryland—MDE, Department of the Environment. Massachusetts—DEP DWS, Department of Environmental Protection, Division of Water Supply. New Hampshire DES WSEB, Department of Environmental Services, Water Supply Engineering Bureau. New Jersey—DEP DWR BSDW, Department of Environmental Protection, Division of Water Resources, Bureau of Safe Drinking Water. New York—DOH BPWSP, Department of Health, Bureau of Public Water Supply Protection. Pennsylvania—DEP DDWM, Department of Environmental Protection, Division of Drinking Water Management. Rhode Island—DOH, Department of Health. Vermont—DEC WSD, Department of Environmental Conservation, Water Supply Division. Virginia—DOH OWP, Department of Health, Office of Water Programs. PWS, public water system; CWS, community water system; NTNCWS, nontransient noncommunity water system; TNCWS, transient noncommunity water system; SW, surface water; GW, ground water; SDWA, Safe Drinking Water Act; EDB, 1,2-dibromoethane; MTBE, methyl-*tert* butyl ether; THM, trihalomethane; VOC, volatile organic compound; GIS, geographic information system; GPS, global positioning system; GWSI, U.S. Geological Survey Ground-Water Site Inventory; ~, approximately; <, less than; >, more than]

State and agency	Number of systems sampled	Analytical coverage and sampling frequency	Period of record	Medium sampled	Laboratories	Ancillary information	Data storage medium	Other comments
Connecticut DPH	~ 600 CWSs and ~650 NTNCWSs	VOCs monitored as per SDWA. Extensive EDB analyses. MTBE required	1988 to present. MTBE data from Feb. 1993	Source (SW and GW) and finished water	Mostly private labs; DPH collects and analyzes samples from ~100 small systems per year	Location (wells) plotted on 1:24,000 maps, some in DEP GIS; well data, aquifer, water use	Some PWSs maintain electronic files; mostly paper files, no standard form; EDB data on disk	MTBE detected at 26 PWSs in 1996 and 31 PWSs in 1997
Delaware DOHSS DPH ODW	~220 CWSs and ~ 100 NTNCWSs	VOCs monitored as per SDWA. No MTBE data	1985 to present	Source (GW) and finished water; some wells "blended"	All by DPH, ODW	Location, aquifer, well data, wellhead protection information at DPH, ODW and DNREC	All data in electronic data base at DPH-ODW, linked to DNREC data base	305b report summarizes data by basin
Maine DOHS DHE	~400 CWSs and ~430 NTNCWSs	VOCs monitored as per SDWA. MTBE analyzed in all samples submitted to DOHS laboratory	1988 to present. MTBE since Feb. 1997	Source (GW) water; finished SW water for THMs only; many medium to large PWSs blend sources	Most by State lab; some private labs	Location, well data, and other data in State GIS	Most data in DOHS electronic (dBase) data base	MTBE detected in 39 of 570 sources sampled through October 1997
Maryland MDE	~510 CWSs and ~490 NTNCWSs	VOCs monitored as per SDWA. MTBE analyzed	1993 to present. MTBE data from Jan. 1995 to present	Source (SW and GW) and finished water	All VOC analyses by State lab	Location, treatment, well data, water use linked to electronic analytical data	All data in DOE electronic (Oracle) data base	~3,000 samples since 1995 with 24 MTBE detections
Massachusetts DEP DWS	~520 CWSs and ~ 1,100 NTNCWSs	VOCs monitored as per SDWA. MTBE analyses are optional	1984 to present. MTBE data from Jan. 1993 to present	Source (SW and GW) and finished water	All analyses by private or county labs; reported on standardized form	Location, well data, treatment linked to analytical data	Some PWSs maintain electronic files; mostly paper files, no standard form	305b summarizes GW VOC data: MTBE detected in 78 PWSs through 1997
New Hampshire DES WSEB	~ 690 CWSs and ~ 430 NTNCWS	VOCs monitored as per SDWA. MTBE analyzed	1988 to present. MTBE data from Jan. 1995 to present	Source (SW and GW) and finished water	State lab and private labs	Locations (from GPS surveys) in GIS; treatment code with data	Electronic (Oracle) data base	
New Jersey DEP DWR BSDW	~610 CWSs and 1,030 NTNCWSs	VOCs monitored as per SDWA. MTBE analyzed	1993 to present. MTBE data from May 1997 to present	Source (SW and small GW PWS) and finished water	Private labs, use standardized form	Some in GWSI and GIS	All data in State electronic (SAS) data base	

Appendix 2. Summary of the availability of public water-supply-monitoring information on MTBE and other VOCs for community water systems in 12 Northeast and Mid-Atlantic States--Continued

[Agency abbreviations: Connecticut—DPH, Dept. of Public Health; DEP, Dept. of Environmental Protection. Delaware—DOHSS DPH ODW, Department of Health and Social Services, Division of Public Health, Office of Drinking Water; DNREC, Department of Natural Resources and Environmental Control. Maine—DOHS DHE, Department of Human Services, Division of Health Engineering. Maryland—MDE, Department of the Environment. Massachusetts—DEP DWS, Department of Environmental Protection, Division of Water Supply. New Hampshire DES WSEB, Department of Environmental Services, Water Supply Engineering Bureau. New Jersey—DEP DWR BSDW, Department of Environmental Protection, Division of Water Resources, Bureau of Safe Drinking Water. New York—DOH BPWSP, Department of Health, Bureau of Public Water Supply Protection. Pennsylvania—DEP DDWM, Department of Environmental Protection, Division of Drinking Water Management. Rhode Island—DOH, Department of Health. Vermont—DEC WSD, Department of Environmental Conservation, Water Supply Division. Virginia—DOH OWP, Department of Health, Office of Water Programs. PWS, public water system; CWS, community water system; NTNCWS, nontransient noncommunity water system; TNCWS, transient noncommunity water system; SW, surface water; GW, ground water; SDWA, Safe Drinking Water Act; EDB, 1,2-dibromoethane; MTBE, methyl-*tert* butyl ether; THM, trihalomethane; VOC, volatile organic compound; GIS, geographic information system; GPS, global positioning system; GWSI, U.S. Geological Survey Ground-Water Site Inventory; ~, approximately; <, less than; >, more than]

State and agency	Number of systems sampled	Analytical coverage and sampling frequency	Period of record	Medium sampled	Laboratories	Ancillary information	Data storage medium	Other comments
New York[1] DOH BPWSP	~2,700 CWSs and ~760 NTNCWSs	VOCs monitored as per SDWA. MTBE required in Suffolk County, optional elsewhere	Pre-1988 to present. MTBE data from Jan. 1995	Source (SW and GW) and finished water	State and private labs		DOH lab electronic data	
New York DOH BPWSP (Synthetic organic contaminant survey)	~300 CWSs and/or NTNCWS	55 VOCs including MTBE sampled once	1994 to present	Finished water	State and private labs	Location and treatment coded with data	DOH lab electronic data base	Initially only schools sampled, subsequently sites with problems
Pennsylvania DEP DDWM	~2,500 CWSs and ~1,500 NTNCWSs	Only 21 regulated VOCs monitored. MTBE not analyzed	Pre-1988 to present	Source (GW) and finished water	All analyses by private labs	Location of source intakes and "entry points"	Electronic data (system operated by contractor); output in SAS format	
Rhode Island DOH	~450 CWSs, NTNCWSs, and TNCWSs	VOCs monitored as per SDWA, but most systems sampled annually. MTBE required	1988 to present, analytical coverage varies. MTBE data from 1989	Source (SW and GW) and finished water	Most analyses by State lab	Locations field checked and in GWSI and GIS	All data in State electronic (Unix-based) data base	>3,000 analyses; MTBE detected in 12 PWS wells (includes NTNCWS) and 1 SW source
Vermont DEC WSD	~650 CWSs and NTNCWSs	VOCs monitored as per SDWA. MTBE analyzed	1988 to present. MTBE data from 1995	Source water (SW and GW) and finished water	Most analyses by State lab	Locations in GIS	Pre-1993, paper files. 1993 to present, State electronic (Clarion) data base	7 PWSs with MTBE detections
Virginia DOH OWP	~3,000 CWSs and NTNCWSs)	VOCs monitored as per SDWA. MTBE analyzed	1970's to present. MTBE data from April 1997	Source and finished water (SW and GW); less than 50 percent of GW sources treated	All samples collected and analyzed by State lab	Locational data (from GPS surveys) stored with analyses	Pre-1995, paper file. Electronic since 1995	~ 50 PWSs have had VOC contamination (12 with MTBE)

[1]New York DOH BPWSP conducts two monitoring programs.

Appendix 3. Summary of information on ambient ground-water-quality sampling networks in the Northeast and Mid-Atlantic States that included MTBE and other VOCs

[U.S. Geological Survey National Water-Quality Assessment (USGS NAWQA) Program study abbreviations: CONN, Connecticut, Housatonic, and Thames River Basins study unit; DLMV, Delaware-Maryland-Virginia Peninsula study unit; POTO, Potomac River Basin study unit; LSUS, Lower Susquehanna River Basin study unit; LINJ, Long Island-New Jersey Coastal Drainage study unit; HDSN, Hudson River Basin study unit; ALMN, Allegheny and Monongahela River Basin study unit; ALBE, Albermarle-Pamlico study unit; KANA, Kanawha-New River Basin study unit; UTEN, Upper Tennessee River Basin study unit. VOC, volatile organic compound, MTBE, methyl *tert*-butyl ether; NWQL, U.S. Geological Survey's National Water Quality Laboratory; GWSI, U.S. Geological Survey Ground-Water Site Inventory data base; GIS, geographic information system; NWIS, U.S. Geological Survey National Water Information System data base; PWS, public water supply; LUST, leaking underground storage tank; ?, unable to determine]

State	Agency and program	Number of sites sampled	Analytical coverage and sampling frequency	Period of record	Type of wells sampled	Laboratories	Ancillary information	Data storage medium
Connecticut	USGS NAWQA Study: CONN	43	60 VOCs	1994-95	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
Delaware	USGS NAWQA Study: DLMV regional ground-water study	17	63 VOCs (no MTBE)	1988-90	Domestic, monitoring and PWS	NWQL	GWSI	NWIS
	Delaware Geological Survey monitoring in New Castle County	50	VOCs analyzed	?	Monitoring, PWS, and other wells	State lab	?	?
Maine	Dept. of Environmental Protection sampling in and near LUST sites; upgradient wells only	?	? (~1,600 MTBE analyses)	~1985 to present	Domestic. monitoring, and PWS	State lab	Locations, aquifer types, well logs	Electronic (Oracle) data base
Maryland	USGS NAWQA Study: DLMV regional ground-water study	18	63 VOCs (no MTBE)	1988-90	Domestic, monitoring, and PWS	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: POTO	2	60 VOCs	1993-95	Domestic	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: LSUS	2	60 VOCs	1993-95	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
	Statewide monitoring network	~100	VOCs analyzed at some wells	?	Domestic and monitoring wells	State lab	?	?
Massachusetts	USGS NAWQA Study: CONN	22	60 VOCs	1994-95	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
New Hampshire	USGS NAWQA Study: CONN	5	60 VOCs	1994-95	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
	Private well inventory	31	40 VOCs; 23 samples include MTBE	1985 to present	Domestic	State lab	GWSI, GIS	State electronic (Oracle) data base linked to GWSI
New Jersey	USGS NAWQA Study: LINJ	135	86 VOCs	1997-98	Monitoring	NWQL	GWSI, GIS	NWIS
	Dept. of Environmental Protection/USGS ambient ground-water network	~300	VOCs at some sites	1985 to present	Domestic, monitoring, and PWS	NWQL	GWSI	NWIS

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State	Agency and program	Number of sites sampled	Analytical coverage and sampling frequency	Period of record	Type of wells sampled	Laboratories	Ancillary information	Data storage medium
New York	USGS NAWQA Study: HDSN	72	60 VOCs	1993-95	Domestic, monitoring, and PWS	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: CONN	2	60 VOCs	1993-95	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study LINJ	3	86 VOCs	1997-98	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: ALMN	15	86 VOCs	1997	Domestic and PWS	NWQL	GWSI, GIS	NWIS
Pennsylvania	USGS NAWQA Study: LSUS	116	60 VOCs	1993-95	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: POTO	4	60 VOCs	1993-95	Domestic	NWQL	GWSI; GIS	NWIS
	USGS NAWQA Study: ALMN	38	86 VOCs	1997	?	NWQL	GWSI, GIS	NWIS
Rhode Island	USGS NAWQA Study: CONN	1	60 VOCs	1995	Domestic	NWQL	GWSI	NWIS
Vermont	USGS NAWQA Study: CONN	19	60 VOCs	1994-95	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
Virginia	USGS NAWQA Study: DLMV regional ground-water study	7	63 VOCs (no MTBE)	1988-90	Domestic, monitoring and PWS	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: ALBE	24	60 VOCs	1994-95	Domestic and monitoring	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: POTO	8	60 VOCs	1993	Domestic	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: KANA	19	86 VOCs	1997	Domestic	NWQL	GWSI, GIS	NWIS
	USGS NAWQA Study: UTEN	11	86 VOCs	1997	?	NWQL	GWSI, GIS	NWIS