MASSACHUSETTS

GROUND-WATER QUALITY

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FOREWORD

This report contains summary information on ground-water quality in one of the 50 States, Puerto Rico, the Virgin Islands, or the Trust Territories of the Pacific Islands, Saipan, Guam, and American Samoa. The material is extracted from the manuscript of the *1986 National Water Summary*, and with the exception of the illustrations, which will be reproduced in multi-color in the *1986 National Water Summary*, the format and content of this report is identical to the State ground-water-quality descriptions to be published in the *1986 National Water Summary*. Release of this information before formal publication in the *1986 National Water Summary* permits the earliest access by the public.

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MASSACHUSETTS
Ground-Water Quality

In Massachusetts, ground water supplies about 2 million people, one-third of the State's population (fig. 1). Most ground water throughout the State meets the drinking-water standards established by the Massachusetts Department of Environmental Quality Engineering (MDEQE) and the U.S. Environmental Protection Agency (EPA); however, concentrations of iron and manganese can exceed drinking-water standards. Most ground water contains small concentrations of dissolved solids and is soft, acidic, and corrosive to pipes and plumbing.

Nearly all public ground-water supplies are derived from unconfined stratified-drift aquifers that are less than 100 feet thick. Because of the permeable nature of these deposits, water from these aquifers and from the bedrock aquifers is extremely susceptible to contamination from activities on the land surface. Degradation is associated with urbanization, agriculture, and waste disposal. Since 1960, more than 100 public wells or well fields out of about 1,400 have been closed because of contamination. Nearly all the wells that yield contaminated water were identified through a monitoring network operated by the MDEQE. Most commonly, initial identification of private well contamination has been through detection of unpleasant or unnatural taste and odor.

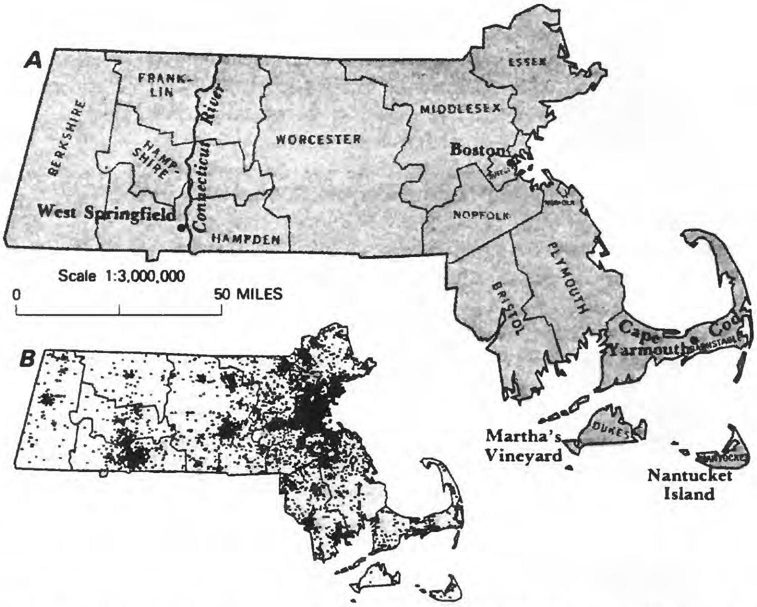

Figure 1. Selected geographic features and 1985 population distribution in Massachusetts. *A*, Counties, selected cities, and major drainages. *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files, adjusted to the 1985 U.S. Bureau of the Census data for county populations.)

Sixteen hazardous-waste sites have been included on the National Priorities (NPL) by EPA. Thirty-one sites are regulated under the Resource Conservation and Recovery Act (RCRA) of 1976. In addition, five sites at one facility were identified by the U.S. Department of Defense for remedial cleanup action.

Contamination of the ground water with organic compounds is the primary cause of well closures in Massachusetts. Sixty public wells or well fields have been closed because of contamination with waste organics, mostly solvents. Several of these wells have been reopened, but the water must be treated by air stripping and activated carbon filtration. Some wells have been closed because of pesticide contamination. At least six public-supply wells and an uncounted number of private wells have been closed because of contamination from the State's 484 active and inactive landfills. As a result, a program has been initiated for closing, capping, and monitoring landfills. Wastewater disposal through municipal sewage-treatment facilities and private septic systems is a source of degradation and a cause for closure of several private wells and one public-supply well. Storage and application of road salt has contaminated nine public-supply wells and an uncounted number of private wells, causing them to be closed. The Massachusetts Department of Public Works has responded by covering salt storage piles to prevent leaching, by decreasing the amount of salt applied to highways in watersheds of public supplies, by experimenting with calcium magnesium acetate as an alternative deicing chemical, and by evaluating experimental paving materials.

The prevention of contamination is paramount in the State's ground-water protection strategy, which has three major elements. First, all public water supplies and waste-disposal facilities are regulated by the State. Second, a program of technical assistance and information provides guidance for local and regional agencies to apply their land-use controls and for other authorities to protect public and private water supplies. Third, an economic assistance program motivates the implementation of ground-water quality planning and management at the town and municipal level.

WATER QUALITY IN PRINCIPAL AQUIFERS

Massachusetts has four principal types of aquifers (fig. 2*A*)—stratified drift; sedimentary-bedrock; crystalline, metamorphic and igneous bedrock; and carbonate rock (U.S. Geological Survey, 1985, p. 249-252). Virtually all the State's ground-water withdrawals for public water supply are from the stratified-drift aquifers. In southeastern Massachusetts, on Cape Cod, and on the islands of Martha's Vineyard and Nantucket the stratified-drift aquifers are the only water source for both public and domestic supply. However, in other parts of the State, about 300,000 people rely on domestic wells in the bedrock aquifer.

BACKGROUND WATER QUALITY

A graphic summary of selected water-quality variables compiled from the U.S. Geological Survey's National Water Data Storage and Retrieval System (WATSTORE) and the MDEQE is presented in figure 2*C*. The summary is based on dissolved-solids, hardness, pH, sodium, and sulfate analyses of water samples collected from 1979 to 1985 from the principal aquifers in Massachusetts. Percentiles of these variables are compared to national standards that specify the maximum concentration or level of a contaminant in drinking-water supply as established by the U.S. Environmental Protection Agency (1986a,b). The primary maximum contaminant level standards are health related and are legally enforceable. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The secondary drinking-water standards include maximum concentrations of 500 mg/L (milligrams per liter) dissolved solids, 6.5-8.5 units of pH, and 250 mg/L sulfate.

Stratified-Drift Aquifers

The stratified drift consists of layers of unconsolidated sand and gravel, whose mineral composition is commonly more than 99 percent quartz and feldspar, which are chemically stable, nonreactive, and virtually insoluble in water. Because of the chemical composition of both the aquifer and precipitation, water from the stratified-drift aquifers generally has small concentrations of dissolved solids and is soft and slightly acidic (fig. 2*C*). In the western part of Massachusetts, the stratified drift locally derived from carbonate rocks has a mineral composition similar to local bedrock and, therefore, possesses water chemistry similar to that described here for the carbonate rock aquifer. The median dissolved-solids concentration was 88 mg/L based on 697 samples of water from public-supply wells in the stratified-drift aquifers analyzed by the MDEQE in 1984, and the median hardness as calcium carbonate was 32 mg/L. Most public and private wells in this aquifer are less than 100 feet deep, and the aquifer generally is unconfined. The water is commonly nearly saturated with dissolved oxygen and has a relatively constant temperature of about 11°C (degrees Celsius). Eighty-five percent of the 697 analyses had a pH of less than 7; the median pH was 6.3. Because the water has a small dissolved-solids concentration and is soft and acidic, it is corrosive to metal and cement pipe. Of 697 analyses of water from public-supply wells, 75 percent had negative Langelier indexes of −2.5 or lower; and the median index was −3.23. Water with a negative Langelier Index (Hem, 1970, p. 24) is undersaturated with respect to calcium carbonate and, therefore, may dissolve metals and cement releasing lead, copper, zinc, and perhaps other metals. Sodium hydroxide or other chemicals are added to some public-water supplies to increase the pH and decrease corrosivity. In 1986, plumbing codes were changed to limit the lead content of solder to less than 0.02 percent, thereby decreasing the potential for dissolution of lead from plumbing. Consumers are advised to flush water which has been in domestic copper plumbing or lead service lines before drawing water for drinking or cooking. The metals may impart an acerbic taste to the water and copper causes blue-green staining of white porcelain sinks and tubs.

Iron and manganese may occur in concentrations requiring treatment before distribution in public supplies. These elements are the products of the weathering of minerals and dissolution of oxide coatings on aquifer materials. They are easily dissolved in acidic water in the absence of oxygen. Water in the stratified drift is almost always acidic, but commonly contains dissolved oxygen, which precludes the solution of iron and manganese. However, dissolved oxygen may be depleted when ground water passes through organic deposits, such as peat or river-bottom sediments, thereby allowing the water to dissolve and mobilize iron and manganese. For example, in Middlesex County, a test well located in an aquifer below a 5-foot thick layer of peat yielded water with 19,000 μg/L (micrograms per liter) dissolved iron. In addition to causing taste, color, and staining problems, iron and manganese can form encrustations on well screens, thereby decreasing well efficiency. Wells, which initially yield water with small concentrations of these metals, may show a trend toward increasing concentrations and decreased well efficiency as a result of reversing ground-water gradients and causing iron- and manganese-bearing water to flow to the well (Gay and Frimpter, 1981, p. 18-23). Aquifers that previously had been bypassed because of large concentrations of iron and manganese are now being developed and the water treated because of increased demand and limited resources.

Organic deposits can cause other problems in addition to large concentrations of iron and manganese. In Provincetown, on the northern tip of Cape Cod, decomposition of organic material in marsh deposits that have been buried by postglacial sand dunes, produces dissolved ammonia, hydrogen sulfide, and iron in the ground water (Frimpter and Gay, 1979, p. 7–9).

Saltwater intrusion into the stratified-drift aquifers has been caused by overpumping in some coastal areas of Massachusetts, but no public-supply well fields have been closed and only one has been affected. Public-supply wells for Provincetown Barnstable County draw freshwater from the upper 100 feet of the stratified-drift aquifer, but overpumping has caused gradual upward migration of saltwater that underlies the shallow freshwater lens in this area. Sodium concentrations have increased from less than 25 to 150 mg/L at one well field. The intrusion has been controlled by decreasing pumping rates in the well field and by areally distributing withdrawal from the aquifer. Massachusetts, which has a 20-mg/L guideline for sodium in public drinking water, requires that suppliers notify all their customers if that guideline is violated.

Sedimentary-Bedrock Aquifer

The Triassic sedimentary-bedrock aquifer in the Connecticut River valley has been developed for private domestic supplies and a few industrial supplies. It consists of sandstone, shale, conglomerate, and interbedded lava flows (traprock). Deposited in a continental basin environment, these rocks contain traces of gypsum, a mineral characteristic of evaporite deposits. Localized ore deposits and prospects contain copper, lead and zinc sulfides, fluoride, and secondary uranium-bearing minerals. The ground water is slightly alkaline and has a median pH of 7.9. Water from the upper 200 feet of this aquifer generally contains moderate levels of dissolved solids and is moderately hard, but water from deeper parts of the aquifer commonly has large concentrations of dissolved solids and is hard. The median dissolved-solids concentration of 15 samples was 360 mg/L, but one 510-foot deep well yielded water with 1,600 mg/L dissolved solids. The water in this aquifer contains larger median concentrations of sulfate (120 mg/L), sodium (21 mg/L), and fluoride (0.2 mg/L) than any other aquifer in Massachusetts.

Carbonate-Rock Aquifer

The carbonate-rock aquifer consists of limestone, dolomite, and marble interbedded with schist and quartzite in the valleys of Berkshire County in western Massachusetts. This aquifer has been developed for domestic supplies and for large-yield wells by industry. Water from this aquifer characteristically is very hard (median 210 mg/L as calcium carbonate) and has moderately large dissolved-solids concentrations (median 220 mg/L), but unlike the sedimentary-bedrock aquifer has little sodium (median 3.7 mg/L), sulfate (median 17 mg/L), and less than 0.1 mg/L fluoride. The water is also slightly alkaline and has a median pH of 7.8

Crystalline-Bedrock Aquifer

The crystalline-bedrock aquifer is composed predominantly of granite, gneiss, and schist, and is relied upon for domestic water supplies, for which only a few gallons per minute are needed and where there are no other easily accessible aquifers. Virtually all water in this aquifer has small dissolved-solids concentrations, with a median concentration of 120 mg/L. It is moderately hard, with a median concentration of 90 mg/L (as calcium carbonate) and is slightly alkaline, with a median pH of 7.8. Iron in concentrations requiring treatment before use is common in those rocks known as "rusty" schist or gneiss which contain an abundance of ferromagnesian minerals or small amounts of pyrite or pyrrhotite. Arsenic, possibly derived from sulfide minerals, has also been found in concentrations between 1 and 560 μg/L in a few wells in Hampden, Worcester, and Middlesex Counties. The median arsenic concentration in 33 samples was 11.5 μg/L. The primary drinking-water standard for arsenic is 50 μg/L. Local variations of bedrock mineralogy affect ground-water quality, particularly where carbonate lenses and sulfide-bearing zones occur in the bedrock of Middlesex County. Radon concentrations larger than 10,000 picocuries per liter have been detected in water from crystalline-bedrock aquifers elsewhere in New England, New York, and Pennsylvania, and in the Triassic sediments of Connecticut and New Jersey. The gas is likely to be present in similar concentrations in some locations in Massachusetts.

Effects of Land Use on Water Quality

Most of Massachusetts' population and water-quality problems are located in the eastern third of the State (figs. 1 and 3). Water quality has been degraded mainly because of the effects of waste disposal, urbanization, and agriculture. Slightly more than 100 of about 1,400 public-supply wells or well fields have been closed since 1960 because of contamination (fig. 3*B*). The total pumping capacity of these closed wells was 54 Mgal/d (million gallons per day), about 7 percent of the State's 765 million gallon average daily demand. Nearly all of the contaminated public-supply wells were identified through programs of periodic water-quality analyses and special organics testing to protect public health by the MDEQE. About 1,400 public-supply wells constitute an extensive ground-water-quality monitoring network in Massachusetts. Sampling consists of frequent bacterial tests, annual analyses for common inorganic constituents and properties, and for metals and organic compounds testing on a 3-year cycle at a minimum.

Waste Disposal

Hazardous waste, which is treated, stored, or disposed of at 31 sites identified under RCRA constitutes a known or possible potential hazard to the quality of ground water (fig. 3*A*). The Massachusetts Division of Solid and Hazardous Waste has determined that some contamination of ground water has been detected at 19 of these sites. Sixteen sites have been included and 5 additional sites have been proposed for inclusion on the U.S. Environmental Protection Agency's NPL under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Contaminants have been detected in ground water at 16 of the CERCLA sites. Many of the hazardous materials sites are located in populous eastern Massachusetts (fig. 3*A*).

As of September 1985, 37 hazardous-waste sites at 6 facilities in Massachusetts had been identified by the U.S. Department of Defense as part of their Installation Restoration Program (IRP) as having potential for contamination (U.S. Department of Defense, 1986). The IRP, established in 1976, parallels the EPA Superfund program under CERCLA. The EPA presently ranks these sites under a hazard ranking system and may include them in the NPL. Five sites at one facility (fig. 3*A*) were considered to present a hazard significant enough to warrant response action in accordance with CERCLA. The remaining sites were scheduled for confirmation studies to determine if remedial action is required.

Organic compounds from industrial waste, mostly solvents, are the major ground-water contaminants in the State—56 public-supply wells have been closed because of contamination with organics. A few wells have been reopened, but require treatment of the water by both air stripping and activated-carbon filtration. Waste lagoons, pits, landfills, transfer stations, improper storage, and illegal discharge are the major avenues of contamination for extremely mobile and persistent organic compounds. Organic wastes are commonly associated with chemical and electronic industries, machine and electroplating works, aircraft engine cleaning, tank-truck and drum washing, and leaking sewer lines. Many of the public-supply wells contaminated with organic compounds are in or near industrial parks. The most common contaminants are trichloroethylene, methyl chloride, and tetrachloroethylene, but additional compounds that have also been identified include 1,1 dichloroethylene, 1,2 dichloroethylene, 1,1 dichlorethane, 1,1,1 trichloroethylene, methyl ethyl ketone, methyl isobutyl ketone, trichlorofluoromethane, dioxane, carbon tetrachloride, chloroform, acetone, benzene, toluene, and phenols.

Disposal of domestic sewage in the ground has been favored by sanitary engineers and regulatory agencies. Land disposal through septic systems and municipal facilities is still the method of choice on the State's two sole-source aquifers, Cape Cod and Nantucket, partly as a consequence of the State's Ocean Sanctuaries Act which prohibits new discharges of wastewater to the ocean. Municipal wastewater recharges the ground through seepage lagoons at several sewage-treatment facilities. About one-third of the State's housing is serviced by septic systems that discharge underground. Numerous private wells and some public-supply wells have been contaminated by wastewater containing nitrates or organics or both. One public-supply well, located 7,500 feet downgradient from sewage-treatment plant lagoons, has been contaminated with organics and showed increased concentrations of nitrate, detergents, boron, and dissolved solids (LeBlanc, 1984, p. 11–22; Thurman and others, 1984 p. 58–63).

The Massachusetts Division of Water Supply estimates that there are 241 active and 243 closed municipal landfills in Massachusetts (fig. 3*C*). At least six public-supply well fields and an uncounted number of private wells have been closed as a result of contamination attributed to landfills. Leachates from landfills commonly cause ground water to contain large concentrations of iron, dissolved solids, and nitrogen (as ammonia or nitrate), but most well closures have resulted from contamination by organics. Inappropriate disposal of waste organics and septic-system degreasing solvents in landfills are the sources of these persistent contaminants. Since 1971, capping of landfills with a relatively impermeable material has been part of the closure requirements. The MDEQE now requires ground-water protection systems, such as liners, leachate-collection systems, and ground-water quality monitoring, for all new landfills and all expansions of landfills.

Urbanization

Twenty of about 1,400 public-supply wells in Massachusetts have been closed in response to unsatisfactory water-quality conditions that can be attributed to the effects of urbanization. The causes of closures may be divided into three major groups—road salt, oils and fuels, and sewage.

Road salt stored and applied to roads for ice and snow control has contaminated nine public wells and an uncounted number of private wells. Three public-supply wells in Weston (Middlesex County) have been closed because of contamination by road salt. Two of these wells were located in the stratified-drift aquifer near a major superhighway intersection including two large toll plazas where "bare pavement" is a highway maintenance policy. In Yarmouth on Cape Cod, a public-supply well in the stratified-drift aquifer was closed because of large concentrations of salt that had been leached by rain from an uncovered salt-storage pile. A scavenger well pumped to remove salt from the site was estimated to have removed 835 tons of salt during 29 months (Frimpter and Gay, 1979, p. 7) . In 1967 the Massachusetts Department of Public Works (MDPW) began covering all of it's stored salt to prevent leaching. Also, in 1978 the Department began providing financial assistance to towns and municipalities for the purpose of covering salt stockpiles. By February of 1987, the MDPW built, or provided financial assistance for building, 395 salt-storage sheds. The salt to sand mixture ratios have been decreased on selected highways, experiments with calcium magnesium acetate as an alternative deicing chemical have begun, and evaluation of pavements which contain encapsulated calcium chloride or rubber particles is planned.

Private wells along highways also are susceptible to road-salt contamination, particularly where more than average amounts of salt are applied at dangerous intersections. For example, near an intersection on a hill in rural Pelham (Hampshire County), a private domestic-supply well was drilled to a depth of 121 feet deep into the crystalline-bedrock aquifer to replace a 25-foot deep well in till that had become contaminated with salt. Soon, that well became contaminated and a new 740-foot deep well was drilled, but that too became contaminated with salt and the property was abandoned as a homesite and the house was removed. Drilling deeper to avoid road-salt contamination has not been a dependable solution in Massachusetts.

Private and public wells have been contaminated by fuel oil or gasoline in several widely scattered locations. A public-supply well field in the stratified-drift aquifer in Truro, which serves Provincetown on Cape Cod, was closed because of a gasoline leak from a nearby underground storage tank. This closing required the development of a temporary emergency-supply well and created increased demands on other well fields where withdrawals must be limited to prevent saltwater intrusion. Domestic wells have also been affected by fuel leaks and spills. For example, 68 domestic wells, more than 95 percent of which are in the crystalline-rock aquifer in Walpole and Dover (both in Norfolk County), were affected by a gasoline leak from an underground storage tank. The leak was stopped and the immediate water-quality problem was solved when the oil company, on it's own initiative, provided public water to the homes.

The MDEQE has established a 400-foot radius for sanitary protection about a public-supply well which successfully protects against biological contamination. Degradation of private and public supplies by sewage from leaking sewers, cesspools, and septic systems occurs mainly in the form of large nitrate levels and organic compounds. Of 5,118 chemical analyses of private-supply wells in Barnstable County from 1979 to 1986, 130 wells had nitrate (as nitrogen) concentrations that equaled or exceeded the primary drinking standard of 10 mg/L (U.S. Environmental Protection Agency, 1986a), and 294 had from 5 to 10 mg/L nitrate (as nitrogen). Most of these occurrences are most easily explained as caused by septic systems and lawn fertilizers. Increasing levels of nitrate have been observed in some public-supply wells and attributed to urban congestion and domestic wastewater (Frimpter and Gay, 1979, p. 9–10), but this condition has not been identified as a cause of recent public-supply well closures.

Agricultural Practices

Agricultural pesticides have been detected in ground-water supplies in the farming areas of the Connecticut River valley in central Massachusetts. Public-supply wells in Southwick (Hampton County) and Deerfield (Franklin County) have been closed because of contamination by ethylene dibromide, which was used as a soil fumigant in the growing of tobacco. The four closed wells in Southwick represent two-thirds of the West Springfield water supply, which serves 27,000 people. The closed well in Deerfield was a standby well and not used, but water from 52 private wells in the Connecticut River valley has been identified as exceeding the standards for a number of pesticides including ethylene dibromide, 1-2 dichloropropane, aldicarb, alachlor, carbofuran, and dinoseb. Also, in southern Bristol County, where potatoes are grown, eight private wells contained aldicarb and one other well contained alachlor at levels exceeding the standards. Of the 556 suspect wells tested by the MEDQE, 28 percent contained detectable amounts of pesticides and 11 percent exceeded the drinking-water standards. Although an actual count is not available, most of the affected wells draw water from shallow water-table aquifers in unconsolidated glacial drift.

POTENTIAL FOR WATER-QUALITY CHANGES

For public water supplies, there are generally no deeper aquifers that can be used as alternatives to the unconfined and shallow unconsolidated stratified-drift aquifers. A 1-Mgal/d public-supply well may draw water from a recharge zone as large as 1 square mile around the wellhead. These zones, where water table is commonly less than 25 feet below land surface, are extremely susceptible to contamination (figs. 2*A*,*B*).

Because the small aquifers are recharged within a short time (Knott and Olimpio, 1986, p. 15–24), they are able to sustain the large withdrawals necessary for public supplies. These conditions also allow relatively rapid flow of contaminants, making restoration a more rapid process (tens of years) than is typical (centuries) in many of the aquifers in the rest of the Nation (James, 1986, p. 4–6).

Because of continued urbanization and land disposal of wastes (fig. 3*C*), water demand will continue to increase and ground-water quality may be expected to be further degraded. As a result, there may be continued demand for longer and larger water diversions to the urbanizing areas, and ground-water-treatment plants may become common, rather than exceptional. State and local governments, as part of the management of ground-water quality, are now designating zones of degraded water to increase identification and protection of supply.

GROUND-WATER-QUALITY MANAGEMENT

In 1983, the MDEQE adopted a ground-water protection strategy, "to protect the quality and quantity of groundwaters to the levels necessary for projected future use." The MDEQE has developed, and is continuing to develop, a program to prevent ground water from being degraded to a quality less than its intended use, and to manage known or suspected contamination. The responsibility for assuring the protection of ground-water quality is shared between local government and the State. Towns and cities have primary responsibility for ground-water quality because they are the only government entities with authority to control land use. The State has regulatory control of all public water supplies, sanitary landfills, hazardous waste, underground storage tanks, industrial wastewater discharges of any size, and sanitary wastewater discharge facilities of 15,000 gallons per day or more. Local government has control of land use, of sanitary wastewater disposal of as much as 15,000 gallons per day, and of private wells. The State Fire Marshall regulates underground storage tanks and the regulations are enforced by local Fire Chiefs.

State regulatory guidance is provided through public water-supply regulations, sanitary-landfill regulations, hazardous-waste-management regulations, land application of sludge and septage regulations, wetlands regulations, onsite and municipal wastewater treatment regulations, and ground-water discharge permitting and classification (S. Roy and D. Terry, Massachusetts Division of Water Supply, written commun., 1986). All discharges to the ground water of the State must meet Massachusetts drinking-water standards and health advisories established by the EPA, except discharges to ground water specifically identified and permitted to be degraded.

A second major element of the program is technical assistance and information. Publication of handbooks and a newsletter and presentation of numerous educational and information workshops are part of this element. Technical assistance is provided for the implementation of local ground-water protection through a series of 1:25,000-scale map overlays containing geographic information for aquifers, public-water supplies, waste-disposal sites, and surface-water drainage divides. A long-range program of water-resources appraisal and aquifer mapping by the U.S. Geological Survey in cooperation with the Massachusetts Division of Water Resources is now nearly statewide in scope, and results are contained in a series of 24 U.S. Geological Survey Hydrologic Investigations Atlases.

In addition to regulatory guidance and technical assistance, Massachusetts is encouraging local management and protection of water supplies by providing economic assistance. Under Chapter

286 of the Acts of 1982, funds are provided to communities for immediate response to the emergency and remedial cleanup of contaminated public water supplies. This Act also provides funds to communities for the delineation of zones of contribution (that part of an aquifer which contributes water to a public supply well) and the purchase of land, development rights, or easements necessary to implement long-range protection of ground-water supplies. This economic incentive is a step that encourages towns and cities to develop measures to help ensure adequate supplies of good-quality ground water for their future and for the future of the State.

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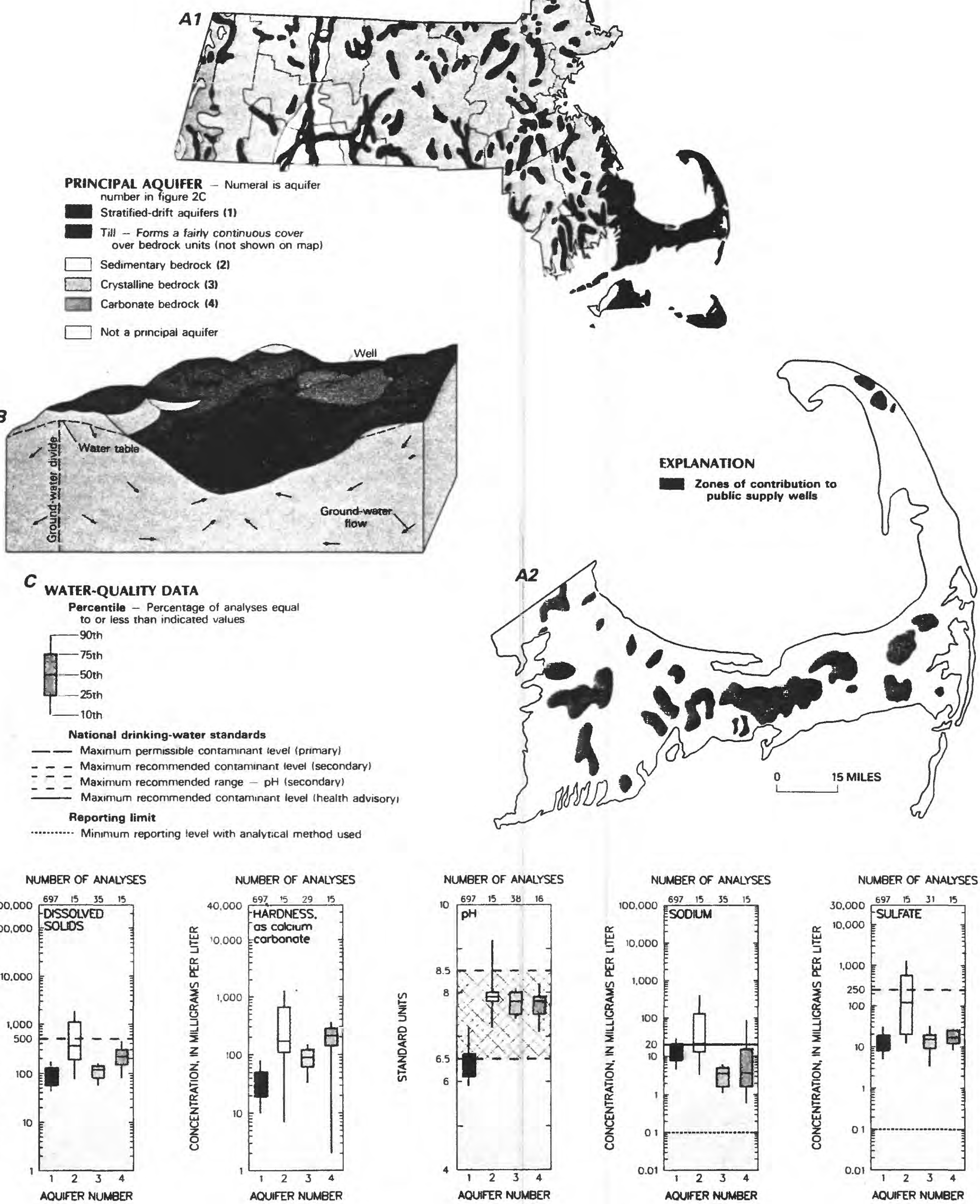

Figure 2. Principal aquifers and related water-quality data in Massachusetts. *A1*, Principal aquifers; *A2*, Map of Cape Cod showing zones of contribution to public supply wells. *B*, Block diagram showing typical characteristics of valley-fill stratified-drift aquifers and the zone of contribution (shaded) to a public supply well. *C*, Selected water-quality constituents and properties, as of 1979-85. (Sources: *A1*, *A2*, U.S. Geological Survey, 1985, p. 251; modified from Cape Cod Planning and Economic Development Commission, 1983. *B*, Frimpter, 1981. *C*, Analyses compiled from U.S. Geological Survey and Massachusetts Department of Environmental Quality Engineering files; national drinking-water standards from U.S. Environmental Protection Agency, 1986b.)

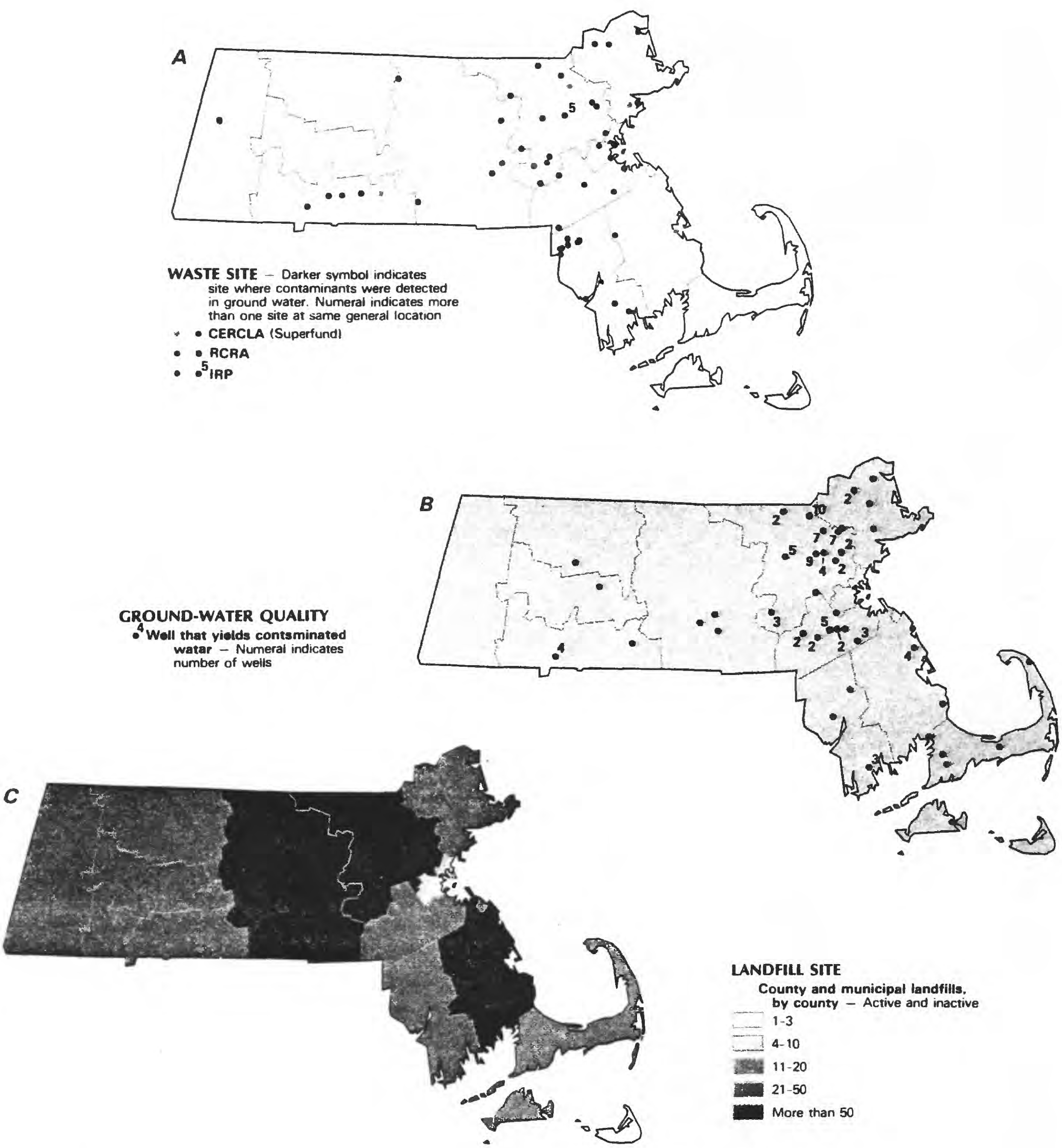

Figure 3. Selected waste sites and ground-water-quality information in Massachusetts. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites, as of 1986; Resource Conservation and Recovery Act, (RCRA) sites, as of 1986; Department of Defense Installation Restoration Program (IRP) sites, as of 1985. *B*, Distribution of wells that yield contaminated water, as of 1960-86. *C*, County and municipal landfills, as of 1986. (Sources: *A*, Massachusetts Department of Environmental Quality Engineering files; U.S. Environmental Protection Agency, 1986c; U.S. Department of Defense, 1986. *B*, Massachusetts Department of Environmental Quality Engineering files. *C*, Massachusetts Division of Water Supply files.