VERMONT GROUND-WATER QUALITY

By John E. Cotton

Ground-Water Quality Management Section

By David Butterfield, Vermont Department of Water Resources
and Environmental Engineering

U.S. Geological Survey Open-File Report 87-0758

DEPARTMENT OF THE INTERIOR

DONALD PAUL HODEL, *Secretary*

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, *Director*

For additional information:

Chief Hydrologist
U.S. Geological Survey
407 National Center
Reston, VA 22092

For sale by:

Open-File Services Section
U.S. Geological Survey, MS 306
Box 25425, Federal Center
Denver, CO 80225
(303) 234-5888

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.

Contents

Illustrations

VERMONT
Ground-Water Quality

Vermont is a water-rich State, and the quality of ground water is generally suitable for human consumption and most other uses. In 1980, Vermont had a resident population of about 511,000 people in 14 counties, with populations ranging from 4,613 in Grand Isle County to 115,534 in Chittenden County (fig. 1). Ground water is the primary water supply for about 54 percent of the population. In addition, ground water is the major source of water for thousands of visitors from outside of the State. There are 527 public community wells, about 1,500 non-community public wells, and about 50,000 private water wells. Ground-water quality generally does not exceed drinking-water standards established by the Vermont Department of Health and the U.S. Environmental Protection Agency (EPA). Although all the aquifers in the State are extremely susceptible to contamination from the surface, only three public-supply wells have been removed from service since 1980.

Ground-water contamination has occurred at scattered locations throughout the State. The distribution of contamination coincides with population density. Of the 123 documented, wells that yield contaminated water (11 public and 112 private), about 40 percent were contaminated with chloride or sodium; 34 percent were contaminated with synthetic organic compounds, petroleum products, or other industrial chemicals; 14 percent were contaminated with agricultural fertilizers from storage leaks, spills, or field application; and 12 percent were contaminated with bacteria. More than 6,000 people have been affected by contamination of aquifers tapped by public-supply wells and more than 300 people have been affected by contaminated private wells.

Two hazardous waste sites in Burlington and Springfield are included on the National Priorities List (NPL) established by the U.S. Environmental Protection Agency (1986c). These Superfund sites are being evaluated and cleaned under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 (U.S. Environmental Protection Agency, 1986c). The U.S. Department of Defense (DOD) has identified two hazardous-waste sites at one facility that are scheduled for confirmation studies to determine if remedial action is required (U.S. Department of Defense, 1986).

Future instances of contamination may follow the pattern of the past, but less contamination is expected because of improved techniques of solid-waste disposal, hazardous-waste storage, and increased surveillance and replacement of underground storage tanks for petroleum products. State agencies with water-related interests are aware of the importance of the ground-water resource, and several regulatory programs respond to instances of ground-water contamination. Other programs help maintain natural water quality. Aquifer protection areas have been established around more than one half of the community public-supply wells. A recent law requires classification of ground water into one of four quality categories, with State control over certain land uses within each category. The State has not found it necessary to regulate the withdrawal, diversion, or use of ground water, and probably will not develop a program to regulate use unless the number and severity of quantity problems increase greatly.

WATER QUALITY IN PRINCIPAL AQUIFERS

Two types of principal aquifers are present in Vermont (fig. 2A1) —unconsolidated deposits and bedrock. Stratified drift forms the most productive unconsolidated aquifer; however, many rural private wells are completed in till aquifers. Although dug wells in till can yield enough water for single-family domestic needs, these aquifers may be unreliable during dry periods. Metamorphic and igneous crystalline rock and carbonate rock, which has been metamorphosed to varying degrees, form the bedrock aquifers of the State (U.S. Geological Survey, 1985, p. 421–426).

The quality of ground water in Vermont aquifers generally is suitable for most purposes, and generally does not exceed the EPA primary and secondary national drinking-water standards (U.S. Environmental Protection Agency, 1986a,b). A summary of water-quality analyses from public-supply systems in the State indicated that the median pH of water from 342 public-supply systems was 7.4 (David Manning, Vermont Department of Health, written commun., 1986). The median pH of water was 7.4 in 54 wells in stratified drift, 7.5 in 229 wells in bedrock, and 6.9 in 69 springs.

Radon levels in 689 ground-water samples from 366 public-supply wells range from 0 to 14,400 pCi/L (picocuries per liter). Water samples from four bedrock wells serving one system had the only radon levels larger than 10,000 pCi/L; the next largest level was 6,200 pCi/L. The mean radon level is 1,054 pCi/L (Manning and Ladue, 1986). Presently, there are no drinking-water standards for radon levels.

Concentration of trace elements in ground-water samples from 342 public-supply systems had small values for the following constituents: arsenic, barium, cadmium, chromium, copper, fluoride, lead, mercury, selenium, and zinc (David Manning, Vermont Department of Health, written commun., 1986).

BACKGROUND WATER QUALITY

A graphic summary of selected water-quality variables compiled from the files of the Vermont Department of Health and from the Vermont Depatment of Environmental Conservation (DEC), formerly theDepartment of Water Resources and Environmental Engineering (Stedman and others, 1980), is presented in figure 2C. The summary is based on hardness (as calcium carbonate), nitrate (as nitrogen), chloride, manganese, and sodium analyses of water samples collected from 1979 to 1986 from the principal aquifers in Vermont. Percentiles of these variables are compared to national standards that specify the maximum concentration or level of a contaminant in drinking-water supplies as established by the U.S. Environmental Protection Agency (1986a,b). The primary maximum contaminant level standards are health related and are legally enforceable for public water supplies. The secondary maximum contaminant level standards apply to esthetic qualities and are recommended guidelines. The primary drinking-water standards include a maximum concentration of 10 mg/L (milligrams per liter) nitrate (as nitrogen), and the secondary drinking-water standards include maximum concentrations of 250 mg/L chloride, and 50 μg/L (micrograms per liter) manganese.

The minimum reporting level, as used in the report, is a unique value assigned by the Vermont Department of Health. The level may be equal to or larger than the minimum detection limit, depending on the constituent.

Stratified-Drift Aquifers

Stratified-drift deposits consist of unconsolidated sand or sand and gravel. These deposits are primarily in valley lowlands throughout the State and in some interstream areas along the western side of the Green Mountains. Most of these deposits are isolated from one another.

The water was soft (hardness 0–60 mg/L as calcium carbonate) in 10 percent of the 58 analyses reviewed (fig. 2*C*, aquifer 1). Almost 40 percent of the water was moderately hard (61–120 mg/L), about 25 percent was hard (121–180 mg/L), and 25 percent was very hard (greater than 180 mg/L). Although dissolved-solids concentrations were larger than 100 mg/L in about 80 percent of the water samples, none of the samples exceeded the secondary drinking-water standard of 500 mg/L for dissolved solids.

At least 75 percent of the 58 samples had iron values at or smaller than the minimum reporting level of 100 μg/L. Iron concentrations exceeded the secondary drinking-water standard of 300 μg/L in less than 5 percent of the water samples. However, ground-water studies in some areas in Vermont indicated that elevated iron concentrations are common (Hodges and others, 1976a,b; 1977; Willey and Butterfield, 1983). At least 50 percent of the 58 water samples had manganese values smaller than the minimum reporting level of 10 μg/L (fig. 2*C*). Manganese concentrations exceeded the secondary drinking-water standard of 50 μg/L in about 15 percent of the water samples.

Combined sodium and potassium concentrations are generally smaller than 10 mg/L, except in the southwestern part of the State where they range from 10 to 50 mg/L. Chloride and sulfate concentrations each were generally smaller than 25 mg/L (Pettyjohn and others, 1979). Seventy-five percent of the 58 water samples have sodium and chloride concentrations smaller than 14 and 24 mg/L, respectively (fig. 2*C*). About 50 percent of these samples have sodium and chloride concentrations at or near the Department of Health's minimum reporting levels of 5 and 15 mg/L, respectively.

The water from 44 samples had a median concentration of nitrate, as nitrogen, of 0.60 mg/L (fig. 2*C*). Ninety percent of the samples had concentrations smaller than 2.0 mg/L.

More than 70 public-supply wells are drilled in stratified-drift aquifers. Of the 29 public-supply wells that have average daily withdrawals larger than 50,000 gallons, 28 are in stratified-drift aquifers. These aquifers commonly have a saturated thickness of less than 70 feet and they are generally unconfined. Because the water table is commonly less than 30 feet deep, stratified-drift aquifers are susceptible to contamination.

Crystalline-Bedrock Aquifer

Crystalline rock units consist of metamorphic and igneous rocks that contain recoverable water only in open fractures (Doll and others, 1961). The storage capacity of these units is small and generally decreases with depth. Domestic wells that penetrate the crystalline-bedrock aquifer are commonly less than 600 feet deep and yield less than 10 gal/min (gallons per minute). In the valleys in mountainous areas, where the crystalline bedrock is extensively fractured, bedrock wells commonly yield 25 to 50 gal/min. More than 250 public-supply wells tap the crystalline-bedrock aquifer, but only 7 have been approved by the Department of Health for production greater than 100 gal/min (David Manning, Vermont Department of Health, written commun., 1986).

Water from the crystalline-bedrock aquifer had slightly less hardness than water from the stratified-drift aquifers (fig. 2*C*, aquifer 2); however, the percentages of soft, moderately hard, hard, and very hard water were approximately the same. Dissolved-solids concentrations were also a little smaller in this aquifer than in the stratified-drift aquifers.

Iron and manganese concentrations in at least 50 percent of 182 water samples were smaller than the minimum reporting levels. In 10 percent of the water samples, iron concentrations exceeded the secondary drinking-water standard of 300 μg/L; the largest concentration was 1,500 μg/L. In 25 percent of the water samples, manganese concentrations exceeded the secondary drinking-water standard of 50 μg/L; 10 percent of the water samples had manganese concentrations larger than 220 μg/L.

Sodium and chloride concentrations in water from crystalline-bedrock aquifers were similar to those in water from stratified-drift aquifers (fig. 2*C*). Seventy-five percent of the water samples from public-supply wells had sodium and chloride concentrations smaller than 14 and 20 mg/L, respectively.

Nitrate, as nitrogen, concentrations in 75 percent of the water samples were smaller than the minimum reporting level of 0.50 mg/L. Distribution of nitrate, as nitrogen, determined from analyses of 174 water samples, indicated smaller concentrations in the crystalline-bedrock aquifer than in the stratified-drift aquifers.

Carbonate-Bedrock Aquifer

The carbonate-bedrock aquifer is present in the Champlain Lowlands east of Lake Champlain and in the Vermont Valley (fig. 2*A*2, Doll and others, 1961). Rock units include limestone, dolomite, marble, and interbedded noncarbonate shale and quartzite. Domestic wells that penetrate this aquifer commonly are less than 300 feet deep and yield less than 20 gal/min. More than 60 public-supply wells tap this aquifer. Where carbonate minerals have been subjected to solution weathering along fractures, hydraulic conductivity and storage have been increased. A commercial well at the Pittsford National Fish Hatchery (Rutland County) had the largest yield; this well was pumped for 72 hours at 900 gal/min (Gary Smith, D. L. Maher Co., oral commun., 1985).

The hardness of water from the carbonate-bedrock aquifer was significantly larger than in water from the crystalline-bedrock or stratified-drift aquifers (fig. 2*C*). Nearly all the water was at least moderately hard; from 50 to 75 percent was very hard. Iron and manganese concentrations in water from this aquifer were smaller than those in water from the crystalline-bedrock aquifer, and concentrations of manganese in water from this aquifer were smaller than those in water from stratified-drift aquifers.

Sodium concentrations in water from the carbonate-bedrock aquifer were larger than in water in both the crystalline-bedrock and stratified-drift aquifers (fig. 2*C*). Chloride concentrations were smaller than the minimum reporting level of 15 mg/L in more than 50 percent of the samples, but slightly larger than those in the other two aquifers.

Nitrate, as nitrogen, concentrations were smaller than the minimum reporting level in more than 50 percent of the water samples. None of the 49 samples had concentrations that exceeded the 10-mg/L drinking-water standard.

EFFECTS OF LAND USE ON WATER QUALITY

The quality of ground water has been degraded in some areas by urbanization, waste disposal, and agricultural practices. Although the affected areas are generally small, they are widespread.

Urbanization

Degradation of ground-water quality has occurred in the most populous counties from land uses associated with urbanization. Increased concentrations of sodium and chloride occur mostly as a result of the use of highway deicing salts and sewage discharge. Petroleum contamination has been caused by leaks from underground petroleum storage tanks, and by spillage of petroleum at the surface.

Elevated concentrations of sodium and chloride occur in some areas. The source of these two constituents is usually highway deicing salts, but sewage discharge and salty backwash from water softeners are also sources. More than 10 percent of the public-supply wells yield water with sodium concentrations larger than 20 mg/L, the maximum recommended sodium concentration in drinking water for people on sodium-restricted diets. About 5 percent of the wells yield water with concentrations of chloride larger than the secondary standard of 250 mg/L.

The State and many municipalities use deicing salts, primarily sodium chloride, in the winter maintenance of roads. Although most contamination of ground water with sodium chloride has resulted from this practice, at least six instances were as a result of runoff from salt-storage areas. More than 40 of the 123 wells that tap contaminated aquifers, summarized by county in figure 3*B*, were contaminated by road salts. Eight public wells serving 1,300 people in Chittenden County were among those affected (Vermont Department of Public Health files; Marshfield Engineering Services, 1982). Since 1978 the Construction Division of the Department of Transportation has replaced more than 30 private wells that were degraded by State roadway salting (Roderick Maclay, Vermont Department of Transportation, oral commun., 1987).

By February 1986, there were 27 documented sites of contaminated ground water by petroleum leaks and spills (fig. 3*B*) (Thomas Moye, Department Conservation, Waste Management Division written commun., 1986). By February 1987, an additional 19 sites (not shown in figure 3*B*) had been identified (Thomas Moye, Waste Management Division, oral commun., 1987). The actual number of wells that tap aquifers contaminated by petroleum is not known, but is probably small. In 1982, Marshfield Engineering Services reviewed 17 instances of petroleum contamination and reported 9 wells that yield contaminated water, including a public-supply well in the stratified-drift aquifer, which served about 560 people in Essex County; this well was removed from service. A municipal well completed in an aquifer contaminated by petroleum in East Middlebury (Addison County) was removed from service. The Waste Management Division has identified 8,000 to 10,000 underground storage tanks for petroleum products. One-half of these are gasoline tanks with capacities greater than 1,100 gallons. These tanks are now subject to registration and testing for leaks

Waste Disposal

Disposal of hazardous and municipal wastes has caused serious local problems with ground-water quality. State agencies also receive about 200 reports of spills of hazardous materials annually. Two hazardous-waste sites in Burlington (Chittenden County) and Springfield (Windsor County) are included on the NPL established by the EPA. These Superfund sites will be evaluated and cleaned under CERCLA (U.S. Environmental Protection Agency, 1986c). A public-supply system serves the area around the Burlington site, which was used for the disposal of coal-tar sludge; thus far, no wells have been affected. Houses have been built adjacent to the old Springfield municipal landfill, which contains industrial machine-tool wastes, including oils, solvents, and plating wastes. Several private wells and springs near this site were found to be contaminated by organic compounds and trace metals.

As of September 1985, two hazardous-waste sites at one facility near Burlington had been identified by the DOD 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. These sites were scheduled for confirmation studies to determine if remedial action is required.

Ground-water contamination by hazardous wastes has occurred at 32 sites to an extent that requires assessment and monitoring under Federal guidelines. These sites are included as "other" sites in figure 3*A*. These sites represent locations identified by the Waste Management Division where hazardous materials are being used, created, or temporarily stored. Three additional sites are being monitored under the Federal Resource Conservation and Recovery Act (RCRA) of 1976. Two of these sites are shown in figure 3*A*. The third site is not shown but is close to the CERCLA site in Burlington. Organic compounds from industrial waste, mostly solvents, are the major contaminants at most of the 32 sites. Some of the more common compounds are trichloroethylene, methyl chloride, tetrachloroethylene, dichloroethylene, methylethyl ketone, methyl isobutyl ketone, carbon tetrachloride, acetone, benzene, toluene, and phenol.

The Waste Management Division has confirmed ground-water contamination at 9 additional sites and contamination is suspected at 10 other sites. These are also identified as "other" sites in figure 3*A*. Major contaminants are organic compounds and trace metals.

Vermont's most publicized case of ground-water contamination involved the release of tetrachloroethylene from an industrial uniform dry cleaning establishment in the village of Williamstown (Orange County). Cleanup efforts are being conducted and a public well downgradient from the site is being monitored.

Vermont has 69 active and 19 inactive landfills. The CERCLA site in Springfield, two of the RCRA sites, and six of the "other" sites were municipal landfills that were either publicly or privately owned. The number of all municipal landfills in each county identified by the Waste Management Division is shown in figure 3*C*. Some degradation of ground-water quality has probably occurred beneath all landfills. The extent of contamination at all of these sites is still being assessed by the Waste Management Division through a network of about 290 monitoring wells (Julie Hackbarth, Waste Management Division, oral commun., 1986). Leachate from landfills commonly adds iron, dissolved solids, nitrogen as ammonia or nitrate, and a variety of organic compounds to the ground water.

Commercial enterprises, which generate less than 100 kilograms of hazardous wastes per month, are still permitted to dispose of these wastes at certified landfills. Private household wastes, which generally include some hazardous materials, have been disposed of in all landfills.

Effluent from septic systems is known to have contaminated 13 wells and 1 spring (Marshfield Engineering Services, 1982). Large septic systems that service second-home developments and resorts and that are in the shallow soils of mountainous terrain are being monitored by the State. Backflushing of water softeners introduces chloride to septic systems and dry wells; this has resulted in contamination of aquifers, including a bedrock aquifer tapped by two wells serving a college in Orange County and a bedrock aquifer tapped by one well serving a mobile-home park in Windsor County (Marshfield Engineering Services, 1982). Discharge of wastewater to leach fields and dry wells from other facilities, such as restaurant kitchens, laboratory and industrial waste water, printing and photography facilities, boilers, and floor residues from vehicle-repair shops have degraded ground-water quality at some sites.

Agricultural Practices

Application of chemical fertilizers has increased nitrate concentrations in aquifers in Orleans and Windsor Counties. In Orleans County, increased concentrations of nitrate in water from a well completed in the stratified-drift aquifer were first detected in 1978. By 1984, concentrations were close to the drinking-water standard of 10 mg/L. Since then, restricted use of fertilizer in cornfields during the growing season has stopped the rise in nitrate concentration. Similar, but less severe instances have been documented in Franklin and Washington Counties and in other areas of Windsor County where private wells have been affected (Marshfield Engineering Services, 1982). In addition, ground water was contaminated and the Lyndonville public-supply well in the stratified-drift aquifer was abandoned after vandals ruptured a storage tank for chemical fertilizer. This well served about 3,000 people.

Manure storage can result in ground-water contamination. In Caledonia County, the ground water was contaminated when manure was dumped directly into a gravel pit dug into the stratified-drift aquifer. In another instance, a shallow aquifer was contaminated by a nearby open silage pit (Marshfield Engineering Services, 1982).

POTENTIAL FOR WATER-QUALITY CHANGES

Changes in ground-water quality in response to potential regional human activities and long-term changes in climatic or atmospheric conditions have not been investigated. For example, acid precipitation on areas underlain by thin soils and noncalcareous bedrock with a small buffering capacity is suspected of decreasing the pH of ground water and increasing the iron and aluminum concentrations in the water.

As the population of Vermont increases, the potential for ground-water contamination also will increase. Some ground-water contamination from sources such as septic tanks and road salts will be unavoidable. However, the degree and extent of contamination from these and other sources will depend in large measure on how rigorously State and local agencies manage land-use activities. Control over the storage and disposal of hazardous wastes, such as limiting the number of new disposal sites, will decrease new instances of contamination. Alternative methods for disposing of municipal wastes, such as incineration and recycling, may further decrease contamination caused by leachate from landfills. Hydrostatic testing of and replacement schedules for underground storage tanks for petroleum products can be expected to decrease instances of petroleum leaks.

Although some changes in agricultural practices, such as application rates and times of fertilization, may decrease the amount of nutrients introduced into ground water, the use of pesticides and the level of agricultural activity throughout the State will probably be the major determinants of future effects on ground-water quality.

The designation of aquifer-protection areas by the Water Quality Division (fig. 4; David Butterfield, Vermont Department of Environmental Conservation, Ground Water Management Section, oral commun., 1986; Water Quality Division, 1983) for community public-supply wells is more than one half complete. These areas and the new classification program should help protect water quality. Aquifer-protection ordinances incorporated into municipal master plans will attempt to assure good water quality in designated stratified-drift and bedrock aquifers (Mullikin, 1984).

GROUND-WATER-QUALITY MANAGEMENT

Vermont's regulatory agencies hope to maintain the good quality of the State's drinking-water sources by limiting those human activities that can degrade ground-water quality. The ability to protect ground-water resources was significantly strengthened in 1985 when the legislature passed Chapter 48 of Title 10 of the Vermont Statues Annotated (10 V.S.A., sections 1390 through 1410). The new law required that ground-water sources be assigned to one of four classes and provided for some State control of land uses within each class.

The Agency of Natural Resources (ANR), formerly the Agency of Environmental Conservation, is responsible for protecting the State's ground-water resources. The Department of Health is responsible for protecting drinking-water supplies. The Department of Agriculture is responsible for controlling the use of pesticides. A ground-water coordinating committee attempts to synchronize agency programs in a comprehensive statewide effort. State and local guidelines for onsite treatment of domestic wastewater are regulated by municipalities. Towns may voluntarily contract with the Vermont Association of Conservation Districts' On-Site Sewage Program (OSSP) to approve the location, review system design, and inspect installation of septic systems.

Regional Planning Commissioners may cooperate with State agencies in establishing local ground-water protection plans and ordinances. The State, assisted by the EPA, supports the New England Interstate Water Pollution Control Commission in activities that pertain to ground water.

Under the provisions of Part b of the Safe Drinking Water Act (SDWA) and Title 18 of the Vermont Statutes Annotated, the Department of Health regulates the quality of water delivered from public water-supply systems and protects ground- and surface-water sources for those systems. The Department of Environmental Conservation under the direction of the ANR, manages the Underground Water Source Protection Program (UWSPP), which is also known as Underground Injection Control (UIC) Program. The Governor has designated the Department of Health to administer the Well-Head-Protection areas program authorized under Section 1428 of the SDWA.

The ANR, which delineates aquifer-protection areas for public water sources, has State Statutory Authority to designate Classes I, II, and IV ground waters; however, Class I designations involving private land must be approved by the State Legislature. Class III ground water is subject to regulations governing subsurface and surface waste disposal.

Classes I and II ground water are for public water-supply use, Class III is for individual domestic water supplies, and Class IV ground water may be used for some agricultural, commercial, and industrial purposes, and its quality may be less than that for potable water. The draft rules for Class IV assume that safe assimilation of most nonhazardous or toxic wastes is possible, and also assume that where necessary the best technical methods will be incorporated into specific regulatory programs.

Classes I and II will replace more than 200 aquifer-protection areas that were formerly mapped as protection areas for existing public-supply community sources (fig. 4). About nine Class I ground-water areas have been proposed for legislative approval. Within 3 years, more than 350 Class II designations are anticipated.

The State has a program under the provisions of RCRA which requires permits for the storage, treatment, transportation, and disposal of hazardous wastes. To date, no facilities for disposing of hazardous waste have been authorized within the State.

Vermont uses Sections 106, 205, and formerly used 208 funds to support its ground-water-quality management program. A study is now underway to determine the importance of septic systems as sources of nitrogen in ground water near residential developments. This study is expected to be useful in determining the optimum density of septic system allowable within Class II ground-water areas.

Until the passage of 10 V.S.A., Chapter 48, the common-law rule of absolute ownership of the land surface (and the ground water beneath it) prevailed. Now, people who cannot use their ground water because of quality problems resulting from acts of others may take the issue to court.

Water-well drillers have been licensed since 1965, and are required to file well reports. These reports now form the largest part of the State's ground-water data base.

The State has not established a network to monitor ground-water quality statewide because existing data are assumed to be adequate to proceed with implementation of a ground-water protection program. As new data about the environment become available, the State will amend its ground-water management decisions. The State will delineate well-protection zones based on its Class I and Class II ground-water boundaries for all new public wells. The Extension Service programs of the University of Vermont and public meetings will help educate the public about the need to protect ground water.

SELECTED REFERENCES

Association of State and Interstate Water Pollution Control Administrators, 1985, America's clean water, the State's nonpoint source assessment 1985—Appendix: Washington, D.C., Association of State and Interstate Pollution Contol Administrators, 530 p.

Doll, C.G., Cady, W.M., Thompson, J.B., and Billings, M.P., 1961, Centennial geologic map of Vermont: Vermont Geological Survey.

Hodges, A.L., Jr., Butterfield, David, and Ashley, J.W., 1976a, Ground-water resources of the Barre-Montpelier area, Vermont [Includes "Ground-water availability in the Barre-Montpelier area (addendum to "A rural comprehensive water and sewer plan for Washington County, Vermont, 1969"), 1972, by A.L. Hodges, Jr., and David Butterfield]: Vermont Department of Water Resources, 27 p.

_____ 1976b, Ground-water resources of the White River Junction area, Vermont. [Includes "Ground-water availability in the White River Junction area (addendum to "A rural comprehensive water and sewer plan for Windsor County, Vermont, 1969"), 1972, by A.L. Hodges, Jr., and David Butterfield]: Vermont Department of Water Resources, 27 p.

Hodges, A.L., Jr., Willey, R.E., Ashley, J. W., and Butterfield, David, 1977, Ground-water resources of the Upper Winooski River basin, Vermont: U.S. Geological Survey Water-Resources Investigations 77-120, 27 p.

Manning, David, and Ladue, Winslow, 1986, Radon in Vermont public water supplies: Burlington, Vt., Vermont Department of Health, 59 p.

Marshfield Engineering Services, 1982, Vermont underground injection practices and groundwater contamination incidents survey: Montpelier, Vt., Department of Water Resources and Environmental Engineering, Ground Water Management Section, 33 p.

Mullikin, E.B., 1984, An ounce of prevention; a ground water protection handbook for local officials: Montpelier, Vt., Vermont Ground Water Coordinating Committee, 48 p.

Pettyjohn, W.A., Studlick, J.R.J., Bain, R.C., and Lehr, J.H., 1979, A ground-water quality atlas of the United States: Dublin, Ohio, National Water Well Association, p. 4, 6, 235-239.

Raisz, Erwin, 1954, Physiographic diagram, p. 59, *in* U.S. Geological Survey, 1970, National Atlas of the United States: Washington, D.C., U.S. Geological Survey, 417 p.

Ratte, Charles, and Bradley, D.C., 1982, The Waits River formation—most favorable bedrock aquifer in southeastern Vermont: Montpelier, Vt., The Green Mountain Geologist, v. 8, no. 4, p. 7.

Stedman, G.D., Thiel, S.A., and Butterfield, David, 1980, Ground water quality for selected Vermont community ground water systems, addendum to Vermont ground water pollution source inventory: Montpelier, Vt., Department of Water Resources and Environmental Engineering, Ground Water Management Section, 20 p.

U.S. Bureau of the Census, 1982, Census of the population, characteristics of the population, number of inhabitants—1980: Published separately by States, Puerto Rico, and outlying areas: PC80-1-A1 to A57a, and A57b.

U.S. Department of Defense, 1986, Status of the Department of Defense Installation Restoration Program—Information paper: Washington, D.C., U.S. Department of Defense, Office of the Assistant Secretary of Defense (Aquisition and Logistics), and Environmental Policy Directorate, February, 35 p.

U.S. Environmental Protection Agency, 1986a, Maximum contaminant levels (subpart part 141), National interim primary drinking water regulations: U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1986, p. 524-528.

_____ 1986b, Secondary maximum contaminant levels (section 143.3 of part 143, national secondary drinking water regulations): U.S. Code of Federal Regulations, Title 40, Parts 100 to 149, revised as of July 1, 1986, p. 587-590.

_____ 1986c, Amendment to National Oil and Hazardous Substances Contingency Plan; national priorities list, final rule and proposed rule: Federal Register, v. 51, no. 111, June 10, 1986, p. 21053-21112.

_____ 1986d, National priorities list fact book—June 1986: U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, report HW-7.3, 94 p.

U.S. Geological Survey, 1985, National Water Summary 1984—Hydrologic events, selected water-quality trends, and ground-water resources: U.S. Geological Survey Water-Supply Paper 2275, 467 p.

Water Quality Division, 1983, Vermont aquifer protection area reference document: Montpelier, Vt., Department of Water Resources and Environmental Engineering, 42 p., pls. 1-4.

Willey, R.E., and Butterfield, David, 1983, Ground-water resources of the Rutland area, Vermont: U.S. Geological Survey Water-Resources Investigations Report 82-4057, 38 p.

Prepared by John E. Cotton, U.S. Geological Survey; "Ground-Water-Quality Management" section by David Butterfield, Vermont Department of Environmental Conservtion, Ground Water Management Section.

FOR ADDITIONAL INFORMATION: Chief, New Hampshire-Vermont Office, 525 Clinton Street, RFD 12, Bow, NH 03301

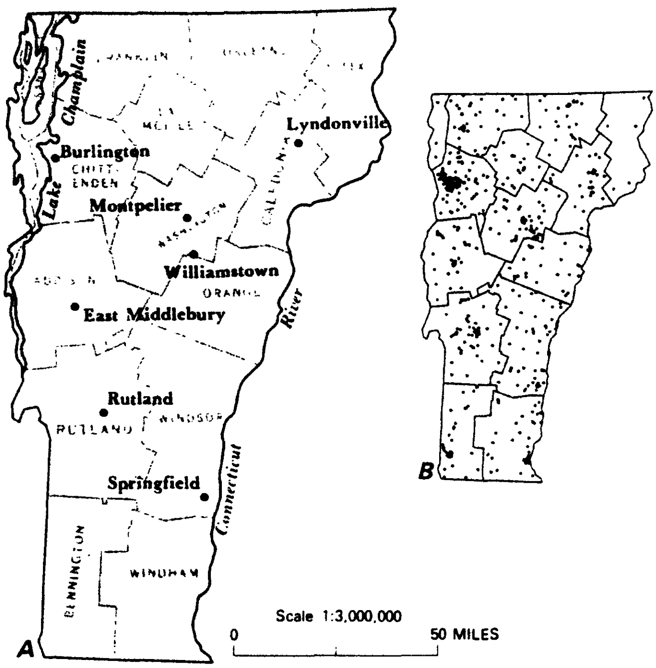

Figure 1. Selected geographic features and 1985 population distribution in Vermont. *A*, Counties, selected communities, and major drainages *B*, Population distribution, 1985; each dot on the map represents 1,000 people. (Source: *B*, Data from U.S. Bureau of the Census 1980 decennial census files,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

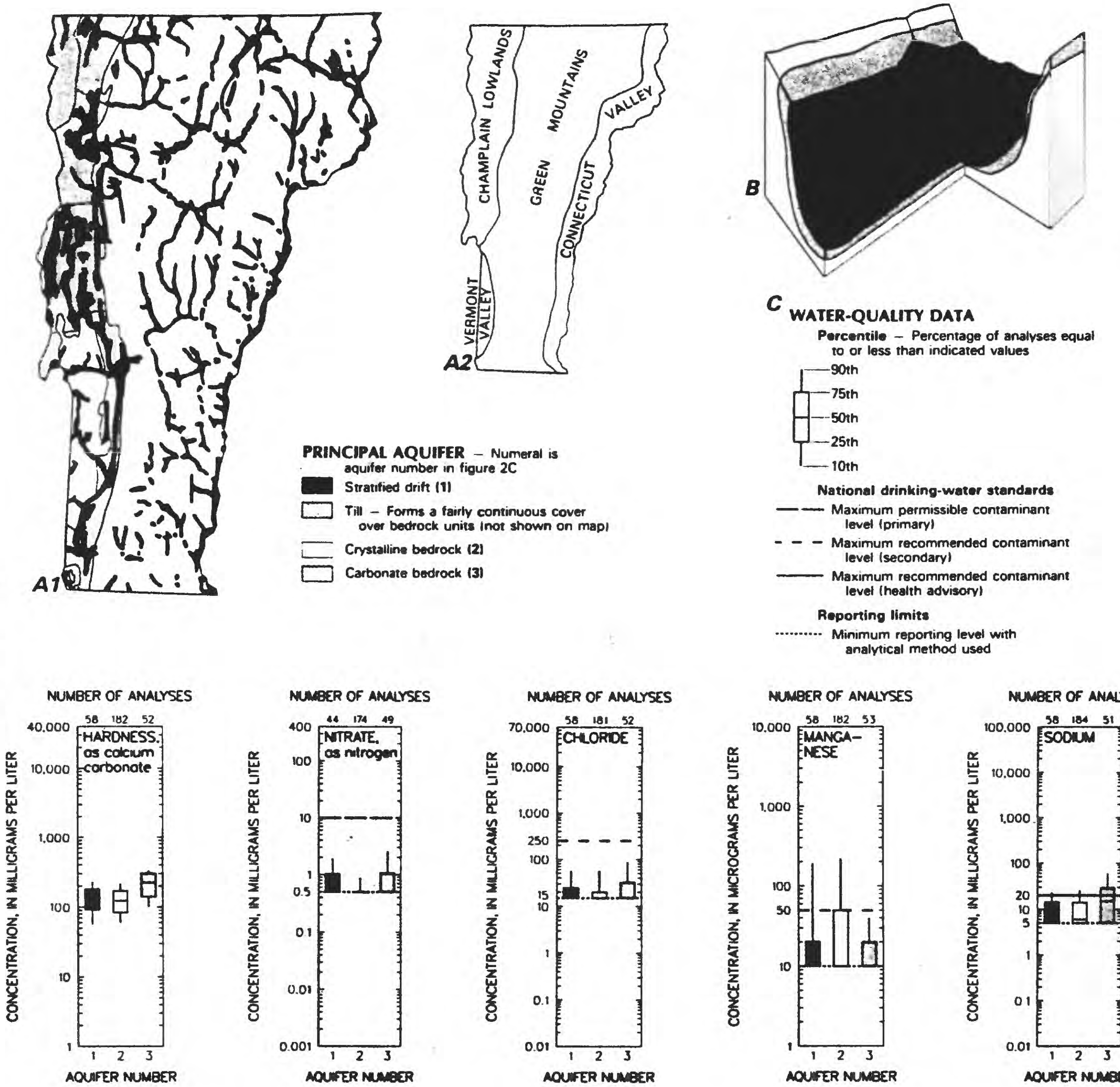

Figure 2. Principal aquifers and related water-quality data in Vermont. *A1*, Principal aquifers; *A2*, Physiographic diagram. *B*, Typical stratigraphic sequences of aquifer materials. *C*, Selected water-quality constituents and properties, as of 1979–86. (Sources: *A*, *B*, Compiled by R.E. Hammond and J.E. Cotton from U.S. Geological Survey files; Raisz, 1954. *C*, Analyses compiled from the files of the Vermont Department of Health and from the Vermont Department of Environmental Conservation (Stedman and others, 1980); national drinking-water standards from U.S. Environmental Protection Agency, 1986a,b.)

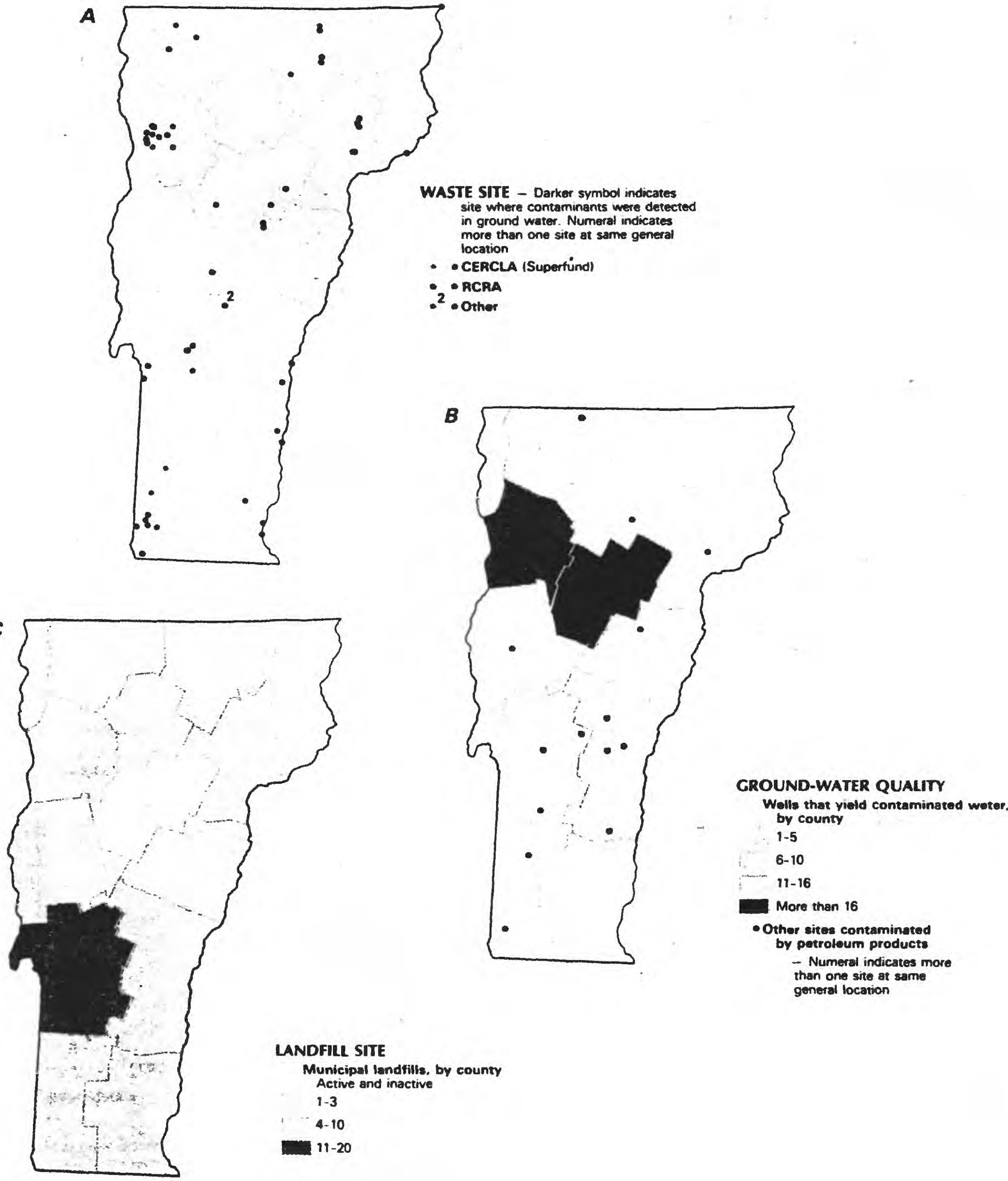

Figure 3. Selected waste sites and ground-water-quality information in Vermont. *A*, Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites; Resource Conservation and Recovery Act (RCRA) sites; and other selected waste sites, as of 1986. *B*, Wells that yield contaminated water, by county, and location of ground-water contamination resulting from spills and leaks of petroleum products, as of 1986. *C*, Municipal landfills, as of 1986. (Sources: *A*, compiled from the files of Vermont Department Environmental Conservation, Waste Management Division and Water Quality Division. *B*, compiled from the files of Vermont Department of Health and Vermont Department of Environmental Conservation; Marshfield, 1982. *C*, compiled from the files of Vermont Department of Environmental Conservation, Waste Management Division.)

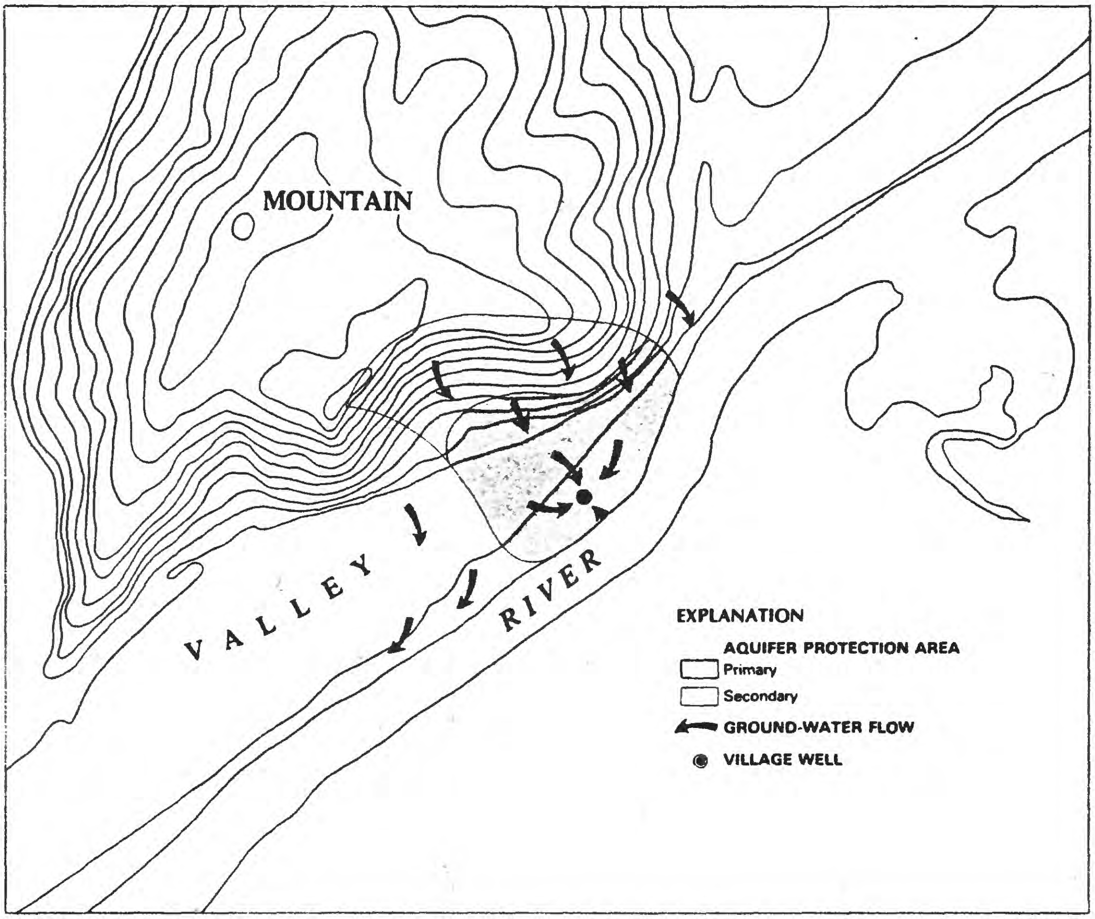

Figure 4. Example of a Vermont aquifer-protection area (Source: Mulliken, 1984, p. 13)