GROUND-WATER RESOURCES IN NEW HAMPSHIRE: STRATIFIED-DRIFT AQUIFERS

U.S. GEOLOGICAL SURVEY
WATER-RESOURCES INVESTIGATIONS REPORT 95-4100

Prepared in cooperation with
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES,
WATER RESOURCES DIVISION

EXPLANATION

MAJOR STRATIFIED-DRIFT AQUIFER

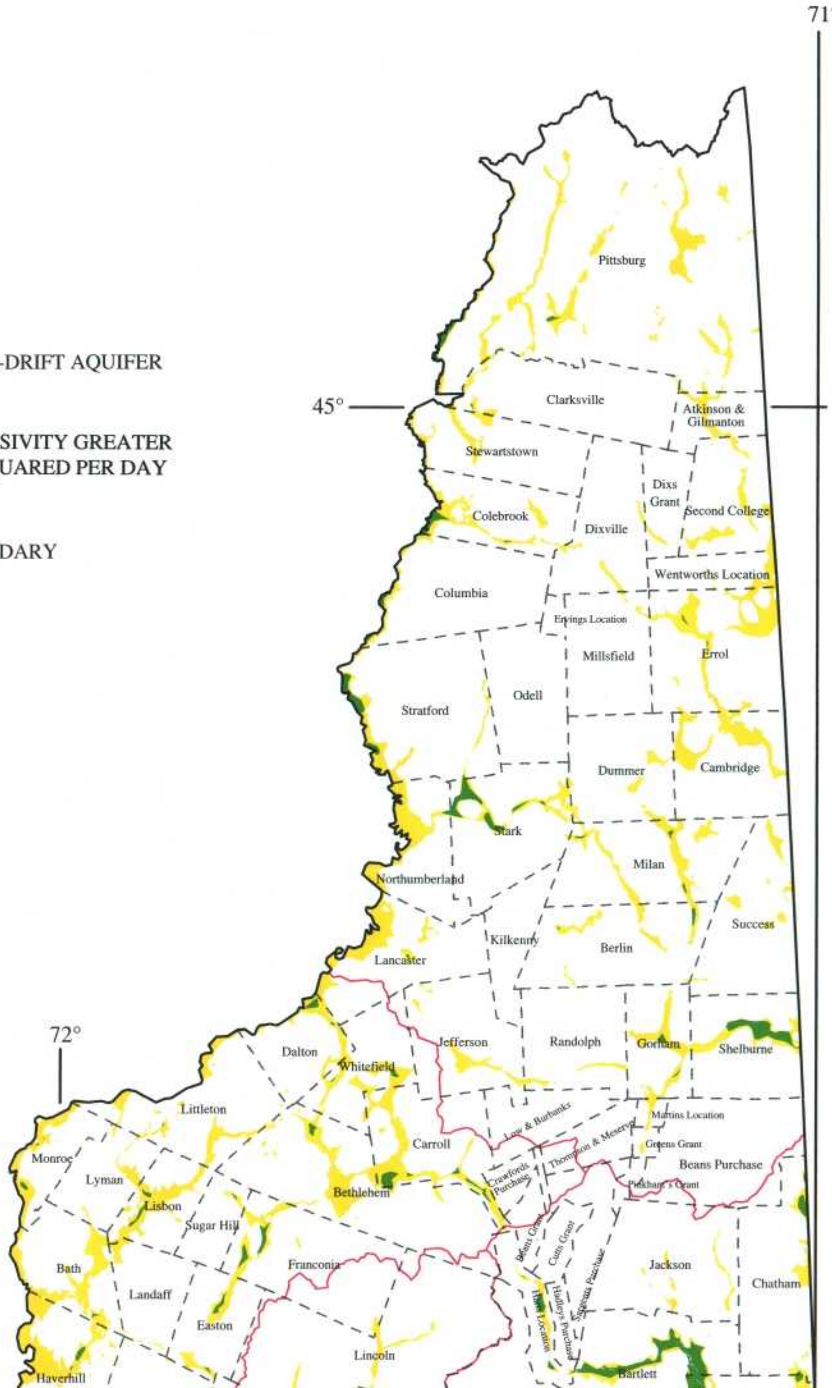
ZONE OF TRANSMISSIVITY GREATER THAN 2,000 FEET SQUARED PER DAY

STUDY AREA BOUNDARY

TOWN BOUNDARY

0 5 10 MILES

0 5 10 KILOMETERS



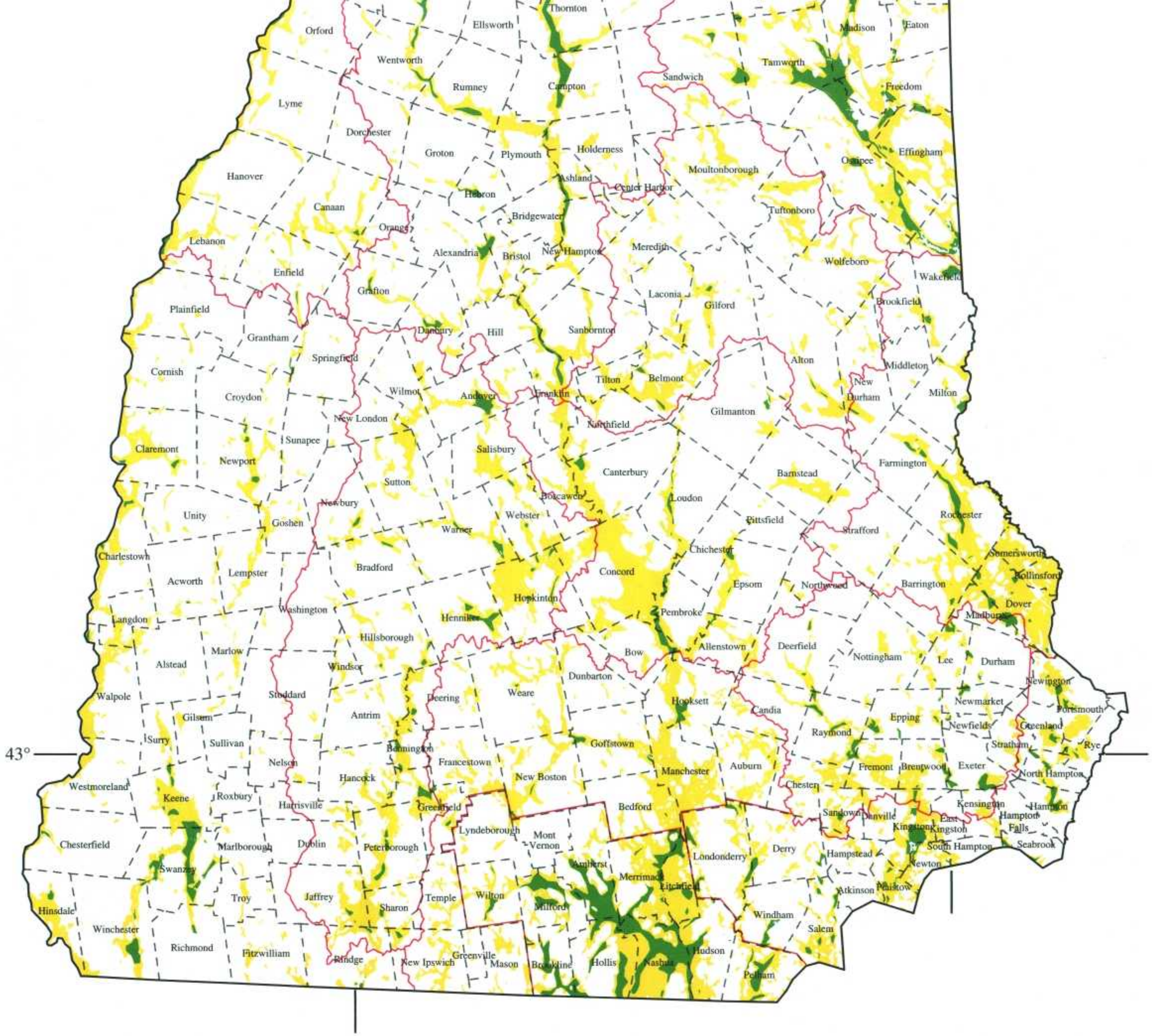


Figure 17. Major stratified-drift aquifers and zones of transmissivity greater than 2,000 square feet per day in New Hampshire.

Winnipesaukee River Basin

The Winnipesaukee River Basin in central New Hampshire has a drainage area of 484 mi^2, of which 66 mi^2, or 14 percent of the basin, are underlain by stratified-drift aquifers. Saturated thickness of parts of an aquifer in Belmont exceeds 100 ft, although generally it is less than 50 ft. Transmissivity, generally less than 1,000 ft^2/d, exceeds 6,000 ft^2/d in areas of Belmont, Alton, and New Durham. Belmont and Alton withdraw ground water from stratified-drift aquifers for municipal public-supply wells. Induced infiltration from nearby rivers could provide additional water for municipal public supplies in Tilton, Belmont, Gilford, Alton, and Meredith. Results of computer model simulations indicate that aquifers in Alton and Belmont can yield up to 1.1 and 1.8 Mgal/d of water, respectively (Ayotte, in press).

Lower Connecticut River Basin

The Lower Connecticut River Basin in southwestern New Hampshire has a drainage area of 1,163 mi^2, of which 116 mi^2, or 10 percent of the basin, are underlain by stratified-drift aquifers. Saturated thickness is greater than 400 ft in parts of Charlestown and Westmoreland. Transmissivity exceeds 4,000 ft^2/d in some aquifers in Newport, Walpole, Charlestown, Grantham, Keene, Hinsdale, and Chesterfield but is less than 1,000 ft^2/d in 80 percent of the aquifers in the area. Municipal public-supply wells withdraw water from stratified-drift aquifers to supply parts of Charlestown, Hinsdale, Keene, Marlborough, Newport, Plainfield, Chesterfield, Troy, Walpole, and Winchester. Additional water is potentially available from stratified-drift aquifers in many towns in the study area (Moore and others, 1994).

Contoocook River Basin

The Contoocook River Basin in southwestern New Hampshire has a drainage area of 766 mi^2, of which 123 mi^2, or 16 percent of the basin, are underlain by stratified-drift aquifers. Saturated thickness exceeds 200 ft in Hancock next to Norway Pond, and in central Andover, but generally is less than 80 ft. Estimated transmissivity was at least 22,000 ft^2/d along the Contoocook River in Bennington. Transmissivity is greater than 8,000 ft^2/d in the Contoocook River valley in part of Peterborough and in New Ipswich, in Antrim, Bennington, Greenfield and Hillsborough, northwestern Henniker, Warner, central Andover, and central Hopkinton, although it generally is less than 2,000 ft^2/d. Public-supply wells in stratified-drift aquifers provide municipal water to Bennington (for Antrim), Henniker, Hillsborough, Hopkinton, Jaffrey, Peterborough, and Warner. Induced infiltration from rivers could provide a source of additional ground water in several towns, including Harrisville, Hillsborough, and Antrim. Results from this study indicate that Peterborough, Hancock, Henniker, Hopkinton, Warner, Bradford, Andover, and Salisbury could potentially derive additional supplies of ground water from stratified-drift aquifers if needed (Harte and Johnson, 1995).

Upper Merrimack River Basin

The Upper Merrimack River Basin in south-central New Hampshire has a drainage area of 519 mi^2, of which 80 mi^2, or 15 percent of the basin, are underlain by stratified-drift aquifers. Parts of aquifers in Canterbury, Concord, and Loudon have transmissivities of at least 5,000 ft^2/d. Saturated thicknesses of aquifers in this river basin are generally less than 80 ft. Additional water is potentially available from stratified-drift aquifers in Bow, Pembroke, Chichester, Loudon, Northfield, Franklin, Allenstown, Epsom, and Concord. Induced infiltration from the Merrimack, Soucook, and Suncook Rivers may provide additional water to aquifers. Municipal public-supply wells currently (1995) provide water from stratified-drift aquifers to Barnstead, Concord, Epsom, and Pembroke (P.J. Stekl, U.S. Geological Survey, written commun., 1994).

Bellamy, Cocheco, and Salmon Falls River Basins

The Bellamy, Cocheco, and Salmon Falls River Basins in southeastern New Hampshire have a drainage area of 330 mi^2, of which 50 mi^2, or 15 percent of the basin, are underlain by stratified-drift aquifers. Aquifers scattered throughout Dover, Farmington, Rochester, and Somersworth have transmissivities that range from 2,400 to 26,700 ft^2/d, and saturated thicknesses greater than 100 ft. Municipal public-supply wells in Dover, Farmington, Rollinsford, Somersworth, Milton, and Wakefield withdraw water from stratified-drift aquifers. Stratified-drift aquifers in Milton, Union, Rochester, Farmington, and New Durham can potentially yield significant quantities of water through induced infiltration from nearby rivers and ponds. Parts of aquifers in Milton, Rochester and Somersworth extend into Maine (Mack and Lawlor, 1992).

Middle Merrimack River Basin

The Middle Merrimack River Basin in south-central New Hampshire has a drainage area of 469 mi^2, of which 98 mi^2, or 21 percent of the basin, are underlain by stratified-drift aquifers. The southern and eastern boundaries of this study area are formed by political divisions rather than by drainage basins. Saturated thickness exceeds 100 ft in Hooksett, and transmissivities exceed 4,000 ft^2/d in parts of Bow and Goffstown but are generally less than 2,000 ft^2/d. Water from municipal public-supply wells is pumped from stratified-drift aquifers in Goffstown and Hooksett. Stratified-drift aquifers in New Ipswich, Greenfield, and New Boston potentially could yield water to small municipal systems. The aquifer in Goffstown could supply significantly larger volumes of water than are currently (1995) being pumped (Ayotte and Toppin, 1995).

Exeter, Lamprey, and Oyster River Basins

The Exeter, Lamprey, and Oyster River Basins in southeastern New Hampshire have a drainage area of 351 mi^2, of which 56 mi^2, or 16 percent of the basin, are underlain by stratified-drift aquifers. Transmissivities greater than 3,000 ft^2/d have been measured in the Madbury-Dover area, the Durham-Lee area, and the Newmarket-Durham area. Water from municipal public-supply wells in Dover, Durham, Epping, Lee, Madbury, Newmarket, and Raymond is pumped from aquifers with transmissivities that exceed 1,000 ft^2/d. Water from municipal public-supply wells in Exeter, Madbury (for Portsmouth), Newfields, and Stratham is pumped from stratified-drift aquifers that are less transmissive than 1,000 ft^2/d. A computer model of ground-water flow indicated that four wells in an aquifer in Epping could yield 2 Mgal/d, and that two wells in an aquifer in Newmarket could yield 0.26 Mgal/d (Moore, 1990).

Lower Merrimack and Coastal River Basins

The Lower Merrimack and Coastal River Basins in southeastern New Hampshire have a drainage area of 327 mi^2, of which 78 mi^2, or 24 percent of the basin, are underlain by stratified-drift aquifers. The western and southern edges of this study area are formed by political rather than drainage-basin boundaries. Although saturated thickness is 100 ft in one section of Kingston, it is generally 20 to 40 ft throughout the rest of the basin. Transmissivity exceeds 4,000 ft^2/d in parts of aquifers in Kingston, North Hampton, Rye, Greenland, and Portsmouth. Municipal public-supply wells provide water from stratified-drift aquifers to customers in Hampton, Portsmouth, Rye, Salem, and Seabrook. Stratified-drift aquifers in the study area can potentially yield additional water for public water supplies in Derry, Greenland, Kingston, North Hampton, and Windham. Some aquifers in the southern part of this study area extend into Massachusetts (Stekl and Flanagan, 1992).

Nashua Regional Planning Commission Area

The Nashua Regional Planning Commission area in south-central New Hampshire has a drainage area of 322 mi^2, of which 129 mi^2, or 40 percent of the basin, are underlain by stratified-drift aquifers. This study area is entirely defined by political boundaries. Saturated thickness of stratified drift is greater than 100 ft in areas of Amherst, Litchfield, Merrimack, and Pelham. Transmissivities exceed 8,000 ft^2/d in parts of aquifers in Amherst, Brookline, Hollis, Hudson, Litchfield, Merrimack, Milford, Nashua, and Pelham. More than 30 municipal public-supply wells in stratified-drift aquifers in Amherst, Hollis, Hudson, Litchfield, Merrimack, Milford, Nashua, Pelham, and Wilton withdraw at least 100 gallons of water per minute (0.14 Mgal/d); many of these pump at a rate of more than 500 gallons per minute (0.72 Mgal/d). Several stratified-drift aquifers, particularly in Amherst, Litchfield, Merrimack, Milford, and Pelham, could supplement municipal public-supply wells (Toppin, 1987).

Quality of Water from Stratified-Drift Aquifers

For water-resources planners, it is not enough to know where the productive aquifers are located or how much water they might yield. The quality of water and its suitability for various uses such as drinking, irrigation, or industry, is equally important.

Ground-water quality is influenced partly by natural processes and partly by human activity. Water quality between aquifers or even within a single aquifer can differ because of influences from the biological communities, aquifer materials, and underlying bedrock that are in contact with the ground water. Natural weathering of rocks and minerals contributes most of the dissolved substances found in uncontaminated ground water and can produce high concentrations of dissolved iron (fig. 18) and manganese, especially in acidic environments. Stratified-drift aquifers near coastal areas can contain higher levels of chloride than the levels found in inland areas. Arsenic, an element derived from earth materials, is sometimes identified in ground water. Radon in ground water from bedrock wells is caused by natural weathering of uranium minerals in a type of granite commonly found in New Hampshire.

The more persistent threats to ground-water quality in New Hampshire are caused by human activity, such as road salting, fertilizing, industrial waste discharge, and detergent discharge. For instance, sodium and chloride are not abundant elements in the types of rocks found in New Hampshire, yet tests on water samples from throughout the State indicate their presence. Sodium chloride is a compound commonly used for winter road salting. Excess nitrate in ground water can be the result of poorly designed or faulty septic systems or other waste-disposal sites, or inappropriate fertilization rates. Infiltration of solvents from industrial wastes can result in ground-water contamination (Morrissey and Regan, 1987). Arsenic

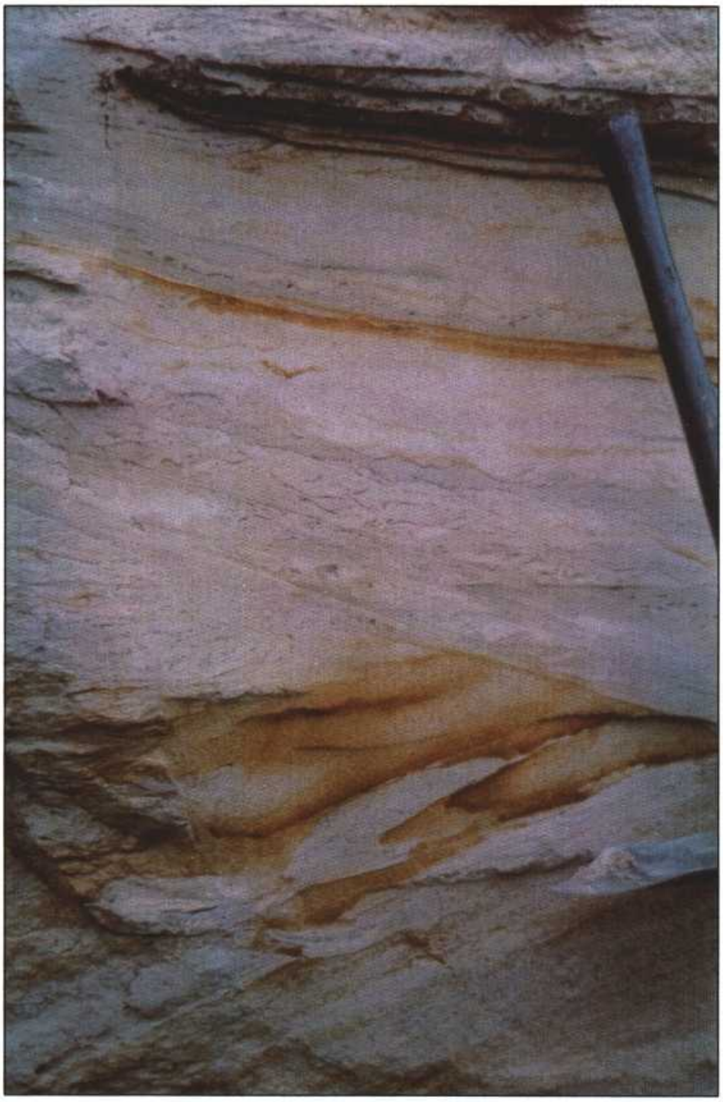


Figure 18. Sand deposits from a former river channel stained red from iron in ground-water seepage. High concentrations of iron are common in New Hampshire ground water. Stick in the upper right corner of the photograph is approximately 1.5 feet long. (Photograph taken by J.D. Ayotte, U.S. Geological Survey.)

also has been found in ground water associated with detergents in septic wastes (Boudette and others, 1985).

Commonly, the potential for ground-water contamination is assessed by analyzing land use for the area that contributes ground-water recharge to an aquifer. Certain land uses can adversely affect the quality of ground water by contributing to **nonpoint source pollution.** In an attempt to account for sources of ground-water pollution in the State, the NHDES maintains a statewide Groundwater Hazards Inventory, which in

November 1991, documented more than 2,000 sites of ground-water contamination. According to this inventory, the most common and serious threats to ground-water quality in New Hampshire include hazardous waste sites, unlined landfills, leaking underground storage tanks, oil spills or releases, and septage or sludge lagoons (Flanders, 1992, p. IV-1).

Maximum levels for contaminants in public-water supplies were established by the U.S. Environmental Protection Agency (USEPA) under the Safe Drinking Water Act of 1986. Two general categories of regulations were created: National Primary Drinking-Water Regulations for contaminants that could adversely affect human health; and National Secondary Drinking-Water Regulations primarily for contaminants that can adversely affect the odor, taste, or appearance of water. Under the National Primary Drinking-Water Regulations, *enforceable* Maximum Contaminant Levels (MCL, U.S. Environmental Protection Agency, 1992) are established for contaminants such as arsenic, cadmium, lead, atrazine, and toluene. Under the National Secondary Drinking-Water Regulations, *advisory* Secondary Maximum Contaminant Levels (SMCL, U.S. Environmental Protection Agency, 1992) are established for contaminants such as chloride, iron, and manganese. Similarly, the NHDES Water Supply Engineering Bureau has established MCLs and SMCLs for certain contaminants such as sodium, cadmium, and lead (New Hampshire Department of Environmental Services, Water Supply Engineering Bureau, written commun., 1987).

On the basis of the results of this statewide assessment, the quality of ground water from stratified-drift aquifers in New Hampshire generally meets all drinking-water regulations (fig. 19). Analyses of water samples from wells and springs reveal that the most common water-quality problems are the high concentrations of iron or manganese. Although neither of these elements poses a threat to human health, excessive amounts of either in water will stain laundry or plumbing fixtures. Of the 257 samples analyzed (table 1), 51 samples (20 percent) had higher dissolved iron levels than the SMCL of 300

***Nonpoint source pollution** is caused by rainfall or snowmelt run-off that carries unnatural and natural pollutants into lakes, rivers, wetlands, and aquifers. Certain land uses have been targeted by the Nonpoint Source Program administered by the New Hampshire Department of Environmental Services and listed as existing and potential sources of ground- or surface-water contamination (Flanders, 1992). Targeted land uses include landfills, septic systems, junkyards, urban areas, agricultural and silvicultural areas, and roads that are salted in the winter.*

Figure 19. A boy collects drinking water from a spring that flows from a stratified-drift aquifer in Sanbornton, central New Hampshire. (Photograph taken by B.R. Mrazik, U.S. Geological Survey.)

Table 1. Summary of selected analyses of ground water from stratified-drift aquifers in New Hampshire

[MCL, Maximum Contaminant Levels are enforceable U.S. Environmental Protection Agency (USEPA) primary drinking-water regulations (U.S. Environmental Protection Agency, 1992). SMCL, Secondary Maximum Contaminant Levels are established by the USEPA to provide advisory levels for certain contaminants in public water supplies. At higher concentrations, some of these constituents may be associated with adverse health effects (U.S. Environmental Protection Agency, 1992). <, actual value is less than value shown; --, not applicable; micrograms per liter is one in one billion parts; milligrams per liter is one thousand times that amount, or one in one million parts]

Chemical constituent and abbreviation	Number of samples analyzed	MCL	SMCL	Minimum value	Median value	Maximum value
		parts per million, milligrams per liter (mg/L)				
Dissolved oxygen, DO	144	--	--	0	6	13.1
pH, measured in the field	229	--	6.5-8.5	5.1	6.3	8.5
Alkalinity as calcium carbonate, as $CaCO_3$	139	--	--	1	22	158
Total hardness as $CaCO_3$	255	--	--	3	26	280
Total dissolved solids, TDS	252	--	500	17	77	612
Calcium, Ca	256	--	--	.04	7.6	87
Magnesium, Mg	256	--	--	.11	1.5	18
Chloride, Cl	256	--	250	.3	10	300
Sodium[1], Na	256	--	20	.3	6.4	220
Potassium, K	255	--	--	.2	1.6	17
Nitrite plus nitrate, NO_2+NO_3	155	10	--	<.05	.22	7.2
Sulfate, SO_4	255	--	250	<.1	7.8	79
Fluoride, F	255	4	2	<.1	.1	2.9
Silicate, SiO_2	256	--	--	<.01	12	40
		parts per billion, micrograms per liter (µg/L)				
Aluminum, Al	173	--	50	<10	<10	790
Cadmium[2], Cd	247	10	5	<1	<1	4
Copper, Cu	246	--	1,000	<1	<10	80
Iron, Fe	257	--	300	<3	10	19,000
Lead[3], Pb	246	50	--	<1	<10	110
Manganese, Mn	257	--	50	<1	63	3,500
Zinc, Zn	247	--	5,000	<3	4	300

[1]New Hampshire Department of Environmental Services (NHDES) MCL for sodium is 250 mg/L; SMCL is 100-250 mg/L.
[2]NHDES MCL for cadmium is 5 µg/L.
[3]NHDES SMCL for lead is 20 µg/L.

µg/L (micrograms per liter), and 136 samples (53 percent) had higher dissolved manganese concentrations than the SMCL of 50 µg/L. Chloride concentrations for 1 percent of the sampled wells and springs exceeded the SMCL of 250 mg/L (milligrams per liter); however, chloride concentrations in 94 percent of the samples of ground water were less than 100 mg/L. The SMCL for sodium is 20 mg/L and is established for people with cardiac or kidney problems or hypertension.

Because this SMCL has been established at such a low concentration, it was exceeded in 18 percent of the samples. Acidity levels, or pH, in 66 percent of the ground-water samples were less (more acidic) than the minimum limit (6.5) of the range recommended by the USEPA. Other New Hampshire studies also have found that ground water from stratified-drift deposits was slightly acidic, and could cause corrosion problems in metal pipes (Cotton, 1989, p.16). Nineteen of the 173 samples analyzed exceeded the SMCL (50 μg/L) for aluminum. These 19 samples with high aluminum may be associated with low pH because aluminum dissolves more readily as pH decreases.

Cleaning up contaminated ground water can be costly in terms of time and money. Ground-water contamination is commonly not detected until it becomes widespread. The source of pollution and the most effective method of clean up is not always obvious. Recognizing the economical benefits of maintaining high-quality water, in 1991, New Hampshire enacted legislation (RSA 485-C) to protect the State's ground waters.

How Stratified-Drift Aquifer Data are Used

The NHDES, the steward for water resources in the State, has several uses for maps and data pertaining to stratified-drift aquifers in New Hampshire. Most importantly, the Groundwater Protection Act (RSA 485-C) authorized local governments to implement ground-water-protection programs through classification of ground water. Under this Act, one of the four designated classes of ground water is GA2— "stratified-drift aquifers mapped by the USGS that are potentially valuable aquifers" (New Hampshire Department of Environmental Services, 1991, p.10). In addition, Phase 1 delineations of wellhead protection areas (WHPA) for public-supply wells are based on available data, such as the "hydrogeologic information from the USGS stratified-drift aquifer maps." Stratified-drift aquifer maps are commonly used in the administration of excavation regulations (RSA 155-E) by local governments.

A WHPA (wellhead protection area) delineation identifies the part of the mapped aquifer that actually supplies water to a particular public-supply well. This delineation defines the area through which contaminants are reasonably likely to move toward and potentially reach the public-supply well.

The aquifer mapping and data collection by the USGS are valuable resources to local government and the private sector as well. For example, municipalities and their consultants use the information as the basis for exploring potentially new or expanded town water supplies and in siting waste disposal or storage sites to avoid ground-water contamination. In assessing plume migration from a contaminated site, all aquifers in the area need to be identified as to whether or not they are currently being tapped for a water supply. Conservation commissions evaluate wetlands and designate areas as Prime Wetlands (RSA 482-A:15) according to the standardized method of Ammann and Stone (1991). Part of this evaluation requires knowledge of the position of the wetland relative to the location of stratified-drift aquifers. Environmental educators use the aquifer maps to complement and enhance their lessons on watersheds.

Because many potential users of the stratified-drift-aquifer reports are town residents and local governments, table 2 provides an index of the USGS aquifer-assessment study areas that pertain to each town in New Hampshire. The geographic area covered by each report is shown on the map in figure 1, and complete citations for each report are included in the Selected References section.

Table 2. List of towns in New Hampshire, U.S. Geological Survey aquifer-assessment study areas, and areas of town and percentage of total town areas underlain by stratified-drift aquifers

[USGS, U.S. Geological Survey; UC, Upper Connecticut; MC, Middle Connecticut; PE, Pemigewasset; SA, Saco and Ossipee; WI, Winnipesaukee; LC, Lower Connecticut; CK, Contoocook; UM, Upper Merrimack; CO, Cocheco; MM, Middle Merrimack; LA, Lamprey; LM, Lower Merrimack and coastal; NS, Nashua Regional Planning Commission area]

Town	USGS aquifer-assessment study area(s)	Area of town underlain by stratified-drift aquifers (square miles)	Percentage of total
ACWORTH	LC	1.5	4
ALBANY	SA	8.3	11
ALEXANDRIA	PE	4.2	10
ALLENSTOWN	UM, MM	5.4	27
ALSTEAD	LC	1.3	3
ALTON	WI, UM, CO	7.2	12
AMHERST	NS	13.1	39
ANDOVER	CK, UM, PE	6.9	17
ANTRIM	CK	3.5	10
ASHLAND	PE	2.9	27
ATKINSON	LM	.7	7
ATKINSON AND GILMANTON ACADEMY GRANT	UC	2.1	11
AUBURN	MM	7.4	30
BARNSTEAD	UM	5.7	14
BARRINGTON	CO, LA	10.7	23
BARTLETT	SA	8.6	11
BATH	MC	8.7	23
BEANS GRANT	SA	0	0
BEANS PURCHASE	UC	0	0
BEDFORD	MM	9.5	29
BELMONT	WI	12.0	39
BENNINGTON	CK	4.3	39
BENTON	MC	.9	2
BERLIN	UC	3.7	6
BETHLEHEM	MC	9.8	11
BOSCAWEN	UM, CK	6.3	25
BOW	UM, MM	6.0	22
BRADFORD	CK	4.0	11
BRENTWOOD	LA	5.6	33
BRIDGEWATER	PE	2.7	13
BRISTOL	PE	3.8	22
BROOKFIELD	CO, WI, SA	1.7	7
BROOKLINE	NS	6.5	33
CAMBRIDGE	UC	7.9	16
CAMPTON	PE	6.8	13
CANAAN	MC	8.4	16
CANDIA	MM, LA	3.0	10
CANTERBURY	UM	7.1	16
CARROLL	MC, UC, SA	10.6	21
CENTER HARBOR	WI, PE	.6	4
CHANDLERS PURCHASE	MC, SA	0	0
CHARLESTOWN	LC	9.5	26
CHATHAM	SA	4.1	7
CHESTER	LA, MM	4.8	18
CHESTERFIELD	LC	2.1	5
CHICHESTER	UM	1.2	6
CLAREMONT	LC	9.4	22
CLARKSVILLE	UC	1.7	3
COLEBROOK	UC	6.7	16
COLUMBIA	UC	2.4	4
CONCORD	UM, CK	34.8	54
CONWAY	SA	22.2	32
CORNISH	LC	2.7	6
CRAWFORDS PURCHASE	MC	.1	2
CROYDON	LC	.9	3
CUTTS GRANT	SA	0	0
DALTON	MC, UC	4.1	15
DANBURY	PE, CK	4.9	13
DANVILLE	LM, LA	2.2	19
DEERFIELD	LA, UM	5.2	10
DEERING	MM, CK	4.1	13
DERRY	LM, LA	5.2	15
DIXS GRANT	UC	0.5	2
DIXVILLE	UC	1.4	3
DORCHESTER	MC, PE	.8	2
DOVER	CO, LA	26.7	99
DUBLIN	CK, LC	1.4	5
DUMMER	UC	2.3	5
DUNBARTON	MM, UM	1.7	6
DURHAM	LA, CO	1.2	5
EAST KINGSTON	LM, LA	1.1	11
EASTON	MC	3.4	11
EATON	SA	2.1	9
EFFINGHAM	SA	15.8	41
ELLSWORTH	PE	0	0
ENFIELD	MC	3.3	8
EPPING	LA	4.0	15
EPSOM	UM	4.9	14
ERROL	UC	14.1	23
ERVINGS LOCATION	UC	0	0
EXETER	LA, LM	2.9	15
FARMINGTON	CO	4.2	12
FITZWILLIAM	LC	2.7	8
FRANCESTOWN	MM	4.4	15
FRANCONIA	MC, PE	4.6	7
FRANKLIN	UM, PE, WI	10.2	37
FREEDOM	SA	9.3	26
FREMONT	LA	6.7	39
GILFORD	WI	5.7	15
GILMANTON	UM, WI	2.5	4
GILSUM	LC	1.1	7
GOFFSTOWN	MM	5.6	15
GORHAM	UC	5.3	17
GOSHEN	LC	2.3	10

Table 2. List of towns in New Hampshire, U.S. Geological Survey aquifer-assessment study areas, and areas of town and percentage of total town areas underlain by stratified-drift aquifers--*Continued*

Town	USGS aquifer-assessment study area(s)	Area of town underlain by stratified-drift aquifers (square miles)	Area of town underlain by stratified-drift aquifers: Percentage of total
GRAFTON	PE, MC	2.9	7
GRANTHAM	LC, MC	.8	3
GREENFIELD	CK, MM	8.3	33
GREENLAND	LM	2.8	28
GREENS GRANT	UC	.3	8
GREENVILLE	MM	.3	4
GROTON	PE	1.0	2
HADLEY'S PURCHASE	SA	0	0
HALE'S LOCATION	SA	.5	27
HAMPSTEAD	LM, LA	2.4	19
HAMPTON	LM	2.5	19
HAMPTON FALLS	LM, LA	.3	3
HANCOCK	CK	3.9	13
HANOVER	MC	5.3	11
HARRISVILLE	CK, LC	1.3	7
HART'S LOCATION	SA	2.4	13
HAVERHILL	MC	14.6	29
HEBRON	PE	1.5	9
HENNIKER	CK, MM	6.2	14
HILL	PE, CK	1.9	7
HILLSBOROUGH	CK	6.1	14
HINSDALE	LC	7.3	35
HOLDERNESS	PE	4.0	14
HOLLIS	NS	11.4	36
HOOKSETT	MM	9.0	25
HOPKINTON	CK, UM	17.3	40
HUDSON	NS	11.1	40
JACKSON	SA, UC	1.8	3
JAFFREY	CK, LC	6.8	18
JEFFERSON	UC, MC	2.9	6
KEENE	LC	10.3	28
KENSINGTON	LM, LA	2.3	19
KILKENNY	UC	0	0
KINGSTON	LM, LA	11.3	57
LACONIA	WI	2.6	13
LANCASTER	UC, MC	8.1	16
LANDAFF	MC	1.2	4
LANGDON	LC	2.8	18
LEBANON	MC, LC	7.1	18
LEE	LA	4.3	22
LEMPSTER	LC	3.2	10
LINCOLN	PE	4.3	3
LISBON	MC	6.5	24
LITCHFIELD	NS	14.1	94
LITTLETON	MC	6.5	13
LIVERMORE	PE, SA	0	0
LONDONDERRY	LM	10.3	25
LOUDON	UM	6.0	13
LOW AND BURBANK'S GRANT	UC, MC	0	0
LYMAN	MC	1.6	6
LYME	MC	5.3	10
LYNDEBOROUGH	NS	2.4	8
MADBURY	CO, LA	5.5	46
MADISON	SA	9.0	23
MANCHESTER	MM	19.7	60
MARLBOROUGH	LC	.5	3
MARLOW	LC	1.6	6
MARTINS LOCATION	UC	.6	14
MASON	MM	3.5	15
MEREDITH	WI, PE	2.8	7
MERRIMACK	NS	18.8	59
MIDDLETON	CO, WI	.2	1
MILAN	UC	7.3	12
MILFORD	NS	9.3	37
MILLSFIELD	UC	.4	1
MILTON	CO	3.7	11
MONROE	MC	4.8	22
MONT VERNON	NS	.4	2
MOULTONBORO	WI, SA, PE	7.9	13
NASHUA	NS	22.1	71
NELSON	LC, CK	.7	3
NEW DURHAM	CO, WI	5.8	14
NEW HAMPTON	PE, WI	6.2	17
NEW IPSWICH	MM, CK, LC	6.1	19
NEW LONDON	CK, LC	1.3	6
NEWBURY	CK, LC	2.1	6
NEWFIELDS	LA	.8	11
NEWINGTON	LM	3.3	41
NEWMARKET	LA	1.1	9
NEWPORT	LC	6.1	14
NEWTON	LM	4.0	40
NORTH HAMPTON	LM	3.2	23
NORTHFIELD	WI, UM	4.4	15
NORTHUMBERLAND	UC	7.6	21
NORTHWOOD	UM, LA, CO	.4	2
NOTTINGHAM	LA	3.4	7
ODELL	UC	0	0
ORANGE	MC, PE	1.0	4
ORFORD	MC, PE	5.8	12
OSSIPEE	SA	24.5	35
PELHAM	NS	9.8	38
PEMBROKE	UM	5.7	25
PETERBOROUGH	CK	10.1	27
PIERMONT	MC	4.0	10
PINKHAM'S GRANT	UC, SA	0	0
PITTSBURG	UC	20.7	7
PITTSFIELD	UM	.4	2
PLAINFIELD	LC, MC	3.2	6
PLAISTOW	LM	5.1	47
PLYMOUTH	PE	6.5	23
PORTSMOUTH	LM	5.2	32
RANDOLPH	UC	1.2	3
RAYMOND	LA	6.2	22
RICHMOND	LC	1.1	3
RINDGE	LC, CK	5.5	15

Table 2. List of towns in New Hampshire, U.S. Geological Survey aquifer-assessment study areas, and areas of town and percentage of total town areas underlain by stratified-drift aquifers--*Continued*

Town	USGS aquifer-assessment study area(s)	Area of town underlain by stratified-drift aquifers (square miles)	Percentage of total
ROCHESTER	CO	20.2	45
ROLLINSFORD	CO	7.2	99
ROXBURY	LC	.1	1
RUMNEY	PE	6.6	16
RYE	LM	2.7	20
SALEM	LM	8.3	33
SALISBURY	CK, UM	5.6	14
SANBORNTON	PE, WI	6.9	14
SANDOWN	LA, LM	3.9	28
SANDWICH	SA, PE, WI	7.6	8
SARGENT'S PURCHASE	SA, MC, UC	0	0
SEABROOK	LM	1.0	11
SECOND COLLEGE GRANT	UC	4.9	12
SHARON	CK	4.2	28
SHELBURNE	UC	6.8	14
SOMERSWORTH	CO	7.3	73
SOUTH HAMPTON	LM	.8	10
SPRINGFIELD	LC, CK, PE	.9	2
STARK	UC	6.9	12
STEWARTSTOWN	UC	3.4	7
STODDARD	CK, LC	.7	1
STRAFFORD	CO, UM	2.2	4
STRATFORD	UC	6.6	8
SUGAR HILL	MC	.5	3
SULLIVAN	LC	.1	1
SUNAPEE	LC	.6	3
SURRY	LC	2.2	14
SUTTON	CK	6.9	16
SWANZEY	LC	11.7	26
TAMWORTH	SA	15.3	26
TEMPLE	MM, CK	3.3	14
THOMPSON AND MESERVES PURCHASE	UC, MC	0	0
THORNTON	PE	9.0	18
TILTON	WI	3.7	33
TROY	LC	1.1	6
TUFTONBORO	WI, SA	8.7	21
UNITY	LC	1.1	3
WAKEFIELD	CO, SA	9.2	24
WALPOLE	LC	7.9	22
WARNER	CK	7.0	12
WARREN	PE, MC	2.6	5
WASHINGTON	CK, LC	.7	2
WATERVILLE VALLEY	PE, SA	2.6	4
WEARE	MM, CK	8.1	14
WEBSTER	CK	6.9	25
WENTWORTH	PE	4.2	10
WENTWORTH LOCATION	UC	2.2	11
WESTMORELAND	LC	3.3	9
WHITEFIELD	MC, UC	5.1	15
WILMOT	CK	3.0	10
WILTON	NS	5.3	20
WINCHESTER	LC	8.3	15
WINDHAM	LM	3.5	13
WINDSOR	CK	1.4	17
WOLFEBORO	WI, SA	6.4	13
WOODSTOCK	PE, MC	4.1	7

SUMMARY

New Hampshire is fortunate to have numerous stratified-drift aquifers that provide generally clean and plentiful ground water for a multitude of uses. These New Hampshire aquifers are products of glacial meltwater deposition from about 14,000 years ago and are scattered primarily in river valleys and other low-lying areas throughout the State. Aquifers composed of coarse sand and gravel materials, with large, interconnected pore spaces, are generally the most transmissive aquifers and yield the most water. These high-yielding aquifers were deposited as eskers, kame terraces, outwash plains, and deltas by meltwater during glacial retreat. Under natural or near-natural conditions, water quality from stratified-drift aquifers is generally good, although threats from natural and human-derived sources of contamination have been identified.

The public is encouraged to seek more information about any of the material presented in this report from the USGS office in Bow or the NHDES, Water Resources Division, in Concord.

USGS
Water Resources Division
525 Clinton Street
Bow, NH 03304
(603) 225-4681

NHDES
Water Resources Division
64 North Main Street
P.O. Box 2008
Concord, NH 03302-2008
603) 271-3406

SELECTED REFERENCES

Titles of reports that were published as part of the cooperative USGS and NHDES stratified-drift aquifer mapping study are in **bold** print.

Ammann, A.P., and Stone, A.L., 1991, Method for the comparative evaluation of nontidal wetlands in New Hampshire: Concord, New Hampshire Department of Environmental Services, Water Resources Division, NHDES-WRD-1991-3, 229 p.

Ayotte, J.D., in press, **Geohydrology and water quality of stratified-drift aquifers in the Winnipesaukee River Basin, central New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 94-4150, 121 p., 12 pls.

Ayotte, J.D., and Toppin, K.W., 1995, **Geohydrology and water quality of stratified-drift aquifers in the Middle Merrimack River Basin, south-central New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 92-4192, 52 p., 8 pls.

Baldwin, H.L., and McGuinness, C.L., 1963, A primer on ground water: U.S. Geological Survey, 26 p.

Boudette, E.L., Canney, F.C., Cotton, J.E., Davis, R.I., Ficklin, W.H., and Mootooka, J.M., 1985, High levels of arsenic in the ground waters of southeastern New Hampshire—a geochemical reconnaissance: U.S. Geological Survey Open-File Report 85-202, 25 p.

Chapman, D.H., 1974, New Hampshire's landscape—how it was formed: New Hampshire Profiles, v. 23, no.1, p 41-56.

Cotton, J.E., 1975a, Availability of ground water in the Androscoggin River Basin, northern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 75-0022, 1 pl.

_____1975b, Availability of ground water in the Pemigewasset and Winnipesaukee River Basins, central New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 75-0047, 1 pl.

_____1975c, Availability of ground water in the Saco River Basin, east-central New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 74-0039, 1 pl.

_____1975d, Availability of ground water in the upper Connecticut River Basin, northern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 75-0053, 1 pl.

_____1976a, Availability of ground water in the middle Connecticut River Basin, southern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 76-0018, 1 pl.

_____1976b, Availability of ground water in the middle Merrimack River Basin, central and southern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 76-0039, 1 pl.

_____1977a, Availability of ground water in the lower Connecticut River Basin, southwestern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 77-0079, 1 pl.

_____1977b, Availability of ground water in the lower Merrimack River Basin, southern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 77-0069, 1 pl.

_____1977c, Availability of ground water in the Piscataqua and other coastal river basins, southeastern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 77-0070, 1 pl.

Cotton, J.E., 1988, Ground-water resources of the Lamprey River Basin, southeastern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 84-4252, 46 p., 1 pl.

Cotton, J.E., 1989, Hydrogeology of the Cocheco River Basin, southeastern New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 87-4130, 47 p., 1 pl.

Cotton, J.E., and Olimpio, J.R., in press, **Geohydrology, yield, and water quality of stratified-drift aquifers in the Pemigewasset River Basin, central New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 94-4083, 258 p., 10 pls.

Diers, R.W., and Vieira, F.J., 1977, Soil survey of Carroll County, New Hampshire, U.S. Department of Agriculture, 63 map sheets, scale 1:24,000, 161 p.

Flanagan, S.M., in press, **Geohydrology and water quality of stratified-drift aquifers in the Middle Connecticut River Basin, west-central New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 94-4181, 149 p., 4 pls.

Flanders, R.A., 1992, New Hampshire Water Quality Report to Congress - 305(b): Concord, New Hampshire Department of Environmental Services, Water Supply and Pollution Control Division, NHDES-WSPCD-92-8, 247 p.

Frost, Robert, 1981, Mending Wall, *in* Early Poems: New York, Avenel Books, p. 80.

Goldthwait, J.W., Goldthwait, Lawrence, and Goldthwait, R.P., 1951, The geology of New Hampshire, part 1—surficial geology: Concord, New Hampshire State Planning and Development Commission, 83 p., 1 pl.

Harte, P.T., and Johnson, William, 1995, **Geohydrology and water quality of stratified-drift aquifers in the Contoocook River Basin, south-central New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 92-4154, 72 p., 4 pls.

Johnson, C.D., Tepper, D.M., and Morrissey, D.J., 1987, Geohydrologic and surface-water data for the Saco River Valley glacial aquifer from Bartlett, New Hampshire, to Fryeburg, Maine: October, 1983, through January, 1986: U.S. Geological Survey Open-File Report 87-44, 80 p.

Kelsey, T.L., and Vieira, F.J., 1968, Soil survey of Belknap County, New Hampshire, U.S. Department of Agriculture, 62 map sheets, scale 1:15,840, 68 p.

Koteff, Carl, 1974, The morphologic sequence concept and deglaciation of southern New England, *in* Coates, D.R., ed., Glacial geomorphology: Binghamton, State University of New York, Publications in Geomorphology, p. 121-144.

Latimer, W.J., Layton, N.H., Lyford, W.H., Coates, W.H., Scripture, P.N., 1939, Soil survey of Grafton County, New Hampshire: Washington D.C., U.S. Department of Agriculture, Bureau of Chemistry and Soils, Series 1935, no. 6, 2 map sheets, scale 1:62,500, 79 p.

Lawlor, S.M., and Mack, T.J., 1992, Geohydrologic, ground-water quality, and streamflow data for the stratified-drift aquifers in the Bellamy, Cocheco, and Salmon Falls River Basins, southeastern New Hampshire: U.S. Geological Survey Open-File Report 89-583, 137 p., 3 pls.

Mack, T.J., and Lawlor, S.M., 1992, **Geohydrology and water quality of stratified-drift aquifers in the Bellamy, Cocheco, and Salmon Falls River Basins, southeastern New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 90-4161, 65., 6 pls.

Medalie, Laura and Horn, M.A., 1994, Estimated withdrawals and use of freshwater in New Hampshire: U.S. Geological Survey Water-Resources Investigations Report 93-4096, 1pl.

Moore, R.B., 1990, **Geohydrology and water quality of stratified-drift aquifers in the Exeter, Lamprey, and Oyster River Basins, southeastern New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 88-4128, 61 p., 8 pls.

_____1992, Geohydrologic and ground-water-quality data for stratified-drift aquifers in the Exeter, Lamprey, and Oyster River Basins, southeastern New Hampshire: U.S. Geological Survey Open-File Report 92-95, 136 p., 4 pls.

_____1993, Geologic evidence for catastrophic draining of glacial lakes in the Contoocook, Souhegan, and Piscataquog River Basins, south-central New Hampshire [abs.]: Geological Society of America Abstracts with Programs, v. 25, no. 6, p. 157.

Moore, R.B., Johnson, C.D., and Douglas, E.M., 1994, **Geohydrology and water quality of stratified-drift aquifers in the Lower Connecticut River Basin, southwestern New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 92-4013, 187 p., 4 pls.

Moore, R.B., and Medalie, Laura, in press, **Geohydrology and water quality of stratified-drift aquifers in the Saco and Ossipee River Basins, east-central New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 94-4182, 133 p.

Morrissey, D.J. and Regan, J.M., 1987, New Hampshire ground-water quality: U.S. Geological Survey Open-File Report 87-0739, 8 p.

New Hampshire Department of Environmental Services, 1991, Phase I wellhead protection area delineation guidance: Water Supply and Pollution Control Division, NHDES-WSPCD-91-9, 13 p.

New Hampshire Water Resources Board, 1984, Water resources management plan: Concord, New Hampshire Water Resources Board, 47 p.

Stekl, P.J., and Flanagan, S.M., 1992, **Geohydrology and water quality of stratified-drift aquifers in the Lower Merrimack and coastal River Basins, southeastern New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 91-4025, 93 p., 6 pls.

Tepper, D.H., Morrissey, D.J., Johnson, C.D., and Maloney, T.J., 1990, Hydrogeology, water quality, and effects of increased municipal pumpage of the Saco River Valley glacial aquifer; Bartlett, New Hampshire, to Fryeburg, Maine: U.S. Geological Survey Water-Resources Investigations Report 88-4179, 113 p.

Toppin, K.W., 1987, **Hydrogeology of stratified-drift aquifers and water quality in the Nashua Regional Planning Commission area, south-central New Hampshire**: U.S. Geological Survey Water-Resources Investigations Report 86-4358, 101 p., 6 pls.

U.S. Environmental Protection Agency, 1992, Final Rule, National primary and secondary drinking-water regulations—Synthetic organic chemicals and inorganic chemicals (sections 141.12, 141.32, 141.50, 141.51, 141.61, and 141.62 of part 141 and 143.3 of part 143): U.S. Federal Register, v. 57, no. 138, July 17, 1992, p. 31,776-31,849.

U.S. Soil Conservation Service, 1981, Soil survey of Hillsborough County, eastern part, New Hampshire, U.S. Department of Agriculture, 152 p.

_____1985a, Soil survey of Hillsborough County, western part, New Hampshire, U.S. Department of Agriculture, 141 p.

_____1985b, Soil survey of Merrimack County, New Hampshire, U.S. Department of Agriculture, 141 p.

Vieira, F.J., and Bond, R.W., 1973, Soil survey of Strafford County, New Hampshire, U.S. Department of Agriculture, 152 p.

Waller, R.M., 1989, Ground water and the rural homeowner: U.S. Geological Survey General Interest Publication, 36 p.

Winkley, H.E., 1965, Soil survey of Merrimack County, New Hampshire: Washington D.C., U.S. Department of Agriculture, Soil Conservation Service, Series 1961, no. 22, 76 map sheets, scale 1:20,000, 94 p.