Prepared in cooperation with the
Vermont Department of Environmental Conservation: Vermont Geological Survey

Estimated Water Withdrawals and Return Flows in Vermont in 2005 and 2020





Scientific Investigations Report 2010–5053

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

Cover. Photographs: Production well for small residential development, snowmaking gun at a Vermont ski resort (photograph used with permission from Smugglers' Notch Resort), swimmers at a municipal pool, fish tank at a Vermont State Fish Culture Station, a thirsty horse on a Vermont farm (photograph by Ann Chalmers, U.S. Geological Survey)

Estimated Water Withdrawals and Return Flows in Vermont in 2005 and 2020

By Laura Medalie and Marilee A. Horn

Prepared in cooperation with the
Vermont Department of Environmental Conservation:
Vermont Geological Survey

Scientific Investigations Report 2010–5053

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2010

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit http://www.usgs.gov or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications,
visit http://www.usgs.gov/pubprod

To order this and other USGS information products, visit http://store.usgs.gov

Suggested citation:
Medalie, Laura, and Horn, M.A., 2010, Estimated water withdrawals and return flows in Vermont in 2005 and 2020: U.S. Geological Survey Scientific Investigations Report 2010–5053, 53 p. (Also available at http://pubs.usgs.gov/sir/2010/5053.)

Contents

Figures

Tables

Conversion Factors, Data, and Acronyms

Inch/Pound to SI

Multiply	By	To obtain
	Length	
mile (mi)	1.609	kilometer (km)
yard (yd)	0.9144	meter (m)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	0.003785	cubic meter (m^3)
million gallons (Mgal)	3,785	cubic meter (m^3)
	Flow rate	
gallon per minute (gal/min)	0.06309	liter per second (L/s)
gallon per day (gal/d)	0.003785	cubic meter per day (m^3/d)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83) and to the Vermont State Plane Coordinate System.

LIST OF ACRONYMS

CWS	Community Water System
DHCA	Department of Housing and Community Affairs
D&B	Dun & Bradstreet
E911	Enhanced 911
HUC	Hydrologic Unit Code
MCD	Minor Civil Division
NTNC	Non-Transient Non-Community Water System
PWS	Public Water System
RPC	Regional Planning Commission
SIC	Standard Industrial Classification
TNC	Transient Non-Community Water System
USEPA	United States Environmental Protection Agency
VCGI	Vermont Center for Geographic Information
VTDEC	Vermont Department of Environmental Conservation
VWU	Vermont Water-Use
WMD	Wastewater Management Division
WSD	Water Supply Division

Estimated Water Withdrawals and Return Flows in Vermont in 2005 and 2020

By Laura Medalie and Marilee A. Horn

Abstract

In 2005, about 12 percent of total water withdrawals (440 million gallons per day (Mgal/d)) in Vermont were from groundwater sources (51 Mgal/d), and about 88 percent were from surface-water sources (389 Mgal/d). Of total water withdrawals, about 78 percent were used for cooling at a power plant, 9 percent were withdrawn by public suppliers, about 5 percent were withdrawn for domestic use, about 3 percent were withdrawn for use at fish hatcheries, and the remaining 5 percent were divided among commercial/industrial, irrigation, livestock, and snowmaking uses.

About 49 percent of the population of Vermont was supplied with drinking water by a public supplier, and 51 percent was self supplied. Some of the Minor Civil Divisions (MCDs) that had large self-supplied populations were located near the major cities of St. Albans, Burlington, Montpelier, Barre, and Rutland, where the cities themselves were served largely by public supply, but the surrounding areas were not. Most MCDs where withdrawals by community water systems totaled more than 1 Mgal/d used predominantly surface water, and those where withdrawals by community water systems totaled 1 Mgal/d or less used predominantly groundwater.

Withdrawals of groundwater greater than 1 Mgal/d were made in Middlebury, Bethel, Hartford, Springfield, and Bennington, and withdrawals of surface water greater than 2 Mgal/d were made in Grand Isle, Burlington, South Burlington, Mendon, Brattleboro, and Vernon. Increases in groundwater withdrawals greater than 0.1 Mgal/d are projected for 2020 for Fairfax, Hardwick, Middlebury, Sharon, Proctor, Springfield, and Manchester. The largest projected increases in surface-water withdrawals from 2005 to 2020 are located along the center axis of the Green Mountains in the ski-area towns of Stowe, Warren, Mendon, Killington, and Wilmington.

In 2005, withdrawals were at least 1 Mgal/d greater than return flows in South Burlington, Waterford, Orange, Mendon, Woodford, and Vernon. Many of these MCDs had small populations themselves but provided water to community water systems in neighboring towns or cities. Wilmington probably will be added to this list by 2020 because of proposed new withdrawals for snowmaking in Dover. About 15 percent of MCDs had greater return flows than withdrawals; possible reasons are water importation, larger service areas for municipal sewer than for municipal water resulting in underestimation of withdrawals, leakage into sewer pipes, faulty assumptions in assigning coefficients, or other limitations of the study methods.

To store and facilitate retrieval of water-use estimates and data for 2005 and projections for 2020, a water-use database for Vermont was designed and populated. Data include withdrawals and return flows from and to groundwater and surface water for all individual facilities and entities that are in Vermont drinking water, discharge permit, or other State water-use databases, along with estimates for many other facilities. Also included are estimates for aggregated domestic and livestock withdrawals and return flows by census block. Retrievals from the database and summaries presented in this report can be used to help identify areas where projected growth in Vermont from 2005 to 2020 might affect groundwater availability.

Introduction

For many years, groundwater regulation in Vermont was defined by the Vermont Water Supply Rule (Agency of Natural Resources—Department of Environmental Conservation, 2005), the primary purpose of which is to regulate water systems in order to provide clean and safe drinking water for Vermont's citizens. With the new millennium, the focus, previously on ensuring adequate quality, expanded to include quantity. Reports of water shortages from overpumping and controversial proposals to withdraw large amounts of water for various industries prompted the 2007–08 Vermont State Legislature to take a proactive role in protecting the groundwater resource. The culmination of this shift resulted in Act 199, legislation adopted in June 2008 that declared Vermont's groundwater a public trust and set up a permitting process for large water withdrawals.

Prior to the new law, the 2006 Legislature had passed Act 144, which authorized the exploration of statewide groundwater-management and protection strategies. Legislators agreed that the effort should start with systematic and comprehensive resource characterization. To that end, the

Vermont Geological Survey began coordinating a statewide favorability study to compile, georeference, and combine into an interactive mapping product all existing datasets related to groundwater. Some of the datasets integrated with bedrock and surficial geology are data from water-well logs, aquifer tests, interference tests of new wells (done by the Vermont Water Supply Division), water-quality analyses, and hazardous waste sites. A component of the resource assessment that is not available from any single State database is detailed information on groundwater withdrawals. This component is necessary so that groundwater-demand scenarios can be developed, impacts of projected growth can be assessed, and statewide and regional planning can proceed in a fact-based and consistent manner.

To further these goals, the U.S. Geological Survey (USGS), in cooperation with the Vermont Geological Survey, has drawn upon the USGS water-use program to characterize current (2005) and future (2020) water usage and develop the USGS Vermont Water-Use (VWU) database. Although groundwater is the focus of the resource assessment, withdrawals and return flows to surface water are included in the database because management of either resource is affected by their interconnections. To increase its utility for planning, the VWU database identifies areas of potential increases in water demand in the future.

Purpose and Scope

The objectives of this report were to identify the relative amounts of groundwater and surface water used throughout Vermont and to identify areas where projected growth in the State during 2005–20 might affect groundwater availability (fig. 1). To explore those questions, base-year (2005) groundwater and surface-water withdrawals and return flows were assessed, projections for population growth as the basis for estimating future withdrawals for water resources were applied, and data to establish a resource-based priority system for planners were obtained. The base year 2005 was chosen because a large quantity of water-use data had already been compiled by the USGS for 2005 as part of the national water-use compilation done every 5 years. The year 2020 was selected as the end year for estimating future water withdrawals because that is the year for which population projection estimates for the State of Vermont, necessary for estimating water withdrawals, were available.

All data presented in this report are 2005 and 2020 annual averages, although some information is available in the VWU database on a seasonal or monthly basis, as well as annual averages for some other years. Although all data have a census-block attribute, for figures and discussion in this report, census blocks generally are aggregated to Minor Civil Divisions[1] (MCDs) (fig. 1).

[1]A census block is the smallest level of geography designated by the Census Bureau. Minor Civil Divisions are official subdivisions of counties—towns and cities.

Water-use activities that are accounted for in this report include only withdrawals from groundwater or surface water transported away from the source. Instream uses, such as for hydroelectric power, habitat, waste assimilation, and recreation, are not included.

Previous Investigations and Databases

Water-use data for Vermont have been compiled and published every 5 years from 1950 through 2005 as part of the USGS National Water-Use Program. Since 1985, data also have been compiled for every state by county. Several water-use reports that are specific to Vermont have been generated from this program (U.S. Geological Survey, 1990; Horn and Medalie, 1995; Medalie, 1997; and Foster and others, 2000).

Databases that have been developed by the USGS to store and retrieve water-use data include Aggregate Water-Use Data System (AWUDS), Site-Specific Water-Use Data System (SWUDS), and New England Water-Use Data System (NEWUDS). AWUDS is the USGS national database that stores aggregated water-use data by county, hydrologic unit, and aquifer. Its primary purpose is to store data used in the national summary of water-use data. SWUDS stores measurements and estimates of water use by individual user, aggregate user, or user-defined geographical area. The relational database supports a link-node data structure where sites represent nodes or points in a hydrologic network. The user can track the movement of water from site to site by connecting sites (nodes) to form conveyances (links). NEWUDS, developed specifically for New England, is similar to SWUDS in that it is a relational database developed to track water-use activities between points, such as withdrawals to distribution and users to return flows (Tessler, 2002; Horn, 2002). In developing the VWU database, the decision was made to forego the effort of trying to fit data from this project into the SWUDS or NEWUDS models, which have exacting requirements, and, instead, to develop a new database structured to accommodate the available data.

Water Resources in Vermont

Vermont has about 36,500 kilometers of streams and rivers (NHDflowline, accessed July 29, 2008, at http://www.vcgi.org/); 1,437 square kilometers of lakes and ponds (NHDWaterbody, accessed August 6, 2008, at http://www.vcgi.org/); and 820 lakes and ponds listed in the Vermont Department of Environmental Conservation (VTDEC) Lake Inventory List (accessed January 7, 2009, at http://www.anr.state.vt.us/dec/waterq/lakes/docs/lp_lakelist.pdf). Major surface-water resources include Lake Champlain, which forms the northwestern border with New York and extends into Canada; Lake Memphremagog, along the northern border with Canada; Lake Bomoseen in Castleton in Rutland County; Harriman Reservoir in southern Vermont; and the Connecticut River, which forms the eastern border with New Hampshire (fig. 1).

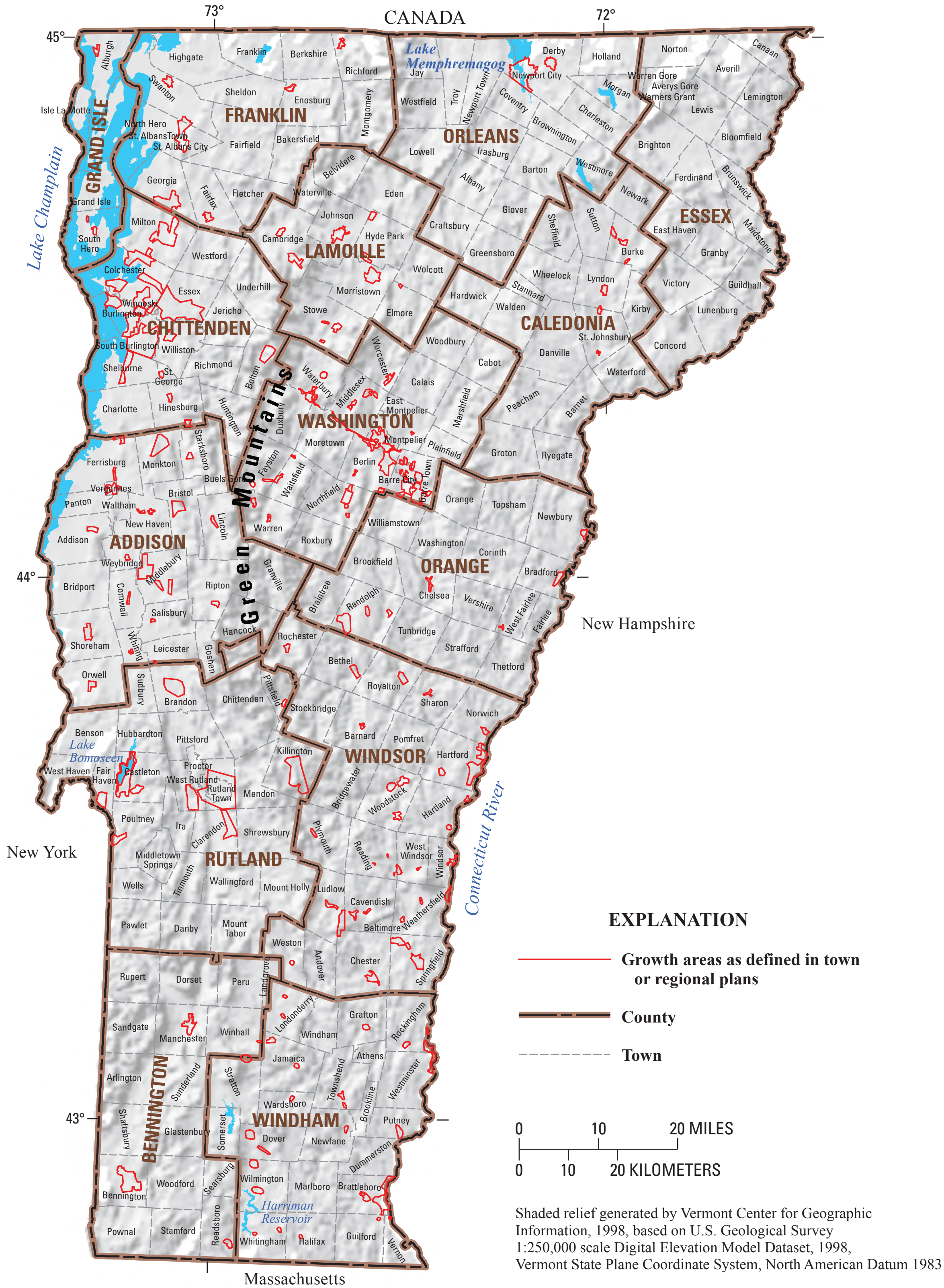


Figure 1. Minor Civil Divisions with growth areas in Vermont.

Most domestic wells in Vermont tap water in crystalline-rock aquifers, which transmit water along bedding planes, fractures, joints, and faults. Yields from these wells vary from about 18 gallons per minute (gal/min) at depths less than 200 feet to about 7 gal/min at depths greater than 800 feet (Gale and others, 2009). Close to Vermont's western border with New York, the bedrock aquifer consists of carbonate rocks and often produces yields of 10 to 30 gal/min (Olcott, 1995). Some wells in or near valley bottoms extract water from surficial aquifers, which consist primarily of coarse-grained sand and gravel deposits that were left as outwash and ice-contact materials by glacial meltwater during multiple advances and retreats of continental glaciers. Yields from wells connected to surficial aquifers are generally larger than from bedrock wells (Dunne and Leopold, 1978); however, the availability of unconsolidated surficial aquifer material is limited.

Several sources provide information about groundwater resources in Vermont. Groundwater from surficial aquifers in most major river basins were investigated and mapped in the late 1960s and early 1970s at various scales by the USGS, in cooperation with the Vermont Agency of Environmental Conservation (Hodges, 1966, 1967a–f, 1968a–d; Hodges and others, 1976). A statewide surficial geologic map was produced at a scale of 1:250,000 in 1970 (Doll, 1970). Beginning with 2001, 1:24,000 groundwater-resource maps that integrate all available surficial and bedrock data, including information from well logs for wells located in valley floors, have been posted online by the Vermont Geological Survey at http://www.anr.state.vt.us/dec/geo/newmaps.htm as they are completed.

Components of Water Use

Withdrawals of groundwater or surface water go either directly to users or indirectly to users through a community water-system treatment and distribution system (fig. 2; table 1). A community water system (CWS) is a public water system that supplies water to the same population year round. Once transported to the user, water has three potential pathways: (1) it can be returned to the local water cycle by way of a wastewater collection and treatment system; (2) it can be returned to the local water cycle directly as return flow to the environment; or (3) it is not returned to the local water cycle (consumptive use). Return flows in towns with municipal services are through a wastewater collection and treatment system; then the treated water usually is piped to a stream or occasionally discharged to groundwater. For permitting purposes in Vermont, piped outflows to surface water are called "direct discharges." Leach fields or sprayfields, whereby water is returned to groundwater, are called "indirect discharges." If there are no municipal services for wastewater, return flows are to groundwater through a septic system and leach field or sprayfield. Some percentage of the volume of water withdrawn is usually used consumptively and is not returned to the local water cycle, as it is either incorporated into a product or evaporated.

Methods

Several steps were needed to create and populate the VWU database: identify and compile data from available sources, identify water-use categories for which withdrawals or return flows would be estimated, determine appropriate methods for estimating data when needed, document any assumptions, and develop a database structure (appendix A1) with a data dictionary (appendix A2) to organize data.

State, Federal, regional, and other sources of data (table 2) were used either to populate the VWU database directly with raw data or as the basis for making estimates. Data from the U.S. Census Bureau, Massachusetts Institute for Social and Economic Research, Vermont Center for Geographic Information, and most town and regional plans were available online. The rest of the data types listed in table 2 were sent to the USGS in response to a request.

Data that were provided in spreadsheet format were organized into a Microsoft Access relational database. Data that originated as coverages were organized into point and polygon datasets within ArcMap file geodatabases (ESRI, 2009). Tabular data from the Access database were joined to the geodata using a common field, such as MCD name, census-block identifier, or 8-digit hydrologic identifier (Hydrologic Unit Code, or HUC), to perform geographic analyses and to generate map displays of the data.

Domestic Water Withdrawals and Return Flows

Domestic withdrawals were determined by multiplying the population that was self supplied in every census block times a per-capita water-use coefficient of 75 gallons per day (gal/d). The per-capita water-use coefficient for Vermont was assumed to be the same as the coefficient derived from a detailed 2003 water-use study of the New Hampshire seacoast region (Horn and others, 2008). It was necessary to estimate populations by census block for 2005 because 2005 is a year midway between two decennial census years (2000 and 2010) when populations by census block are assessed by the U.S. Census Bureau. Accordingly, populations by census block in 2005 were estimated by equation 1

$$\text{Estimated pop of CB-}y\text{ within MCD-}z\text{ in 2005} = \left(\text{pop of CB-}y\text{ in 2000}\right)\frac{\left(\text{pop of MCD-}z\text{ in 2005}\right)}{\left(\text{pop of MCD-}z\text{ in 2000}\right)}, \quad (1)$$

where

pop = population,

CB-y = sample census block, and

MCD-z = sample MCD.

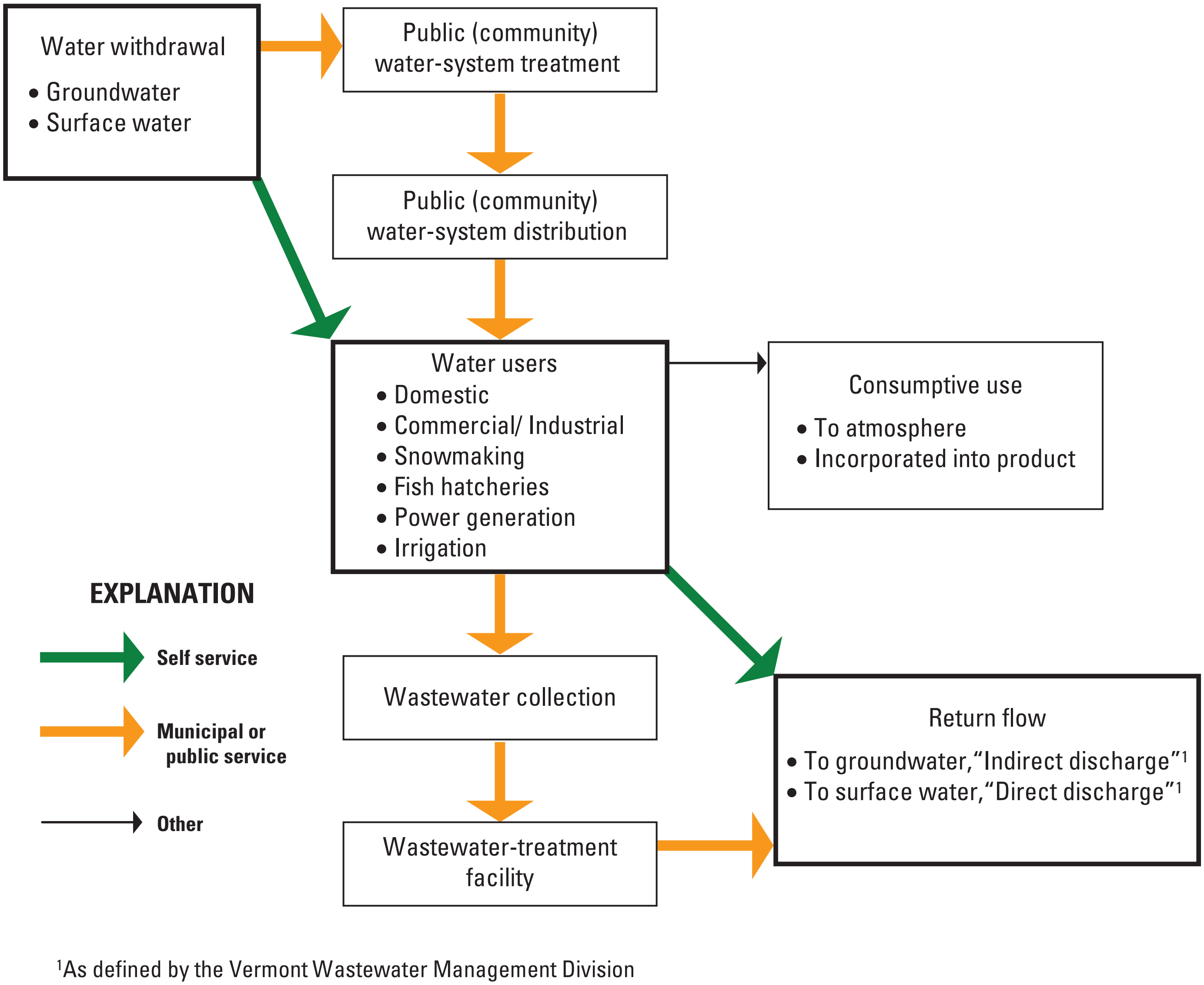


Figure 2. The components of water use and the conceptual flow of water between components.

Table 1. Definitions of water-use categories and other selected terms.

[From glossary in Hutson and others, 2004. Examples of water uses listed in the definitions are based on a national compilation and may not all be relevant to water use in Vermont or applicable to methods of populating the Vermont Water-Use database]

Water-use category or term	Definition
Commercial	Water for motels, hotels, restaurants, office buildings, other commercial facilities, and military and nonmilitary institutions.
Consumptive use	The part of water withdrawn that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment.
Domestic	Water used for all such indoor household purposes as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and such outdoor purposes as watering lawns and gardens.
Fish hatchery	Water used for raising fish for later release and in association with the operation of fish hatcheries or fishing preserves.
Industrial	Water used for fabrication, processing, washing, and cooling, and includes such industries as chemical and allied products, food, bottled water, mining, paper and allied products, petroleum refining, and steel.
Irrigation	Water that is applied by an irrigation system to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands such as parks and golf courses.
Livestock	Water for livestock watering, feedlots, dairy operations, and other on-farm needs.
Mining	Water used for the extraction of naturally occurring minerals including solids, such as coal, sand, gravel, and other ores; liquids, such as crude petroleum; and gases, such as natural gas. Also includes uses associated with quarrying, milling, and other preparations customarily done at the mine site or as part of a mining activity. Does not include water associated with dewatering of the aquifer that is not put to beneficial use.
Public-supply	Water withdrawn by public and private water suppliers that furnish water to at least 25 people or have a minimum of 15 connections. Public suppliers provide water for a variety of uses, such as domestic, commercial, industrial, thermoelectric power, and public water use.
Return flow	Water that reaches a groundwater or surface-water source after release from the point of use and thus becomes available for further use.
Self-supplied water use	Water withdrawn from a groundwater or surface-water source by a user rather than being obtained from a public supply.
Snowmaking	Water used during the winter at ski areas to increase snow coverage of ski trails.
Thermoelectric-power	Water used in the process of generating electricity with steam-driven turbine generators.

Once populations of census blocks were determined, the populations were split into self-supplied populations and populations served by a CWS. Digital coverages of service areas for CWSs were used to determine that split. Coverages were provided electronically for large CWSs by 8 of the 11 Regional Planning Commissions (RPCs) in Vermont and by the towns of St. Johnsbury and Bennington. Coverages of service areas for the remaining three RPCs and for most of the smaller CWSs that were not provided digitally were estimated by one or more of several methods: (1) perusing the town plan for a verbal description, (2) using a cluster of (Enhanced) E911_sites near a well(s) whose location(s) was provided by the Vermont Water Supply Division (WSD), (3) matching the name of the CWS for a mobile home park or development with the name of a road, or (4) using information from a town official. Documentation of the estimation method is recorded with the service-area coverages. E911_sites is a point coverage where each point (site) depicts an accurate physical location, as well as other characteristics, of all buildings that existed at the time of data compilation.

Polygon coverages of census blocks and of service areas for CWSs were overlain onto the subset of the E911_site point coverages categorized as “residential” using ArcMap geographic information system software (ESRI, 2009). The population of a census block served by a CWS is the total census-block population multiplied by the ratio of E911_sites within the CWS service area in that census block to total E911_sites in the census block. The population of a census block that is self supplied was calculated as the difference between the total population of the census block and the population served by the CWS. In the conceptual example shown in figure 3, there are 15 residential E911 sites in census block 500 (one site is represented by one dot); one-third of those are served by a CWS and two-thirds are self supplied.

Table 2. Sources of data for the Vermont Water-Use database.

[VT, Vermont; ANR, Agency of Natural Resources; SIC, Standard Industrial Classification; CB, census block; MCD, Minor Civil Division; VCGI, Vermont Center for Geographic Information]

Data type	Data source	Time period
Tables or spreadsheets		
Withdrawals for snowmaking	VT ANR, Water Quality Division	2004–2008
Return-flow data for indirect discharges	VT ANR, Wastewater Management Division	2007
Populations served for indirect discharges	Medalie, 1995 or E911_sites point coverage	1990 or 2008
Return-flow data for direct discharges	VT ANR, Wastewater Management Division	1999–2008
Withdrawal volume and intake locations, and populations served by public-water suppliers	VT ANR, Water Supply Division	2005
Number of employees and SIC codes for commercial and industrial facilities	Dun & Bradstreet, Inc. (2008)	2008
2000 populations by CB	U.S. Census Bureau (2001)	2000
2005 population estimates by MCD	U.S. Census Bureau (2005)	2005
2020 population estimates by MCD	Massachusetts Institute for Social and Economic Research (Rayer, 2003)	2020
Projected growth of public-water suppliers	VT ANR, Water Supply Division: Priority list of Water Supply Load Applicants 2008 and Tim Raymond (Water Supply Division, 2008, oral commun.)	2008
Geospatial data or coverages		
Service areas for public-water suppliers	Unpublished from Regional Planning Commissions, some town officials, or estimates	2008
Service areas for public-wastewater systems	Unpublished from VT Department of Housing & Community Affairs, or estimates	2008
(Enhanced) E911_sites point coverage	VCGI	2008
CB polygon coverage	VCGI	2008
Approximate boundaries of growth areas	Unpublished from various town and regional plans	2002–2008[1]

[1]Town and regional plans generally were dated within the indicated time period; the time period pertaining to growth areas is unspecified.

If the population of the census block is 75, then 25 people are served by a CWS, and 50 people are self supplied.

Similarly, domestic return flows were determined by multiplying the population not covered by municipal wastewater service in every census block by a per-capita return-flow coefficient of 63 gal/d. This coefficient is the difference between domestic per-capita coefficients for withdrawals (75 gal/d) and consumptive use (12 gal/d) (Horn and others, 2008). The same technique of splitting census-block populations into parts covered and not covered by water service was used to estimate parts covered and not covered by municipal wastewater service. The coverage of municipal wastewater service areas that was provided by the RPCs through the Vermont Department of Housing and Community Affairs (DHCA) was complete for 8 of the 11 RPCs. For the remaining RPCs, three sources were used to digitize estimated wastewater service areas: (1) maps of service areas available online from town- or regional-plan maps; (2) descriptions in town plans; or (3) in the absence of any other information, service areas were digitized, assuming they covered the same area as municipal water-service areas. Estimates of withdrawals and return flows for domestic use are shown in appendix B.

Non-Domestic Water Withdrawals and Return Flows

All facilities (users of water) in the VWU database were assigned to one of two categories: public water systems (PWS), consisting of all facilities in the WSD database of PWSs, or non-PWSs, consisting of all other facilities (table 3). The U.S. Environmental Protection Agency (USEPA) definition of a PWS is “a system for the provision to the public of water for human consumption through pipes or

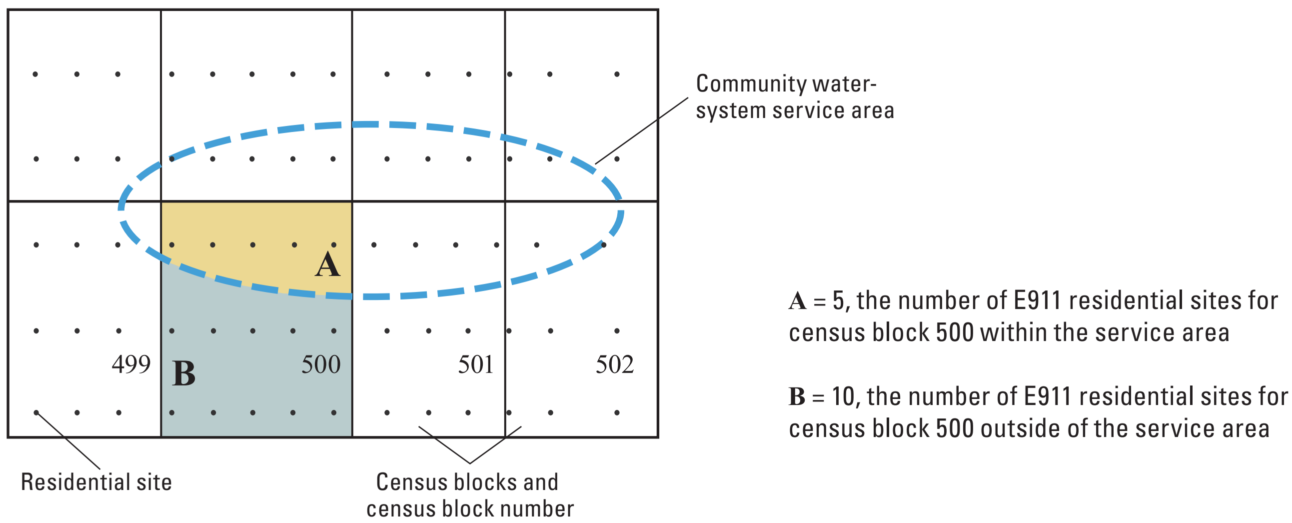


Figure 3. Diagram showing conceptual method used to determine the self-supplied population for each census block in Vermont.

Table 3. Organization and examples of types of facilities in the Vermont Water-Use database.

[PWS, public water system; WSD, Water Supply Division; CWS, community water systems; TNC, transient non-community water systems; NTNC, non-transient non-community water systems; WB, water bottlers; numbers in parentheses () indicate the number of each type of facility in the Vermont Water-Use database]

PWS facilities (1,382)—*registered with WSD*	Non-PWS facilities (3,027)—*all other facilities*
CWS (419)	• Commercial (2,460)
• Municipal systems	• Industrial (339)
• Mobile home parks	• Mining (10)
• Condominiums	• Snowmaking operations (20)
	• Fish hatcheries (6)
	• Power generation (3)
TNC (705)	• Wastewater-treatment facilities (110)
• Hotels/motels/inns	• Institutions or private associations (6)
• Restaurants	• Golf courses (72)
• Campgrounds	• Livestock (1)
• Stores	
NTNC (250)	
• Schools	
• Hospitals	
• Business/industrial facilities	
WB (8)	

other constructed conveyances, if such system has at least 15 service connections or regularly serves at least 25 individuals" (accessed February 4, 2009, at http://www.epa.gov/safewater/pws/pwsdef2.htm). Facilities in the WSD database of PWSs meet the USEPA definition of community (CWS) or non-community water systems (including transient and non-transient non-community water systems, TNC and NTNC) and are entities such as public-water suppliers, hospitals, schools, campgrounds, hotels, restaurants, water bottlers, and other businesses. The important distinction between PWS and non-PWS facilities is that locations of water-withdrawal points (latitude and longitude) of PWSs are known and were provided to USGS from the WSD, whereas locations of water-withdrawal points for non-PWS were not available. Instead, non-PWSs were assigned to a census block with no specific location within the census block. This distinction of whether or not the withdrawal locations are known comes into play when designing retrievals of data because of the structure and relationships between tables in the Access database, as further explained in appendix A1.

Community Water Systems

Seventy-four percent of CWSs, including all that withdrew water from surface-water sources and many that withdrew from groundwater sources, reported water-withdrawal data to the WSD in 2005. Of the remaining 26 percent that were registered but did not report withdrawals, 40 percent purchased water from other public suppliers. For these purchasers, withdrawal locations and volumes are accounted for in the VWU database by the CWS that sold the water, reflecting where the impact to the water resource occurs. For CWSs without reported withdrawals that did not purchase water, withdrawal volumes were estimated as the population served (information provided by the WSD for every CWS) multiplied by the domestic per-capita water-use coefficient of 75 gallons per person per day. Since most of the facilities in this group of small CWSs whose withdrawals were estimated were housing developments and mobile home parks, the underlying assumption that deliveries to non-domestic users were insignificant probably results in minimal underestimation of withdrawals.

The WSD provided data for total withdrawals made by CWSs. Because the VWU database is intended to be a tool used to assess the effects of withdrawals on local water resources, many of the reported withdrawals had to be split between several sources. The default method was to split total withdrawals equally between each active non-emergency source. However, it became important to determine an accurate split between withdrawals from multiple sources when the sources were not close to one another or if there were both groundwater and surface-water sources. For a few cases where large populations were served and reported sources were in more than one MCD, telephone calls were made to individual CWS facilities to get accurate information for allocating portions of withdrawals between separate locations and between groundwater and surface-water sources.

Non-Community Water Systems

Data on water withdrawals and return flows for all non-CWS facilities, including TNC and NTNC PWS facilities and non-PWS facilities (table 3), came from several sources: reported withdrawals, reported direct-discharge return flows, reported indirect-discharge return flows, and estimates based on coefficients. Reported withdrawals were available for 13 percent of TNC and NTNC facilities included in the WSD dataset.

Eighty percent of non-PWS facilities in the VWU database, because they discharge water to surface water, have Direct Discharge permits from the Vermont Wastewater Management Division (WMD). The WMD has had authority delegated by the USEPA to administer their National Pollutant Discharge Elimination System permit program. Although reporting requirements of the WMD Direct Discharge Permit Section vary by individual facility on the basis of design (maximum) flow and history of violations, most facilities are required to report monthly return-flow volumes in addition to water-quality and physical characteristics. Typically, monthly return flows were reported as daily values averaged for each month. Facilities for which only monthly maximum, rather than average, values for return flows were available from the WMD include 6 landfills (the median 2005 annual value was 0.008 and the maximum was 0.051 Mgal/d) and 15 industrial facilities (the median 2005 annual value was 0.006 and the maximum was 0.225 Mgal/d). A field (Basis of water-use value, fig. A1) in the Water use table of the VWU database tracks these facilities when reported values are maximums. Since return flows reported for the single largest water user in the State, Entergy Nuclear-Vermont Yankee, were maximum daily values for the month, that facility was contacted directly to get an accurate average value for the VWU database for 2005.

Return-flow volumes reported to the WMD by each of the 13 facilities with indirect (leach field) discharges and design capacities of at least 50,000 gal/d also were obtained. These data include discharges for one municipal-wastewater facility, eight ski areas (base lodges, hotels, condominiums, and other buildings), and four private communities that were not tied into a municipal-wastewater facility.

Return-flow volumes for eight small (less than 50,000 gal/d) municipal-wastewater facilities with indirect discharges to groundwater were estimated using the domestic per-capita coefficient of 63 gal/d plus a water-use estimate of 900 gal/d for each commercial facility. A commercial component was included in this estimate because most of these small wastewater systems with indirect discharges were located in mountain resort towns with substantial commercial activity. The estimate used for commercial facilities, which is the median for all commercial facilities (1,000 gal/d) less 10 percent consumptive use, was derived by Horn and others (2008, table 11). Populations served by the municipal-wastewater systems were determined from a 1990 report on wastewater (Medalie, 1995) or by counting residences in the E911_sites coverage and multiplying by the average number of people per occupied household in Vermont (2.5) (accessed May 8, 2009, at http://factfinder.census.gov/home/saff/main.html?_lang=en). The E911_sites coverage provided the number of commercial facilities when overlain with service areas.

For the remaining facilities with no reported withdrawal or return-flow data, water withdrawals were estimated by assigning each facility to an industrial or commercial water-use group that represents users with similar water-use characteristics. The list of industrial and commercial facilities that are included in this category consists of TNC and NTNC facilities (referred to in this report as non-community water systems, or non-CWSs) from the PWS dataset, as well as the Dun & Bradstreet (D&B) dataset. Duplicate entries were culled. Facilities located within service areas of municipal CWSs were excluded from the VWU database because they did not withdraw water.

Water withdrawals were estimated for industries by using a coefficient based on the median number of employees (for example, facilities in the food industry use 469 gallons per employee per day) and for commercial users by using a coefficient based on the type of facility (for example, a very small restaurant uses 500 gallons per day). The number of employees is a data element included with the D&B dataset. For the non-CWS dataset, determination of the appropriate water-use group for individual users was attempted initially on the basis of the facility name. For facilities without descriptive names, the Internet was used to search for information with which to categorize the facility. For the D&B dataset, Standard Industrial Classification (SIC) codes that were included with the purchased data were used to classify facilities into water-use groups.

The VWU database has 362 industrial facilities from the non-CWS and the D&B datasets that were assigned to industrial water-use groups (table 4). Water-use coefficients for the industrial water-use groups in table 4 were developed by Planning and Management Consultants, Ltd., (1995) on the basis of water-meter readings at individual industrial

Table 4. Water-use coefficients for industrial facilities.

[Employee water-use coefficients are from Planning and Management Consultants, Ltd., 1995; SIC, Standard Industrial Classification]

Water-use group	Two-digit SIC code	Water-use coefficient (gallons per employee per day)		Number of facilities in Vermont Water-Use database
		Range	Median	
Industrial unclassified	20–39	21–2,160	116	7
Food	20	96–677	469	44
Textile mill products	22	246–1,076	315	7
Apparel	23	6–43	13	8
Lumber and wood	24	32–109	78	55
Furniture	25	25–65	30	11
Paper	26	114–8,304	863	6
Printing	27	15–66	42	46
Chemicals	28	128–653	289	7
Petroleum	29	278–1,437	1,045	2
Rubber	30	73–170	119	9
Stone, clay, glass, and concrete	32	13–224	202	34
Primary metal	33	87–424	178	3
Fabricated metal	34	48–585	95	19
Machinery	35	28–153	58	38
Electrical equipment	36	30–169	71	30
Transportation equipment	37	14–143	63	11
Instruments	38	40–141	66	9
Jewelry, precious metals	39	27–61	36	16

facilities across the Nation (Horn and others, 2008). The range and median of these national coefficients and the number of facilities in the VWU database for each water-use group are shown in table 4.

The VWU database has 3,240 commercial facilities from the non-CWS and the D&B datasets that have been assigned to commercial water-use groups. Facilities within these broad water-use groups were divided into subgroups based generally on the size of the facility (number of employees or population served) or size in combination with other factors related to water use (table 5) that were determined from Internet searches. Subgroups in table 5 were defined according to natural groupings in metered delivery data for commercial facilities in the New Hampshire Seacoast study (Horn and others, 2008) and identification of factors that might contribute to the natural breaks, such as further definition by SIC code, or the presence of water-using amenities. For example, the presence of a pool or a restaurant at a hotel would be grounds for that facility to be assigned a larger coefficient within a given water-use group.

Water withdrawals for irrigation at golf courses were estimated as 0.005 Mgal/d per 1,000 yards of course length. This coefficient is the average of 55 withdrawals for irrigation at golf courses reported to the New Hampshire Department of Environmental Services Water User Registration database (Frederick Chormann, written commun., 2006). New Hampshire and Vermont have similar climates and irrigation needs; therefore, irrigation practices are assumed to be similar. The list of golf courses in Vermont and their yardage was found online at http://www.golflink.com/golf-courses/state.aspx?state=VT (accessed June 15, 2009).

Withdrawals for livestock are accounted for in the VWU database as the sum of estimates for dairy withdrawals plus an estimate for withdrawals at the State's largest egg farm in Highgate. For the 2005 USGS national water-use compilation, withdrawals for dairy use comprised 84 percent of withdrawals for livestock watering, which accounted for about 15 percent of total withdrawals from groundwater in Vermont (Kenny and others, 2009). Water withdrawals for livestock watering typically are based on county-wide estimates of the numbers of animals multiplied by animal-specific water-use coefficients (Lovelace, 2009). County-wide water withdrawals for dairy in Vermont were estimated for the six counties (Addison, Caledonia, Chittenden, Franklin, Orleans, and Rutland) that accounted for 86 percent of the dairy cows in Vermont in 2002 (U.S. Department of Agriculture, 2004), using the number of dairy cows times the coefficient for dairy water use of 35 gallons per animal per day (Pennsylvania State University, 2002). County-wide dairy water use was disaggregated by overlaying the 2002 land-cover raster dataset (University of Vermont Spatial Analysis Laboratory, 2005) with the census-block data layer and prorating water use to census blocks on the basis of area classified as agricultural land. The assumption was made that, for census blocks, land area classified as agricultural and the number of dairy cows are directly related. Adopting assumptions used for the national water-use compilation (Kenny and others, 2009), 75 percent of withdrawals for dairy were presumed to be from groundwater, and 25 percent were presumed to be from surface water. Estimated withdrawals for livestock use are shown by MCD in appendix B.

Consumptive Use

The methods discussed in the preceding paragraphs describe how either withdrawal or return-flow information was obtained or estimated. Both types of reported data were available for only three facilities. Thus, one type of data usually was estimated from the other, as well as by factoring in an estimate of consumptive use. A conventional consumptive-use coefficient of 10 percent of commercial and industrial withdrawals (Shaffer and Runkle, 2007, table 9; Horn and others, 2008) was used in this study. Consumptive-use coefficients of 90 and 2 percent were used to estimate return flows from withdrawals for irrigation of golf courses and for cooling at thermoelectric-power producing facilities (Shaffer and Runkle, 2007). Consumptive use at Entergy Nuclear-Vermont Yankee was estimated to be 1 percent of withdrawals from May through October (Lynn DeWald, Entergy Nuclear-Vermont Yankee, written commun., 2009).

When either withdrawals or return flows were estimated from the other and from an estimate of consumptive use, an assumption was needed regarding whether groundwater or surface water was the source of withdrawals and the receiving body of return flow. Unless otherwise known, the source of withdrawals that were estimated for facilities was assumed to be groundwater rather than surface water. This assumption is supported by the PWS database provided by the WSD. Of the 954 TNC and NTNC facilities in the database, only 14 (1 percent) made withdrawals from surface-water sources (all from Lake Champlain or Arrowhead Mountain Lake); the rest of the withdrawals were from groundwater. Likewise, return flows that were estimated for facilities were assumed to discharge to groundwater because all discharges to surface water theoretically should be reported according to the discharge permitting program. Implicit in this assumption of 100 percent compliance for discharge permits is the reality that there is no way to obtain information about facilities that do not comply with the permitting process—facilities operating illegally without a permit.

Fish Hatcheries and Snowmaking

Two types of activities, fish hatcheries and snowmaking at ski areas, were given more attention in this study than other types of facilities because they use more water. Facilities for these activities were the only non-PWS facilities in the database with water-withdrawal locations assigned as points (latitude and longitude) in addition to census blocks to account, with relative geographic precision, for potentially large impacts on resources.

Table 5. Water-withdrawal estimates for commercial facilities, by water-use group and subgroup.

[gal/d, gallons per day; SIC, Standard Industrial Classification]

Water-use group	Water-use subgroup: Number of employees[1]	Water-use subgroup: Facility water-withdrawal estimate (gal/d)	Water-use subgroup: Number of facilities in Vermont Water-Use database	Basis for assigning facilities to subgroups
Retail stores	5–19	250	318	Combination of number of employees and SIC code.
	20–75	500	38	
	40–120	750	20	
	50–290	1,000	3	
	200	1,500	1	
Grocery stores	5–40	500	175	Combination of number of employees and SIC code.
	25–175	1,000	19	
	16–75	3,000	1	
Restaurants	5–10	500	46	Combination of population served or number of employees and restaurant type, such as carry-out, fast food, or eat in.
	5–35	1,000	115	
	6–130	1,500	59	
	25–180	2,000	15	
	5–110	2,500	7	
Motels and inns	5–15	500	108	Combination of number of employees and the presence of water-using amenities such as restaurants, pools, and jacuzzis.
	7–30	1,000	122	
	10–93	1,500	59	
	45–200	2,000	17	
	100–300	2,500	9	
	502–1,600	12,000	4	
Campgrounds and youth recreational camps	5–10	250	13	Combination of population served or number of employees, presence of water-using amenities, and seasonal activity.
	12–20	500	48	
	25–36	1,000	40	
	40–80	1,500	5	
Businesses	5–20	250	614	Combination of number of employees and SIC code.
	11–30	500	241	
	20–132	750	91	
	75–450	1,500	8	
Recreational facilities	5–20	250	53	Combination of population served or number of employees, presence of water-using amenities, and seasonal activity.
	15–99	500	62	
	20–135	1,000	27	
	245–404	2,000	6	
	400	3,000	1	
Health-care facilities	5–42	500	15	Number of employees.
	50–145	1,000	8	
	150–200	2,000	2	
Medical offices and hospitals	5–30	500	90	Number of employees.
	34–60	750	3	
	79–750	1,000	5	
	1,000–4,000	3,000	1	
Schools and day cares	5–32	250	239	Number of employees.
	31–80	500	56	
	80–147	1,000	33	
	150–700	2,000	19	
	970–2,500	6,000	2	
Offices	5–53	500	397	Combination of number of employees and SIC code.
	45–375	750	17	
	99–900	1,000	5	
	423–4,000	2,500	3	

[1]There is overlap between some of the subgroup ranges within water-use groups because factors other than the number of employees also go into the assignment to subgroups.

Four State and two national fish hatcheries report monthly return flows to the Direct Discharge Permit Section of the WMD. Withdrawals at fish hatcheries are inferred as 100 percent of return flows because water circulates quickly through the raceways without perceptible losses (Thomas Wiggins, Fish Culture Operations Chief, Vermont Fish & Wildlife Department, oral commun., 2008). Sources of water for fish hatcheries were determined either from information provided on the Internet or by telephoning the facility.

Monthly water withdrawals for snowmaking by source are reported by 12 resorts to the Vermont Agency of Natural Resources to ensure compliance with legislation designed to sustain aquatic communities and other stream functions (Title 10 V.S.A. Chapter 41, Subchapter 3. Water Withdrawal for Snowmaking). Less than 5 percent of water withdrawn for snowmaking in this humid region is estimated to evaporate (consumptive use) (James Shanley, U.S. Geological Survey, oral commun., 2009); thus at least 95 percent (97 percent was used for this study) of the annual withdrawal volume is estimated to be the annual return flow. Because meltwater from mid-winter thaws would produce predominantly surface-water runoff and spring meltwater recharges both groundwater and surface water, over the entire snowmaking season, return flows are estimated as 50 percent each to surface water and groundwater.

Projecting Future Water Use

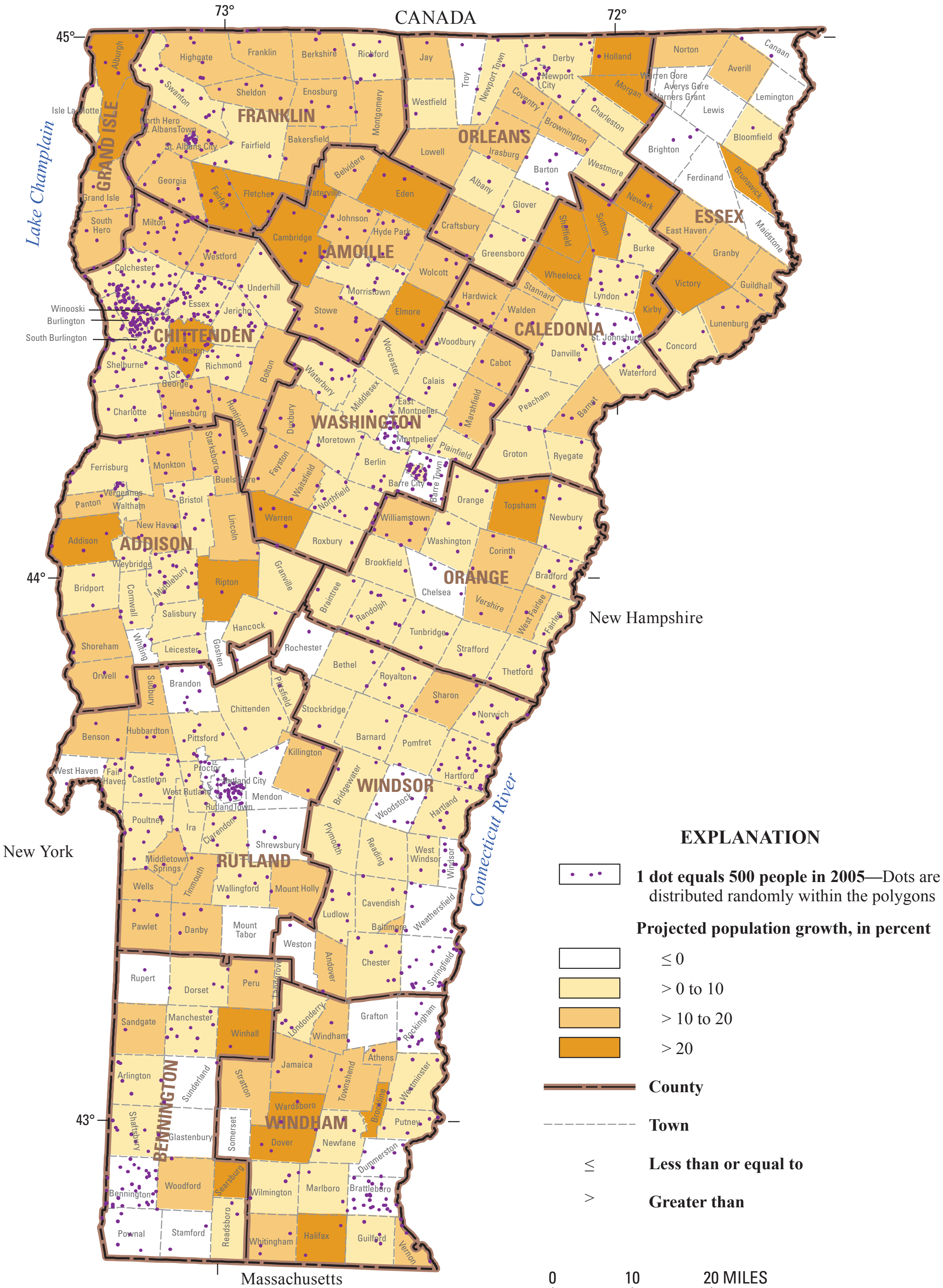
Projections of future water use were based on the Massachusetts Institute for Social and Economic Research (MISER) population projections, by MCD, for 2020 (Rayer, 2003). The same procedure that was described above to estimate 2005 population for census blocks based on MCD populations was used to calculate the growth factor between 2005 and 2020. This growth factor was multiplied by the 2005 census-block populations to project populations for 2020 by census block. Growth factors for MCDs (fig. 4) range from minus 25 percent (Buels Gore) to 94 percent (Victory), the median is 7 percent, and quartiles are 1 and 18 percent.

Future domestic water use was estimated by multiplying the census block 2020 population projections by the per-capita coefficient of 75 gallons per person per day. Projections of growth for non-domestic water use were made using the following assumptions: (1) per-capita domestic water use would not change between 2005 and 2020 (there is no basis to presume change); (2) the same growth rate calculated for domestic use applies to commercial facilities; (3) growth in industrial production would be offset by increases in water efficiencies, rendering 2020 projections for industrial use the same as 2005 values; and (4) similar to [3], potential expansions at fish hatcheries would be offset by greater water efficiencies, resulting in no change between 2005 and 2020 (Thomas Wiggins, Vermont Fish & Wildlife, oral commun., 2008). Projected increased withdrawals for snowmaking were from build-out (maximum expansion) analyses conducted by ski resorts (Brian Fitzgerald, VTDEC-Water Quality Division, written commun., 2009). Projected increases in withdrawals by CWSs were derived from two sources: Timothy Raymond, VTDEC-Water Supply Division (oral commun., 2008) and a spreadsheet of WSD revolving loan applications (accessed November 25, 2008, at http://www.vermontdrinkingwater.org/DWSRFGuidanceDocuments/2008_Priority_List_Aug.xls).

Data for growth areas (fig. 1) came from maps of future land use or growth centers from town or regional plans, verbal descriptions of growth areas in town or regional plans, and for some MCDs, from build-out analyses from online sources. The list of data sources used in this compilation of growth-area coverage is available at the New Hampshire-Vermont Water Science Center in Montpelier, Vermont. A field (growth area, fig. A1) in the Census block table of the VWU database indicates whether any part of the census block is contained within a growth area. The growth-area layer is intended to depict areas that towns or regions have identified as likely to grow and is independent of the previously described sources of projected changes in water use. This information can be useful in performing analyses comparing current withdrawals to projected withdrawals at scales finer than the MCD level, such as at the census-block level. The analysis of data and maps shown in this report is summarized by MCD (with one exception, Dover, shown at a larger scale) and, for the analysis, it was assumed that the projected population growth for 2020 occurred evenly throughout the MCD.

Quality Assurance of Service Areas

Spatial coverages of service areas were approximated for about 24 percent of the 99 municipal wastewater facilities and for about 69 percent of the 419 CWS facilities in the VWU database because this information was not readily available. Most of the CWS service areas that were approximated due to unavailability of data were for small facilities serving mobile home parks and condominiums. It was possible to get an idea of the accuracy of the methods used to delineate the approximated sewer service areas by focusing on Franklin County, where sewer service areas were both approximated and provided by the DHCA. Method 1, of approximating the sewer service area, resulted in about 31.5 percent (7,221 out of 22,954) inclusion of E911_sites within the service area. Method 2, which uses the sewer service area that was provided by the DHCA, resulted in about 29.5 percent (6,781 out of 22,954) inclusion of E911_sites within the sewer service area. Thus, approximating the sewer service area resulted in an overestimation of 2 percent, and demonstrates the viability of this approximation method.



U.S. Geological Survey 1:250,000 scale, Digital Elevation Model Dataset, 1998, Vermont State Plane Coordinate System, North American Datum 1983

Figure 4. Population distribution in Vermont by Minor Civil Division in 2005, and projected growth in population from 2005 to 2020.

Data Limitations

The VWU database contains over 36,000 entries of site-specific water-use data (in many cases several hundred records for monthly values for individual facilities), out of which about 25,000 are based on reported data and 11,000 are based on estimates. In addition, more than 23,000 census blocks with estimated self-supplied domestic and livestock withdrawals and return flows are stored in the database. Checks of occasional anomalous values in reported data resulted in corrections to units or to decimal placement.

Many of the coefficients used, such as per-capita water withdrawals and return flows, water use for industrial facilities based on number of employees and SIC codes, and water use for commercial facilities based on SIC codes and other site-specific characteristics, were assumed to be the same as those determined in the 2003 New Hampshire seacoast water-use study (Horn and others, 2008) because there have been no similarly comprehensive studies in Vermont. Use of these coefficients in a study for Vermont assumes that factors related to water use—human behavior, climate, and economics—are comparable between the two areas. Furthermore, coefficients represent averages and are meant to provide relative approximations, rather than absolute accuracy for individual people or facilities. Similarly, assumptions about consumptive use, which is used to estimate withdrawals or return flows depending on which of the two types of data are available, introduce imprecision at the individual person or facility level.

Another limitation relates to using data from the VWU database at a finer resolution than MCDs, such as the census-block level. Populations by census block for 2005 and 2020 were extrapolated from 2000 populations as a single growth factor applied uniformly for all the census blocks in a given MCD. This method does not take into account changes in population growth rates within the town, that is, intra-MCD differences. This would be relevant if a planner, for example, was interested in honing in on a specific part of a town, such as a potential growth area, or was interested in an assessment of the impact of increasing withdrawals on a particular local resource.

Other limitations of data in the VWU database relate to seasonal differences in water use. Seasonal differences in domestic water use can be significant because summer car washing, lawn and garden watering, and filling of swimming pools creates greater demand than in winter (Horn and others, 2008). Seasonal housing and visits to resorts for summer, winter, and fall foliage, as well as college or university attendance, all may substantially affect water use for particular MCDs. Water withdrawals in winter increase in areas with heavy snowmobile traffic and at ski areas (especially those that make snow) because of the increase in seasonal travelers using hotels, restaurants, stores, and condominiums. Water withdrawals for crop irrigation were not estimated because these data are not collected by any agency, although estimates are made at the county level of acres of irrigated land. Also, very little crop land in the State is irrigated, and irrigators of crop land generally use efficient drip systems (Vern Grubinger, University of Vermont Extension, written commun., 2008). The structure of the VWU database is flexible enough to accommodate inputs and retrievals of seasonal water-withdrawal and return-flow data, and the database can be populated with seasonal estimates for all categories of usage.

Differences from Previous Water-Use Compilations

A few differences in the categorization and methods used in this study and those used for estimates of water use in Vermont published in recent USGS Circulars (Solley and others, 1998; Hutson and others, 2004; Kenny and others, 2009) should be mentioned. Water withdrawals for snowmaking were included in the commercial category of water use as defined in the circulars, and these withdrawals are treated as a separate category in this report. The D&B dataset used as the basis for estimating commercial and industrial withdrawals and return flows in this report, in the absence of reported data for the VWU database, was not used for the previous USGS compilations. Withdrawals for mining, livestock, and fish hatcheries in Vermont were estimated by national, rather than State, compilers for the 2005 USGS compilation. An explanation of other differences in estimating procedures, for example in allocating aggregate estimates between groundwater and surface-water sources, can be obtained from the authors.

2005 and 2020 Population

Areas in Vermont with the largest and densest 2005 population clusters were centered around St. Albans City, Burlington, Barre-Montpelier, and Rutland City (fig. 4). MCDs with fewer than 2,000 people were spread throughout the State. Of the MCDs with projected growth greater than 20 percent, only four had 2005 populations greater than 2,000: Alburgh, Fairfax, Cambridge, and Williston. Of the towns or cities with projected changes less than zero (that is, population loss), three had 2005 populations greater than 10,000 people: Rutland City, Bennington, and Brattleboro. A listing of 2005 populations and 2020 population projections by MCD, as well as populations for 2005 that were self supplied for domestic water needs, appears in appendix B.

Water Withdrawals and Return Flows Estimated for 2005 and Projected for 2020

Summaries of water withdrawals and return flows by MCD for 2005 and projected for 2020 using data retrieved from the VWU database are presented in this section. Withdrawal data first are presented Statewide by category and source of water, then by MCD showing categories of self-supplied domestic, CWS, and all other water users aggregated. Next, withdrawals of groundwater and surface water are presented by MCD. Total withdrawals, return flows, and total withdrawals minus return flows are illustrated and discussed. A final summary shows withdrawals by major watershed. The figures showing MCDs and categories of usage, total withdrawals, total return flows, and withdrawals by watershed also show percent of totals from or to groundwater. Appendix B shows all of the withdrawal estimates by category and source of water, and return flows to groundwater and surface water, for each MCD.

Withdrawals by Category

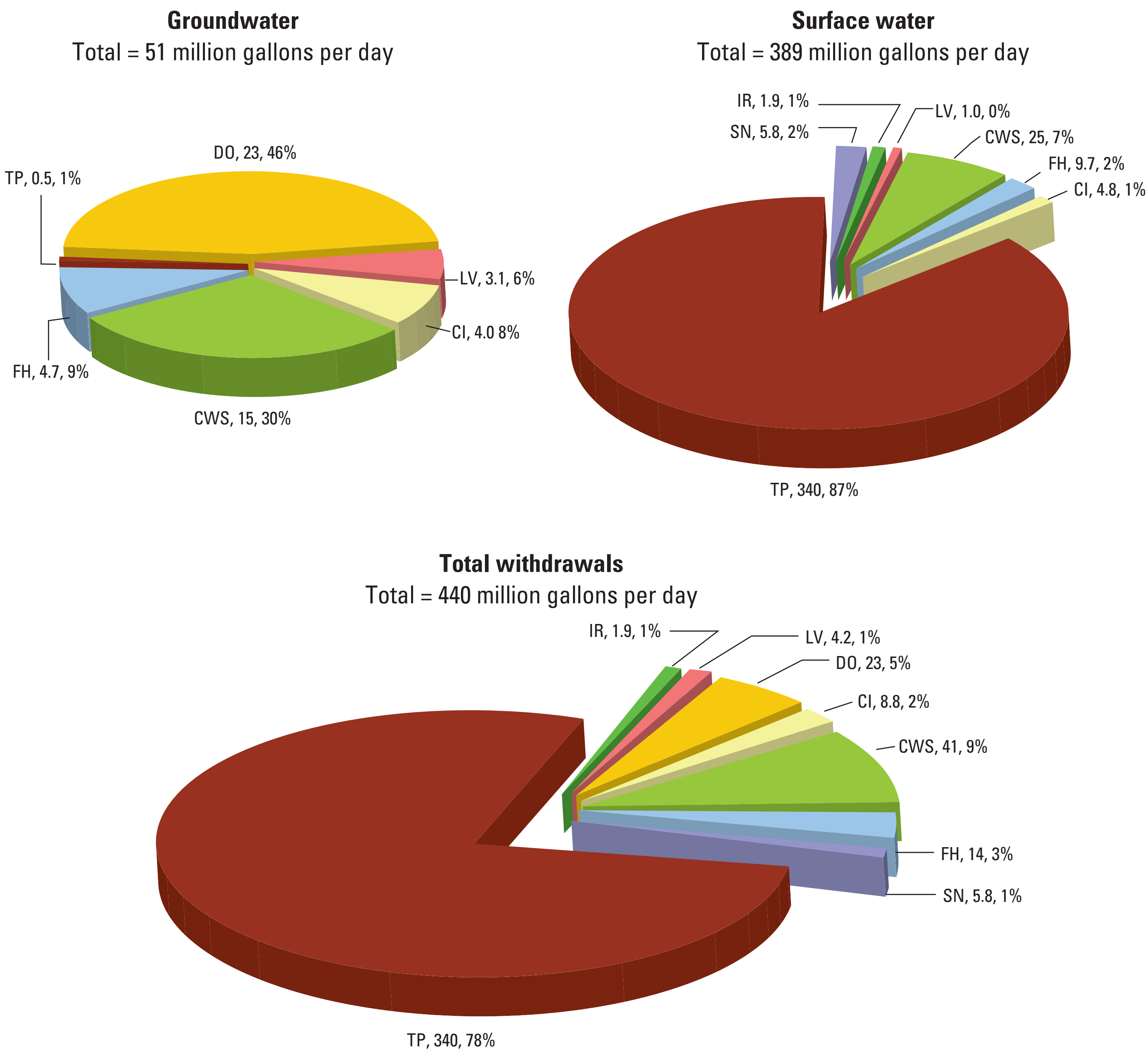
In 2005, about 12 percent of total withdrawals (440 Mgal/d) were from groundwater sources (51 Mgal/d), and about 88 percent were from surface-water sources (389 Mgal/d) (fig. 5). If the Entergy Nuclear-Vermont Yankee plant, which accounted for the largest withdrawals in Vermont, was excluded from the analysis, total withdrawals would have been about 100 Mgal/d, and withdrawals of surface water would have been about 49 Mgal/d, or about 49 percent of the total water withdrawn.

Withdrawals for thermoelectric-power use (340 Mgal/d) were about 78 percent of total withdrawals and about 87 percent of withdrawals from surface water (fig. 5). Withdrawals for public supply by CWSs (41 Mgal/d) accounted for about 9 percent of total withdrawals, about 7 percent of surface-water withdrawals (25 Mgal/d), and about 30 percent of groundwater withdrawals (15 Mgal/d). Withdrawals for domestic use (23 Mgal/d), almost entirely groundwater, accounted for about 5 percent of total withdrawals and about 46 percent of groundwater withdrawals. Withdrawals for snowmaking use (5.8 Mgal/d) were entirely from surface water and accounted for about 1 percent of total withdrawals and 2 percent of surface-water withdrawals. Withdrawals for commercial and industrial use (8.8 Mgal/d) accounted for about 2 percent of total withdrawals, about 8 percent of groundwater withdrawals, and about 1 percent of surface-water withdrawals. Withdrawals for fish hatcheries (14 Mgal/d) accounted for about 3 percent of total withdrawals, 9 percent of groundwater withdrawals, and 2 percent of surface-water withdrawals. Withdrawals for irrigation (1.9 Mgal/d) accounted for less than 1 percent of both total withdrawals and surface-water withdrawals. Withdrawals for livestock watering (4.2 Mgal/d) accounted for about 1 percent of total withdrawals, 6 percent of groundwater withdrawals, and less than 1 percent of surface-water withdrawals. In order to calculate total domestic, commercial, or industrial water use, a value for water delivered to these types of users by public suppliers would need to be estimated and added to the self-supplied withdrawals that are provided by the VWU database.

Withdrawals for three types of use across Vermont in 2005 are shown in figure 6, along with the approximate percentage obtained from groundwater sources. About 51 percent of the statewide population obtained domestic water on-site, and about 49 percent was supplied by a CWS (appendix B). Towns and cities with withdrawals greater than 0.1 Mgal/d for self-supplied domestic use were located throughout the State and accounted for at least half of the MCDs of Franklin, Chittenden, Lamoille, and Washington Counties (fig. 6A). It also can be seen in figure 6 that large self-supplied populations tended to be in towns near the major cities of St. Albans, Burlington, Montpelier, Barre, and Rutland; the cities themselves were served mostly or entirely by municipal water systems, but the surrounding areas were not. The population distribution map (fig. 4) illustrates that people lived in towns within easy commuting distance of these and other major cities but where extensive municipal water supply and wastewater services may have been absent. Withdrawals by households for self-supplied domestic use were virtually all from groundwater, although there were a few individual residences, mostly summer camps, that used lake water for household needs (not shown on map fig. 6A). The number of residences using lake water is dwindling as grandfathered permits for withdrawing surface water expire.

About 61 percent of MCDs in Vermont had some withdrawals by CWSs in 2005 (fig. 6B). St. Albans Town, Burlington, South Burlington, Waterford, Orange, Middlebury, Mendon, and Woodford had CWSs that withdrew greater than 1 Mgal/d. Many of these withdrawals were for CWSs that served large populations in neighboring cities or towns, such as St. Albans City (withdrawal in St. Albans Town), St. Johnsbury (withdrawals in Waterford), Barre City (withdrawals in Orange), Rutland City (withdrawals in Mendon), and Bennington (withdrawals in Woodford). Most of the large CWSs served, in addition to households, a variety of water users such as hospitals, schools, office complexes, malls, and manufacturers. The largest single withdrawal in Vermont by a CWS (5 Mgal/d in 2005) was from Lake Champlain by the Champlain Water District in South Burlington and provided water to about 68,000 users through 12 municipal water systems in Chittenden County (accessed June 9, 2009, at http://www.cwd-h2o.org/PDFs/2008%20Water%20Quality.pdf).

All MCDs that withdrew more than 1 Mgal/d, except Middlebury, obtained the water predominantly from surface-water sources. Most (72 percent) of the MCDs with less than 1 Mgal/d of CWS withdrawals obtained at least 95 percent of those withdrawals from groundwater.



EXPLANATION

LV, 4.2, 1%	Category of water withdrawal, volume withdrawn by users in the category, in million gallons per day, percent of total for the pie chart contributed by withdrawals within this category.
TP	Thermoelectric power
FH	Fish hatcheries
DO	Domestic
LV	Livestock
CI	Commercial and industrial
IR	Irrigation
SN	Snowmaking
CWS	Public supply, community water system

Figure 5. Water withdrawals in Vermont by category of use and source in 2005.

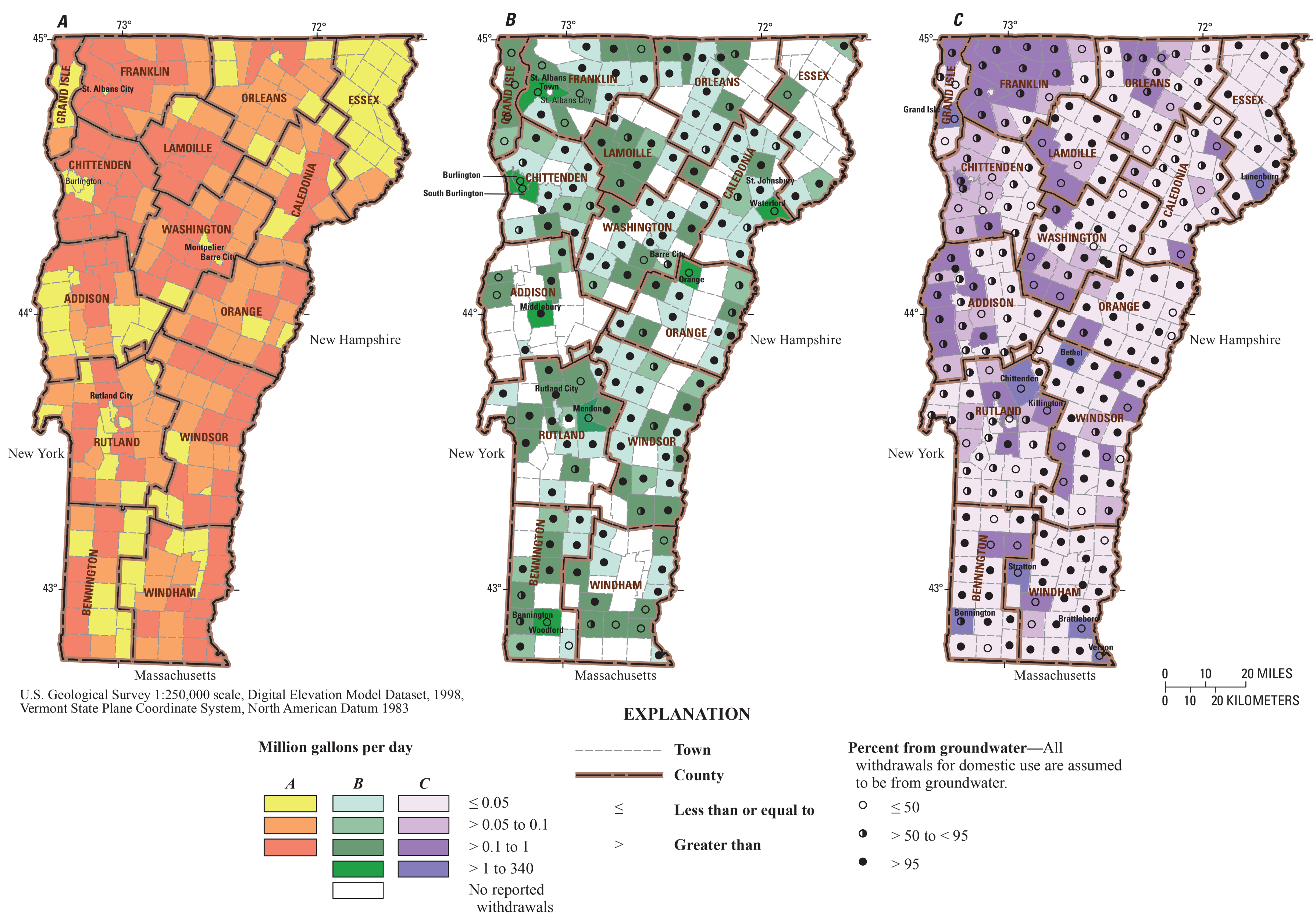


Figure 6. Total water withdrawals by *(A)* domestic self-supplied users, *(B)* community water systems, and *(C)* all other users, and percent of total from groundwater sources in Vermont, 2005.

Large withdrawals for other uses, greater than 1 Mgal/d (fig. 6C), generally corresponded to areas where public suppliers were absent because these withdrawals were for single users—snowmaking (Killington and Stratton), fish hatcheries (Grand Isle, Bethel, Chittenden, and Bennington), industries (Lunenburg and Brattleboro), and a power producer (Vernon). Except for Bethel, these large single users withdrew predominately surface water. The fish hatchery in Bethel withdrew groundwater from a zone near a stream that could appropriately be described as groundwater under the influence of surface water.

For 95 out of 247 MCDs that had less than 1 Mgal/d withdrawn for other uses, greater than 95 percent of the withdrawals were groundwater. This percentage might have been slightly overestimated because of the assumption that all estimated water withdrawals for industrial and commercial uses, if not otherwise known, were groundwater.

Groundwater

In 2005, Middlebury, Bethel, Hartford, Springfield, and Bennington had the largest withdrawals of groundwater, all greater than 1.0 Mgal/d (fig. 7). The smallest amounts of groundwater withdrawn generally corresponded to the smallest populations (fig. 4) in towns scattered throughout the State, such as in the northeast and the southern-central sections of the State.

Statewide in 2005, the largest percentage of groundwater withdrawals (46 percent) was for domestic use, with the largest amount (0.44 Mgal/d) for this use withdrawn by residents of Milton (appendix B). Withdrawals by CWSs, accounting for about 30 percent of withdrawals from groundwater statewide, were largest (greater than 0.87 Mgal/d) in Newport City, Middlebury, Hartford, and Springfield, where they comprised at least 75 percent of groundwater withdrawals. Withdrawals by fish hatcheries in Bethel (2.86 Mgal/d) and Bennington (1.11 Mgal/d) accounted for at least 73 percent of groundwater withdrawals in those towns. Withdrawals by self-supplied commercial and industrial facilities, spread throughout 93 percent of Vermont's MCDs, were largest (greater than 0.2 Mgal/d) in Sheldon and Sharon. At least 80 percent of groundwater withdrawals in the towns of Panton, Addison, and Bridport were for livestock use. In addition to those three, other towns with groundwater withdrawals greater than 0.1 Mgal/d for livestock use were Highgate, Swanton, Sheldon, Berkshire, Newport, St. Albans, and Fairfield. About 94 percent of groundwater withdrawals in Burlington were for thermoelectric-power production (0.47 Mgal/d) at the McNeil Generating Station.

Five towns, North Hero, Brunswick, Victory, Guildhall, and Searsburg have large projected percent increases in population resulting in large projected percent increases in groundwater withdrawals (greater than 20 percent) but very small projected volumetric increases (less than or equal to 0.01 Mgal/d) because the populations are small (figs. 7, 8). Fairfax, Hardwick, Middlebury, Sharon, Proctor, and Manchester are noteworthy because they have large projected increases both in terms of amounts (greater than 0.1 Mgal/d) and percentages (greater than 20 percent). Alburgh, Lunenburg, Williston, Warren, Winhall, and Dover have moderately large projected changes in total gallons (greater than 0.05 Mgal/d), as well as projected percent increases greater than 20 percent.

In addition to population growth causing projected increases in groundwater withdrawals, in some communities the increase in projected withdrawals also may be due to a single facility, such as a CWS or an industry. These possible explanatory factors appear as patterns superimposed onto MCDs with changes in groundwater withdrawals greater than 0.05 Mgal/d (fig. 8). Although both factors may contribute to the projected increase, the pattern shown is that which explains over 50 percent of the increase. The implications are that (1) withdrawals for MCDs with projected increases due to population increases are distributed within the MCD proportionately with the population distribution and (2) withdrawals for MCDs with projected increases due to an individual facility would affect a single location within the MCD.

In 2005, groundwater withdrawals minus return flows to groundwater were larger than 1 Mgal/d in Middlebury, Bethel, Hartford, and Bennington, reflecting places where large groundwater withdrawals were predominantly returned to surface water (fig. 9). Projections for 2020 put the same four towns into the same largest grouping. In contrast, return flows to groundwater were larger than withdrawals from groundwater in MCDs with ski areas that withdrew surface water for snowmaking and returned an estimated 50 percent of those withdrawals to groundwater.

The town of Dover, Vt., illustrates the capability of the VWU database to show details of groundwater withdrawals at the census-block level within an MCD. The 2005 withdrawals of groundwater were the largest in the census block (labeled 1 in fig. 10A) to the east of Route 100 where the road's direction turned northerly and in the census block (labeled 2) to the west of Route 100. Withdrawals of groundwater were large (> 0.01–0.03 Mgal/d) in four additional census blocks (3 through 6). Projected withdrawals of groundwater in 2020 show three additional census blocks (7 through 9) that fall into the large (> 0.01–0.03 Mgal/d) grouping (fig. 10B). This detail may help planners target specific areas for in-depth resource availability assessments if water availability is a concern. As more information becomes available, refinements can be made to the map based on factors such as population distribution within the MCD.

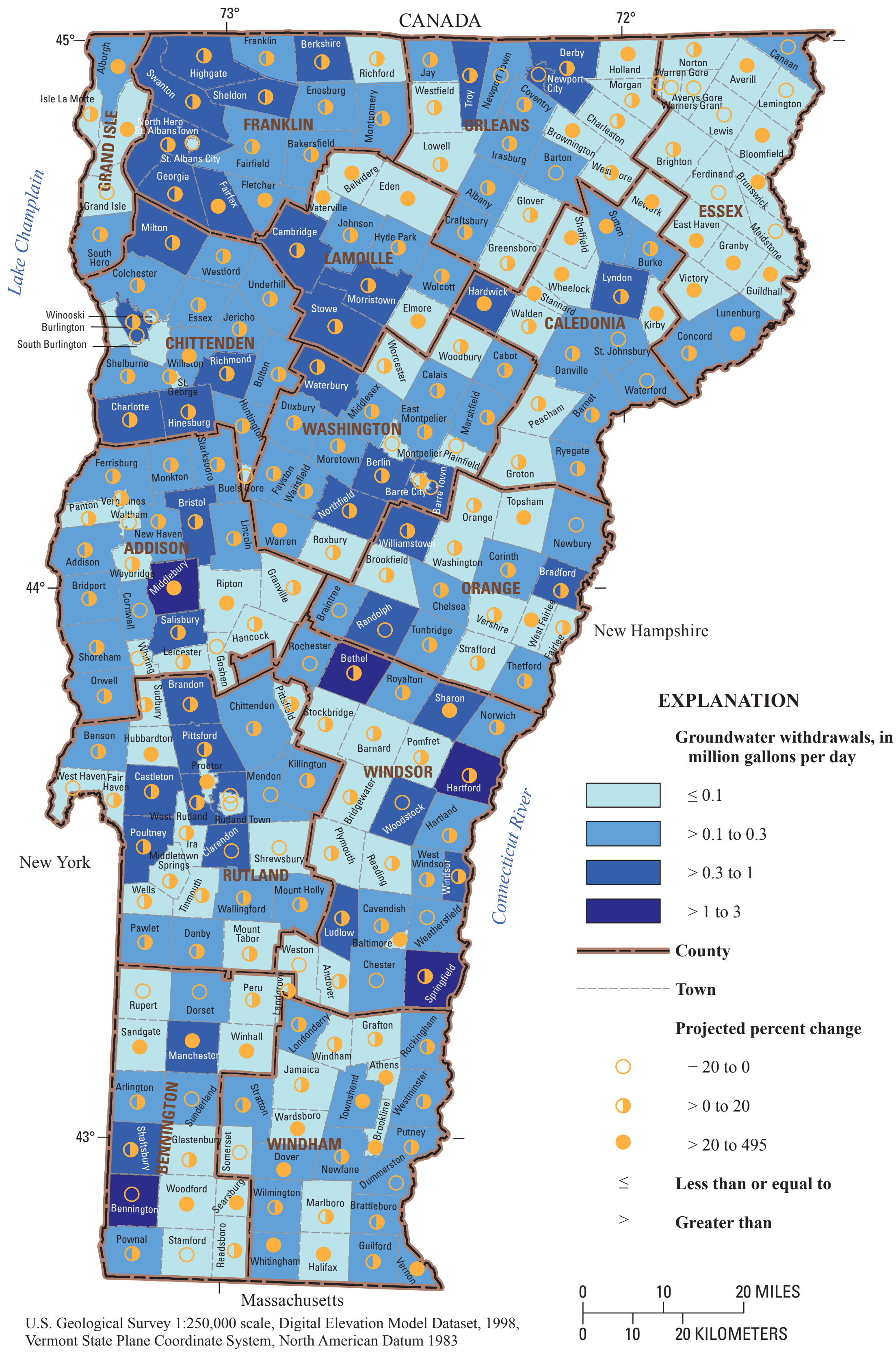


Figure 7. Withdrawals of groundwater in Vermont in 2005 and projected percent changes in withdrawals of groundwater from 2005 to 2020.

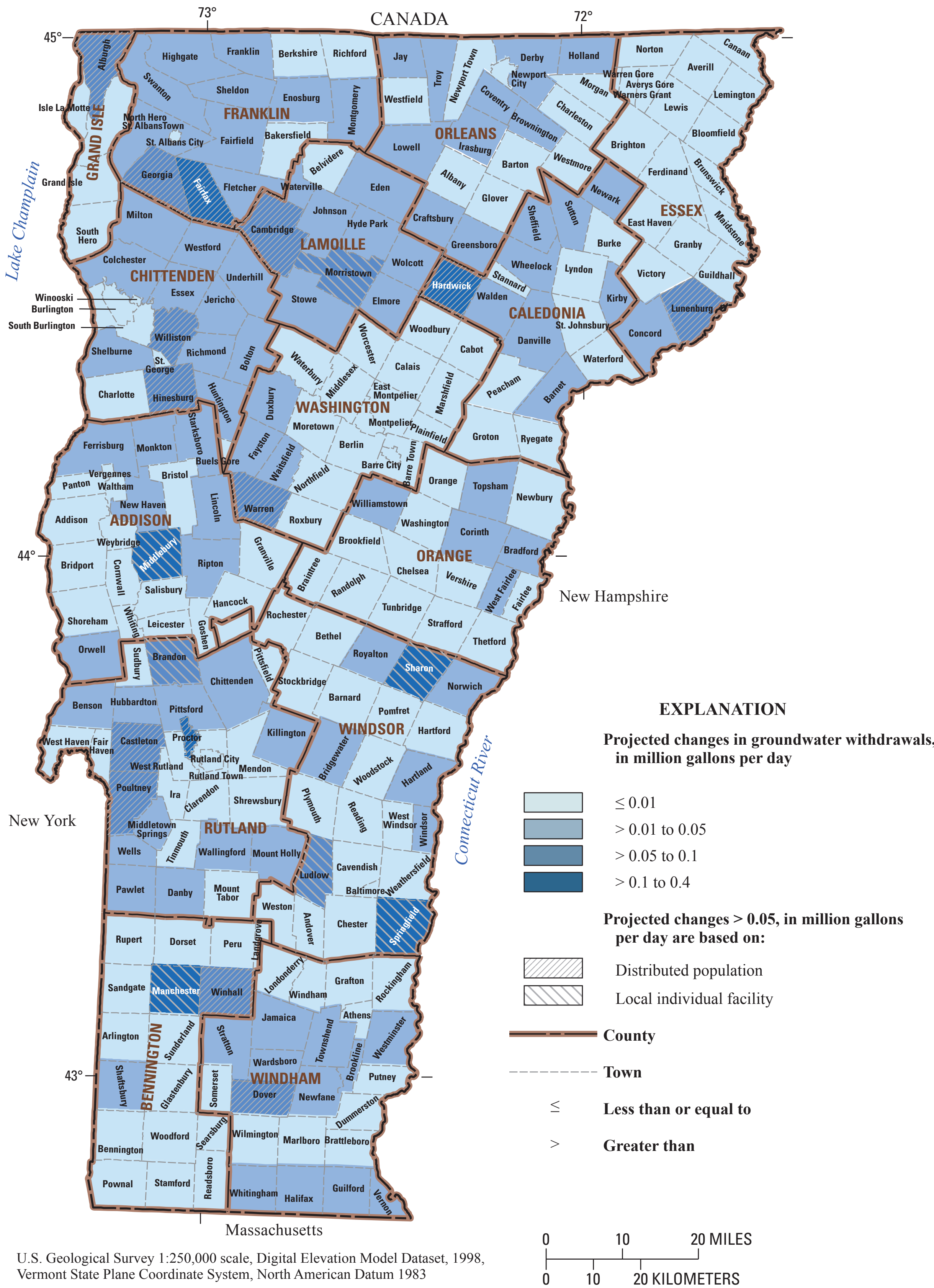


Figure 8. Projected changes in groundwater withdrawals in Vermont from 2005 to 2020.

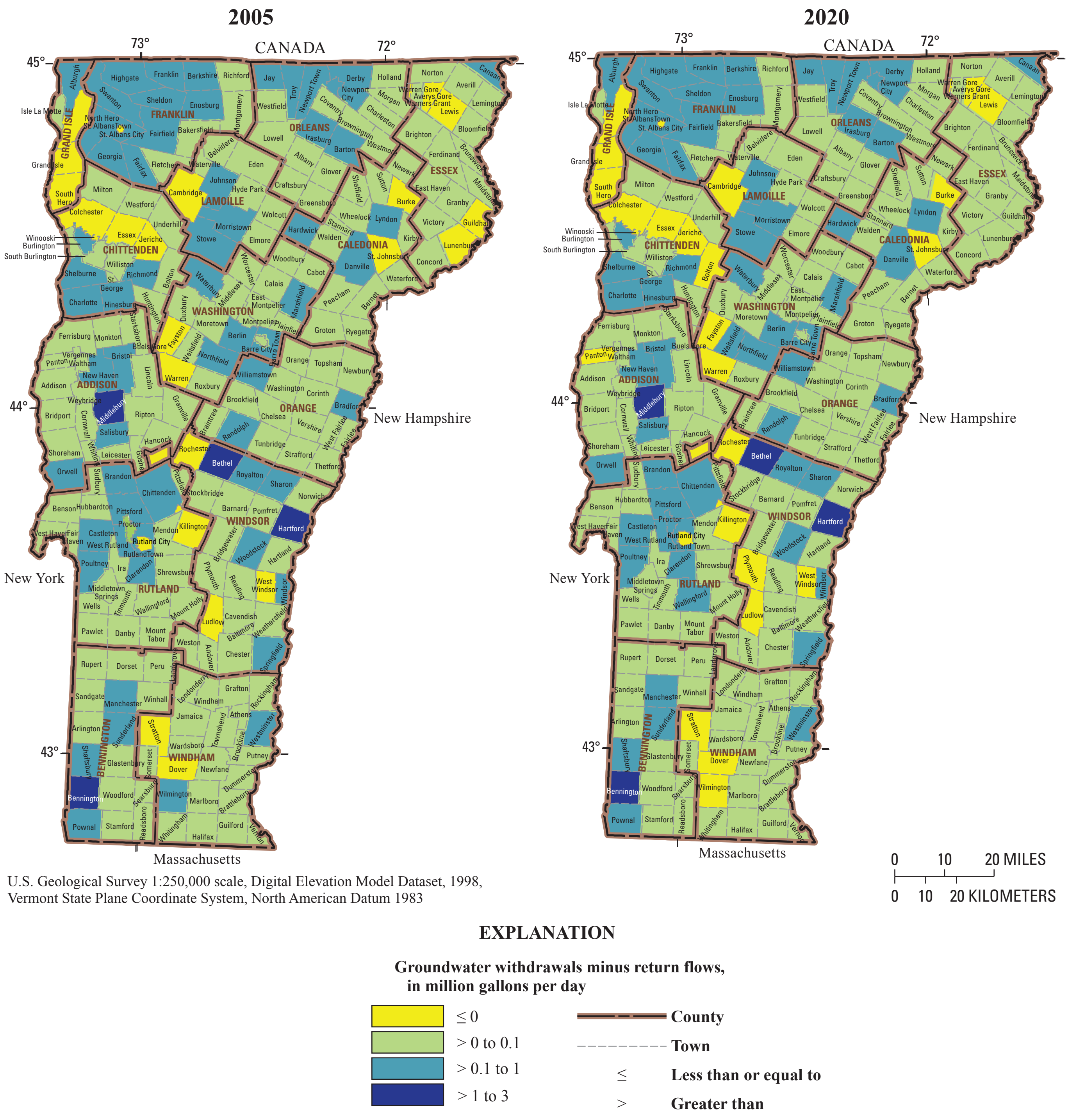


Figure 9. Groundwater withdrawals minus return flows to groundwater in Vermont in 2005 and projected for 2020.

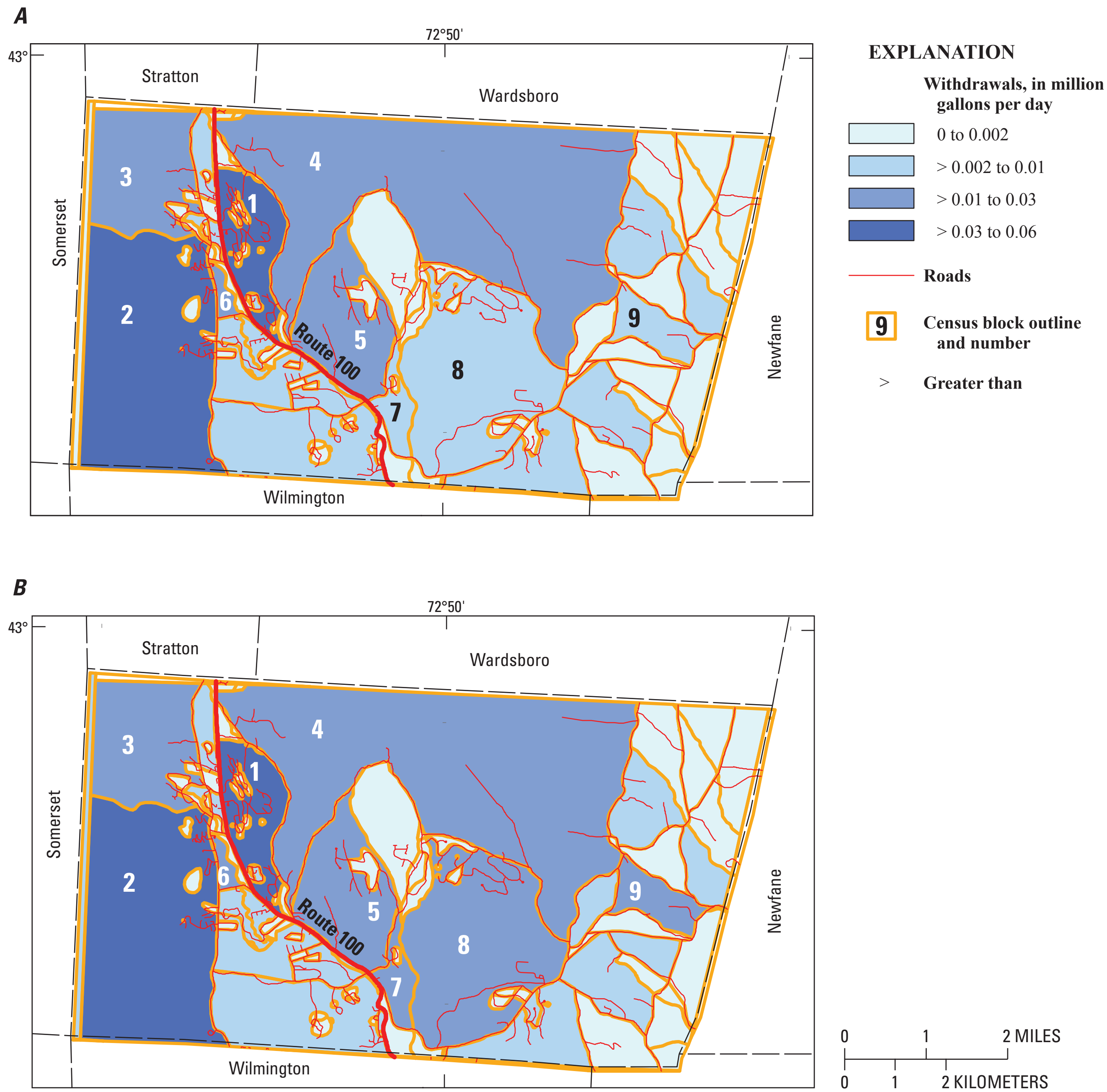


Figure 10. Census blocks in Dover, Vermont, showing *(A)* withdrawals of groundwater in 2005 and *(B)* projected withdrawals of groundwater in 2020.

Surface Water

In 2005, Grand Isle, Burlington, South Burlington, Mendon, Brattleboro, and Vernon had the largest withdrawals of surface water, greater than 2 Mgal/d (fig. 11). For all of those MCDs except Brattleboro, single categories of users accounted for at least 95 percent of the withdrawals: fish hatchery (Grand Isle), CWS (Burlington, South Burlington, and Mendon), and thermoelectric power (Vernon). The largest withdrawal of surface water from a single facility, about 340 Mgal/d in 2005, was from the Connecticut River for thermoelectric-power production (once-through cooling) at the Entergy Nuclear-Vermont Yankee plant in Vernon, and the second largest, about 7 Mgal/d, was from Lake Champlain for the Grand Isle Fish Hatchery. St. Albans Town, Waterford, Orange, and Woodford also had CWS withdrawals from surface water greater than 1 Mgal/d. Chittenden and Bennington, in addition to Grand Isle, withdrew greater than 1 Mgal/d from surface water for use at fish hatcheries. Withdrawals from surface water for snowmaking were largest, greater than 0.5 Mgal/d, in Stowe, Killington, Ludlow, Stratton, and Dover. Close to 100 percent of withdrawals from surface water (greater than 0.06 Mgal/d) in the towns of Hartford and Manchester were for irrigation at golf courses. Golf courses in Stowe and Killington also withdrew greater than 0.06 Mgal/d for irrigation. Close to 100 percent of withdrawals from surface water in Highgate and Newport Town, about 0.05 and 0.04 Mgal/d, respectively, were for livestock use. Overall, only about 18 percent of the State's MCDs withdrew at least 0.1 Mgal/d from surface water in 2005.

Because few MCDs in the State withdrew more than 0.1 Mgal/d of surface water in 2005, projected changes in withdrawals of surface water from 2005 to 2020 consist of values that are predominantly less than or equal to 0 (fig. 12). Large (greater than 0.5 Mgal/d) projected increases in withdrawals of surface water generally reflect estimated expansion of snowmaking operations at Green Mountain ski resorts in Stowe, Warren, Mendon, Killington, and Wilmington (fig. 1). A new surface-water source in Wilmington proposed to be used for snowmaking at Mount Snow in Dover accounts for Wilmington having both the greatest projected percent change and the greatest projected surface-water withdrawals.

Total Withdrawals and Return Flows

Eight MCDs had total withdrawals greater than 2 Mgal/d, and 41 had total withdrawals of 0.5 to 2 Mgal/d (fig. 13). Of MCDs with total withdrawals greater than 2 Mgal/d, one, Bethel, obtained greater than 95 percent of its water from groundwater, and one, Bennington, obtained 50 to 95 percent of its water from groundwater. The rest of the MCDs obtained most of their water from surface-water sources. Of MCDs with total withdrawals of 0.5 to 2 Mgal/d, 6 (Milton, Lyndon, Northfield, Middlebury, Salisbury, and Springfield) obtained more than 95 percent of their water from groundwater, and 14 others obtained 50 to 95 percent of their water from groundwater.

The largest projected total withdrawals by gallons and percent change generally occur in or near towns with ski areas, such as Cambridge, Burke, Stowe, Bolton, Warren, Killington, Plymouth, Ludlow, and Wilmington (fig. 14). This pattern may reflect that projections of water use for the snowmaking category were more readily available than for other categories. Counties where more than one-half of the MCDs have projected increases greater than 0.01 Mgal/d are Franklin, Orleans, Chittenden, Lamoille, Caledonia, Rutland, and Windham.

The pattern of return-flow volumes (fig. 15) is similar to the pattern of total withdrawals (fig. 13). Return flow to groundwater comprises indirect discharges, leach fields, and an estimated 50 percent of snowmaking withdrawals at ski areas that are returned to the local environment as snowmelt (fig. 15). In 2005, most (21 out of 24) of the MCDs with return flows greater than 1 Mgal/d returned less than 50 percent to groundwater because more than one-half of their return flows were from municipal wastewater-treatment facilities with direct discharges to surface water. All MCDs with return flows of as much as 0.05 Mgal/d and most MCDs with return flows of 0.05 to 0.2 Mgal/d returned greater than 95 percent of their water to groundwater. The largest return flows to groundwater (appendix B) occurred in towns with ski areas (Stowe, Warren, Killington, Ludlow, Stratton and Dover) and also in Bennington and the Chittenden County towns of Milton, Colchester, Essex, and Jericho, where municipal sewer service areas did not cover large segments of the population. The seasonal element of return flows from snowmaking is important from a resource availability perspective.

The pattern of projected return flows for 2020 looks similar to the return-flow pattern for 2005 (fig. 15) because planned changes in the capacity of wastewater-treatment facilities were not assessed. Changes in volumetric groupings of return flows from 2005 to 2020 are based either on changes in population projections or on increases in snowmelt at ski areas due to increased withdrawals for snowmaking.

In 2005, South Burlington, Waterford, Orange, Mendon, Woodford, and Vernon had the largest differences between withdrawals and return flows, greater than 1 Mgal/d (fig. 16). Except for South Burlington and Vernon, these were small towns with no obvious industry or large public supplier; however, water from these towns was withdrawn by CWSs for use and return to the environment in neighboring towns or cities. That is, the source of water used by the St. Johnsbury Water System was in Waterford; the source for the Barre City Water System was in Orange; the source for the Rutland City Water Department was in Mendon; and the primary source for the Bennington Water Department was in Woodford. Projections for 2020 indicate that Wilmington will join the previously listed MCDs whose differences between withdrawals and return flows are greater than 1 Mgal/d. A projected increase in withdrawals for snowmaking at a Dover ski area accounts for the increase in Wilmington.

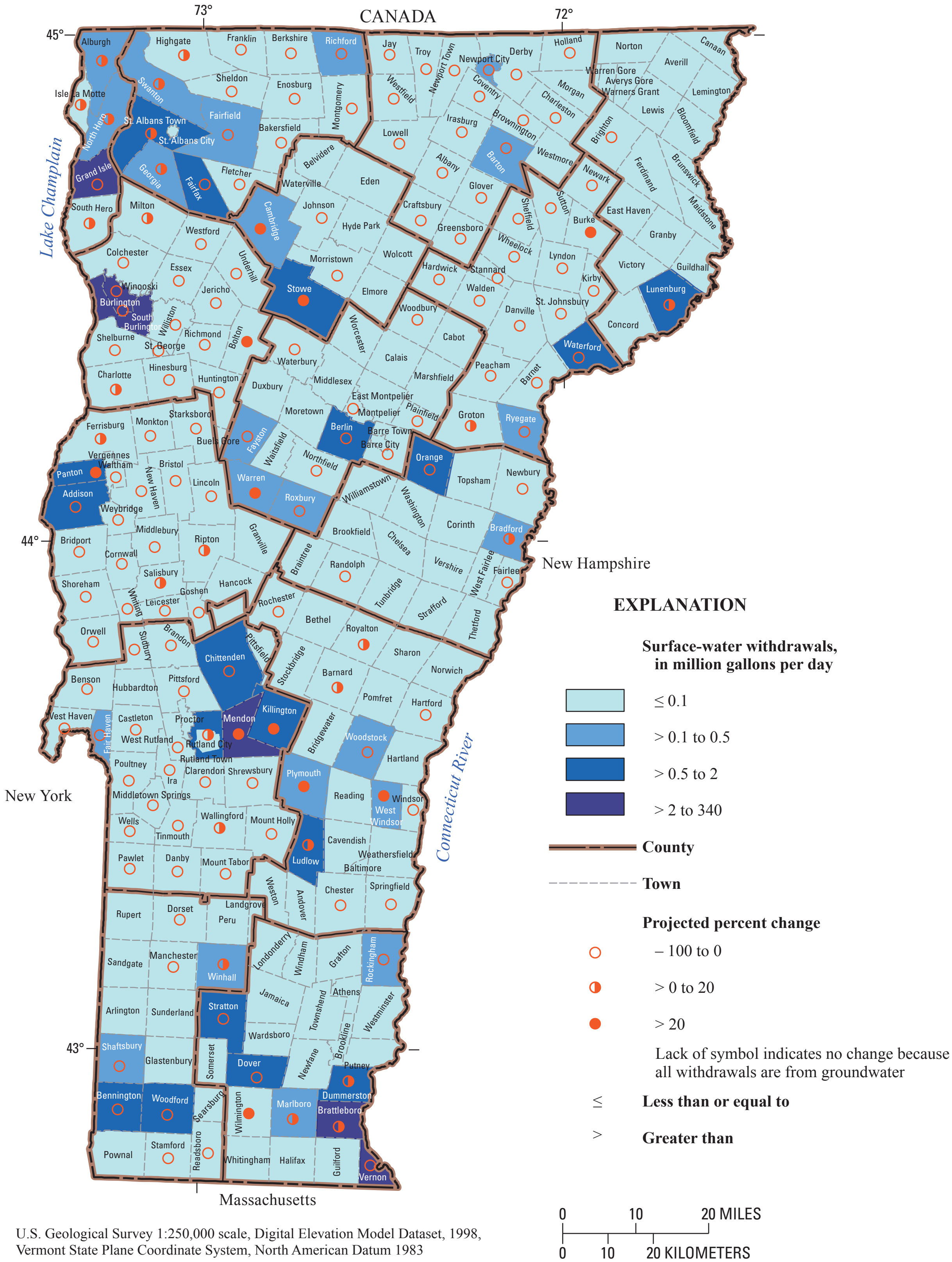
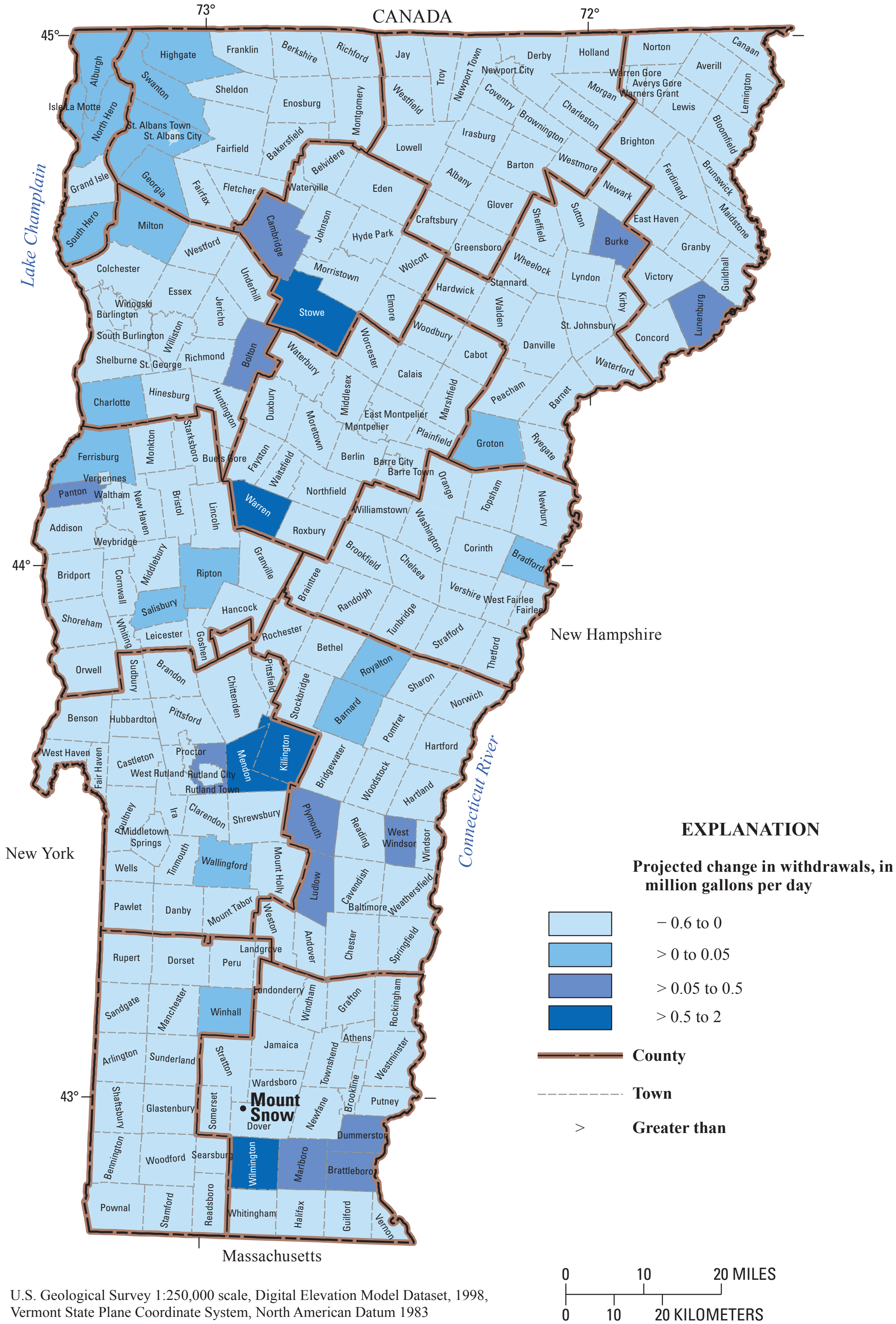


Figure 11. Withdrawals of surface water in 2005 and projected percent changes in withdrawals of surface water from 2005 to 2020 in Vermont.



U.S. Geological Survey 1:250,000 scale, Digital Elevation Model Dataset, 1998,
Vermont State Plane Coordinate System, North American Datum 1983

Figure 12. Projected changes in withdrawals of surface water from 2005 to 2020 in Vermont.

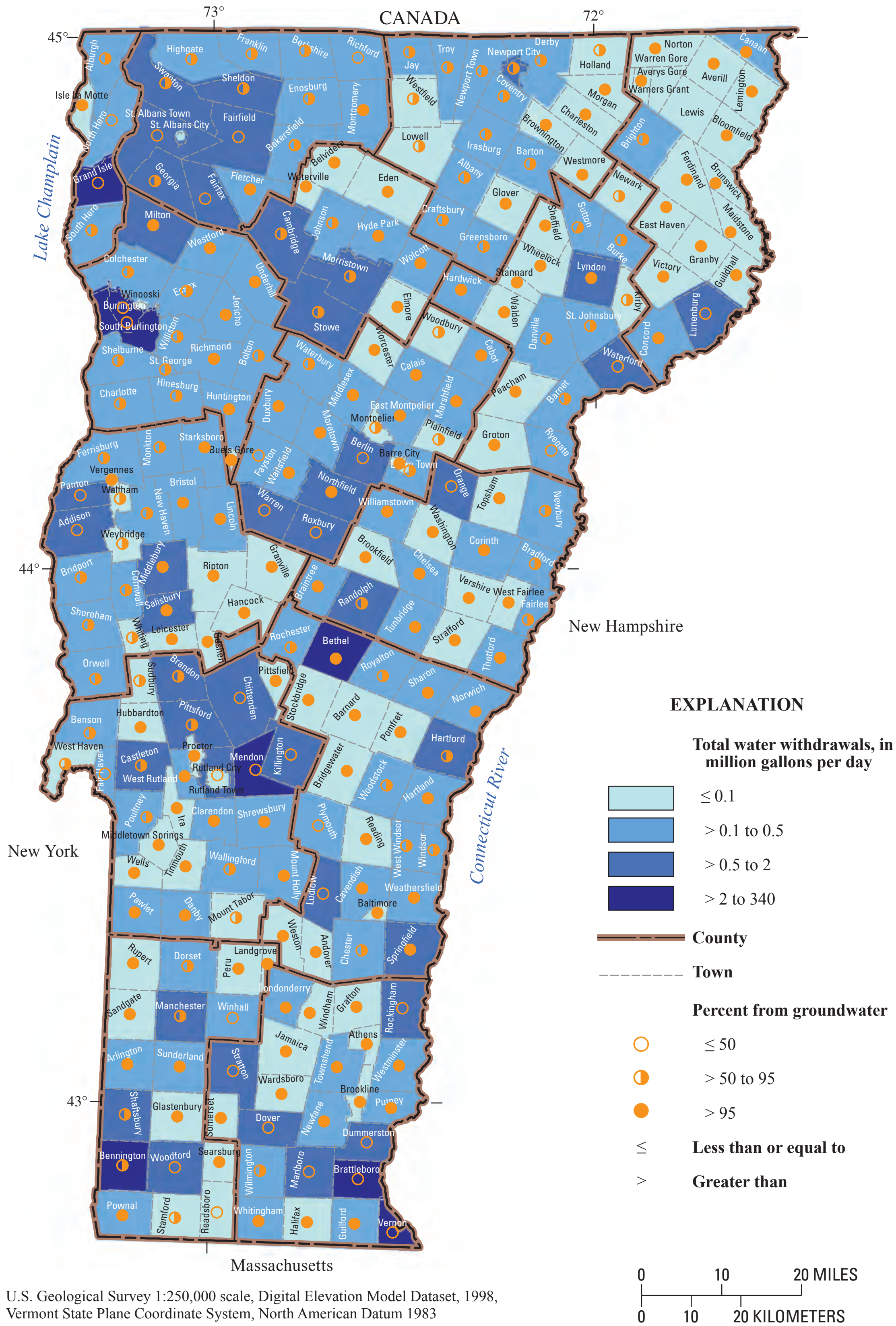
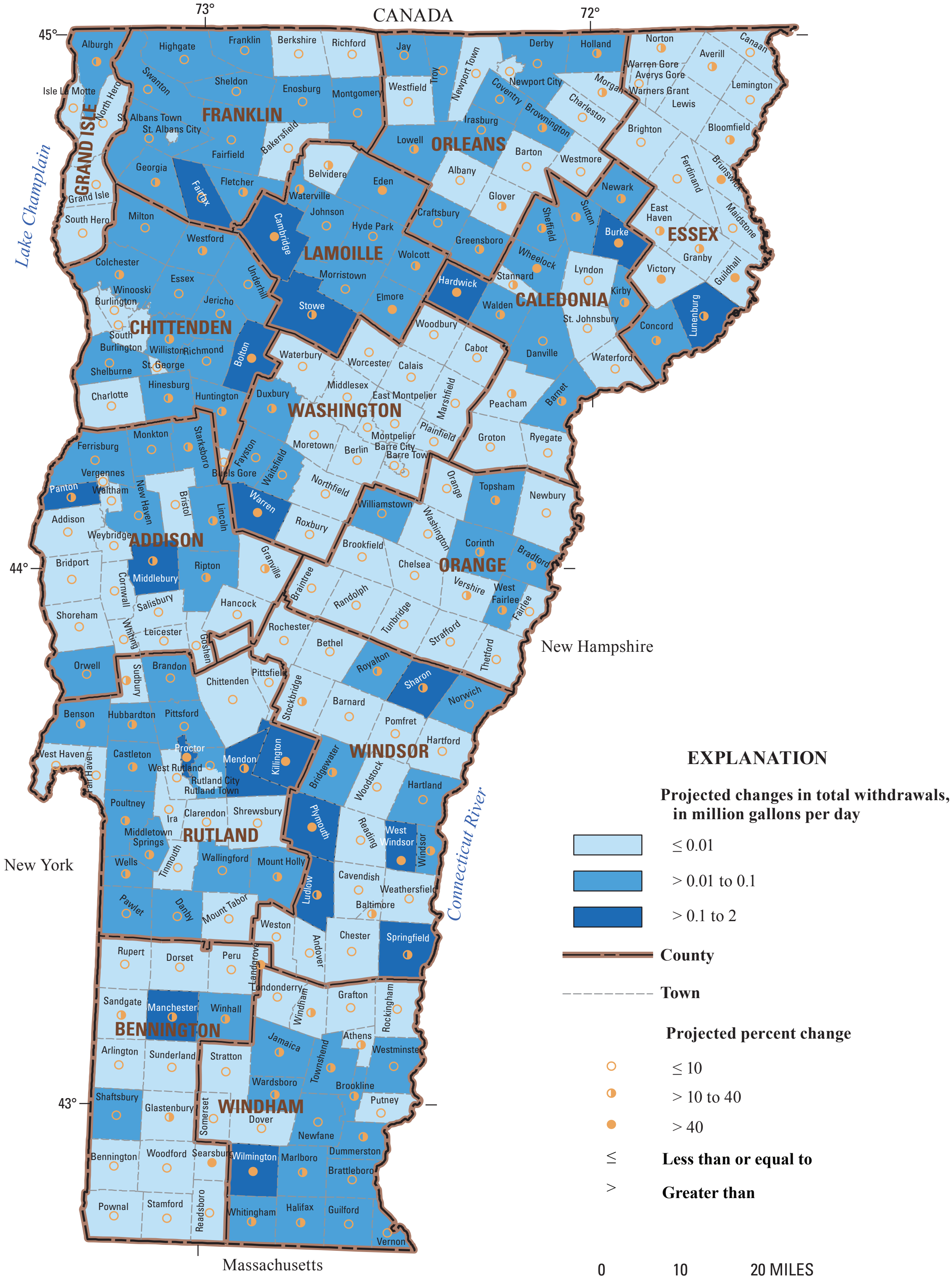


Figure 13. Total water withdrawals and percent of total from groundwater sources in Vermont in 2005.



U.S. Geological Survey 1:250,000 scale, Digital Elevation Model Dataset, 1998, Vermont State Plane Coordinate System, North American Datum 1983

Figure 14. Projected changes in total water withdrawals and projected percent changes in total water withdrawals in Vermont from 2005 to 2020.

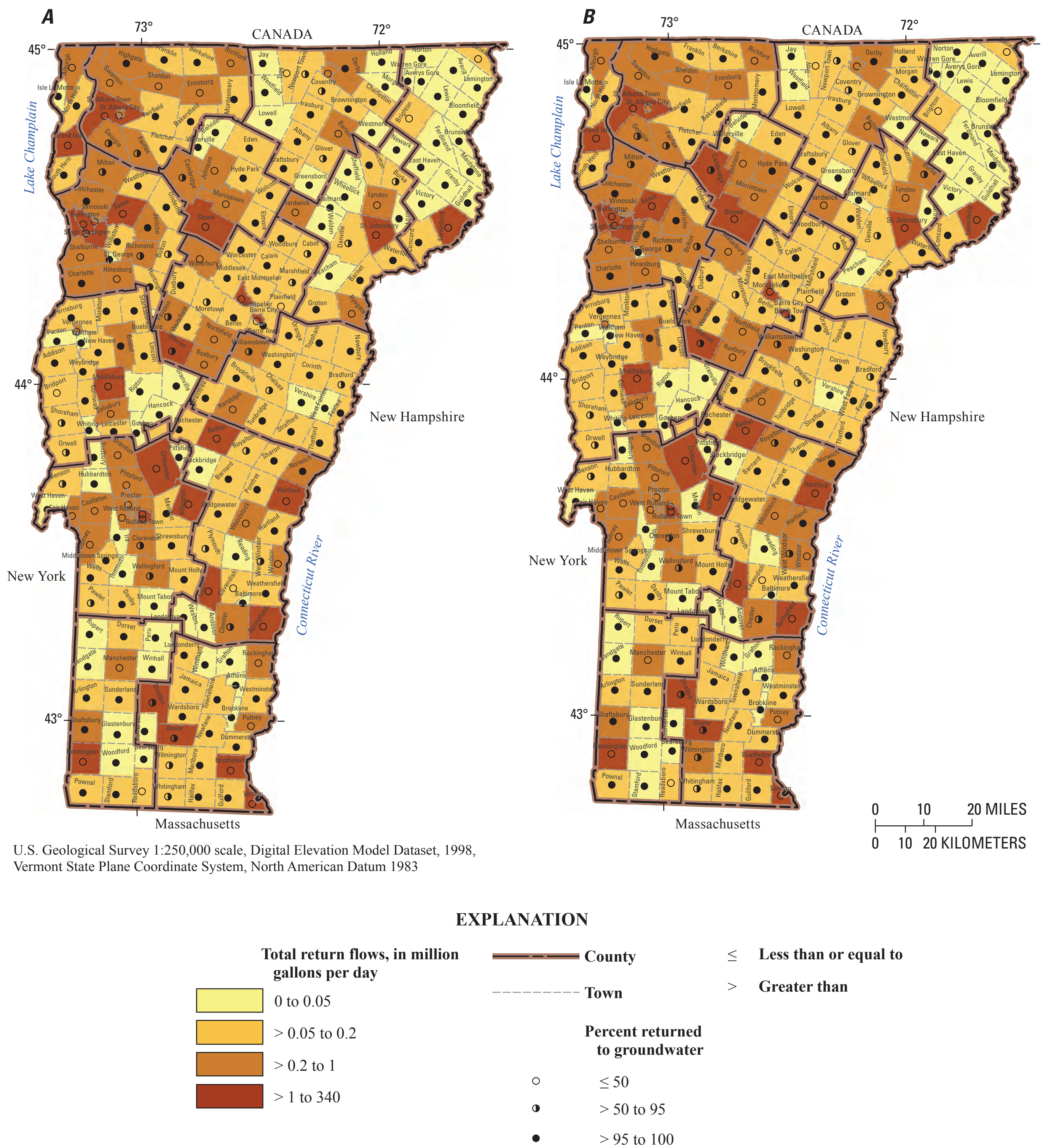


Figure 15. Total return flows and percent of return flows to groundwater in Vermont in *(A)* 2005 and *(B)* projected for 2020.

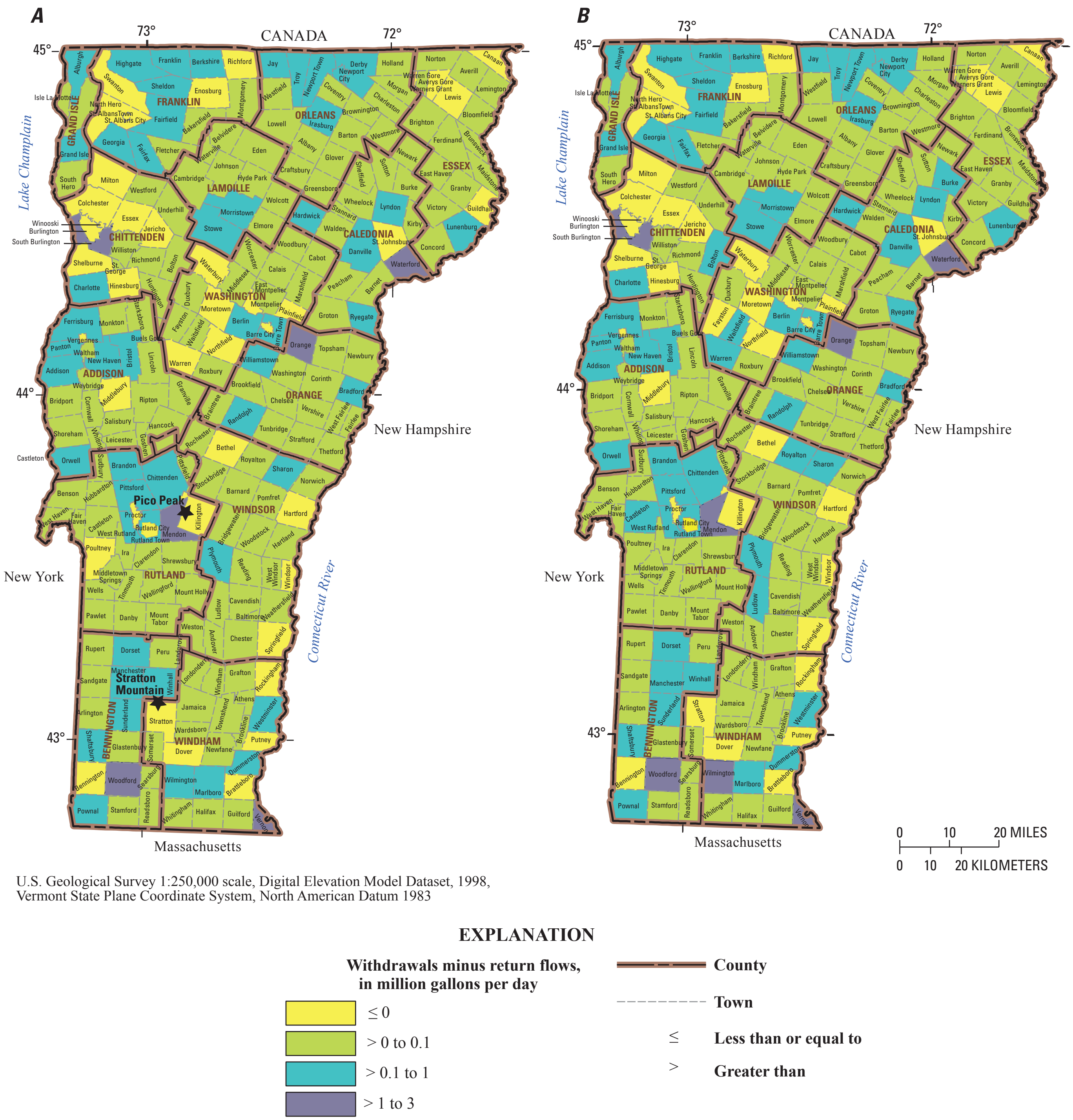


Figure 16. The difference, in million gallons per day, between total water withdrawals and return flows in Vermont in *(A)* 2005 and *(B)* projected for 2020.

About 15 percent of the MCDs had greater return flows than withdrawals. One or more of the following explanations may apply. The first possibility is water importation; for example, Milton, Colchester, Winooski, Essex, Jericho, Shelburne, and Hinesburg all used water that was withdrawn from Lake Champlain in South Burlington and returned that water within their own town boundaries. Other towns that had some sources of municipal water supplies in neighboring towns included Enosburg, St. Albans Town, Canaan (sources were in Canada), Guildhall (sources were in New Hampshire), Waterbury, Montpelier, Plainfield, Vergennes, Proctor, Stratton, and Brattleboro. Similarly, Pico Peak in Killington and Stratton Mountain in Stratton withdrew some water they used for snowmaking from sources in the neighboring towns of Mendon and Winhall, respectively. A second explanation for towns having greater return flows than withdrawals was that some towns, such as Bethel, Hartford, Poultney, Windsor, and Dover, had larger service areas for municipal sewer than for municipal water. In these cases, reported return flows were greater than reported (or estimated) withdrawals for CWSs, and non-reported withdrawals could have been underestimated. These two explanations accounted for 31 out of the 38 cases where return flows were greater than withdrawals. A third explanation is that return flows actually might have been greater than withdrawals if groundwater leaked into sewer pipes and inflated return-flow volumes to greater than the volumes withdrawn and used. Errors in estimating water withdrawals or return flows due to limitations of methods based on coefficients, or erroneous assumptions, also could account for some of this imbalance.

Withdrawals by Watershed

The largest total withdrawals in 2005 were 346.75 Mgal/d from the West River watershed and 24.98 Mgal/d from the Lake Champlain Direct watershed (table 6, fig. 17). In 2005, the largest withdrawals of

Table 6. Groundwater and surface-water withdrawals estimated for major watersheds in Vermont, 2005 and projected for 2020.

[HUC-8, 8-digit hydrologic-unit code; values may not sum to totals because of independent rounding]

HUC-8	Watershed	Withdrawals, in million gallons per day					
		Groundwater		Surface water		Total	
		2005	2020	2005	2020	2005	2020
01080101	Upper Connecticut	0.30	0.33	0.00	0.00	0.30	0.33
01080102	Passumpsic	1.67	1.82	1.77	2.13	3.44	3.95
01080103	Waits	.76	.81	2.19	2.37	2.95	3.18
01080104	Upper Connecticut-Mascoma	2.19	2.32	.16	.17	2.35	2.49
01080105	White River	5.21	5.40	.59	.60	5.80	6.00
01080106	Black-Ottauquechee	4.38	4.68	2.86	4.44	7.24	9.12
01080107	West River	2.16	2.39	344.59	344.51	346.75	346.90
01080201	Middle Connecticut	.20	.24	.00	.00	.20	.24
01080203	Deerfield	.77	.87	.75	1.88	1.52	2.75
01110000	Saint Francois	2.63	2.76	.70	.70	3.33	3.46
02010001	Lake Champlain Canal	1.63	1.85	.39	.39	2.02	2.24
02010002	Otter Creek	7.03	7.76	4.93	5.48	11.96	13.24
02010003	Winooski River	6.52	6.90	4.32	6.14	10.84	13.04
02010005	Lamoille	4.23	4.91	.76	1.12	4.99	6.03
02010007	Missisquoi	3.26	3.42	.79	.79	4.05	4.21
02010008	Lake Champlain Direct	4.33	4.70	20.65	20.84	24.98	25.54
02020003	Hudson-Hoosic	3.71	3.91	3.23	3.23	6.94	7.14
	TOTAL	50.97	55.05	388.70	394.81	439.67	449.86

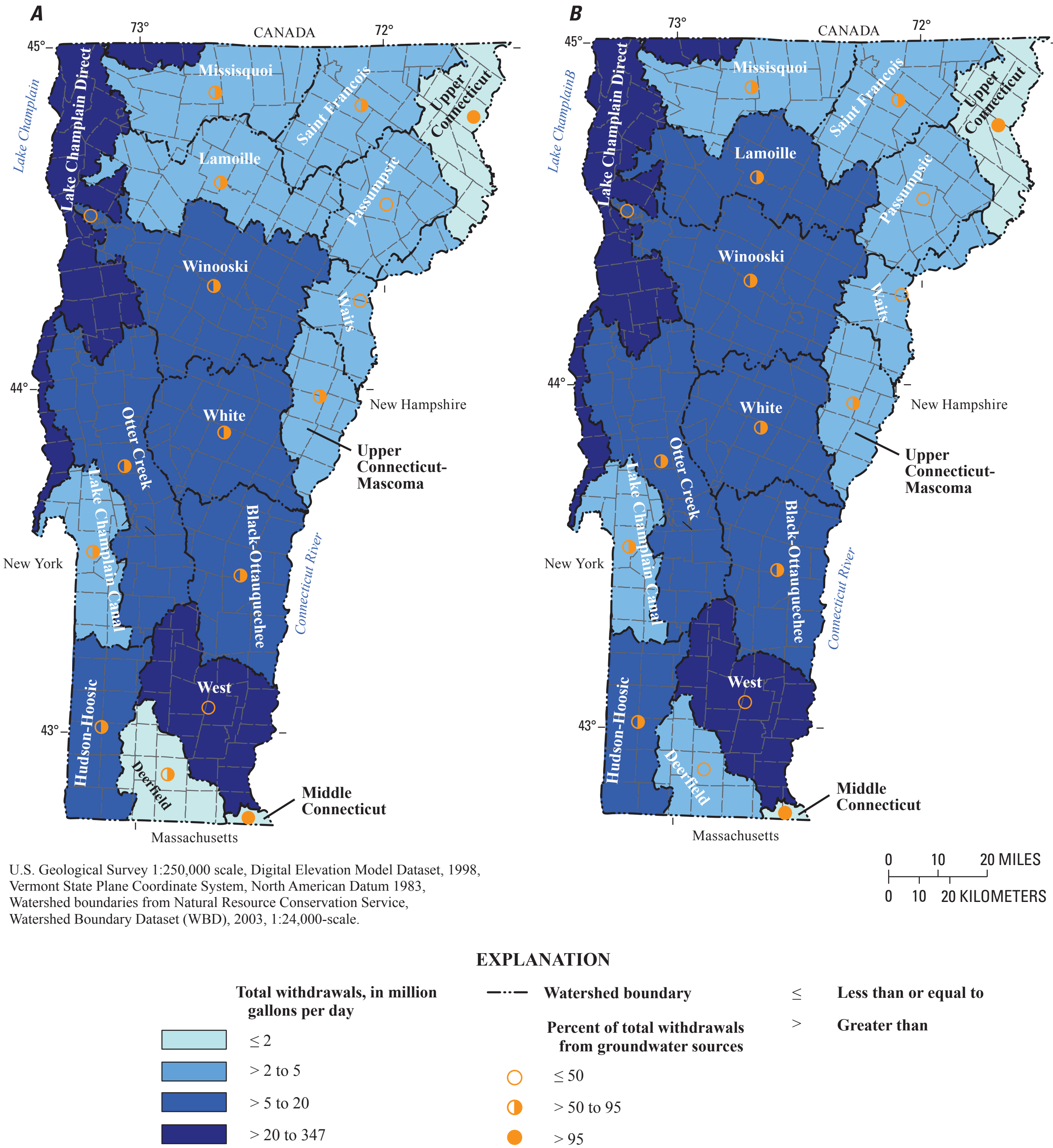


Figure 17. Major watersheds in Vermont with total water withdrawals and percent of total withdrawals from groundwater sources in *(A)* 2005 and *(B)* projected for 2020.

groundwater were in the Otter Creek watershed, 7.03 Mgal/d, and the Winooski River watershed, 6.52 Mgal/d. Large withdrawals from groundwater, 5.21, 4.38, and 4.33 Mgal/d, also were made in the White River, the Black-Ottauquechee River, and the Lake Champlain Direct watersheds, respectively. The largest withdrawals of surface water were made in the West River watershed, 344.59 Mgal/d, and the Lake Champlain Direct watershed, 20.65 Mgal/d.

Increases in surface-water withdrawals of at least 1 Mgal/d are projected in the Winooski River (1.82 Mgal/d), the Black-Ottauquechee River (1.58 Mgal/d), and the Deerfield River (1.13 Mgal/d) watersheds. These increases are due largely to estimated increases for snowmaking at ski areas. Increases in groundwater withdrawals of at least 0.5 Mgal/d are projected in the Otter Creek watershed (0.73 Mgal/d) largely due to projected increases in CWS capacity and in the Lamoille River watersheds (0.68 Mgal/d) largely due to projected population growth.

Summary

The U.S. Geological Survey, in cooperation with the Vermont Geological Survey, characterized 2005 and 2020 water usage and developed a water-use database for Vermont to assist in determining current and future groundwater demand in the State. The objective of this study was to identify areas where projected growth in Vermont might affect groundwater availability by (1) assessing base-year (2005) withdrawals and return flows, (2) applying projections for population growth as the basis for estimating future demand (2020) for water resources, and (3) producing estimates that could help to establish a priority system for State water-resource managers to direct more in-depth resource analyses. The projection of future water demand is based on population projections for each Minor Civil Division (MCD) for the year 2020, build-out analyses for ski areas, and community water systems that are seeking loans for upgrades.

In 2005, about 12 percent of total withdrawals 440 million gallons per day (Mgal/d) were from groundwater sources (51 Mgal/d) and about 88 percent were from surface-water sources (389 Mgal/d). If withdrawals by Entergy Nuclear-Vermont Yankee (thermoelectric power) were excluded from the analysis, total withdrawals would be about 100 Mgal/d, and withdrawals from surface water would be about 49 Mgal/d, or about 49 percent of the total.

In 2005, households in towns and cities throughout the State withdrew groundwater for self-supplied domestic use. Many of the MCDs where withdrawals by community water systems were greater than 1 Mgal/d had small populations, but the water was transferred to community water systems in neighboring cities or towns with large populations. All of the MCDs, except for Middlebury, with withdrawals by community water systems that totaled more than 1 Mgal/d, predominantly used surface water. Other large withdrawals were made mostly by single users (snowmaking facilities, fish hatcheries, industries, and power producers) and were generally surface water. For most MCDs that had withdrawals totaling less than 1 Mgal/d, withdrawals were predominantly groundwater.

The largest groundwater withdrawals (greater than 1 Mgal/d) in 2005 were in Middlebury, Bethel, Hartford, Springfield, and Bennington. Large withdrawals from groundwater occurred in Milton for domestic use, in Bethel and Bennington for fish hatcheries, in Burlington for thermoelectric-power production, and in Sheldon and Sharon for self-supplied commercial or industrial use. Community water systems in Newport City, Middlebury, Hartford, and Springfield had large withdrawals of groundwater. Highgate, Swanton, Sheldon, Berkshire, Newport, St. Albans, Fairfield, Panton, Addison, and Bridport withdrew greater than 0.1 Mgal/d of groundwater for livestock use.

The largest withdrawals from surface water, greater than 2 Mgal/d, in 2005 were in Grand Isle, Burlington, South Burlington, Mendon, Brattleboro, and Vernon. The largest single withdrawals of surface water were in Vernon for thermoelectric-power production (340 Mgal/d) and in Grand Isle for a fish hatchery (7 Mgal/d). Withdrawals of surface water greater than 1 Mgal/d were made in St. Albans Town, Burlington, South Burlington, Waterford, Orange, Mendon, and Woodford by community water systems and in Grand Isle, Chittenden, and Bennington by fish hatcheries. Withdrawals from surface water were greater than 0.5 Mgal/d for snowmaking in Stowe, Killington, Ludlow, Stratton, and Dover. Withdrawals greater than 0.06 Mgal/d from surface water for irrigation at golf courses occurred in Stowe, Hartford, Killington, and Manchester. Nearly 100 percent of withdrawals from surface water in Highgate and Newport Town were for livestock use. Large projected increases in withdrawals of surface water generally reflect estimated expansion of snowmaking operations at ski resorts.

Eight MCDs had total water withdrawals greater than 2 Mgal/d in 2005 and 41 had total withdrawals of 0.5 to 2 Mgal/d. Most of these large withdrawals were from surface water, except in Bethel and Bennington, which withdrew predominantly from groundwater. The largest projected changes in total withdrawals are generally in or near towns with ski areas.

MCDs that had large return-flow volumes were generally the same ones that had large total withdrawals. Most of the return flows greater than 1 Mgal/d were to surface water via direct discharges from wastewater-treatment facilities. Most of the return flows up to 0.2 Mgal/d went to groundwater. In 2005, six MCDs had withdrawals that were at least 1 Mgal/d greater than return flows. In several of these cases, withdrawals were made by community water systems to be used in neighboring towns or cities. About 15 percent of MCDs had greater return flows than withdrawals.

Acknowledgments

Many sets of data and responses to inquiries were provided to the authors from State agencies, regional commissions, and municipal departments. Especially helpful were Timothy Pricer, Timothy Raymond, Brian Fitzgerald, Virginia Little, and Bryan Harrington from the Vermont Department of Environmental Conservation and Melissa Prindiville from the Vermont Department of Housing and Community Affairs. Kevin Behn, Jim Henderson, Dan Currier, Pam Brangan, Karyl Fuller, Tracy McIntyre, Bethany Haase Remmers, April Harkness, Pete Fellows, and Jeff Nugent, geographic information systems specialists from the Regional Planning Commissions, provided digital datasets. Thanks also to Laurence Becker and Marjorie Gale of the Vermont Geological Survey for making this project happen.

References Cited

Agency of Natural Resources—Department of Environmental Conservation, 2005 (revised; original effective date: 1992), Environmental Protection Rules Chapter 21 Water Supply Rule, Water Supply Division, 236 p.

Doll, C.G., ed., 1970, Surficial Geologic Map of Vermont: Vermont Geological Survey, scale 1:250,000.

Dun & Bradstreet, 2008, Dun & Bradstreet Information Database: Murray Hill, N.J.

Dunne, Thomas, and Leopold, L.B., 1978, Water in environmental planning: New York, W.H. Freeman and Company, 818 p.

Environmental Systems Research, Inc. (ESRI), 2009, ArcGIS Desktop: Redlands, Calif., v. 9.3.

Foster, D.H., Batorfalvy, T.N., and Medalie, Laura, 2000, Water use in Vermont: An activities guide for teachers: U.S. Geological Survey outreach product, 1 map, 17 p.

Gale, Marjorie, Knos, Ryan, Springston, George, and Becker, Laurence, 2009, Data summary, Vermont water wells—preliminary map, Vermont Geological Survey, 1 pl.

Hodges, A.L., Jr., 1966, Ground-water favorability map of the Batten Kill, Walloomsac River and Hoosic River Basins: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1967a, Ground-water favorability map of the Otter Creek Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1967b, Ground-water favorability map of the Winooski River Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1967c, Ground-water favorability map of the Lamoille River Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1967d, Ground-water favorability map of the Missisquoi River Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1967e, Ground-water favorability map of the Lake Memphremagog Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1967f, Ground-water favorability map of the Nulhegan-Passumpsic River Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1968a, Ground-water favorability map of the Wells-Ompompanoosuc River Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1968b, Ground-water favorability map of the White River Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1968c, Ground-water favorability map of the Ottauquechee-Saxton River Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., 1968d, Ground-water favorability map of the West-Deerfield River Basin, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Hodges, A.L., Jr., Butterfield, D., and Ashley, J.W., 1976, Ground-water resources of the Barre-Montpelier area, Vermont: Vermont Department of Water Resources, scale 1:125,000.

Horn, M.A., 2002, User's Manual for the New England Water-Use Data System (NEWUDS): U.S. Geological Survey Open-File Report 01–328, 392 p.

Horn, M.A., and Medalie, Laura, 1995, Estimated withdrawals and use of freshwater in Vermont, 1990: U.S. Geological Survey Water-Resources Investigations Report 93–4097, 1 pl.

Horn, M.A., Moore, R.B., Hayes, Laura, and Flanagan, S.M., 2008, Methods for and estimates of 2003 and projected water use in the Seacoast Region, southeastern New Hampshire: U.S. Geological Survey Scientific Investigations Report 2007–5157, 87 p.

Hutson, S.S., Barber, N.L., Kenny, J.F., Linsey, K.S., Lumia, D.S., and Maupin, M.A., 2004, Estimated use of water in the United States in 2000: U.S. Geological Survey Circular 1268, 46 p.

Kenny, J.F., Barber, N.L., Hutson, S.S., Linsey, K.S., Lovelace, J.K., and Maupin, M.A., 2009, Estimated use of water in the United States in 2005: U.S. Geological Survey Circular 1344, 52 p.

Lovelace, J.K., 2009, Method for estimating water withdrawals for livestock in the United States, 2005: U.S. Geological Survey Scientific Investigations Report 2009–5041, 7 p.

Medalie, Laura, 1995, Wastewater collection and return flow in New England, 1990: U.S Geological Survey Water-Resources Investigations Report 95–4144, 79 p.

Medalie, Laura, 1997, Estimated water withdrawals and use in Vermont, 1995: U.S. Geological Survey Water-Resources Investigations Report 97–4178, 18 p.

Olcott, P.G., 1995, Ground water atlas of the United States: Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, Vermont: U.S. Geological Survey Hydrologic Investigations Atlas HA–730M, 28 p.

Pennsylvania State University, College of Agricultural Sciences Cooperative Extension, 2002, Agricultural water needs and sources water supply, Fact Sheet F–195, 4 p.

Planning and Management Consultants, Ltd., 1995, IWR-MAIN Water demand analysis software, User's manual and system description, version 6.1: Carbondale, Ill., 497 p.

Rayer, Stefan, 2003, MISER Population projections for Vermont, 2000–2020: Amherst, Mass., Massachusetts Institute for Social and Economic Research, 5 p.

Shaffer, K.H., and Runkle, D.L., 2007, Consumptive water-use coefficients for the Great Lakes Basin and climatically similar areas: U.S. Geological Survey Scientific Investigations Report 2007–5197, 191 p.

Solley, W.B., Pierce, R.R., and Perlman, H.A., 1998, Estimated use of water in the United States in 1995: U.S. Geological Survey Circular 1200, 71 p.

Tessler, Steven, 2002, Data model and relational database design for the New England water-use data system (NEWUDS): U.S. Geological Survey Open-File Report 01–359, 70 p., 1 pl., on 1 CD–ROM.

U.S. Census Bureau, 2001, DemoCensus_BLCK2000, accessed December 12, 2008, at http://www.vcgi.org/dataware/?page=./search_tools/search_action.cfm&query=theme&theme_id=016-0040.

U.S. Census Bureau, 2005, Population estimates Minor Civil Divisions: 2000 to 2005, accessed July 8, 2008, at http://www.census.gov/popest/cities/SUB-EST2005-5.html.

U.S. Department of Agriculture National Agricultural Statistics Service, 2004, 2002 Census of agriculture: Vermont State and County data, v. 1: Geographic Area Series part 45, AC-02-A-45, 379 p.

U.S. Geological Survey, 1990, Vermont water supply and use, *in* Carr, J.E., Chase, E.B., Paulson, R.W., and Moody, D.W., comps., National Water Summary 1987–Hydrologic events and water supply and use: U.S. Geological Survey Water-Supply Paper 2350, p. 499–504.

University of Vermont Spatial Analysis Laboratory, 2005, 2002 land cover/land use dataset for Vermont, accessed August 3, 2006, at http://www.vcgi.org/dataware/default.cfm?layer=LCLU2002.

THIS PAGE INTENTIONALLY LEFT BLANK

Appendixes A1, A2, and B

Appendix A1. Description of the Vermont Water-Use Database

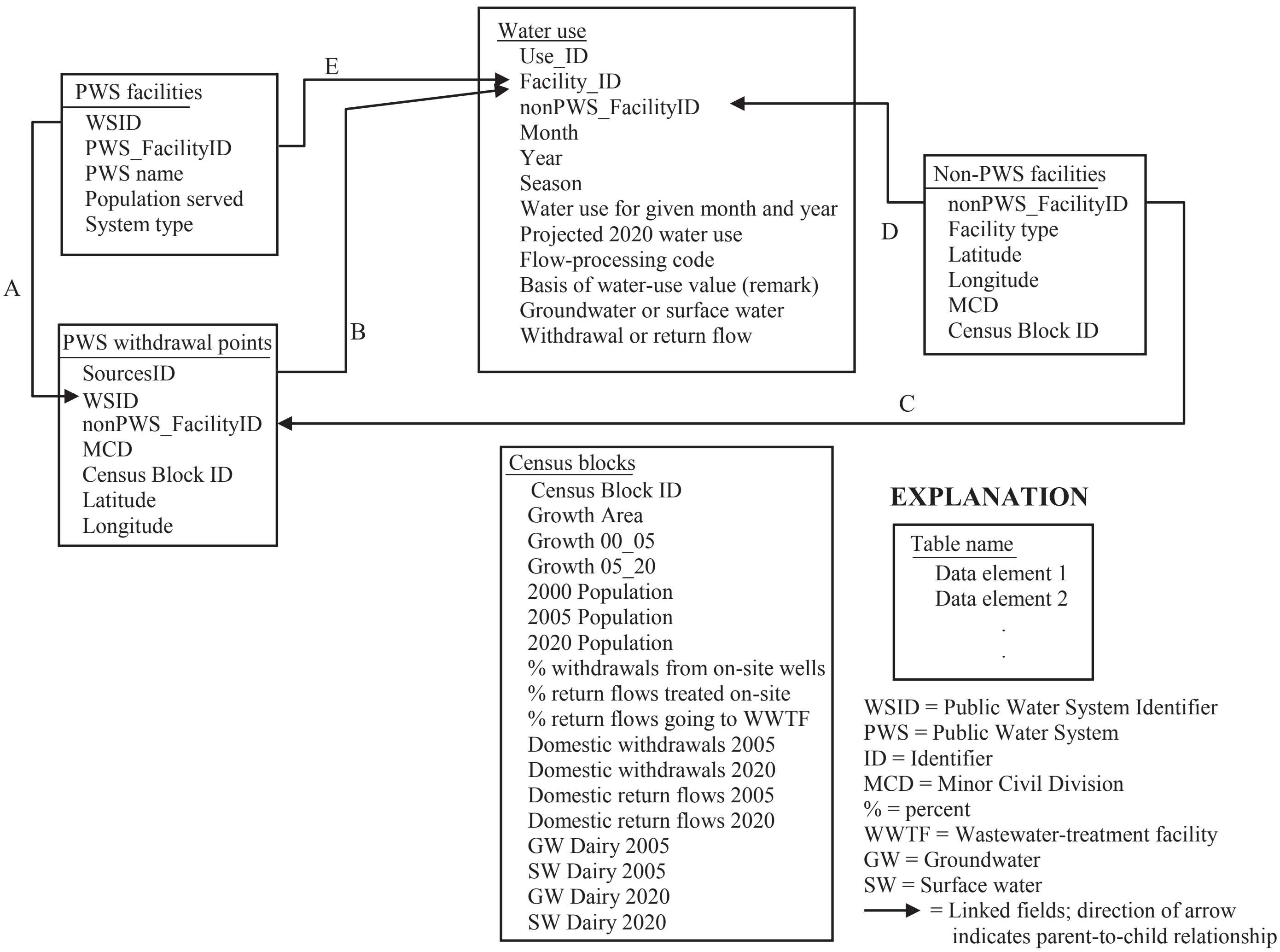
The Vermont Water-Use (VWU) database uses Microsoft Access software and a relational table structure to accommodate over 36,000 records of site-specific water-use data for 1,382 public-water-supply (PWS) facilities and 3,027 non-PWS facilities. The VWU database is available in digital format from the Vermont Geological Survey in Waterbury, Vermont. The basic organization of the VWU database consists of four main linked tables—PWS facilities, Non-PWS facilities, PWS withdrawal points, and water use—shown in figure A1. Appendix A2 provides a dictionary of the data elements that are listed in figure A1. All water-withdrawal and return-flow values, estimated or reported, for facilities are listed as records in the Water use table. Identifying and locational information for records in the Water Use table can be tracked by following links between data elements in common with the other three main tables. For all facilities in the database, at a minimum, there are reported or estimated annual values for 2005 and projected estimates of water use for 2020. In addition, some entities have water-use values for months or for other years (1999 through 2008).

Facilities are divided into two types, PWS and non-PWS facilities, which are organized differently in the database. Water-use values for withdrawals from PWS facilities are associated with individual points of withdrawal, listed in the PWS withdrawal points table, rather than with the facilities. This feature was designed to allow separate accounting for cases of multiple withdrawal points and imparts a benefit when withdrawals are in different census blocks or minor civil divisions (MCDs). In contrast, water-use values for withdrawals from non-PWS facilities are associated directly with the facility record, assuming that withdrawals and return flows occur at or near the facility. The only exceptions are for snowmaking and fish hatchery non-PWS facilities. Withdrawal points for these types of facilities are defined in the PWS withdrawal point table and are linked to the Water use table, whereas return flows link directly to the Water use table. This design enables accounting that is closely tied to the water resource for large water users.

In addition to the four main tables for individual facilities in the VWU database, the Census blocks table (fig. A1) contains a record with aggregated information for every census block in Vermont. Information in the Census blocks table includes 2000, 2005 estimated, and 2020 projected populations; population growth factors from 2000 to 2005 and from 2005 to 2020; a code to indicate whether part of or the entire census block is within a designated growth area; percent of withdrawals from on-site wells; percent of return flows treated on-site; percent of return flows going to a wastewater-treatment facility; domestic withdrawals for 2005 and projected withdrawals for 2020; domestic return flows for 2005 and projected return flows for 2020; and estimated withdrawals for dairy livestock use from groundwater and surface water in 2005 and projected dairy livestock withdrawals for 2020.

Several sequences of queries have been established to retrieve the data in meaningful arrays. For example, there are sequences of queries to retrieve withdrawals of groundwater, withdrawals of surface-water, total withdrawals, withdrawals by category, and return flows. The standard queries that were set up to create tables for values grouped by MCD can be adapted to group data instead by watershed, county, or census block, or to select a base year other than 2005. The tables that are created by running these queries are linked by MCD name to geographic datasets to create the summaries of data shown in the map figures in this report.

Data received from State agencies were reported as annual daily averages, monthly daily averages, monthly maximum values, or total monthly volumes. For consistency, all monthly data were entered into the VWU database as daily averages over the month, unless a maximum was the only available value. A remark field tracks whether water-withdrawal and return-flow values were based on reported data, estimated data (with different codes for different types of estimates), or maximum values. All data also were entered into the database as annual daily averages for 2005. The annual average was calculated as the total of withdrawals or return flows over the year divided by 365. While this method distorted data for activities that withdrew large volumes of water for only part of the year, the purpose was to maintain consistency on an annual basis because some of the seasonal data were only available as annual values. Since some data also were entered in the database as monthly values, retrievals can be made by month or season that could more realistically portray seasonal water use.



Public water supply (PWS) facilities (includes community, transient non-community, and non-transient non-community water systems) are listed in the PWS facilities table.

- Locations of sources of PWS withdrawals are listed in the PWS withdrawal points table (link A); records of withdrawals from PWS facilities are listed in the Water use table (link B).
- Records of return flows from PWS facilities are listed in the Water use table (link E).

Non-PWS facilities are listed in the Non-PWS facilities table.

- For fish hatcheries and ski areas, locations of sources of withdrawals are listed in the PWS withdrawal points table (link C); records of withdrawals are listed in the Water use table (link B).

- Records of return flows from fish hatcheries and ski areas are listed in the Water use table (link D).

- Records of withdrawals to, and return flows from, all other types of non-PWS facilities are listed in the Water use table (link D).

Figure A1. Schematic diagram of Vermont Water-Use database showing main tables with selected fields and links between fields.

Appendix A2. Data dictionary for selected data elements in the Vermont Water-Use database.

[%, percent; WWTF, wastewater-treatment facility; ID, identifier; PWS, public water system; Mgal/d, million gallons per day; MCD, Minor Civil Division]

Data element	Table name	Explanation of data element
% return flows going to WWTF	Census blocks	Percentage of population for the census block that is served by a municipal wastewater-treatment facility
% return flows treated on-site	Census blocks	Percentage of population for the census block that treats and discharges domestic wastewater on-site
% withdrawals from on-site wells	Census blocks	Percentage of population for the census block whose source of water is from on-site wells
2000 Population	Census blocks	Population in census block in 2000
2005 Population	Census blocks	Population in census block in 2005
2020 Population	Census blocks	Population in census block in 2020
Basis of water-use value (remark)	Water use	Code to indicate whether water-use values are reported, estimated, monthly maximums, based on number of employees and Standard Industrial Classification code, based on data from 2007, based on a telephone call to a facility, or primarily for dewatering at a mine. Records where the value for this field represents mine dewatering are not included with data presented in this report
Census Block ID	PWS withdrawal points, Non-PWS facilities, and Census blocks	Unique identifier for census blocks
Domestic return flows 2005	Census blocks	Estimate of aggregate domestic wastewater returned from on-site disposal systems in the census block to the ground in 20051
Domestic return flows 2020	Census blocks	Estimate of aggregate domestic wastewater returned from on-site disposal systems in the census block to the ground in 20202
Domestic withdrawals 2005	Census blocks	Estimate of aggregate withdrawals from on-site wells for the census block for 20053
Domestic withdrawals 2020	Census blocks	Estimate of aggregate withdrawals from on-site wells for the census block for 20204
Facility_ID	Water use	Link to either PWS_FacilityID in PWS Facilities table or SourcesID in PWS withdrawal points table
Facility type	Non-PWS facilities	Code for water–use type to use as basis for queries by category. Possible types are agricultural, bottled water, commercial, fish hatcheries, industries, institutions, irrigation, mining, power generation, hydroelectric power, snowmaking, sewage treatment, and solid waste
Flow-processing code	Water use	Code to indicate direction and source or resource destination of flow; for example, intake from surface water, groundwater withdrawal, direct discharge, indirect discharge, estimate for snowmaking return flow as melt, or intermediate step, such as reported outflow from treatment to storage
Groundwater or surface water	Water use	Code to indicate groundwater or surface water
Growth area	Census blocks	“Yes” or “no” if part or all of this census block is or is not within a designated growth area
Growth 00_05	Census blocks	Projected percentage growth from 2000 to 2005 based on population projections
Growth 05_20	Census blocks	Projected percentage growth from 2005 to 2020 based on population projections
GW Dairy 2005	Census blocks	Estimate for withdrawals from groundwater in 2005 for dairy livestock use
GW Dairy 2020	Census blocks	Estimate for withdrawals from groundwater in 2020 for dairy livestock use

Appendix A2. Data dictionary for selected data elements in the Vermont Water-Use database.—Continued

[%, percent; WWTF, wastewater-treatment facility; ID, identifier; PWS, public water system; Mgal/d, million gallons per day; MCD, Minor Civil Division]

Data element	Table name	Explanation of data element
Latitude	PWS withdrawal points and Non-PWS facilities	Latitude in decimal degrees
Longitude	PWS withdrawal points and Non-PWS facilities	Longitude in decimal degrees
MCD	PWS Facilities, PWS withdrawal points, and Non-PWS facilities	Name of Minor Civil Division. Used to generate summary queries by MCD
Month	Water use	Numbers 1 through 12 or null if annual value
nonPWS_FacilityID	PWS withdrawal points and Non-PWS facilities	Unique identifier for entries in Non-PWS facilities table
Population served	PWS facilities	Population served by PWS facility
Projected 2020 water use	Water use	Projected 2020 water-use value, in million gallons per day
PWS_FacilityID	PWS facilities	Unique identifier for entries in PWS facilities table
PWS Name	PWS facilities	Name of PWS facility
Season	Water use	“A” for an annual value; “W” for a winter month, November through March; “S” for a summer month, June through September; or “R” for rest of the year, October, April, or May
SourcesID	PWS withdrawal points	Unique identifier for entries in PWS withdrawal points table
SW Dairy 2005	Census blocks	Estimate for withdrawals from surface water in 2005 for dairy livestock use
SW Dairy 2020	Census blocks	Estimate for withdrawals from surface water in 2020 for dairy livestock use
System type	PWS facilities	Code to indicate whether PWS facility type is community, transient non-community, non-transient, non-community, or bottled water
Use_ID	Water use	Unique identifier for entries in Water use table
Water use for given month and year	Water use	Water-use value, in million gallons per day
Withdrawal or return flow	Water use	Code to indicate whether water is a withdrawal or a return flow
WSID	PWS facilities and PWS withdrawal points	PWS identifier from data provided by Vermont Water Supply Division
Year	Water use	Year associated with data element

[1] Value in Mgal/d = 2005 Population * % return flows treated on-site * 63 (per capita return-flow coefficient) /1,000,000.

[2] Value in Mgal/d = 2020 Population * % return flows treated on-site * 63 (per capita return-flow coefficient) /1,000,000.

[3] Value in Mgal/d = 2005 Population * % withdrawals from on-site wells * 75 (per capita water-use coefficient) /1,000,000.

[4] Value in Mgal/d = 2020 Population * % withdrawals from on-site wells * 75 (per capita water-use coefficient) /1,000,000.

Appendix B. Minor Civil Divisions with 2005 and projected 2020 populations, 2005 and projected 2020 groundwater and surface-water

[CWS, community water system; --, no data; values may not sum to totals because of independent rounding, Return flows to groundwater include estimates

Minor Civil Division	Population			Withdrawals						
				Groundwater						
	2005		2020	2005						2020
	Total	Self supplied	Total	Domestic	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total	
				Million gallons per day						
Addison	1,457	300	1,843	0.02	0.12	0.00	--	--	0.14	0.15
Albany	851	844	914	0.06	0.03	0.00	0.01	--	0.11	0.11
Alburgh	2,083	1,663	2,777	0.12	--	0.11	--	--	0.23	0.29
Andover	540	536	575	0.04	--	0.00	--	--	0.04	0.04
Arlington	2,448	1,475	2,485	0.11	--	0.03	0.07	--	0.21	0.22
Athens	334	336	429	0.03	--	0.00	--	--	0.03	0.03
Averill	8	8	10	0.00	--	0.00	--	--	0.00	0.00
Averys Gore	1	0	0	0.00	--	--	--	--	0.00	0.00
Bakersfield	1,373	1,049	1,504	0.08	0.02	0.00	0.03	--	0.13	0.14
Baltimore	262	261	323	0.02	--	--	--	--	0.02	0.02
Barnard	958	946	1,049	0.07	--	0.01	0.01	--	0.09	0.09
Barnet	1,768	1,390	1,985	0.10	0.01	0.00	0.02	--	0.13	0.15
Barre City	9,128	415	9,376	0.03	--	0.00	--	--	0.04	0.04
Barre Town	8,002	3,797	7,408	0.28	--	0.04	0.06	--	0.39	0.38
Barton	2,915	1,296	2,681	0.10	0.01	0.02	0.13	--	0.26	0.25
Belvidere	292	290	373	0.02	--	0.01	--	--	0.03	0.04
Bennington	15,375	3,129	15,109	0.23	--	0.12	0.06	1.11	1.52	1.52
Benson	1,036	1,039	1,313	0.08	0.02	0.00	0.00	--	0.11	0.13
Berkshire	1,575	1,430	1,633	0.11	0.11	0.00	0.22	--	0.43	0.44
Berlin	2,888	2,467	2,962	0.19	--	0.09	0.05	--	0.32	0.33
Bethel	1,980	1,507	2,135	0.11	--	0.01	0.03	2.86	3.01	3.02
Bloomfield	263	257	287	0.02	--	--	--	--	0.02	0.02
Bolton	982	938	1,164	0.07	0.00	0.01	0.05	--	0.13	0.14
Bradford	2,716	1,129	2,786	0.08	--	0.01	0.25	--	0.34	0.38
Braintree	1,237	1,226	1,209	0.09	--	0.00	0.02	--	0.11	0.11
Brandon	3,947	2,503	3,813	0.19	0.02	0.02	0.43	--	0.65	0.71
Brattleboro	11,849	1,764	11,716	0.13	--	0.03	0.03	--	0.19	0.19
Bridgewater	956	957	1,100	0.07	--	0.01	0.01	--	0.09	0.11
Bridport	1,275	388	1,319	0.03	0.12	--	--	--	0.15	0.15
Brighton	1,332	550	1,110	0.03	--	0.00	0.07	--	0.10	0.10
Bristol	3,795	2,051	3,963	0.15	0.01	0.02	0.27	--	0.45	0.46
Brookfield	1,267	1,247	1,365	0.09	--	0.00	--	--	0.10	0.11
Brookline	457	459	597	0.03	--	0.00	--	--	0.04	0.05
Brownington	899	893	1,110	0.07	0.01	0.00	--	--	0.08	0.09
Brunswick	107	107	159	0.01	--	0.00	--	--	0.01	0.01
Buels Gore	12	12	9	0.00	--	--	--	--	0.00	0.00
Burke	1,676	1,528	1,708	0.11	0.00	0.01	0.02	--	0.15	0.15
Burlington[1]	38,531	2	43,501	0.00	0.00	0.03	--	--	0.50	0.51
Cabot	1,307	1,112	1,431	0.08	--	0.00	0.02	--	0.10	0.11
Calais	1,552	1,431	1,646	0.11	--	0.02	0.01	--	0.13	0.14
Cambridge	3,152	2,167	4,175	0.16	--	0.01	0.17	--	0.34	0.40
Canaan	1,116	609	1,035	0.04	--	0.00	0.09	--	0.13	0.13
Castleton	4,368	3,260	4,738	0.24	0.01	0.03	0.20	--	0.49	0.57
Cavendish	1,435	869	1,513	0.07	--	0.01	0.08	--	0.15	0.15
Charleston	906	901	963	0.07	0.01	0.00	--	--	0.08	0.08
Charlotte	3,651	3,537	3,741	0.27	0.05	0.02	0.01	--	0.34	0.34

withdrawals, and 2005 return flows in Vermont.

for snowmelt from snowmaking operations at ski areas.]

Withdrawals								2005 Return flows	
Surface water									
2005							2020		
Snowmaking	Irrigation	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total		Groundwater	Surface water
Million gallons per day									
--	--	0.04	--	0.77	--	0.81	0.81	0.09	--
--	--	0.01	--	--	--	0.01	0.01	0.05	--
--	0.03	--	0.00	0.10	--	0.13	0.13	0.09	0.16
--	--	--	--	--	--	0.00	--	0.03	--
--	--	--	--	--	--	0.00	--	0.15	0.00
--	--	--	--	--	--	0.00	--	0.02	--
--	--	--	--	--	--	0.00	--	0.00	--
--	--	--	--	--	--	0.00	--	0.00	--
--	0.03	0.01	--	--	--	0.04	0.04	0.09	--
--	--	--	--	--	--	0.00	--	0.02	--
--	--	--	0.00	--	--	0.00	0.00	0.06	--
--	--	0.00	--	0.00	--	0.01	0.01	0.11	--
--	--	--	--	--	--	0.00	--	0.02	2.81
--	--	--	--	0.03	--	0.03	0.03	0.16	--
--	0.06	0.00	--	0.11	--	0.18	0.18	0.07	0.27
--	--	--	--	--	--	0.00	--	0.02	--
--	0.03	--	--	0.05	1.20	1.28	1.28	0.36	6.98
--	--	0.01	--	--	--	0.01	0.01	0.05	0.01
--	--	0.04	--	--	--	0.04	0.04	0.10	--
--	--	--	--	0.66	--	0.66	0.66	0.14	--
--	--	--	--	--	--	0.00	--	0.09	2.93
--	--	--	--	--	--	0.00	--	0.02	--
0.00	0.03	0.00	--	0.02	--	0.04	0.53	0.08	0.02
--	0.02	--	--	0.08	--	0.10	0.12	0.12	0.07
--	--	--	--	--	--	0.00	--	0.08	--
--	0.03	0.01	--	--	--	0.04	0.04	0.11	0.36
--	0.03	--	1.50	0.51	--	2.04	2.12	0.10	3.11
--	--	--	--	--	--	0.00	--	0.05	--
--	--	0.04	--	--	--	0.04	0.04	0.08	0.09
--	--	--	--	0.07	--	0.07	0.07	0.04	0.09
--	--	0.00	--	--	--	0.00	0.00	0.24	--
--	--	--	--	--	--	0.00	--	0.08	--
--	--	--	--	--	--	0.00	--	0.03	--
--	--	0.00	--	--	--	0.00	0.00	0.06	--
--	--	--	--	--	--	0.00	--	0.01	--
--	--	--	--	--	--	0.00	--	0.00	--
0.09	--	0.00	--	--	--	0.10	0.45	0.15	0.05
--	0.03	0.00	--	4.13	--	4.16	4.16	0.02	4.64
--	--	--	--	--	--	0.00	--	0.06	0.03
--	--	--	--	--	--	0.00	--	0.10	--
0.33	--	--	--	0.01	--	0.34	0.68	0.44	0.20
--	--	--	--	--	--	0.00	--	0.03	0.14
--	0.03	0.00	--	--	--	0.03	0.03	0.16	0.31
--	--	--	--	--	--	0.00	--	0.06	0.08
--	--	0.00	--	--	--	0.00	0.00	0.06	--
--	--	0.02	0.00	0.00	--	0.02	0.02	0.23	--

Appendix B. Minor Civil Divisions with 2005 and projected 2020 populations, 2005 and projected 2020 groundwater and surface-water

[CWS, community water system; --, no data; values may not sum to totals because of independent rounding, Return flows to groundwater include estimates

Minor Civil Division	Population			Withdrawals						
				Groundwater						
	2005		2020	2005						2020
	Total	Self supplied	Total	Domestic	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total	
				Million gallons per day						
Chelsea	1,256	1,098	1,247	0.08	--	0.01	0.03	--	0.12	0.12
Chester	3,112	1,803	3,095	0.14	--	0.01	0.08	--	0.22	0.22
Chittenden	1,227	1,217	1,274	0.09	0.00	0.01	0.18	--	0.28	0.31
Clarendon	2,891	2,882	2,846	0.22	0.00	0.12	0.00	--	0.34	0.34
Colchester	17,165	1,738	19,492	0.13	0.01	0.02	0.02	--	0.18	0.20
Concord	1,208	1,177	1,339	0.09	--	0.01	0.01	--	0.10	0.12
Corinth	1,484	1,471	1,678	0.11	--	0.00	--	--	0.11	0.13
Cornwall	1,223	1,220	1,164	0.09	0.05	0.00	--	--	0.15	0.14
Coventry	1,032	940	1,197	0.07	0.05	0.01	0.02	--	0.14	0.16
Craftsbury	1,147	1,140	1,339	0.09	0.05	0.00	0.02	--	0.15	0.17
Danby	1,292	1,158	1,489	0.09	0.02	0.00	0.04	--	0.14	0.16
Danville	2,287	2,044	2,341	0.14	0.03	0.01	0.06	--	0.23	0.25
Derby	4,886	3,242	4,656	0.20	0.03	0.03	0.13	--	0.39	0.42
Dorset	2,123	1,704	2,104	0.13	--	0.02	0.07	--	0.21	0.21
Dover	1,445	1,145	2,028	0.09	--	0.07	0.11	--	0.26	0.32
Dummerston	1,940	1,936	1,839	0.15	--	0.02	0.00	--	0.16	0.16
Duxbury	1,346	1,158	1,537	0.09	--	0.02	--	--	0.11	0.12
East Haven	304	292	363	0.02	--	0.00	0.01	--	0.03	0.04
East Montpelier	2,699	2,414	2,825	0.18	--	0.02	0.04	--	0.23	0.24
Eden	1,141	1,144	1,666	0.09	--	0.00	--	--	0.09	0.13
Elmore	939	933	1,318	0.07	--	0.00	--	--	0.07	0.10
Enosburg	2,778	1,654	3,300	0.12	0.06	0.05	0.02	--	0.26	0.28
Essex	19,146	3,330	20,947	0.25	0.01	0.01	--	--	0.27	0.30
Fair Haven	2,969	673	3,064	0.05	0.00	0.01	--	--	0.07	0.07
Fairfax	4,011	3,400	5,695	0.26	0.06	0.01	0.05	--	0.38	0.49
Fairfield	1,877	1,578	2,039	0.12	0.11	0.00	0.03	--	0.27	0.28
Fairlee	1,017	575	1,074	0.04	--	0.00	0.05	--	0.10	0.10
Fayston	1,235	1,194	1,461	0.09	--	0.01	0.01	--	0.11	0.13
Ferdinand	33	33	32	0.00	--	--	--	--	0.00	0.00
Ferrisburg	2,723	2,092	2,953	0.16	0.09	0.02	--	--	0.27	0.28
Fletcher	1,285	1,274	1,622	0.10	0.01	0.00	--	--	0.11	0.14
Franklin	1,340	1,088	1,538	0.08	0.08	0.00	0.03	--	0.20	0.21
Georgia	4,520	3,523	5,313	0.26	0.09	0.15	0.02	--	0.53	0.58
Glastenbury	15	95	17	0.01	--	0.00	--	--	0.01	0.01
Glover	975	968	1,099	0.07	0.01	0.00	0.00	--	0.09	0.10
Goshen	224	226	217	0.02	0.00	0.00	--	--	0.02	0.02
Grafton	635	642	653	0.05	--	0.00	--	--	0.05	0.05
Granby	86	86	106	0.01	--	0.00	--	--	0.01	0.01
Grand Isle	2,302	51	2,266	0.00	--	0.00	--	--	0.01	0.01
Granville	296	285	339	0.02	--	0.00	--	--	0.03	0.03
Greensboro	797	784	808	0.05	0.00	0.00	0.04	--	0.09	0.10
Groton	961	950	982	0.07	0.00	0.01	--	--	0.08	0.08
Guildhall	269	268	314	0.02	--	0.00	--	--	0.02	0.02
Guilford	2,006	2,006	2,167	0.15	--	0.01	--	--	0.16	0.17
Halifax	816	815	1,033	0.06	--	0.00	--	--	0.06	0.08
Hancock	374	377	401	0.03	--	0.01	--	--	0.04	0.05

withdrawals, and 2005 return flows in Vermont.—Continued

for snowmelt from snowmaking operations at ski areas.]

Withdrawals								2005 Return flows	
Surface water									
2005							2020		
Snowmaking	Irrigation	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total		Groundwater	Surface water
Million gallons per day									
--	--	--	--	--	--	0.00	--	0.06	0.03
--	0.03	--	--	0.04	--	0.07	0.07	0.16	0.14
--	--	0.00	--	0.39	1.14	1.53	1.33	0.08	1.14
--	--	0.00	--	--	--	0.00	0.00	0.18	0.08
--	0.02	0.00	--	0.00	--	0.03	0.03	0.85	0.00
--	--	--	--	--	--	0.00	--	0.07	--
--	--	--	--	--	--	0.00	--	0.09	--
--	--	0.02	--	--	--	0.02	0.02	0.08	--
--	--	0.02	--	--	--	0.02	0.02	0.06	0.05
--	--	0.02	--	--	--	0.02	0.02	0.07	--
--	--	0.01	--	--	--	0.01	0.01	0.08	--
--	--	0.01	--	0.02	--	0.03	0.03	0.12	0.03
--	--	0.01	--	0.09	--	0.10	0.10	0.26	--
--	0.03	--	--	--	--	0.03	0.03	0.13	--
0.60	0.06	--	--	--	--	0.66	0.06	0.97	0.29
--	--	--	0.00	0.50	--	0.50	0.58	0.12	--
--	--	--	--	--	--	0.00	--	0.08	--
--	--	--	--	--	--	0.00	--	0.02	--
--	--	--	--	--	--	0.00	--	0.17	0.00
--	--	--	--	--	--	0.00	--	0.07	--
--	--	--	--	--	--	0.00	--	0.06	--
--	--	0.02	--	--	--	0.02	0.02	0.10	0.27
--	0.05	0.00	--	--	--	0.06	0.06	0.35	5.22
--	--	0.00	--	0.21	--	0.21	0.21	0.03	0.23
--	--	0.02	--	0.72	--	0.74	0.74	0.22	0.04
--	--	0.04	--	0.28	--	0.32	0.32	0.12	--
--	0.03	--	--	--	--	0.03	0.03	0.06	--
0.13	0.02	--	--	--	--	0.15	0.15	0.14	0.06
--	--	--	--	--	--	0.00	--	0.00	--
--	0.03	0.03	0.01	--	--	0.07	0.07	0.18	--
--	--	0.00	--	--	--	0.00	0.00	0.08	--
--	--	0.03	--	--	--	0.03	0.03	0.08	--
--	--	0.03	0.10	--	--	0.13	0.15	0.28	0.10
--	--	--	--	--	--	0.00	--	0.01	--
--	--	0.00	--	--	--	0.00	0.00	0.05	0.00
--	--	0.00	--	--	--	0.00	0.00	0.01	--
--	--	--	--	--	--	0.00	--	0.04	--
--	--	--	--	--	--	0.00	--	0.01	--
--	0.02	--	--	0.23	6.85	7.10	7.10	0.14	6.85
--	--	--	--	--	--	0.00	--	0.02	--
--	0.03	0.00	--	0.00	--	0.03	0.03	0.05	--
--	--	0.00	0.00	--	--	0.00	0.00	0.06	--
--	--	--	--	--	--	0.00	--	0.02	--
--	--	--	--	--	--	0.00	--	0.12	--
--	--	--	--	--	--	0.00	--	0.05	--
--	--	--	--	--	--	0.00	--	0.02	--

Appendix B. Minor Civil Divisions with 2005 and projected 2020 populations, 2005 and projected 2020 groundwater and surface-water

[CWS, community water system; --, no data; values may not sum to totals because of independent rounding, Return flows to groundwater include estimates

Minor Civil Division	Population			Withdrawals						
				Groundwater						
	2005		2020	2005						2020
	Total	Self supplied	Total	Domestic	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total	
				Million gallons per day						
Hardwick	3,230	3,169	3,705	0.10	0.05	0.03	0.26	--	0.43	0.61
Hartford	10,822	1,821	11,226	0.14	--	0.04	0.96	--	1.14	1.14
Hartland	3,155	2,842	3,372	0.21	--	0.02	0.02	--	0.25	0.27
Highgate	3,660	3,630	4,066	0.27	0.14	0.03	--	--	0.44	0.49
Hinesburg	4,425	3,173	5,314	0.24	0.02	0.06	0.12	--	0.45	0.51
Holland	597	592	840	0.04	0.02	0.00	--	--	0.06	0.08
Hubbardton	777	772	931	0.06	--	0.00	--	--	0.06	0.07
Huntington	1,939	1,919	2,280	0.14	0.00	0.01	0.02	--	0.18	0.20
Hyde Park	3,092	2,267	3,329	0.17	--	0.02	0.10	--	0.28	0.30
Ira	452	453	483	0.03	0.00	0.00	--	--	0.04	0.04
Irasburg	1,091	1,034	1,283	0.08	0.08	0.01	0.01	--	0.18	0.19
Isle La Motte	520	517	534	0.04	--	0.01	--	--	0.05	0.05
Jamaica	926	931	1,119	0.07	--	0.01	0.01	--	0.09	0.10
Jay	484	458	534	0.03	0.01	0.01	0.17	--	0.23	0.24
Jericho	5,068	2,646	5,562	0.20	0.00	0.01	0.04	--	0.26	0.28
Johnson	3,260	1,747	3,800	0.13	--	0.01	0.10	--	0.24	0.26
Killington	1,134	973	1,364	0.07	0.01	0.10	0.10	--	0.29	0.32
Kirby	509	510	648	0.04	0.01	0.00	--	--	0.05	0.06
Landgrove	140	141	154	0.01	--	0.00	--	--	0.01	0.02
Leicester	1,024	1,022	1,032	0.08	0.01	0.00	--	--	0.09	0.09
Lemington	110	109	97	0.01	--	0.00	--	--	0.01	0.01
Lewis	1	0	0	0.00	--	--	--	--	0.00	0.00
Lincoln	1,268	1,275	1,472	0.10	0.00	0.00	--	--	0.10	0.12
Londonderry	1,779	1,695	1,789	0.13	--	0.04	0.02	--	0.18	0.18
Lowell	747	742	938	0.06	0.03	0.00	--	--	0.09	0.10
Ludlow	2,694	1,374	2,513	0.10	--	0.02	0.40	--	0.53	0.60
Lunenburg	1,321	1,323	1,562	0.07	--	0.00	0.06	--	0.13	0.18
Lyndon	5,602	1,770	5,598	0.13	0.01	0.01	0.43	--	0.59	0.59
Maidstone	108	107	96	0.01	--	0.00	--	--	0.01	0.01
Manchester	4,359	1,584	4,527	0.12	--	0.03	0.59	--	0.74	0.92
Marlboro	988	984	1,027	0.07	--	0.01	--	--	0.08	0.09
Marshfield	1,631	1,200	1,736	0.09	--	0.01	0.10	--	0.20	0.20
Mendon	1,068	1,004	914	0.08	0.00	0.03	0.02	--	0.13	0.11
Middlebury	8,152	1,490	8,277	0.11	0.04	0.01	1.13	--	1.29	1.62
Middlesex	1,847	1,844	1,944	0.14	--	0.01	--	--	0.15	0.15
Middletown Springs	820	823	979	0.06	0.01	0.00	--	--	0.07	0.08
Milton	10,169	5,822	11,076	0.44	0.03	0.02	0.07	--	0.55	0.59
Monkton	1,946	1,936	2,125	0.15	0.03	0.00	--	--	0.18	0.19
Montgomery	1,063	933	1,222	0.07	0.00	0.00	0.05	--	0.12	0.13
Montpelier	8,003	430	7,827	0.03	--	0.00	0.01	--	0.04	0.04
Moretown	1,709	1,580	1,838	0.12	--	0.01	0.00	--	0.13	0.14
Morgan	738	718	864	0.05	--	0.00	--	--	0.06	0.07
Morristown	5,522	2,891	5,418	0.22	--	0.02	0.50	--	0.75	0.81
Mount Holly	1,236	1,241	1,486	0.09	0.00	0.01	--	--	0.11	0.13
Mount Tabor	202	139	205	0.01	0.00	0.00	--	--	0.02	0.02

withdrawals, and 2005 return flows in Vermont.—Continued

for snowmelt from snowmaking operations at ski areas.]

Withdrawals								2005 Return flows	
Surface water									
2005							2020		
Snowmaking	Irrigation	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total		Groundwater	Surface water
Million gallons per day									
--	--	0.02	--	--	--	0.02	0.02	0.09	0.22
--	0.07	--	--	0.00	--	0.07	0.07	0.13	1.23
--	--	--	--	--	--	0.00	--	0.20	--
--	--	0.05	0.00	--	--	0.05	0.05	0.23	--
--	0.03	0.01	--	--	--	0.04	0.04	0.23	0.31
--	--	0.01	--	--	--	0.01	0.01	0.04	--
--	--	--	--	--	--	0.00	--	0.05	--
--	--	0.00	--	--	--	0.00	0.00	0.12	--
--	--	--	--	--	--	0.00		0.20	--
--	--	0.00	--	--	--	0.00	0.00	0.03	--
--	--	0.03	--	--	--	0.03	0.03	0.07	--
--	--	--	0.00	--	--	0.00	0.00	0.03	--
--	--	--	--	--	--	0.00		0.06	--
--	0.02	0.00	--	--	--	0.02	0.02	0.03	--
--	--	0.00	--	--	--	0.00	0.00	0.32	--
--	--	--	--	0.05	--	0.05	0.05	0.10	0.15
0.82	0.06	0.00	--	--	--	0.89	1.62	0.64	0.79
--	--	0.00	--	--	--	0.00	0.00	0.03	--
--	--	--	--	--	--	0.00	--	0.01	--
--	--	0.00	--	--	--	0.00	0.00	0.06	--
--	--	--	--	--	--	0.00	--	0.01	--
--	--	--	--	--	--	0.00	--	0.00	--
--	--	0.00	--	--	--	0.00	0.00	0.08	--
--	--	--	--	--	--	0.00	--	0.11	--
--	--	0.01	--	--	--	0.01	0.01	0.05	--
0.90	0.03	--	--	--	--	0.93	1.11	0.54	0.83
--	--	--	1.86	--	--	1.86	2.05	0.14	1.73
--	--	0.00	--	--	--	0.00	0.00	0.11	0.27
--	--	--	--	--	--	0.00	--	0.01	--
--	0.10	--	--	--	--	0.10	0.10	0.18	0.30
--	--	--	--	0.50	--	0.50	0.58	0.06	--
--	--	--	--	--	--	0.00	--	0.08	0.02
0.02	--	0.00	--	2.23	--	2.26	2.93	0.05	--
--	0.03	0.01	--	--	--	0.05	0.05	0.17	2.40
--	--	--	--	--	--	0.00	--	0.12	--
--	--	0.00	--	--	--	0.00	0.00	0.05	--
--	0.01	0.01	0.00	--	--	0.02	0.02	0.45	0.21
--	--	0.01	--	--	--	0.01	0.01	0.12	--
--	--	0.00	--	--	--	0.00	0.00	0.07	--
--	0.03	--	--	--	--	0.03	0.03	0.03	1.92
--	--	--	--	--	--	0.00	--	0.11	0.03
--	--	--	--	--	--	0.00	--	0.05	--
--	0.06	--	--	--	--	0.06	0.06	0.18	0.35
--	--	0.00	--	--	--	0.00	0.00	0.08	--
--	--	0.00	--	--	--	0.00	0.00	0.01	--

Appendix B. Minor Civil Divisions with 2005 and projected 2020 populations, 2005 and projected 2020 groundwater and surface-water

[CWS, community water system; --, no data; values may not sum to totals because of independent rounding, Return flows to groundwater include estimates

Minor Civil Division	Population			Withdrawals						
				Groundwater						
	2005		2020	2005						2020
	Total	Self supplied	Total	Domestic	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total	
				Million gallons per day						
New Haven	1,815	1,814	2,034	0.14	0.08	0.01	--	--	0.23	0.24
Newark	464	464	691	0.03	0.00	0.00	--	--	0.04	0.06
Newbury	2,139	1,662	1,994	0.12	--	0.02	0.03	--	0.17	0.16
Newfane	1,724	1,715	1,886	0.13	--	0.01	--	--	0.14	0.16
Newport City	5,207	0	5,253	0.00	--	0.00	0.90	--	0.90	0.90
Newport Town	1,806	1,619	1,632	0.11	0.13	0.00	0.03	--	0.27	0.27
North Hero	910	0	1,376	0.00	--	0.00	--	--	0.00	0.00
Northfield	5,816	1,881	6,092	0.14	--	0.07	0.38	--	0.59	0.59
Norton	227	220	272	0.02	--	0.00	--	--	0.02	0.02
Norwich	3,567	2,454	3,947	0.18	--	0.01	0.09	--	0.29	0.31
Orange	982	957	1,083	0.07	--	0.01	--	--	0.08	0.09
Orwell	1,231	1,218	1,384	0.09	0.07	0.01	--	--	0.17	0.18
Panton	699	52	780	0.00	0.04	--	--	--	0.05	0.05
Pawlet	1,442	1,441	1,602	0.11	0.02	0.02	--	--	0.15	0.16
Peacham	683	678	710	0.04	0.01	0.00	0.01	--	0.06	0.07
Peru	432	374	520	0.03	--	0.01	0.04	--	0.07	0.08
Pittsfield	424	426	455	0.03	--	0.01	0.00	--	0.04	0.05
Pittsford	3,213	2,113	3,275	0.16	0.01	0.15	0.18	--	0.51	0.54
Plainfield	1,372	804	1,342	0.06	--	0.01	--	--	0.07	0.06
Plymouth	580	572	610	0.04	--	0.02	0.01	--	0.07	0.08
Pomfret	999	1,002	1,032	0.08	--	0.01	--	--	0.09	0.09
Poultney	3,577	2,036	3,718	0.15	0.01	0.01	0.17	--	0.33	0.39
Pownal	3,535	3,022	3,558	0.23	--	0.01	0.05	--	0.29	0.29
Proctor	1,847	524	1,750	0.04	--	--	0.00	--	0.04	0.23
Putney	2,660	2,291	2,778	0.17	--	0.01	0.03	--	0.21	0.22
Randolph	5,054	3,017	4,869	0.23	--	0.11	0.23	--	0.56	0.55
Reading	721	713	765	0.05	--	0.00	--	--	0.05	0.06
Readsboro	792	520	888	0.04	--	0.00	--	--	0.04	0.04
Richford	2,351	871	2,400	0.07	0.02	0.01	--	--	0.09	0.09
Richmond	4,110	2,968	4,421	0.22	0.00	0.01	0.10	--	0.33	0.35
Ripton	586	585	778	0.04	--	0.00	--	--	0.05	0.06
Rochester	1,170	839	1,154	0.06	--	0.00	0.04	--	0.10	0.10
Rockingham	5,131	1,673	5,149	0.13	--	0.01	0.01	--	0.15	0.15
Roxbury	569	584	671	0.04	--	0.00	--	--	0.05	0.05
Royalton	2,542	2,151	2,958	0.16	--	0.02	0.06	--	0.24	0.28
Rupert	718	706	698	0.05	--	0.00	--	--	0.05	0.05
Rutland City	17,046	0	16,326	0.00	--	--	--	--	0.00	0.00
Rutland Town	4,135	3,328	3,870	0.25	0.00	0.06	0.07	--	0.38	0.38
Ryegate	1,194	1,014	1,235	0.08	0.02	0.04	0.02	--	0.16	0.17
Salisbury	1,129	1,126	1,208	0.08	0.03	0.01	--	0.74	0.86	0.87
Sandgate	347	349	444	0.03	--	0.00	--	--	0.03	0.04
Searsburg	93	93	136	0.01	--	0.00	--	--	0.01	0.01
Shaftsbury	3,749	2,296	3,989	0.17	--	0.03	0.29	--	0.49	0.51
Sharon	1,384	1,391	1,781	0.10	--	0.26	--	--	0.37	0.47
Sheffield	721	708	969	0.05	0.00	0.00	0.00	--	0.06	0.08
Shelburne	6,995	2,173	7,492	0.16	0.02	0.01	--	--	0.19	0.21

withdrawals, and 2005 return flows in Vermont.—Continued

for snowmelt from snowmaking operations at ski areas.]

Withdrawals								2005 Return flows	
Surface water									
2005							2020		
Snowmaking	Irrigation	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total		Groundwater	Surface water
Million gallons per day									
--	--	0.03	--	--	--	0.03	0.03	0.11	--
--	0.01	0.00	--	--	--	0.01	0.01	0.03	--
--	--	--	--	0.02	--	0.02	0.02	0.12	--
--	--	--	--	--	--	0.00	--	0.11	--
--	--	--	0.25	--	--	0.25	0.25	0.00	1.00
--	--	0.04	--	--	--	0.04	0.04	0.10	0.02
--	--	--	0.00	0.14	--	0.14	0.14	0.06	--
--	0.03	--	--	--	--	0.03	0.03	0.20	0.72
--	--	--	--	--	--	0.00	--	0.01	--
--	--	--	--	--	--	0.00	--	0.22	--
--	--	--	--	1.91	--	1.91	1.91	0.06	--
--	--	0.02	--	--	--	0.02	0.02	0.07	0.02
--	--	0.01	--	0.62	--	0.63	0.82	0.04	--
--	--	0.01	--	--	--	0.01	0.01	0.07	0.01
--	--	0.00	--	--	--	0.00	0.00	0.04	--
--	--	--	--	--	--	0.00	--	0.05	--
--	--	--	--	--	--	0.00	--	0.03	--
--	0.03	0.00	--	--	--	0.03	0.03	0.16	0.18
--	0.03	--	--	--	--	0.03	0.03	0.05	0.06
0.33	--	--	--	--	--	0.33	0.79	0.06	0.02
--	--	--	--	--	--	0.00	--	0.06	--
--	0.03	0.00	--	--	--	0.03	0.03	0.12	0.25
--	--	--	--	--	--	0.00	--	0.17	--
--	--	--	--	--	--	0.00	--	0.01	0.25
--	--	--	--	--	--	0.00	--	0.15	0.26
--	0.03	--	--	0.03	--	0.06	0.06	0.14	0.23
--		--	--	--	--	0.00	--	0.04	--
--		--	--	0.04	--	0.04	0.04	0.03	0.04
--	0.03	0.01	--	0.13	--	0.17	0.17	0.05	0.24
--	--	0.00	--	--	--	0.00	0.00	0.20	0.08
--	--	--	0.00	--	--	0.00	0.00	0.04	--
--	0.02	--	--	--	--	0.02	0.02	0.12	--
--	0.03	--	--	0.32	--	0.35	0.35	0.11	0.62
--	--	--	--	--	0.48	0.48	0.48	0.04	0.48
--	--	--	--	0.03	--	0.03	0.03	0.14	0.04
--	--	--	--	--	--	0.00	--	0.04	--
--	--	--	--	--	--	0.00	--	0.00	5.59
--	--	0.00	0.76	--	--	0.76	0.83	0.21	0.64
--	--	0.01	0.28	--	--	0.29	0.29	0.07	0.27
--	--	0.01	0.00	--	--	0.01	0.01	0.07	0.74
--	--	--	--	--	--	0.00	--	0.02	--
--	--	--	--	--	--	0.00	--	0.01	--
--	--	--	--	0.12	--	0.12	0.12	0.24	--
--	--	--	--	--	--	0.00	--	0.09	--
--	--	0.00	--	--	--	0.00	0.00	0.04	--
--	0.03	0.01	--	--	--	0.04	0.04	0.08	0.75

Appendix B. Minor Civil Divisions with 2005 and projected 2020 populations, 2005 and projected 2020 groundwater and surface-water

[CWS, community water system; --, no data; values may not sum to totals because of independent rounding, Return flows to groundwater include estimates

Minor Civil Division	Population			Withdrawals						
				Groundwater						
	2005		2020	2005						2020
	Total	Self supplied	Total	Domestic	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total	
				Million gallons per day						
Sheldon	2,240	1,662	2,494	0.12	0.11	0.22	0.04	--	0.50	0.52
Shoreham	1,305	434	1,424	0.03	0.10	0.00	--	--	0.13	0.13
Shrewsbury	1,141	1,076	1,114	0.08	0.00	0.01	0.01	--	0.10	0.10
Somerset	5	5	4	0.00	--	--	--	--	0.00	0.00
South Burlington	16,993	315	16,796	0.02	0.01	0.03	0.01	--	0.07	0.07
South Hero	1,888	1,286	2,005	0.10	--	0.01	--	--	0.11	0.11
Springfield	8,891	3,145	8,556	0.24	--	0.04	0.87	--	1.15	1.27
St. Albans City	7,476	0	8,019	0.00	--	--	--	--	0.00	0.00
St. Albans Town	5,911	3,402	6,315	0.26	0.11	0.01	--	--	0.37	0.39
St. George	682	680	717	0.05	0.00	0.00	0.02	--	0.07	0.08
St. Johnsbury	7,495	1,649	7,427	0.12	0.01	0.02	0.03	--	0.18	0.18
Stamford	818	815	769	0.06	--	0.01	--	--	0.07	0.06
Stannard	193	196	248	0.01	0.00	--	--	--	0.02	0.02
Starksboro	1,928	1,669	2,392	0.13	0.01	0.00	0.07	--	0.21	0.24
Stockbridge	683	679	769	0.05	--	0.01	0.01	--	0.06	0.07
Stowe	4,732	3,428	5,051	0.26	--	0.05	0.54	--	0.85	0.87
Strafford	1,103	1,087	1,153	0.08	--	0.01	--	--	0.09	0.09
Stratton	171	138	165	0.01	--	0.01	0.11	--	0.13	0.15
Sudbury	610	607	691	0.05	0.01	0.00	--	--	0.06	0.06
Sunderland	896	800	851	0.06	--	0.01	0.14	--	0.20	0.20
Sutton	1,056	1,064	1,305	0.07	0.02	0.01	0.02	--	0.12	0.15
Swanton	6,454	3,094	6,904	0.23	0.13	0.01	0.01	--	0.38	0.39
Thetford	2,784	2,782	2,835	0.21	--	0.02	0.02	--	0.24	0.25
Tinmouth	615	611	665	0.05	0.01	0.00	--	--	0.05	0.06
Topsham	1,160	1,141	1,491	0.09	--	0.00	--	--	0.09	0.11
Townshend	1,122	1,125	1,368	0.08	--	0.02	--	--	0.10	0.13
Troy	1,710	1,123	1,565	0.08	0.10	0.01	0.16	--	0.36	0.37
Tunbridge	1,329	1,318	1,409	0.10	--	0.01	--	--	0.11	0.11
Underhill	3,020	2,526	3,183	0.19	0.00	0.01	0.04	--	0.25	0.26
Vergennes	2,763	261	2,955	0.02	--	0.00	--	--	0.02	0.02
Vernon[2]	2,100	2,104	2,661	0.16	--	0.01	0.01	--	0.18	0.22
Vershire	639	643	763	0.05	--	0.00	--	--	0.05	0.06
Victory	98	97	190	0.01	--	--	--	--	0.01	0.01
Waitsfield	1,719	1,704	1,911	0.13	--	0.05	0.02	--	0.20	0.22
Walden	771	775	945	0.06	0.01	0.00	--	--	0.07	0.08
Wallingford	2,322	1,738	2,360	0.13	0.00	0.00	0.13	--	0.27	0.29
Waltham	490	454	489	0.03	0.02	0.00	--	--	0.05	0.05
Wardsboro	895	892	1,112	0.07	--	0.00	--	--	0.07	0.09
Warners Grant	-	0	0	0.00	--	--	--	--	0.00	0.00
Warren	1,734	1,588	2,250	0.12	--	0.03	0.09	--	0.23	0.29
Warren Gore	10	10	8	0.00	--	--	--	--	0.00	0.00
Washington	1,098	878	1,147	0.07	--	0.00	0.02	--	0.08	0.09
Waterbury	5,211	2,600	5,253	0.20	--	0.06	0.10	--	0.35	0.36
Waterford	1,216	1,199	1,199	0.09	0.01	0.01	--	--	0.11	0.11
Waterville	693	692	907	0.05	--	0.00	0.01	--	0.06	0.07

withdrawals, and 2005 return flows in Vermont.—Continued

for snowmelt from snowmaking operations at ski areas.]

Withdrawals								2005 Return flows	
Surface water									
2005							2020		
Snowmaking	Irrigation	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total		Groundwater	Surface water
Million gallons per day									
--	--	0.04	--	--	--	0.04	0.04	0.14	0.20
--	--	0.03	--	--	--	0.03	0.03	0.07	0.01
--	--	0.00	--	--	--	0.00	0.00	0.07	--
--	--	--	--	--	--	0.00	--	0.00	--
--	0.04	0.00	--	4.99	--	5.03	5.03	0.00	2.45
--	0.01	--	0.01	0.06	--	0.08	0.09	0.12	--
--	0.03	--	--	--	--	0.03	0.03	0.28	1.48
--	--	--	--	--	--	0.00	--	0.00	0.39
--	--	0.04	0.00	1.45	--	1.48	1.48	0.20	2.95
--	0.03	0.00	--	--	--	0.03	0.03	0.04	--
--	0.03	0.00	--	--	--	0.03	0.03	0.19	1.38
--	0.03	--	--	--	--	0.03	0.03	0.05	--
--	--	0.00	--	--	--	0.00	0.00	0.01	--
--	--	0.00	--	--	--	0.00	0.00	0.12	--
--	--	--	--	--	--	0.00	--	0.04	--
0.67	0.06	--	--	0.06	--	0.80	1.43	0.52	0.60
--	--	--	--	--	--	0.00	--	0.07	--
1.29	--	--	--	--	--	1.29	0.98	0.89	0.70
--	--	0.00	--	--	--	0.00	0.00	0.04	--
--	--	--	--	--	--	0.00	--	0.06	--
--	--	0.01	--	--	--	0.01	0.01	0.07	--
--	0.03	0.04	0.00	0.28	--	0.35	0.35	0.20	0.65
--	--	--	--	--	--	0.00	--	0.18	--
--	--	0.00	--	--	--	0.00	0.00	0.04	--
--	--	--	--	--	--	0.00	--	0.07	--
--	--	--	--	--	--	0.00	--	0.07	--
--	--	0.03	--	--	--	0.03	0.03	0.05	0.13
--	--	--	--	--	--	0.00	--	0.08	--
--	--	0.00	--	--	--	0.00	0.00	0.19	--
--	--	--	--	--	--	0.00	--	0.00	0.44
--	--	--	--	--	--	340.00	340.00	0.13	339.04
--	--	--	--	--	--	0.00	--	0.04	--
--	--	--	--	--	--	0.00	--	0.01	--
--	--	--	--	--	--	0.00	--	0.11	--
--	--	0.00	--	--	--	0.00	0.00	0.05	--
--	--	0.00	0.04	0.02	--	0.06	0.06	0.19	0.11
--	--	0.01	--	--	--	0.01	0.01	0.03	--
--	--	--	--	--	--	0.00	--	0.06	--
--	--	--	--	--	--	0.00	--	0.00	--
0.32	--	--	--	0.00	--	0.33	1.05	1.31	0.16
--	--	--	--	--	--	0.00	--	0.00	--
--	--	--	--	--	--	0.00	--	0.07	--
--	0.06	--	--	--	--	0.06	0.06	0.24	0.32
--	--	0.00	--	1.59	--	1.59	1.59	0.08	--
--	--	--	--	--	--	0.00	--	0.04	--

Appendix B. Minor Civil Divisions with 2005 and projected 2020 populations, 2005 and projected 2020 groundwater and surface-water

[CWS, community water system; --, no data; values may not sum to totals because of independent rounding, Return flows to groundwater include estimates

Minor Civil Division	Population 2005 Total	Population 2005 Self supplied	Population 2020 Total	Groundwater withdrawals 2005 Domestic	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total	2020
				Million gallons per day						
Weathersfield	2,853	2,476	2,710	0.19	--	0.02	0.03	--	0.23	0.22
Wells	1,115	1,119	1,337	0.08	0.01	0.01	--	--	0.09	0.11
West Fairlee	738	706	915	0.05	--	0.01	0.00	--	0.06	0.08
West Haven	308	307	272	0.02	0.01	--	--	--	0.03	0.03
West Rutland	2,529	452	2,695	0.03	0.00	0.00	0.34	--	0.39	0.39
West Windsor	1,116	1,097	1,122	0.08	--	0.00	0.03	--	0.11	0.11
Westfield	531	442	552	0.03	0.02	0.00	0.03	--	0.09	0.09
Westford	2,129	2,126	2,427	0.16	0.01	0.00	0.00	--	0.18	0.20
Westminster	3,238	2,836	3,404	0.21	--	0.04	0.03	--	0.28	0.30
Westmore	321	318	335	0.02	--	0.00	--	--	0.03	0.03
Weston	649	643	619	0.05	--	0.01	--	--	0.06	0.05
Weybridge	852	716	883	0.05	0.03	0.00	--	--	0.08	0.09
Wheelock	614	618	856	0.04	0.00	--	0.00	--	0.05	0.07
Whiting	410	350	382	0.03	0.02	0.00	0.00	--	0.05	0.05
Whitingham	1,245	1,267	1,507	0.10	--	0.01	--	--	0.11	0.13
Williamstown	3,284	2,181	3,718	0.16	--	0.05	0.22	--	0.44	0.46
Williston	8,243	2,121	10,942	0.16	0.01	0.01	0.01	--	0.19	0.24
Wilmington	2,331	1,413	2,327	0.11	--	0.03	0.11	--	0.24	0.25
Windham	346	342	416	0.03	--	0.00	--	--	0.03	0.03
Windsor	3,735	699	3,582	0.05	--	0.02	0.33	--	0.40	0.44
Winhall	762	661	962	0.05	--	0.02	0.03	--	0.10	0.15
Winooski	6,353	0	6,748	0.00	--	--	--	--	0.00	0.00
Wolcott	1,672	1,662	1,861	0.12	--	0.01	0.01	--	0.14	0.16
Woodbury	823	813	854	0.06	--	0.00	--	--	0.06	0.07
Woodford	397	319	485	0.02	--	0.00	0.00	--	0.03	0.03
Woodstock	3,224	1,824	2,941	0.14	--	0.04	0.17	--	0.35	0.33
Worcester	887	741	958	0.06	--	0.00	0.01	--	0.06	0.07
Total	623,050	315,714	666,045	23	3	4	15	5	51	55

[1] Totals of groundwater withdrawals includes water withdrawn from wells for power production at Burlington Electric McNeil Generating Station.

[2] Totals of surface-water withdrawals and return flows includes water for thermoelectric power production at Entergy Nuclear Vermont Yankee.

withdrawals, and 2005 return flows in Vermont.—Continued

for snowmelt from snowmaking operations at ski areas.]

Withdrawals								2005 Return flows	
Surface water									
2005							2020		
Snowmaking	Irrigation	Livestock	Commercial & industrial	CWS	Fish hatcheries	Total		Groundwater	Surface water
Million gallons per day									
--	--	--	--	--	--	0.00	--	0.18	--
--	--	0.00	--	--	--	0.00	0.00	0.07	--
--	--	--	--	--	--	0.00	--	0.04	--
--	--	0.00	--	--	--	0.00	0.00	0.02	--
--	--	0.00	--	--	--	0.00	0.00	0.02	0.20
0.11	--	--	--	--	--	0.11	0.33	0.12	0.05
--	--	0.01	--	--	--	0.01	0.01	0.03	--
--	--	0.00	--	--	--	0.00	0.00	0.13	--
--	--	--	--	--	--	0.00	--	0.17	--
--	--	--	--	--	--	0.00	--	0.02	--
--	--	--	--	--	--	0.00	--	0.04	--
--	--	0.01	--	--	--	0.01	0.01	0.05	--
--	--	0.00	--	--	--	0.00	0.00	0.04	--
--	--	0.01	--	--	--	0.01	0.01	0.03	--
--	--	--	--	--	--	0.00	--	0.07	0.03
--	--	--	--	--	--	0.00	--	0.17	0.11
--	0.04	0.00	--	--	--	0.05	0.05	0.17	0.01
0.00	0.04	--	--	0.01	--	0.05	1.79	0.11	0.09
--	--	--	--	--	--	0.00	--	0.02	--
--	0.03	--	--	--	--	0.03	0.03	0.06	0.46
0.16	0.03	--	--	--	--	0.19	0.20	0.04	--
--	--	--	--	--	--	0.00	--	0.00	0.86
--		--	--	--	--	0.00	--	0.10	--
--	--	--	--	--	--	0.00	0.01	0.05	--
--	--	--	--	1.71	--	1.71	1.71	0.02	--
--	0.03	--	--	0.11	--	0.14	0.14	0.12	0.26
--	--	--	--	--	--	0.00	--	0.06	0.00
6	2	1	5	25	10	389	395	28	413

Prepared by the Pembroke and West Trenton Publishing Service Centers.

For more information concerning this report, contact:

Director
U.S. Geological Survey
New Hampshire-Vermont Water Science Center
331 Commerce Way, Suite 2
Pembroke, NH 03275
dc_nh@usgs.gov

or visit our Web site at:
http://nh.water.usgs.gov

Medalie and Horn—**Estimated Water Withdrawals and Return Flows in Vermont in 2005 and 2020**—Scientific Investigations Report 2010–5053