# Report on the Status of Groundwater and Aquifer Mapping in the State of Vermont January 2003

Submitted to the Chairs of the
Senate and House Committees on Natural Resources and Energy

As Required in Act 133 of the 2002 Vermont Legislative Session

Developed by:
Department of Environmental Conservation
Division of Geology and Division of Water Supply

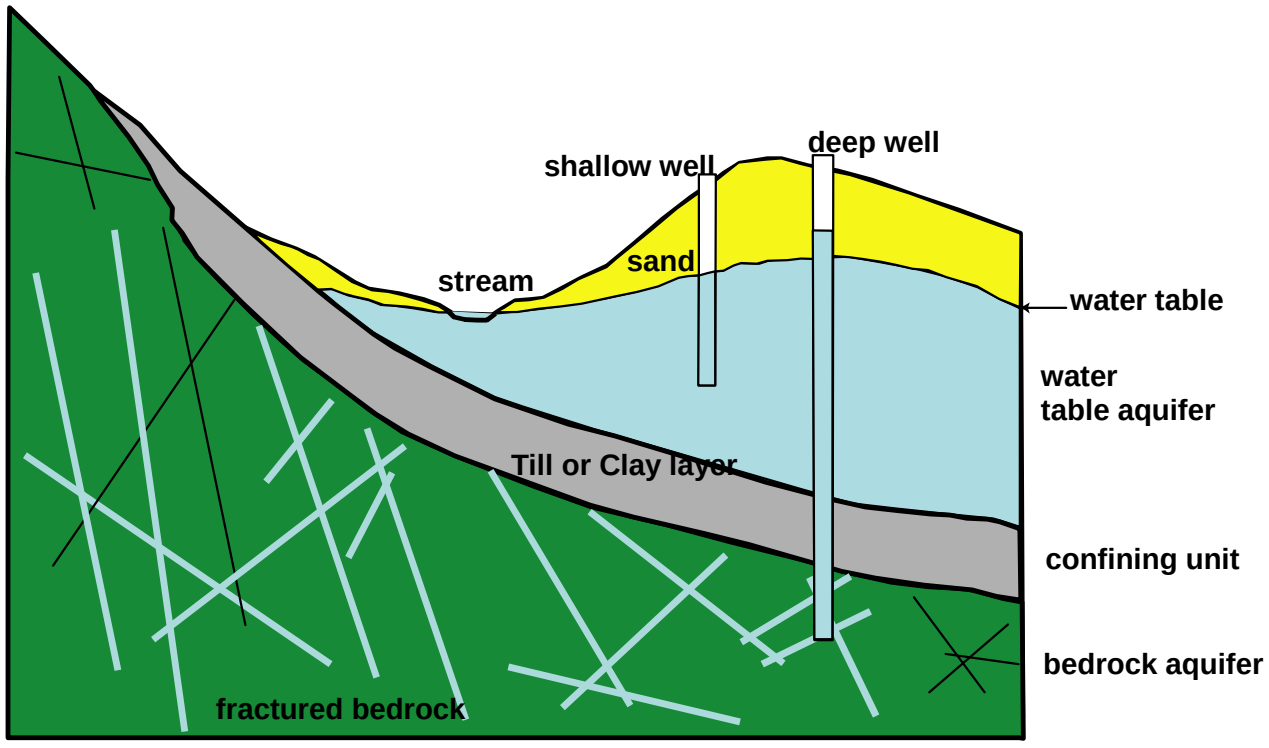


Diagram showing a cross-section through the water table and bedrock aquifers

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**Executive Summary**

Groundwater is one of Vermont's most important and least understood natural resources. The science of groundwater and aquifers—hydrogeology—is a growing field of knowledge. To better assess these resources, Vermont needs to apply new science and tools for mapping groundwater. Act 133 of the 2002 Legislative Session recognized the importance of the resource and requires the Secretary of the Agency of Natural Resources to prepare a report on the status of groundwater and aquifers in Vermont.

Sixty-six percent of Vermont's population depends on groundwater for their drinking water supply. Groundwater is also used for manufacturing, agriculture, commercial enterprises, and to support aquatic habitat. Following a drought in the mid-1960s, Vermont took the first steps towards understanding the groundwater resource. This work includes research on the sand and gravel aquifers in the valley bottoms. Since the 1960s, mapping has been performed at increasing levels of detail and decreasing degrees of coverage.

Under 10 V.S.A., Chapter 48, the Secretary of the Agency of Natural Resources is responsible for groundwater classification. The Secretary has reclassified several areas as Class IV (non-potable), but has not completed any Class I or Class II designations. The Agency of Natural Resources has established protective measures for Source Protection Areas that are comparable to Class II Groundwater Areas. Source Protection Areas have been identified for all of the Public Community Water Systems in the state.

Naturally-occurring contaminants of concern pose a health risk to Vermonters. The location and severity of these threats in groundwater are not well understood. The Vermont Geological Survey has completed some initial research and mapping on radioactivity, arsenic, and radon.

Existing maps and data can be used to create rudimentary aquifer maps for some parts of the state. However, the most obvious obstacle to completing aquifer mapping statewide is the lack of a dedicated funding source for employing people to analyze and compile data, to provide contracts and grants to partners, and to purchase scientific equipment to collect data. This report identifies three levels of research to develop groundwater and aquifer maps of increasing accuracy. Each level builds upon the previous level in detail and time using increasingly sophisticated tools, technical expertise, and scientific evaluation.

The proposed Basic Mapping effort relies upon the use, analysis, and interpretation of existing data. This work will result in a series of maps showing groundwater recharge potential, groundwater levels, groundwater availability, surficial material thickness, regional areas of concern for naturally-occurring contaminants, and classification of existing public water sources. These maps can be used for regional planning purposes to identify areas for groundwater protection and growth opportunities. The basic mapping work could be completed by July 1, 2007 assuming that at least 9 positions are filled starting in July 2003 and are fully funded through July 1, 2007. The total cost of personnel, equipment, contracts, and grants is estimated at $2.7 million.

The second level, Expanded Mapping, would develop all of the maps and information discussed in the basic level and also develop aquifer maps for planning and protection at a town level. The maps of naturally-occurring contaminants would identify specific areas of concern. Due to the complexity of this work, the Expanded Mapping Program would take seven years. The cost to complete the Basic and Expanded work, including personnel, equipment, grants, and contracts, is $4.7 million.

The Premium Mapping would produce maps that support appropriate regional development, sustainable economies, protection of future drinking water resources, and environmental health. In addition to the work identified in the Basic and Expanded Mapping, the Agency of Natural Resources would identify Class I and II Groundwater Areas that would be suitable for potential future public water supply sources; identify Class IV Groundwater Areas for naturally-occurring contaminants of concern; and research and map groundwater and surface water interaction studies. This entire set of work, Basic, Expanded, and Premium, would take ten years and cost $6.9 million.

The existing grants from EPA to Agency of Natural Resources have the flexibility to fund groundwater research; however, funding would have to be moved from existing base programs. These base programs include permitting, technical assistance and outreach on other statutorily required programs. A number of scientific organizations would be interested in partnering with the State of Vermont to complete aquifer or groundwater mapping in the state. These organizations could provide scientific, technical, and administrative expertise. Usually, these organizations seek financial support as part of their work.

## Introduction

Groundwater is one of Vermont's most important and least understood natural resources. The science of groundwater and aquifers—hydrogeology—is a growing field of knowledge. To better assess these resources, Vermont needs to apply new science and tools for mapping groundwater. Act 133 of the 2002 Legislative Session recognized the importance of the resource and requires the Secretary of the Agency of Natural Resources to prepare a report on the status of groundwater and aquifers in Vermont.

This report addresses the status of aquifer mapping, statewide groundwater classification, and mapping of naturally occurring contaminants of concern that may preclude use of an aquifer for drinking water supplies. The potential obstacles, difficulties, and resources needed to complete the mapping and other work by July 1, 2007 are discussed in this report, along with potential funding sources and partners. A time frame is included for completing the work, assuming that the necessary resources are provided.

## Background

Sixty-six percent of Vermont's population depends on groundwater for their drinking water supply. Groundwater is also used for manufacturing, agriculture, and commercial enterprises. Groundwater contributes flow to surface water that in turn protects and supports wildlife. Lakes, streams, and wetlands are recharged by groundwater. While Vermont appears to have an abundance of groundwater, Vermonters need to be vigilant to maintain our apparent good water quality and quantity. As Vermont's population and economy grow, the demands for groundwater increase. Understanding Vermont's groundwater system can help predict the location of useable groundwater supplies. Without the knowledge of aquifers and the groundwater system, this valuable resource may not be sustainable for the multiple uses in the future.

In Vermont, the groundwater system is complex due to the state's unique geology. Figure 1 and 2 show simplified views of the water cycle and how groundwater can be intercepted by wells.

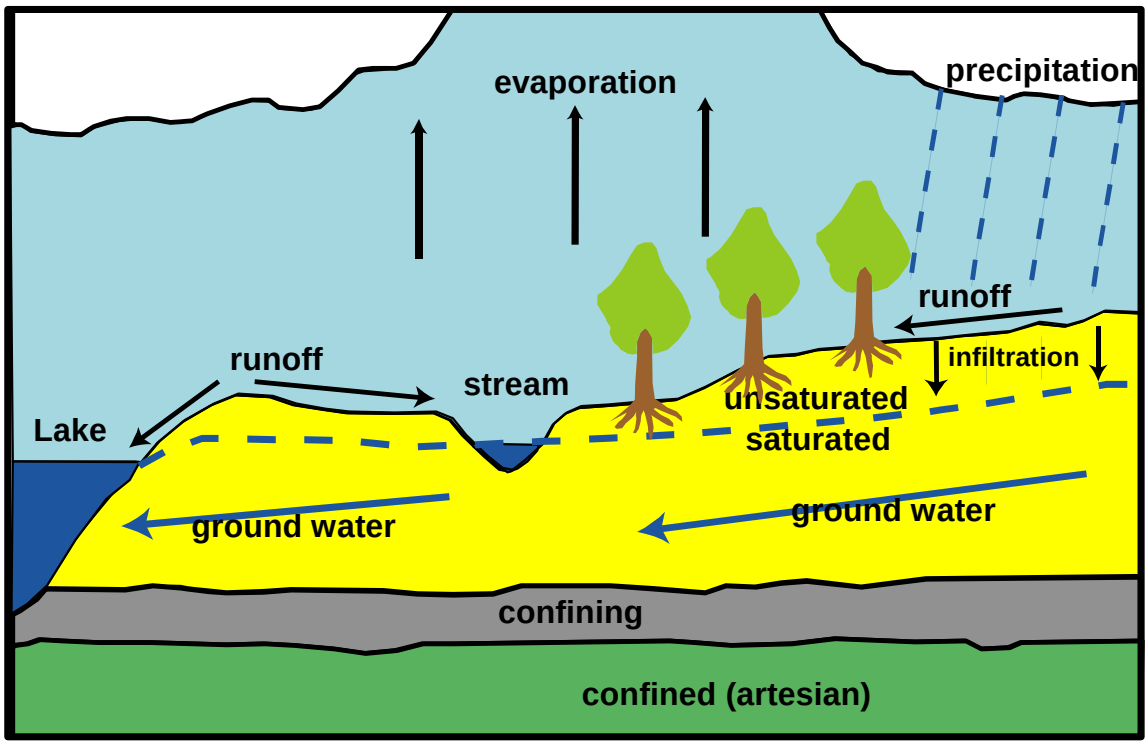


Figure 1- Diagram showing a cross-section through the earth's surface and the water cycle

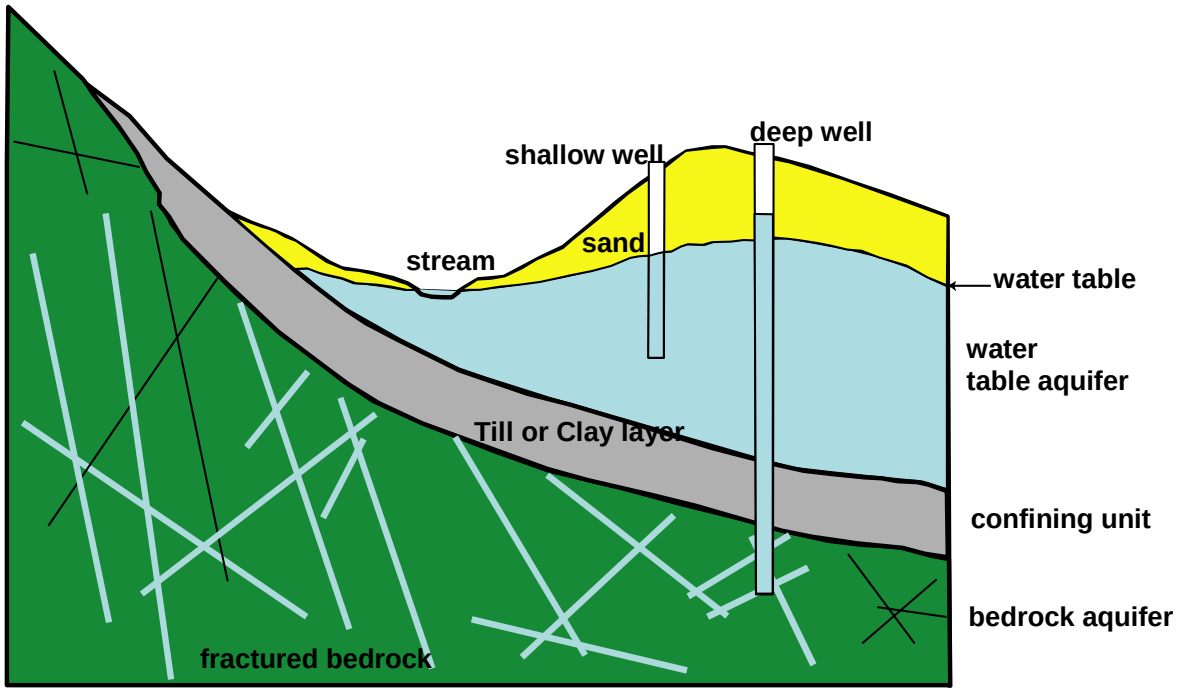


Figure 2- Diagram showing a cross-section through the water table and bedrock aquifers

Under all of Vermont lies the state's bedrock geology. These rocks are tightly folded and broken as a result of the uplift of the Green Mountains. On top of the bedrock are earth materials—boulders, gravel, sand and clay—deposited as the glaciers retreated more than 12,000 year ago. Since that time, the landscape has been reworked by water. All of these layers comprise the vessel that contains Vermont's groundwater.

In order to understand Vermont's aquifers, studies are needed on a statewide basis to reveal the complex dynamics of groundwater. The level of detail will determine the appropriate uses of the data. The data may be suitable for regional and town planning, locating wells for new development, or protecting areas for future uses. Even with well-researched locations, the predicted water quality and quantity may be difficult to achieve. However, with every added level of detail, the probability of finding high quality and quantity increases.

**Status of Aquifer Mapping**

Following a drought in the mid-1960s, Vermont took the first steps towards understanding the groundwater resource. This work includes research on the sand and gravel aquifers in the valley bottoms. Geologic work completed in the 1950s and 1960s supports more recent hydrogeologic work. Starting in 1966, well drillers have been completing and submitting a report on each well drilled in the state with information on the well characteristics, the owner's name, general location, depth, rock and soil types, and yield. The locations of many of these wells are not accurate and therefore the corresponding data is impractical to use. Since the 1960s, mapping has been performed at increasing levels of detail and decreasing degrees of coverage. The appendices contain a comprehensive list of major groundwater studies in the state.

By 1975, the Vermont Geological Survey completed work on a map series known as *Geology for Environmental Planning*. This series includes groundwater potential maps for seven regions of the State that covers 66% of Vermont's land area. Potential groundwater quantities are characterized on these maps. These data can be used for a general picture of groundwater potential, but they are not suitable for regional or town planning due to the scale and no topographic detail. In the series, the primary data used to enhance groundwater designations include the *Surficial Geologic Map of Vermont* (1970) and the *Centennial Geologic Map of Vermont* (1961).

Between 1976 and 1982, four additional studies were completed -- the *Ground-water Resources* maps for the White River Junction Area, the Rutland Area, the Barre-Montpelier Area, and Upper Winooski River Basin. These studies cover 11.2% of the state's land area and were conducted by the Vermont Department of Water Resources and the United States Geological Survey (USGS). These maps added detail largely gained through locating a significant number of water well logs; interpreting sand, gravel, and bedrock favorability from well logs; and geologic information. At least two of these reports lack the level of detail and information necessary to conduct adequate regional and town planning. A significant number of wells have been drilled since 1982. Locating new wells and analyzing the data could provide a useful product for regional planning.

In addition to the regional studies conducted above, all Public Community Water Systems have identified their Source Protection Areas. Most of the areas are based on located water wells, geology, and groundwater flow parameters derived from tests performed when public groundwater sources are located. A small subset of the Source Protection Areas are 3000 foot radius circles.

Since the 1980s, towns have requested groundwater information for planning purposes. The Agency of Natural Resources has provided assistance to almost twenty towns using the existing information and resources to create maps for town planning purposes. Two years ago, the Vermont Geological Survey produced an aquifer recharge map, a groundwater surface map, a thickness of overburden map, and aquifer delineations for part of Arlington using federal State Map Grant monies. This effort created new surficial geologic maps and located water wells. Due to resource constraints, the Agency of Natural Resources has only been able to assistance one or two towns per year with detail information and mapping.

**Status of Statewide Groundwater Classification**

The Secretary of the Agency of Natural Resources is responsible for reclassifying groundwater. According to 10 V.S.A., Chapter 48 (see Appendix 6), four classes of groundwater exist. Class I is suitable as a public water supply source with no risk associated with it. Class II is suitable as a public water supply source with some risk associated with it. Class III is suitable for private water supplies, agricultural, industrial, and commercial use. Class IV is considered non-potable, but may be suitable for some other uses. The statute also provides for all groundwater to be Class III until the Secretary reclassifies it.

In order to define the method of reclassification, the Agency of Natural Resources developed a process in the Groundwater Protection Rule and Strategy and established procedures for mapping Class I and II Groundwater Areas and for mapping Class IV Groundwater Areas.

In the Groundwater Protection and Management Report to the Legislature for 1988, the Agency noted that it had identified and mapped nine potential Class I areas. A separate report on these areas was submitted to the legislature with the Report for Calendar Year 1990. Class I Groundwater Areas require legislative approval. No Class I Groundwater Areas have been designated. In the Report to the Legislature for 1992, the Agency stated, "The mapping of groundwater resources for future use has been deferred pending available resources . . . " At this point in time, the Water Supply Division began to implement the federal Wellhead Protection Program and Source Approval process required by 10 V.S.A., Chapter 56 for protecting public drinking water supplies. The Agency of Natural Resources has established protective measures for Source Protection Areas that are comparable to Class II Groundwater Areas. Source Protection Areas, also known as Wellhead Protection Areas, have been identified for all of the Public Community Water Systems in the state.

Since 1993, the Secretary has approved four areas to be reclassified from Class III to Class IV. These areas are the Pine Street Barge Canal in Burlington; Tansitor Electronics in Bennington; Bennington Landfill in Bennington; and Windham Solid Waste Management District Landfill in Brattleboro. The Secretary is reviewing five proposed Class IV groundwater areas.

**Status of Mapping Naturally-occurring Contaminants of Concern That May Preclude the Use of an Aquifer for Drinking Water Supplies**

Naturally-occurring contaminants of concern are found in all rocks, soil, and water. While some naturally-occurring elements do not pose a risk to public health, others can cause serious health problems. The United State Environmental Protection Agency has established a number of maximum contaminant levels for the elements that occur in drinking water. Additionally, the Vermont Department of Health has established Health Advisories for Drinking Water for additional contaminants of concern. The naturally-occurring contaminants of concern include radon, arsenic, radionuclides, and a variety of metals. Additionally, some elements cause concern because of appearance and odor problems, but they do not lead to health problems.

Radioactivity can be naturally-occurring. Vermont rocks contain radioactive elements such as, Uranium. Radioactive elements decay releasing atomic particles and energy.

The Vermont Geological Survey released a statewide map on radioactivity in September 2002. This map, *Compilation and Assessment of Radioactivity Data in Vermont*, is a compilation of areas where historical ground and air surveys have indicated the presence of elevated naturally-occurring radioactivity relative to surrounding areas. Public water systems with elevated radioactivity are also shown. The map does not show where bedrock wells will have elevated radioactivity; it only provides a compilation of historical data. The impetus for the statewide map was the discovery of elevated radioactivity in domestic wells in Milton and Colchester. Further work in Milton and Colchester is the basis of a map series showing the bedrock geology, a cross-section of the geology, a fracture map, a draft radioactivity hazard map, detailed Geiger counter grids, and a well yield map. These maps enable local officials to understand the geologic context of the elevated radioactivity in bedrock and serve as a framework from which to propose further action.

Radon, a naturally occurring contaminant in air and groundwater, is under investigation by the Vermont Geological Survey. A draft statewide map of radon in air shows the number of radon tests per town and the percentage of tests equaling or exceeding the EPA level of concern. A second version of this map is currently being scientifically reviewed and will incorporate over 6000 radon analyses. The EPA published a report, *EPA's Map of Radon Zones--Vermont*, in 1993. The Vermont Department of Health published a report on radon in public water supplies in 1986 (Manning and Ladue, 1986).

The Water Supply Division collects arsenic data from public water supplies and has constructed a GIS database from these data. Statewide maps showing public drinking water systems that are above and below a level of concern have been prepared using town and geologic maps. The Vermont Geologic Survey is investigating the connection between bedrock and arsenic as part of the map preparation. A draft version of the map is under scientific review.

Although no statewide specific studies have been completed on any of the other naturally occurring contaminants of concern, such as asbestos, barium, cadmium, chromium, copper, lead, mercury, selenium, antimony, beryllium, cyanide, nickel, thallium, or natural gas, the Water

Supply Division maintains a database of chemicals and elements sampled for by public water supplies that can be used for future studies.

## Potential Obstacles and Difficulties in Completing Aquifer Mapping Statewide

The Agency of Natural Resources currently collects a wide variety of data on groundwater quality and quantity. This includes well log data for 90,000 wells, water quality from public water supplies, pump test data from public water sources, water quality from hazardous sites, geologic studies, source protection areas for public water supplies, and identification of Class IV Groundwater Areas.

These data exist in a variety of formats, including paper, mylar, GIS datalayers, and computer spreadsheets. The accuracy of the data varies significantly depending upon the methods and tools used to collect the data, the scale of the map, and other factors. In some locations, a great deal of information exists to produce aquifer maps and in many other areas of the state little to no information exists on which to base an aquifer map on. Additionally, the information is spread between several divisions in the Agency of Natural Resources. Existing maps and data can be used to create rudimentary aquifer maps for some parts of the state. However, the most obvious obstacle to completing aquifer mapping statewide is the lack of a dedicated funding source for employing people to analyze and compile data, to provide contracts and grants to partners, and to purchase scientific equipment to collect data.

## Completing Aquifer Mapping of the State

Groundwater mapping can be very broad and used for regional planning purposes or more detailed and used for locating a specific well. This report includes three levels of research to develop groundwater and aquifer maps of increasing accuracy. The three levels are presented to provide a broad picture of the work that could be completed given the available resources. Each level builds upon the previous level in detail and time using increasingly sophisticated tools, technical expertise, and scientific evaluation.

### *Basic Mapping*

The basic level of effort relies upon the use, analysis, and interpretation of existing data. The data to be used includes the well log database, the statewide surficial and bedrock maps, public water system pump test data, and water quality data. The Agency of Natural Resources would field verify and analyze this information, in particular the water well data, using Geographical Information Systems, computer databases, and hydrogeologic studies to produce a generalized assessment and delineation of the surficial and bedrock aquifers.

This work will result in a series of maps showing groundwater recharge potential, groundwater levels, groundwater availability, and surficial material thickness. These maps can be used for regional planning purposes to identify areas for groundwater protection and growth opportunities. This approach would also collate existing data for other contaminants of concern to produce maps of similar detail to the statewide radioactivity map completed by the Vermont Geologic Survey in 2002. The naturally-occurring maps could then be used as guidance for

testing private wells for specific contaminants of concern. The existing Public Water System Source Protection Areas would be reviewed to determine which are appropriate for proposing as Class I and II Groundwater Areas. Additionally, pilot studies in selected growth areas would be conducted to gather detailed information on bedrock aquifers, surficial aquifers and radionuclides.

Basic Mapping Timeline, Resources, and Partners

The basic mapping work can be completed by July 1, 2007 assuming that at least 9 positions are filled starting in July 2003 and are fully funded through July 1, 2007. These positions would include field personnel to verify data, professional hydrogeologists to analyze and interpret the data, administrative support, computer and project oversight personnel. Contracts or grants with the United States Geological Survey would be necessary to provide expertise in select areas. Additional expenses in computer, office and field equipment are expected to be significant because the Agency of Natural Resources currently lacks the equipment to conduct the necessary level of research.

| **Basic Mapping Costs**<br>Timeframe: July 2003-July 2007 | | |
|---|---|---|
| Personnel Costs (Salary, Travel, Office Equipment Fringe, Indirect, Other Service Charges) | $564,250 year x 4 years | $2,257,000 |
| Scientific Equipment (gamma ray spectrometer, map plotter, GPS units, etc.) | $35,000 | $35,000 |
| Grants & Contracts | $100,000/year x 4 years | $400,000 |
| TOTAL | | $2,692,000 |

*Expanded Mapping*

The second level of effort would develop aquifer details to a more predictable and reliable level for planning and protection at a town level. The Agency of Natural Resources would prioritize areas for in-depth studies due to pressures from economic growth, environmentally sensitive areas, and concurrent studies within the Agency of Natural Resources. Using field research, the aquifer boundaries and characteristic would be identified and mapped. This work would build upon the work completed under the Basic Mapping Program.

The Agency would partner with scientific organizations, such as the USGS and EPA, to develop comprehensive maps. These maps would involve geophysical studies, test drilling to verify subsurface characteristics, extensive geologic and orthophotograph map analysis, groundwater sampling, statistical assessments, and fieldwork to verify rock types and structures. The maps of naturally-occurring contaminants would be developed using in-depth research to provide maps on specific areas of concern identified during the Basic Mapping. These maps could be used by homeowners, health and real estate professionals to identify areas that may warrant additional testing for potential health risks.

Expanded Mapping Timeline, Resources, and Partners

Due to the complexity of this work, the initial assessment discussed under Basic Mapping could be completed by July 1, 2007, but the Expanded Mapping Program would take until July 2010. Additional costs include the continuation of the nine positions identified in the Basic Mapping Program for another three years, continued grants and contracts with scientific partners, and purchasing additional scientific equipment.

| **Expanded Mapping Costs**<br>Timeframe: July 2003-July 2010 | | |
|---|---|---|
| Personnel Costs (Salary, Travel, Office Equipment Fringe, Indirect, Other Service Charges) | $564,250 year x 7 years | $3,949,750 |
| Scientific Equipment & Water Testing (gamma ray spectrometer, map plotter, GPS units, lab costs, geophysical equipment, etc.) | $160,000 | $160,000 |
| Grants & Contracts | $100,000/year x 7 years | $600,000 |
| TOTAL | | $4,709,750 |

*Premium Mapping*

The most intensive level of effort to map groundwater and aquifers would produce maps that support appropriate regional development, sustainable economies, protection of future drinking water resources, and environmental health. This work would build on the Basic and Expanded Mapping discussed above and would focus on the high growth and environmentally sensitive areas. The Agency would conduct pump tests and monitor wells to investigate the three-dimensial aspects of aquifers and groundwater flow. Additionally, computer modeling would be used to further define aquifer characteristics.

The Agency of Natural Resources would use the information to identify and map Class I and II Groundwater Areas that would be suitable for potential future public water supply sources using the criteria discussed in 10 VSA§1394(h). Future public water supply sources can be critical to identifying reliable water supplies for planned growth areas. The Agency would also identify and establish Class IV Groundwater Areas for naturally-occurring contaminants of concern. Finally, groundwater maps and groundwater and surface water interaction studies would be conducted for the watershed and basin planning processes.

Premium Mapping Timeline, Resources, and Partners

This Premium Mapping Program will build upon the Basic and Expanded Mapping Program. In order to complete the work through the premium level, ten years of funding is necessary. Additionally, the work with scientific partners will need to continue and additional scientific and technical equipment will be necessary.

| **Premium Mapping Costs**<br>Timeframe: July 2003-July 2013 | | |
|---|---|---|
| Personnel Costs (Salary, Travel, Office | | |

| | | |
|---|---|---|
| Equipment Fringe, Indirect, Other Service Charges) | $564,250 /year x 10 years | $5,642,500 |
| Scientific Equipment and Water Testing (gamma ray spectrometer, map plotter, GPS units, lab costs, geophysical equipment, etc.) | $210,000 | $210,000 |
| Grants & Contracts | $100,000/year x 10 years | $1,000,000 |
| TOTAL | | $6,852,500 |

**Potential Funding Sources and Partners**

When the Groundwater Protection Statute was created in 1985, a mix of federal grants and state general fund dollars funded the work of groundwater protection and mapping. Over the years, funding sources for groundwater protection work at the state level have been reduced. Concurrently, the USGS and EPA have also seen a decrease in their resources for groundwater and aquifers.

The existing grants from EPA to Agency of Natural Resources have the flexibility to fund groundwater research; however, funding would have to be moved from existing base programs. These base programs include permitting, technical assistance and outreach on other statutorily required programs. The state general fund dollars are no longer committed to work on groundwater mapping with the exception of some of the state geologist's funding and matching funds provided for the state public water supply program.

The Vermont Geological Survey applies annually for a competitive federal grant to map basic geologic formations with added resources for groundwater mapping. This work is comparable to the level of detail discussed under Expanded Mapping without all of the in-depth scientific research. Typically, the Survey receives $50,000 to fund one or two groundwater-related projects each year and an equal state match is required. The Agency of Natural Resources provides the administrative and technical support for groundwater reclassification reviews. In 2002, the Agency estimated that less than 10% of a position was available for reclassification review. These funds and resources have not been sufficient to support a large groundwater mapping and reclassification program.

The Water Supply Division has a loan program for developing new public drinking water sources. The loan monies can be used to delineate the Source Protection Area for a new public community water system source, but not a groundwater classification area. The loan program is based on a priority system and the amount of federal funding varies each year.

A number of scientific organizations would be interested in partnering with the State of Vermont to complete aquifer or groundwater mapping in the state. The two primary organizations are the United States Environmental Protection Agency (EPA) and the United States Geological Survey (USGS). The EPA does not typically fund large groundwater and aquifer mapping projects. They do provide technical expertise in naturally-occurring contaminants of concern and drinking water sources. The USGS welcomes opportunities to work with states in a variety of

groundwater, surface water, and geologic areas. They work on a cost-share basis which is typically 50-50.

In addition to the EPA and USGS, partnerships could be developed with the Regional Planning Commissions, colleges, and universities. The Vermont Geological Survey has already developed partnerships with some of these organizations as part of current mapping efforts. These efforts could include data analysis, data gathering, and report review.

**Appendix 1 Explanation of Terms**

*Aquifer* - A water bearing stratum of permeable rock, sand, gravel or other alluvial soils. (Definition in Vermont Statute)

*Bedrock* - A general term for any consolidated rock.

*Confining unit or layer* - Geological material through which significant quantities of water can not move; located below unconfined aquifers, above and below confined aquifers. Also known as a confining bed.

*GPS (Global Positioning System)* - A satellite navigation system. GPS is funded by and controlled by the U. S. Department of Defense (DOD). GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time.

*Geiger counter* - Geiger counters are instruments that can detect and measure radioactivity. Survey meters convert electrons ionized by radiation into a current that produces the clicks popularly associated with the instrument.

*Groundwater* - Water below the land surface, but does not include surface waters within the meaning of 10 V.S.A. § 1251(13). (13) - "Waters" includes all rivers, streams, creeks, brooks, reservoirs, ponds, lakes, springs and all bodies of surface waters, artificial or natural, which are contained within, flow through or border upon the state or any portion of it; (Definition in Vermont Statute)

*Groundwater potential* - Refers to potential well yield in any given area.

*Hydrogeology* - The science that deals with subsurface waters and with related geologic aspects of surface waters.

*Orthophotograph* - An overlapping pair of aerial photographs mathematically and optically corrected so the result is an accurate map with the pictorial quality of an aerial photograph.

*Overburden* – The loose soil, silt, sand, gravel, or other unconsolidated material overlying bedrock, either transported or formed in place.

*Radionuclide* - A radioactive nuclide. An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation.

*Recharge* - The processes involved in the addition of water to the zone of saturation; also the amount of water added.

*Recharge areas* - The area of land that allow water to replenish an aquifer; this process occurs naturally when rainfall filters down through the soil or rock into an aquifer, usually in the higher

gradient section overlying the aquifer; artificial recharge is through injection wells or by spreading water over ground water reservoirs reservoir for any given area.

*Unconfined aquifer* - An aquifer in which the water table is at or near atmosphere pressure. A permeable geologic bed, only partially filled with water that overlies a relatively impervious underground layer.

*Unsaturated zone* - The area between the land surface and the water table where the soil is not fully saturated with water, although some water may be present.

*Water table* - The water level of an unconfined aquifer, below which the pore spaces are generally saturated. The top of the zone of saturation.

**Appendix 2 Groundwater Resources Relevant Data**

| TYPE | KIND | LEVEL OF DETAIL | % OF LAND AREA OF STATE | FORMAT |
|---|---|---|---|---|
| Aquifer Information | Groundwater Favorability Maps - generalized maps (Vermont in cooperation with USGS) | Scale 1:125,000[1]- reconnaissance map, some sand and gravel wells, bedrock wells, & bridge borings located | 100%; 11 River Basins | Image files on CD |
| Aquifer Information | Geology for Environmental Planning Series - includes Groundwater Potential Maps (Vermont Geological Survey) | Scale 1:100,000[1]- integrated favorability map data above, with additional well logs, seismic lines, and 1970 Surficial Geologic Map of Vermont; shows polygons for sand and gravel with addition of bedrock potential and interpretation of buried channels. | 66%; Six Printed Volumes, One Additional Unpublished | Paper & Image files on CD |
| Aquifer Information | Groundwater Resources of White River Jct., Barre-Montpelier, Upper Winooski and Rutland Areas, (Vermont in cooperation with USGS) | Scale 1:48,000[1]- numerous well logs located and some yield data assessed, some borings from engineered projects, seismic lines, existing pump tests considered, chemical analyses for some wells, groundwater availability in unconsolidated materials and bedrock. | 11.2%; Four complete reports, One report on Lower Connecticut River that focuses on public water supply withdrawals and seismic lines | Paper |
| Aquifer Information - Aquifer Recharge, Pieziometric Surface | Arlington Quadrangle Open File Report (Vermont Geological Survey) | Scale 1:24,000[1] - Surface Overburden Aquifer, Bedrock Aquifer Pieziometric Surface, Aquifer Recharge Potential Map, Surficial Geologic Map, and located water well database. | One 7.5 minute quadrangle[2] | Paper & GIS |

| TYPE | KIND | LEVEL OF DETAIL | % OF LAND AREA OF STATE | FORMAT |
|---|---|---|---|---|
| Source Protection Area Maps & Classification | Class I Aquifers: Suitable for public water supply use; uniformly excellent character; no exposure to activities which pose a risk to its current or potential use as a public water supply source; and is in use as a public water supply source, or is determined by the Secretary to have a high probability for such use. | Scale 1:24,000- field located water sources; designation based on water quality, geology, and groundwater level monitoring; some Source Protection Plans for Public Community and Non-transient, Non-community Public Water Systems. | Less than 0.5%; Nine Draft Reports | Paper |
| Source Protection Area Maps& Classification | Class II: Similar to Class I above but is also exposed to activities which may pose a risk to its current or potential use as a public water supply source. | Scale 1:24,000 or better- based on aquifer analysis, field located wells, groundwater flow direction, well yield, hydraulic boundaries, and geology. Includes other Class II public water supply source protection areas delineated based on 3,000 foot radius around water source, and Source Protection Plans (see above). | None approved; 4.5% | Paper & GIS |
| Source Protection Area Maps& Classification | Class III: suitable for private water supplies, agricultural, industrial, and commercial use. | Statute provides for all groundwater to be Class III until the Secretary reclassifies it. | | |
| Source Protection Area Maps & Classification | Class IV: Not suitable as a source of potable water but suitable for some agricultural, industrial and commercial use | Scale 1:24,000 or better - water sources field located, designations based on water quality, geology, and groundwater level monitoring. | Less than 0.5 %; Four Class IV designations with five pending petitions | Paper & GIS |

| TYPE | KIND | LEVEL OF DETAIL | % OF LAND AREA OF STATE | FORMAT |
|---|---|---|---|---|
| Groundwater Information by Town | Data gathered and collated for town aquifer information requests | Various scales- unpublished reports based on existing information, located wells, surficial geology and depth to bedrock. | Nineteen towns | Paper, Mylar, & one GIS |
| Overburden Thickness | Contour Map of Depth to Bedrock (Vermont Geological Survey, US Geological Survey) | 1:24,000 scale – derived from located well logs and surficial geology. | Eight quadrangles plus 11.2% of State from the Water Resources and USGS reports | Mylar, Paper, & GIS |
| Other Supporting Data | Seismic Lines, Highway and Other Borings, Water Quality Tests, and Pump Tests | Seismic reflection data (provides depth to bedrock data), borings at bridges and hazardous waste sites (have accurate location of log), water quality tests for a range of parameters, pump tests primarily for defining potential yield at public water supplies. | Not yet characterized | Not yet characterized |
| Naturally Occurring Constituents of Concern | Colchester Quadrangle Open File Report (Vermont Geological Survey, 2002) | Scale 1:24,000 – intensive study of bedrock geology, fracture analysis (fractures have the potential to be water bearing), gamma ray spectrometer surveys, and radioactivity data. | One Quadrangle | Paper & GIS |
| Naturally Occurring Constituents of Concern | Compilation and Assessment of Radioactivity Data in Vermont (Vermont Geological Survey, 2002) | Scale 1:250,000 - statewide distribution of elevated radioactivity areas in Vermont based on an assessment and compilation of data from older sources, including uranium exploration data. | | Paper & GIS |
| Naturally Occurring Constituents of Concern | Arsenic database (Water Supply Division) | GIS coverage based on data collected from Public Water Supplies | | Paper & GIS |

**Appendix 3 Scales**

| | |
|---|---|
| 1:250,000 | 1 inch represents 4 miles |
| 1:125,000 | 1 inch represents 2 miles |
| 1:100,000 | 1 inch represents 1.6 miles |
| 1:62,500 | 1 inch represents 1 mile |
| 1:48,000 | 1 inch represents 4000 feet |
| 1:24,000 | 1 inch represents 2000 feet |
| 7.5 Minute Quadrangle is a topographic map at a scale of 1:24,000. Each quadrangle covers approximately 49 square miles. | |

**Appendix 4 Bedrock and Surficial Geologic Information**

| TYPE | MAP NAME/ KIND OF PUBLICATION | NUMBER | FORMAT |
|---|---|---|---|
| Bedrock Geology | 1:250,000 scale- Centennial Geologic Map of Vermont (1961) – map of bedrock formations in Vermont | One State Map | Image file on CD |
| Bedrock Geology | 1:62,500 to 1:12,000 scale - VGS Bulletins and Special Bulletins – maps and descriptions of bedrock geology | 44 Maps and Reports | Paper |
| Bedrock Geology | 1:24,000 and 1:100,000 scale- Open File Digital Bedrock Maps prepared by VGS and USGS. | 34 Maps | Digital data (GIS Arcinfo coverages) & Paper |
| Surficial Geology | 1:250,000 scale- Surficial Geologic Map of Vermont (1970) – identifies deposits of sand, silt, gravel, etc. | One State Map | Paper |
| Surficial Geology | 1:62,500 scale – Original drafts of surficial geologic maps used as data source for the 1970 Statewide compilation. | 55 Maps | Image files on CD & Paper |
| Surficial Geology | 1:62,500 scale -White River Drainage Basin – digitized data of 9 original Surficial geology quadrangles. | One Map | GIS Arcinfo coverage |
| Surficial Geology | 1:24,000 scale- Surficial geologic maps, cross-sections, physical hazard maps, isopach maps, and water well database with 4,400 located well logs. | Approximately 9 7.5 minute quadrangles | Digital data (GIS) & Paper |
| Topographic Information | Various scales – shows contoured land surface of Vermont | Statewide | Digital data & Paper |
| Aerial Photographs | Various scales – photographs taken from an airplane of the land surface; can be used to compare landscape changes over time. | Statewide | Digital data & Paper |

**Appendix 5 Selected Text from Act 133 of the 2001-2002 Vermont Legislative Session**

NO. 133. AN ACT RELATING TO INCREASING THE TECHNOLOGIES THAT MAY BE USED IN THE STATE FOR ON-SITE DISPOSAL OF WASTEWATER.

(S.27)

It is hereby enacted by the General Assembly of the State of Vermont:

. . .

(i) Groundwater.

(1) In implementing 10 V.S.A. chapter 64, the secretary shall assure consistency with the requirements of 10 V.S.A. chapter 48.

(2) By July 1, 2007, the secretary shall implement the provisions of 10 V.S.A. chapter 48 and complete the aquifer mapping of the state required under that chapter.

(3) By January 15, 2003, the secretary shall submit a report to the chairs of the Senate and House committees on natural resources and energy, addressing the following:

(A) the status of aquifer mapping;

(B) the status of statewide groundwater classification;

(C) the status of mapping of naturally-occurring contaminants of concern that may preclude use of an aquifer for drinking water supplies;

(D) potential obstacles and difficulties in completing the work specified in this subsection, including the resources necessary to complete the aquifer mapping by July 1, 2007, and to complete the other work required within a reasonable timeframe;

(E) potential funding sources and partners for completing the work specified in this subsection; and

(F) a reasonable timeline for implementing the work specified in this subsection, assuming that the recommended resources are provided.

## Appendix 6  10 VSA, Chapter 48

### § 1390. Policy

It is the policy of the state of Vermont that it shall protect its groundwater resources to maintain high quality drinking water and shall manage its groundwater resources to minimize the risks of groundwater quality deterioration by limiting human activities that present unreasonable risks to the use classifications of groundwater in the vicinities of such activities while balancing the state's groundwater policy with the need to maintain and promote a healthy and prosperous agricultural community. (Added 1985, No. 53, § 1.)

### § 1391. Definitions

As used in this chapter:

(1) "Abandoned well" means any well or hole whose original purpose and use has been permanently discontinued or which is in such a state of disrepair that the well or hole has the potential for transmitting contaminants into an aquifer or otherwise threatens the public health or safety.

(2) "Agency" means the agency of natural resources.

(3) "Aquifer" means a water bearing stratum of permeable rock, sand, gravel or other alluvial soils.

(4) "Beneficial uses" means those uses included in each groundwater class.

(5) "Commissioner" means the commissioner of the department of environmental conservation or the commissioner's designated representative.

(6) "Department" means the department of environmental conservation.

(7) "Groundwater" means water below the land surface, but does not include surface waters within the meaning of 10 V.S.A. § 1251(13).

(8) "Hole" means any excavation, deeper than twenty feet with at least one horizontal dimension less than five feet.

(9) "Public water supply" means a water supply system with ten or more connections.

(10) "Secretary" means the secretary of the agency of natural resources or the secretary's designated representative.

(11) "Servicing" means developing of well yields, placing liners or seals, grouting, restricting the flow of flowing wells, repairing or closing wells and installing or maintaining well pump systems. "Servicing" does not include work performed on monitoring wells.

(12) "Technical criteria" means the numerical parameters or scientific parameters which, when followed, will result in groundwater suitable for the uses defined in its class.

(13) "Well" means any hole deeper than 20 feet drilled, driven or bored into the earth to locate, monitor, extract or recharge groundwater or any hole deeper than 20 feet drilled, driven or bored for the primary purpose of transferring heat to or from the earth's subsurface.

(14) "Well contractor" means any person who constructs or services wells. (Added 1985, No. 53, § 1; amended 1987, No. 76, § 18; 1989, No. 201 (Adj. Sess.), § 1.)

**§ 1392. Duties; powers of secretary**

(a) The secretary shall develop a comprehensive groundwater management program to protect the quality of groundwater resources by:

(1) developing a strategy for the management and protection of the state's groundwater resources;

(2) continuing studies and investigations of groundwater in the state;

(3) cooperating with other government agencies in collecting and compiling data on the quantity and quality of groundwater and location of aquifers;

(4) identifying and mapping groundwater currently used as public water supply sources and groundwater determined by the secretary as potential future public water supply sources;

(5) providing technical assistance to municipal officials and other public bodies in the development of regional or municipal plans or bylaws, the purpose of which is the protection of groundwater resources;

(6) classifying groundwater resources according to the provisions of this chapter and adopting technical criteria and standards for the management of activities that may pose a risk to their beneficial uses;

(7) integrating the groundwater management strategy with other regulatory programs administered by the secretary;

(8) developing public information and education materials; and

(9) cooperating with federal agencies in the development of programs for protecting the quality and quantity of the groundwater resources.

(b) The secretary is authorized to accept and administer grants for groundwater management purposes in accord with the administrative procedures of the state.

(c) The secretary shall establish a groundwater coordinating committee, with representation from the departments of agriculture, food and markets, forests, parks and recreation, and health to provide advice in the development of the program and its implementation. In carrying out his or her duties under this subchapter the secretary shall give due consideration to the recommendations of the groundwater coordinating committee. The secretary may request representatives of other agencies and the private sector to serve on the groundwater coordinating committee.

(d) The groundwater management strategy, including groundwater classification and associated technical criteria and standards, shall be adopted as a rule in accordance with the provisions of 3 V.S.A., chapter 25. The secretary shall file any final proposed rules regarding the groundwater management strategy, with the water resources board not less than 30 days prior to filing with the legislative committee on administrative rules. The board shall review the final proposed rules and comment regarding their compatibility with the Vermont water quality standards and the objectives of the Vermont Water Pollution Control Act. The secretary shall include the water resources board's comments in filing the final proposed rules with the legislative committee on administrative rules.

(e) [Repealed.] (Added 1985, No. 53, § 1; amended 1989, No. 256 (Adj. Sess.), § 10(a), eff. Jan. 1, 1991; 1995, No. 189 (Adj. Sess.), § 3.)

**§ 1393. Coordination**

Nothing in this subchapter is intended to interfere with authority granted other agencies of state government by statute. The secretary will coordinate the development of the program with other state agencies as necessary. (Added 1985, No. 53, § 1.)

**§ 1394. Classification of groundwater**

(a) The state adopts, for purposes of classifying its groundwater, the following classes and definitions thereof:

Class I. Suitable for public water supply. Character uniformly excellent. No exposure to activities which pose a risk to its current or potential use as a public water supply.

Class II. Suitable for public water supply. Character uniformly excellent but exposed to activities which may pose a risk to its current or potential use as a public water supply.

Class III. Suitable as a source of water for individual domestic water supply, irrigation, agricultural use and general industrial and commercial use.

Class IV. Not suitable as a source of potable water but suitable for some agricultural, industrial and commercial use.

(b) All groundwater of the state is hereby classified as Class III water unless reclassified by the secretary.

(c) Any hearing on a classification or reclassification shall be held in a location convenient to the users or potential users of the groundwater which is the subject of the hearing.

(d) Class I or II classification shall apply to aquifers in use as a public water supply source or which in the opinion of the secretary have a high probability for such use.

(e) In determining the appropriate classification of groundwater, the secretary shall consider:

(1) its use or potential future use as a public water supply source;

(2) the extent of activity which poses a risk to the groundwater;

(3) its current water quality;

(4) its availability in quantities needed for beneficial use;

(5) the consequences of its potential contamination and the availability of alternate sources of water; and

(6) the classification of adjacent surface waters; and other factors relevant to determine the maximum beneficial use of the aquifer.

(f) It is the policy of the state to protect permanently Class I aquifers. The secretary pursuant to subsection (h) of this section shall establish by rule activities which pose risks to Class I aquifers and which activities shall be prohibited in Class I aquifers. Any classification of Class I waters involving privately owned lands or reclassification of Class I waters by the secretary shall become effective only when approved by act of the general assembly.

(g) The secretary's classifications shall be presumed correct if, in establishing the geographical limits of each class of groundwater, he or she uses generally accepted methods of determining aquifers based on existing knowledge of surficial and bedrock geology and available hydrological data.

(h) The secretary by rule may establish technical criteria and standards to define the classes of groundwater and manage activities that may pose risks to groundwater classes. The criteria and standards shall include the identification of activities which constitute risks to the groundwater and which may be precluded. In adopting criteria and standards, the secretary shall consider:

(1) drinking water standards adopted by the department of health and United States Environmental Protection Agency;

(2) the nature and quantity of groundwater at risk;

(3) the availability, cost and effectiveness of measures to mitigate risks;

(4) the nature and quantity of risks that activities may generate;

(5) the expense and effectiveness of correcting the damage the risks may cause;

(6) the consequences to the public interest should damage occur and be irremediable;

(7) the economic, social and environmental value of existing activities;

(8) the surface water quality standards including the classification of surface waters; and

(9) other factors relevant to designating appropriate groundwater classes or managing risks to groundwater quality.

(i) The secretary shall not promulgate criteria and standards to manage activities that restrict agricultural activities or those activities under the jurisdiction of the commissioner of agriculture, food and markets without the commissioner's consent. Nor shall the secretary promulgate criteria and standards that restrict forestry management activities without consultation with the commissioner of forests, parks and recreation. (Added 1985, No. 53, § 1.)

§ 1395. APPLICATION

Any person who intends to engage in the business of drilling *[~~or servicing~~]* wells in the state of Vermont shall file an application with the department of environmental conservation for a license to do so on forms provided by the department on which the person’s qualifications and other information which may

be required by the department shall be stated. The fee for a license or a renewal shall be in accordance with 3 V.S.A. § 2822. The licenses so issued shall expire every three years on June 30, shall not be transferable and may be renewed on filing of a complete application and payment of the required fee in accordance with 3 V.S.A. § 2822. The fee shall be paid on an annual basis.

(Added 1965, No. 206, § 1; amended 1981, No. 222 (Adj. Sess.), § 29; 1987, No. 76, § 6; 1989, No. 201 (Adj. Sess.), § 2; 1995, No. 103 (Adj. Sess.), § 1.)

§ 1395a. LICENSES; RULES

(a) The department shall issue licenses under this subchapter. A licensee may be authorized to perform more than one class of activities under a single license. The department shall, by rule, establish appropriate application, testing, and renewal procedures for each class of activity under a license. The rule shall include the opportunity for an applicant to take the licensing test orally or by demonstration if the applicant fails the written test. The classes of activities under a license shall be as follows:

(1) Water well driller. This class shall consist of any person engaged in the business of constructing wells for the purpose of locating, extracting or recharging groundwater, or for the purpose of transferring heat to or from the earth's subsurface.

(2) Monitoring well driller. This class shall consist of any person engaged in the business of constructing, servicing or closing wells drilled for the purpose of monitoring groundwater quantity or quality.

(3), (4) [Repealed.]

(b) The department may adopt rules to implement the provisions of this subchapter and to establish well construction standards for persons engaged in the business of well construction.

(c) Rules relating to licensing standards shall be fair and reasonable and shall be designed and implemented to insure that all applicants are granted licensure if they demonstrate that they possess the minimal occupational qualifications necessary for the purposes of groundwater protection. They shall not be designed or implemented for the purpose of limiting the number of licensees. All other rules to implement the provisions of this subchapter shall be rationally related to the purposes of this chapter, and shall be designed to achieve a reasonable balance between the expected governmental, societal and occupational costs and the expected benefits.

(Added 1989, No. 201 (Adj. Sess.), § 3; amended 1995, No. 103 (Adj. Sess.), § 2.)

**§ 1395b. Water well advisory committee**

(a) The Vermont water well advisory committee is created. The committee shall consist of seven members: the director of the groundwater and water supply division, the state geologist, a representative from the department of health, and four members appointed by the governor. Three of the four public members shall be licensed well drillers, with at least five years of experience. The fourth public member shall be a person not associated with the well-drilling business who has an interest in wells and water quality.

(b) The purpose of the committee is to advise and assist agency personnel in the formulation of policy, including recommended statutory and regulatory changes, regarding the proper installation and maintenance of water wells, licensing of well drillers, and groundwater issues impacted by well-drilling activities. The committee shall promote and encourage cooperation and communication between governmental agencies, licensed well drillers, and members of the general public.

(c) Members shall be appointed for terms of five years, with the initial appointments of the public members made for lesser terms, so that the appointments do not all expire simultaneously. Vacancies shall be filled by the governor for the length of an unexpired term.

(d) The committee shall elect a chair and a secretary, and shall meet from time to time as may be necessary, but not less than quarterly.

(e) The public members of the committee shall be volunteers, and will serve without compensation. (Added 1995, No. 103 (Adj. Sess.), § 3.)

**§ 1396. Records and reports**

(a) Each licensee shall keep accurate records and file a report with the department and well owner on each water well constructed or serviced, including but not limited to the name of the owner, location, depth, character of rocks or earth formations and fluids encountered, and other reasonable and appropriate information the department may, by rule, require.

(b) The reports required to be filed under subsection (a) of this section shall be on forms provided by the department as follows:

(1) Each licensee classified as a water well driller shall submit a well completion report within 90 days after completing the construction of a water well.

(2) Each licensee classified as a monitoring well driller shall submit a monitoring well completion or closure report or approved equivalent within 90 days after completing the construction or closure of a monitoring well. Reporting on the construction of a monitoring well shall be limited to information obtained at the

time of construction and need not include the work products of others. The filing of a monitoring well completion or closure report shall be delayed for one or more six-month periods from the date of construction upon the filing of a request form provided by the department which is signed by both the licensee and well owner.

(3), (4) [Repealed.]

(c) No report shall be required to be filed with the department if the well is hand driven or is dug by use of a hand auger or other manual means. (Added 1965, No. 206, § 2; amended 1981, No. 222 (Adj. Sess.), § 29; 1987, No. 76, § 18; 1989, No. 201 (Adj. Sess.), § 4; 1995, No. 103 (Adj. Sess.), § 4.)

**§ 1397. Repealed. 1995, No. 103 (Adj. Sess.), § 5.**

**§ 1398. Repealed. 1995, No. 103 (Adj. Sess.), § 10.**

**§ 1399. Penalties**

Any person who violates a provision of this subchapter shall be fined not more than $1,000.00 for each violation. (Added 1965, No. 206, § 6; amended 1981, No. 222 (Adj. Sess.), § 29; 1989, No. 201 (Adj. Sess.), § 5.)

**§ 1400. Appeals**

(a) A person aggrieved by a decision of the commissioner under section 1402 of this title may appeal the decision to the water resources board and from there to Washington superior court or the superior court of the county in which the person's principal place of business is located.

(b) A person aggrieved by a decision or order of the commissioner under section 1403 of this title may appeal the decision or order to the water resources board and from there to the superior court for the county in which he or she resides or the well is located. (Added 1965, No. 206, § 3; amended 1981, No. 222 (Adj. Sess.), § 29; 1987, No. 76, § 18; 1989, No. 201 (Adj. Sess.), § 6.)

**§ 1401. Repealed. 1989, No. 98, § 4(b)**

§ 1402. DENIAL AND REVOCATION OF LICENSE

A license may be denied, suspended, or revoked, or the renewal thereof denied by the commissioner on the commissioner’s own investigation and motion or upon written complaint of others, if after notice and opportunity for hearing the commissioner finds that the applicant or license holder has committed conduct specified under 3 V.S.A. § 129a as constituting unprofessional conduct by a licensee.

(Added 1981, No. 222 (Adj. Sess.), § 29; amended 1989, No. 201 (Adj. Sess.) § 7; 2001, No. 133 (Adj. Sess.) § 3, eff. June 13, 2002.)

**§ 1403. Closure of abandoned wells**

The commissioner may order a person legally responsible for an abandoned well to close the abandoned well in accordance with the rules established by the department for the purpose of groundwater protection. An order shall not be issued under this section until the person legally responsible for the abandoned well has been given notice and an opportunity for an informal conference with the commissioner. (Added 1989, No. 201 (Adj. Sess.), § 8.)

**§ 1410. Groundwater; right of action**

(a) Findings and policy. The general assembly hereby finds and declares that:

(1) surface and subsurface water are inherently interrelated in both quality and quantity;

(2) groundwater hydrology is a science that allows groundwater quality and quantity to be mapped and forecast;

(3) groundwater is a mobile resource that is necessarily shared among all users;

(4) all persons have a right to the beneficial use and enjoyment of groundwater free from unreasonable interference by other persons; and

(5) it is the policy of the state that the common-law doctrine of absolute ownership of groundwater is hereby abolished.

(b) Definitions.

(1) "Groundwater" means water below the land surface.

(2) "Surface water" means any water on the land surface.

(3) "Person" means any individual, partnership, company, corporation, association, unincorporated association, joint venture, trust, municipality, the state of Vermont, or any agency, department or subdivision of the state, federal agency, or any other legal or commercial entity.

(c) Any person may maintain under this section an action for equitable relief or an action in tort to recover damages, or both, for the unreasonable harm caused by another person withdrawing, diverting or altering the character or quality of groundwater.

(d) Notwithstanding the provisions of subsection (c) of this section, a person who alters groundwater quality or character as a result of agricultural or silvicultural activities, or other activities regulated by the commissioner of the department of agriculture, food and markets, shall be liable only if that alteration was either negligent, reckless or intentional.

(e) Factors to be considered in determining the unreasonableness of any harm referred to in subsection (c), above, shall include, but need not be limited to, the following:

(1) the purpose of the respective uses or activities affected;

(2) the economic, social and environmental value of the respective uses, including protection of public health;

(3) the nature and extent of the harm caused, if any;

(4) the practicality of avoiding the harm, if any;

(5) the practicality of adjusting the quantity or quality of water used or affected and the method of use by each party;

(6) the maintenance or improvement of groundwater and surface water quality;

(7) the protection of existing values of land, investments, enterprises and productive uses;

(8) the burden and fairness of requiring a person who causes harm to bear the loss; and

(9) the burden and fairness of requiring a person to bear the loss, who causes harm in the conduct of reasonable agricultural activities, utilizing good agricultural practices conducted in conformity with federal, state and local laws and regulations.

(f) Nothing in this section shall be construed to preclude or supplant any other statutory or common-law remedies. (Added 1985, No. 69, §§ 1, 2; amended 1989, No. 256 (Adj. Sess.), § 10(a), eff. Jan. 1, 1991.)

## Appendix 7 References


Cotton, J.E., 1986, Vermont Groundwater Quality, National Water Summary: U.S. Geological Survey Water-Supply Paper 2325, pp. 501-508.

De Simone, D.J., 2001, Surficial geology and ground water resources of Arlington, VT: A report and history for town residents: Vermont Geological Survey.

De Simone, D.J., 2001, Surficial geology of Arlington, VT: A technical discussion: Vermont Geological Survey.

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

Dudley, J., compiler, 1993, Sand and Gravel Resource Map of Vermont: New England Governors' Conference.

Environmental Protection Agency, 1993, EPA's Map of Radon Zones- Vermont: Radon Division, Office of Radiation and Indoor Air.

Groundwater Management Section, Vermont Dept. of Water Resources and Environmental Engineering, 1982, Background Water Quality for Selected Groundwater Supplies- 1978-1981: Preliminary Findings, 17 p.

Hodges, Jr., A. L., 1966, Ground Water Favorability of the Batten Kill, Walloomsac River, and Hoosic River Basins, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L., 1967, Ground Water Favorability of the Otter Creek Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1967, Ground Water Favorability of the Winooski River Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1967, Ground Water Favorability of the Lake Memphremagog River Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1967, Ground Water Favorability of the Lamoille River Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1967, Ground Water Favorability of the Missisquoi River Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1967, Ground Water Favorability of the Nulhegan-Passumpsic River Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1968, Ground Water Favorability of the Ottauquechee-Saxtons River Basins, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1968, Ground Water Favorability of the Wells-Ompampanoosuc River Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1968, Ground Water Favorability of the West Deerfield River Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L. and Butterfield, D., 1968, Ground Water Favorability of the White River Basin, Vermont: Vermont Department of Water Resources.

Hodges, Jr., A. L., Butterfield, D., and Ashley, J.A., 1976, Ground-water resources of the White River Junction area, Vermont: Vermont Dept. of Water Resources.

Hodges, Jr., A. L., Butterfield, D., and Ashley, J.A., 1976, Ground-water resources of the Barre-Montpelier area, Vermont: Vermont Dept. of Water Resources.

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

Kim, J., 2002, Compilation and assessment of radioactivity in Vermont: Vermont Geological Survey.

Kim, J., and Thompson, P., 2002, Bedrock geologic map of the Colchester 7.5 minute quadrangle, Vermont: Vermont Geological Survey Open File Report (in progress).

Larsen, F.D., 1999, Surficial geologic map of the Montpelier quadrangle, Vermont: Vermont Geological Survey Open File Map VG99-7.

Manning, D. and Ladue, W., 1986, Radon in Vermont Public Water Supplies: Vermont Dept. of Health, Division of Environmental Health, 59 p.

Stewart, D.P., 1971, Geology for environmental planning in the Barre-Montpelier region, Vermont: Vermont Geological Survey, Environmental Planning No. 1.

Stewart, D.P., 1972, Geology for environmental planning in the Rutland-Brandon region, Vermont: Vermont Geological Survey, Environmental Planning No. 2.

Stewart, D.P., 1973, Geology for environmental planning in the Burlington-Middlebury region, Vermont: Vermont Geological Survey, Environmental Planning No. 3.

Stewart, D.P., 1974, Geology for environmental planning in the Milton-St. Albans region, Vermont: Vermont Geological Survey, Environmental Planning No. 5.

Stewart, D.P., 1975, Geology for environmental planning in the Brattleboro-Windsor region, Vermont: Vermont Geological Survey, Environmental Planning No. 7.

Stewart, D.P., and MacClintock, P., 1970, Surficial Geologic Map of Vermont: C.G. Doll, Editor, Vermont Geological Survey.

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

Wright, III, F. N., 1974, Geology for environmental planning in the Johnson-Hardwick region, Vermont: Vermont Geological Survey, Environmental Planning No. 4.

Wright, III, F. N., 1975, Geology for environmental planning in the Bennington-Manchester region, Vermont: Vermont Geological Survey unpublished report.