Chapter 4
Groundwater

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

Overview

Groundwater in New Hampshire supplies water to 60 percent of the state's population. In addition, water stored beneath the ground surface replenishes rivers, lakes and wetlands during dry periods, ensuring healthy ecosystems and water for other uses. Groundwater in New Hampshire is both closely connected to surface waters and what occurs on the land surface (see Figure 1-17, the fold-out graphic). Landscape change can negatively impact groundwater quantity and quality if it is not conducted in a water-wise manner. More education is needed for citizens to better understand the occurrence and importance of groundwater. State and, particularly, local efforts to protect this resource are necessary to ensure a plentiful future supply of high quality groundwater. Because it is an unseen resource, ongoing routine monitoring of groundwater levels and quality is also critical to effectively protect this important resource.

4.1 Occurrence and Significance

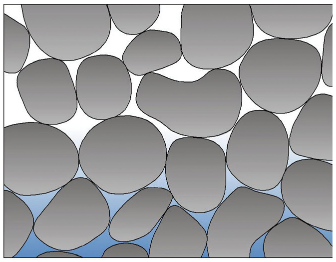
4.1.1 Occurrence

Groundwater is a key component of the hydrologic cycle depicted in Figure 1-17 (the fold-out graphic) and described in Chapter 1 – Introduction and Overview. Groundwater is the water beneath the surface of the land. In New Hampshire groundwater resides within bedrock fractures and between particles of soil, sediment, and loose rock that lie on top of bedrock. The upper boundary of an underground area that is completely filled with water is called the "water table." The depth to the water table varies based on geology, elevation, precipitation trends, and the season, but it is typically 10 to 20 feet below the land surface in New Hampshire .

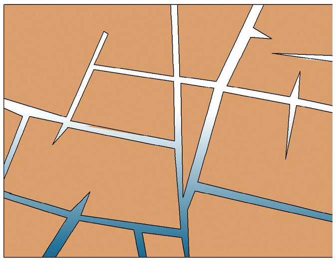
New Hampshire, the Granite State, is underlain with fractured crystalline bedrock. Groundwater is stored in and moves through these fractures as well as the unconsolidated material above the bedrock. This material was carried, deposited and shaped by glaciers that covered New Hampshire between 10 thousand and one million years ago.

The overburden material compressed beneath or carried within glaciers is called "glacial till." Glacial till consists of a mixture of materials ranging from clay to boulders and is often very dense. Due to their high density and mixture of particle sizes, these materials generally do not yield large quantities of water to wells. Glacial till underlies most of New Hampshire's landscape.

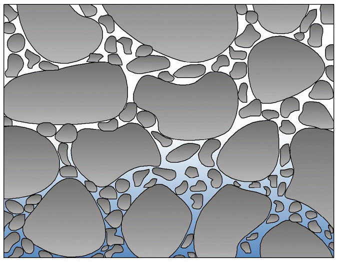
Some of the surficial materials left by the retreating glaciers were redistributed by glacial meltwater. These materials were transported away from the glacier ice front and deposited as "stratified drift" throughout the landscape. These deposits consist mainly of sand, silt, and gravel-sized particles. Depending on the velocity of the glacial meltwater, the stratified drift may contain very coarse materials such as gravel and cobbles. Saturated, coarser grain, stratified drift materials typically have a large percentage of pore space between the grains, which is very efficient at storing and transmitting ground water. Thus, saturated, stratified drift can yield large quantities of groundwater to wells. The thickness of stratified drift materials throughout the state is generally less than 100 feet. Stratified drift materials underlie approximately 14 percent of the state and are primarily located in lowlands and river valleys because glacial meltwater flowed through these topographic low areas (Medalie & Moore, 1995). Unsurprisingly, 79 percent of the high-capacity wells in New Hampshire are located in stratified-drift materials.



Well-sorted sedimentary material



Fractured crystalline rocks



Poorly sorted sedimentary material

Figure 4-1. Well-sorted sediments and highly-fractured bedrock store some of the most accessible groundwater. Areas with these types of subsurface sediments or bedrock are valuable for water that is more easily withdrawn through wells. *Source: Colorado Geological Survey [CGS], 2003.*

The crystalline bedrock, which can either be exposed or covered by till or stratified drift material, conveys groundwater within cracks (fractures) in the rock. Generally, a bedrock water supply well that is capable of supplying a single household can be developed anywhere in the state. Higher yielding bedrock wells also can be developed in most areas of the state, but identifying networks of fractures that can yield large quantities of water often requires the expertise of hydrogeologists and the use of sophisticated technology. Fractures that contain large quantities of groundwater are typically encountered within the first 400 feet of bedrock. Bedrock is often less fractured with increasing depth, but there are notable exceptions to this generalization.

An aquifer is an area of the subsurface that is water bearing. Accordingly, there are aquifers beneath virtually all of New Hampshire. The amount of space and the connection between spaces varies with the rock and soil type of the aquifer (Figure 4-1). This greatly influences how much water can be stored or withdrawn and the rate at which groundwater moves. The amount of water stored in the subsurface, ability of subsurface formations to transmit the flow of water, and the rate of groundwater recharge to the subsurface determine how much water a well in any aquifer can produce. Stratified drift aquifers left by the glaciers have been extensively mapped and categorized for their ability to transmit water, where as only a preliminary assessment of the more complex bedrock aquifers has occurred.

Groundwater, like all water, flows downhill as it is pulled by gravity. Groundwater can also move from areas of higher pressure to areas of lower pressure. As water moves through the overburden and rock fractures towards lower elevations it can interact with rivers, wetlands, lakes, estuaries or the ocean (see Figure 1-17, the fold-out graphic). Generally, groundwater discharges to surface waters in New Hampshire, although under certain conditions, surface waters seep into the ground and replenish groundwater (see figure 4-4).

Groundwater is primarily recharged by precipitation. Unless low impact development techniques are used, the amount of precipitation that enters the ground to replenish groundwater can be significantly reduced as impervious cover increases (see Chapter 1 – Introduction and Overview and Chapter 10 – Stormwater). Groundwater recharge can also be diminished if the groundwater withdrawn from an area for domestic purposes leaves the area where it is used via a sewer line versus being discharged on-site to a septic system.

Aquifers receive the majority of recharge in the spring when the snowpack melts and the growing season is just beginning. Significant recharge also occurs in the fall when the growing season has ended. Less recharge occurs in winter and summer. During the summer a greater portion of rainwater that reaches the soil is taken up by plant roots, just when withdrawals increase for outdoor irrigation. Given the nature and timing of recharge and water use, groundwater levels generally decline from late spring to early fall. Levels typically recover from late fall through early spring. On average, the annual recharge rate for most New Hampshire watersheds is about 14 to 30 inches per year based on a USGS study (Flynn & Tasker, 2004).

In summary, groundwater in New Hampshire occurs in bedrock fractures and the unconsolidated materials left by glaciers. Water beneath the ground in New Hampshire is stored at relatively shallow depths and is well connected to surface waters and the land surface. The nature of New Hampshire aquifers differs significantly from many other parts of the country where aquifers are more uniform and much deeper. Unlike these places, the amount of water that can be stored in New Hampshire as groundwater is limited naturally by the state's climate and geology. Land use change also alters the occurrence of groundwater in the state. More information about the occurrence of groundwater in the environment can be found in Chapter 12 – Floods and Droughts.

4.1.2 Quality

Groundwater quality is influenced by the bedrock and overburden material it moves through. It also can be greatly influenced by land use.

There are a variety of naturally occurring contaminants found in New Hampshire's groundwater. Chapter 8 – Drinking Water describes naturally occurring drinking water contaminants in detail. Briefly, there are contaminants such as iron and manganese that can be bothersome in terms of staining and taste, and there are contaminants that pose a health risk. Radon and arsenic, in particular, are commonly found in groundwater in certain areas of New Hampshire. Fluoride, beryllium, and other radionuclides are much less common but do occur naturally at levels of concern for human consumption in a few places.

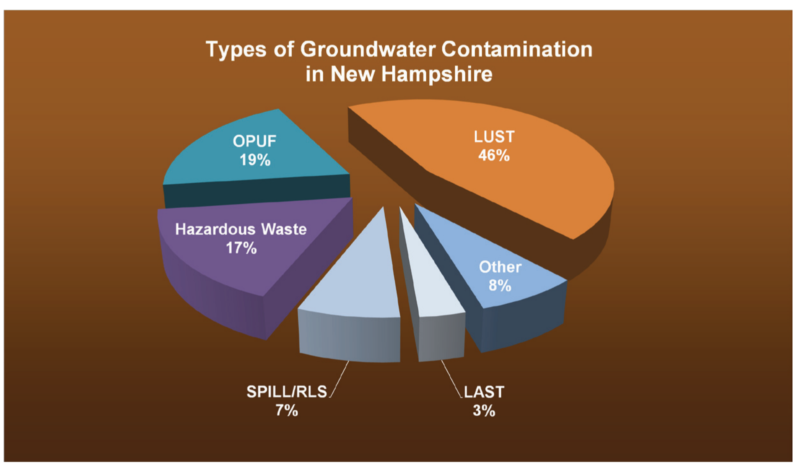


Figure 4-2. Types of manmade groundwater contamination sites that require remediation in New Hampshire. The leading causes of contamination are LUST (leaking underground storage tank) sites, followed by OPUF (on-premise heating oil tank) sites, hazardous waste sites, SPILL/RLS (oil spill or release) sites, other types of contamination, and LAST (aboveground bulk storage containing motor fuel) sites. *Source: NHDES, 2008b.*

Groundwater quality has also been affected in many locations by land use. According to the New Hampshire Department of Environmental Services Groundwater Hazard Inventory, there are currently 6,939 sites where contaminants have been released to the ground. Of those, 2,294 have or at some time had levels of contamination that required remediation (Figure 4-2) (NHDES, 2008b). These sites are cleaned up and managed in accordance with state and federal remediation programs and the rate of new contaminated site occurrence has slowed significantly with the regulation of certain land uses. At most of the sites, groundwater was contaminated with petroleum constituents, which leaked or were spilled at underground or above-ground storage tank sites. Landfills and old or failed septic systems are other common land uses that have caused groundwater contamination. In addition, road salt and fertilizer have degraded groundwater in some places. For the most part, groundwater contamination at levels of concern for human consumption is limited to localized areas near where the release occurred. A notable exception to this is road salt, which is not a significant drinking water concern but can be a significant concern for surface water ecology when it is carried by groundwater to lakes and rivers and wetlands.

4.1.3 Significance

According to the DES Drinking Water and Groundwater Bureau, 3,000 individual wells and springs are registered as active public water supply sources. Approximately 2,400 wells (or 80 percent) yield water from crystalline bedrock aquifers while the other 600 (20 percent) yield water from stratified-drift aquifers. Although fewer public supplies draw water from stratified-drift aquifers, they tend to yield a higher quantity of water than wells withdrawing from bedrock aquifers (Medalie & Moore, 1995).

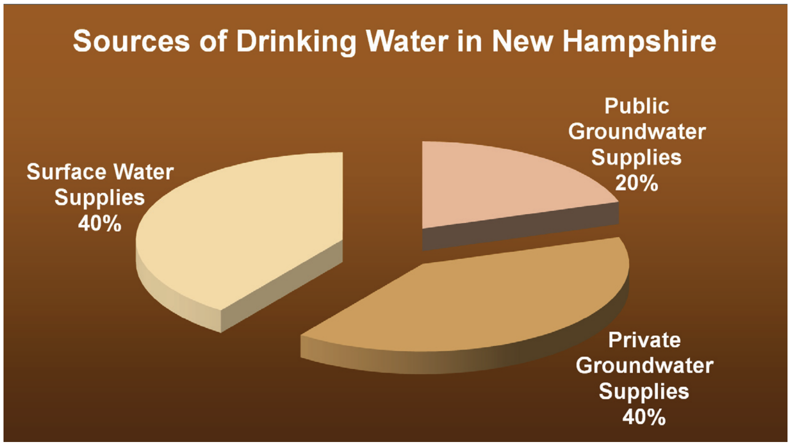


Figure 4-3. Groundwater is the main source of water for approximately 60 percent of New Hampshire's population. *Source: NHDES, 2007a.*

Approximately 60 percent of New Hampshire's population relies on groundwater for their drinking water supply (NHDES, 2007). While there has not been a study of the economic value of groundwater as a drinking water supply, there is a study that estimates the drinking water value of surface water at $151 million (Shapiro & Kroll, 2003). Because surface waters supply only 40 percent of New Hampshire's population with drinking water (Figure 4-3), the amount of groundwater used for drinking water should be in excess of this value. In addition to supplying drinking water, groundwater is also used for irrigation, aquaculture, thermoelectric cooling, and industrial processes. Geothermal wells are increasingly installed to provide heating and cooling for homes and commercial buildings.

Dependence on groundwater is not isolated to humans. Aquifers naturally supply water to streams and ponds where groundwater seeps through the banks and beds of surface water bodies. While most surface water bodies receive much of their water from other surface waters, e.g., streams that feed lakes and rivers, some depend solely on groundwater, e.g., kettle hole ponds. The water in many streams during dry-weather periods is from groundwater. This groundwater derived flow, called base flow, is critical to the sustenance of aquatic habitats as it provides stream flow during dry conditions. Because the average temperature of groundwater in New Hampshire is 55° F, some aquatic organisms, such as trout, depend on base flow to maintain the low water temperatures that can be essential for survival.

4.2 Issues

4.2.1 Groundwater – Unseen and Not Well Understood by Many

Because rivers, lakes, wetlands, and the coast are visible and provide recreation and scenic value, many people in New Hampshire recognize the benefits these surface waters hold for the economy and their own quality of life. However, they do not experience groundwater as directly as they might experience a stream or lake. For example, they may not recognize the significant role that groundwater plays in wetland, stream, and lake ecosystems through base flow (Figure 4-4). In the eyes of someone unaware of this role, it is more likely that the surface water effects of groundwater depletion will be perceived as an intrinsic problem with surface water, rather than associated with groundwater. Because of the invisibility of groundwater in the everyday experiences of New Hampshire residents, effective public education to raise awareness of the significance and issues affecting groundwater is needed.

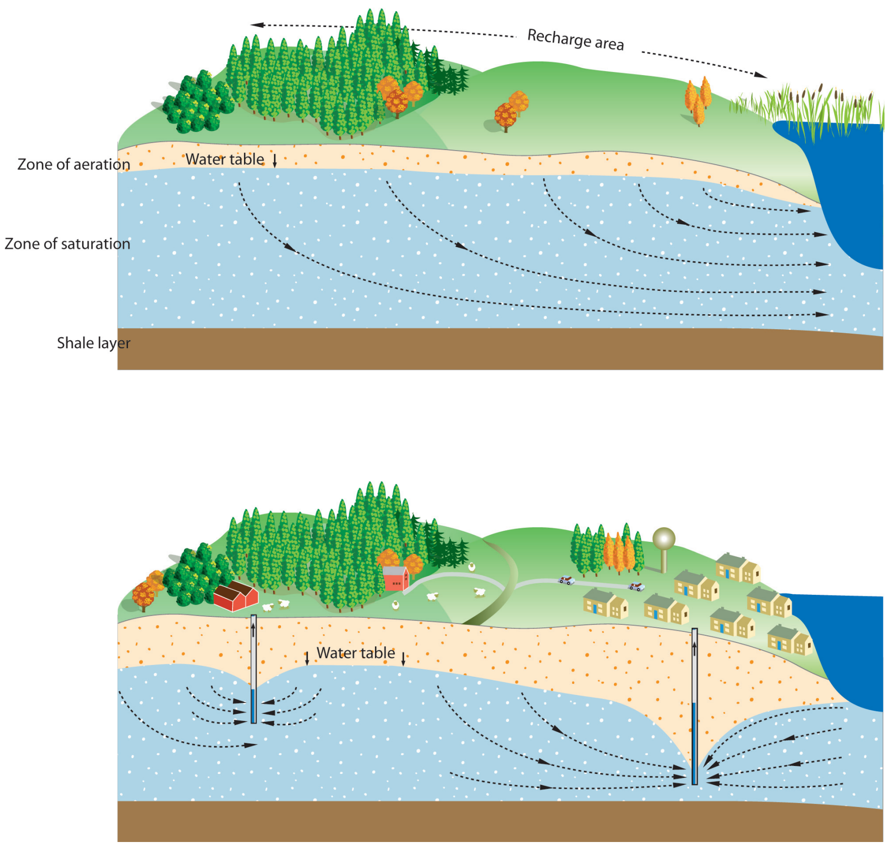


Figure 4-4. Wells withdrawing large volumes of water can have detrimental effects by depleting both groundwater and nearby surface waters. In this case, the well reverses the direction of base flow, in effect drying up local streams and possibly pulling surface water contaminants closer to the well. ***Source: Ground Water Protection Council, 2007; Artwork by Poshen Wang.***

4.2.2 Landscape Change Affects Both Groundwater Quantity and Quality

Effect on Quantity

Land use changes pose some of New Hampshire's biggest challenges to groundwater management and protection. Increased development may be affecting long-term groundwater availability by preventing or reducing recharge after precipitation events. This is explained in detail in Chapter 1 – Introduction and Overview and Chapter 10 – Stormwater. Briefly, when land is developed, forest and farmland are converted to buildings, roads, parking lots and lawns. For each acre of impervious area that drains directly to surface water, approximately 250,000-550,000 gallons per year of recharge is lost. Impervious surfaces displace more groundwater than groundwater withdrawals in some areas of the state. Moderate to high rates of land conversion are now found throughout the southeastern third, if not half, of New Hampshire (Society for the Protection of New Hampshire Forests, 2005). Groundwater recharge could be significantly reduced if stormwater management is not designed properly in developing areas.

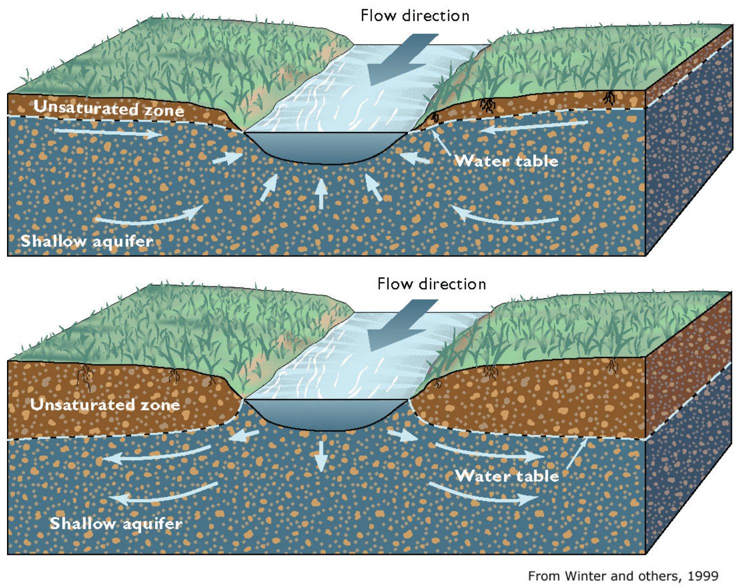


Figure 4-5. Groundwater is essential to providing water for the surface flows in streams and rivers through baseflow. If the water table (groundwater level) is lower than the surface water elevation, streams lose water to the ground. ***Source: CGS, 2003; Winter et al., 1998.***

The reduction in groundwater infiltration has had its greatest impact on shallow aquifers without large storage capacities. Wells drawing water from these aquifers rely heavily on infiltration and recharge to maintain sustainable yields. When impervious surfaces impact these shallow wells, they also can cause damage to surface waters that depend on base flow. Excessively low groundwater levels can reverse flow away from surface waters, in effect draining streams, ponds, and wetlands as gravity pulls water towards the voids left by depleted groundwater (Figure 4-5).

Effect on Quality and Well Siting

As previously described, many land uses have caused groundwater contamination, the most common include leaking underground storage tanks, mishandling of industrial solvents, and storage and use of road salt (NHDES, 2007a). In addition to impacting groundwater quality, some contaminants, including road salt and nutrients from fertilizers and septic systems, have been carried by groundwater into surface water and impaired water quality. An emerging concern is the presence of trace amounts of pharmaceuticals and personal care products originating from septic systems.

A significant number of potentially good well sites cannot be tapped because of encroaching development.

Surprisingly, relatively common land uses may be responsible for the loss of more future well sites than the land uses already mentioned. This is because stratified drift aquifers, where water can be extracted with the least chance of arsenic and radon, tend to be located in some of the most developed areas of the state where little space is left for potential future well sites. Because stratified-drift aquifers tend to

Figure 4-6. Although there are many high-yield, stratified-drift aquifers in New Hampshire, several factors can severely limit the actual areas of the aquifer that can be used for water supply. The above figures show loss of the Henniker Aquifer in New Hampshire due to low transmissivity (ease of water withdrawal), built roads, and necessary buffers for surface waters and potential contamination sites. ***Source: Lough & Congalton, 2005.***

occur with rivers and flat land, they are often near a relatively high concentration of roads, villages and other development. Accordingly, the risk of groundwater quality impairment in these areas compromises their suitability as municipal well sites.

The extent to which land development drastically reduces the availability of future well sites was revealed by a statewide study published in 2005 (Lough and Congalton, 2005). The study included an analysis of constraints to the construction of new, large municipal wells (pumping 75 gallons or greater per minute) in New Hampshire's stratified-drift aquifers. Areas with restrictions or limitations to well construction, i.e., developed sites, potential contamination sources, limited yield, etc., were mapped within the state's high yield aquifers (Figure 4-6).

New community wells must be located at least 150 to 400 feet (depending on the yield of the well) from existing development. As a consequence, nearly two-thirds of the 328 square miles of high-yield stratified-drift aquifers in New Hampshire that have the potential to support wells yielding 75 gallons per minute or more are already unavailable as future well sites; not because of ownership, but because of nearby development. Predictably, the situation is worse in areas where water demand is likely to grow the most. Figure 4-7 shows the location of existing high-yield stratified-drift wells and all 1,245 square miles of New Hamsphire's stratified-drift aquifers (Lough & Congalton, 2005).

4.2.3 Data Limits Groundwater Protection Efforts

Key data needed to understand and effectively manage the groundwater resource include a robust groundwater level monitoring network, sufficient stream flow gaging, and a water quality network to identify areas of man-made and naturally occurring contamination. Some limited data is available but more is needed if we are going to be able to understand and address issues related to groundwater withdrawals, reduced recharge associated with landscape change and climate change (see Chapter 1 – Introduction and Overview), and impaired groundwater flowing to wells and surface waters.

The following describes important information the state currently has about the groundwater resource and identifies the current limitations.

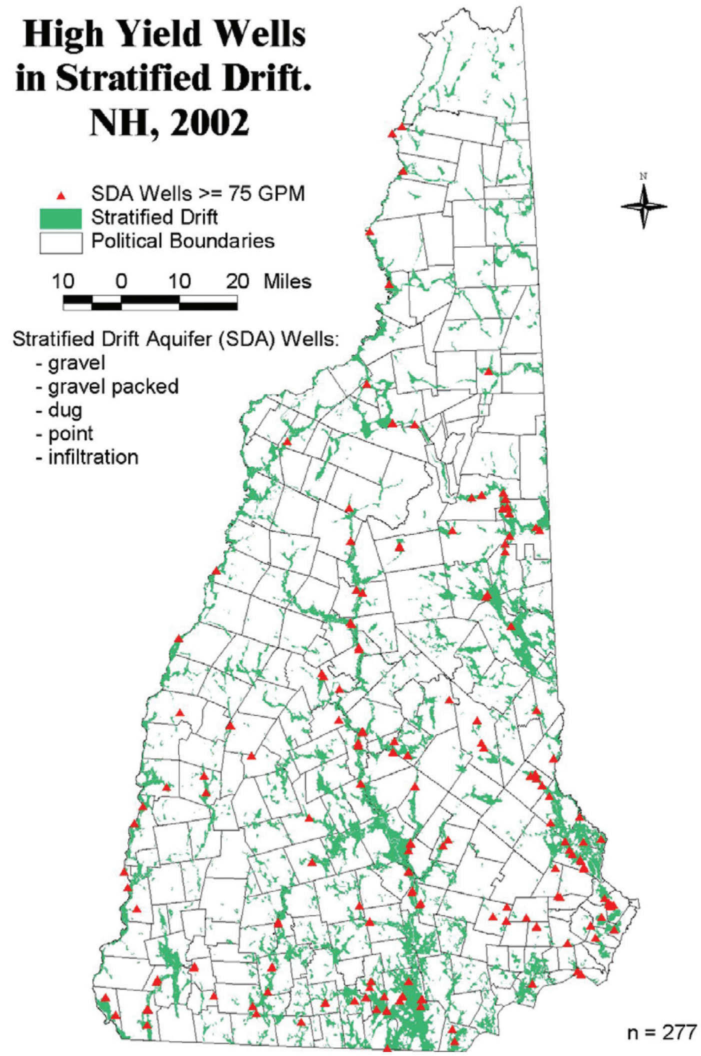


Figure 4-7. New Hampshire's stratified-drift aquifers provide water supplies scattered all over the state. Locations where high-yield wells can be installed, however, are limited. *Source: Lough & Congalton, 2005.*

Groundwater and Stream Flow Monitoring

The monitoring of statewide groundwater levels currently relies on a network of 25 observation wells located at 22 sites throughout the state. Groundwater levels are measured every month on a year-round basis by staff from the New Hampshire Geological Survey at DES. Each well serves as an indicator of regional hydrologic conditions, registering changes in the amount of water stored in the aquifer it represents. If this network were expanded to include more aquifer types throughout the state, it could be used to compare conditions today with those existing at some time in the past or to predict future conditions, helping to inform management decisions. A modest expansion to monitor bedrock at existing sites is underway. In 2007 DES also began groundwater level monitoring at Hubbard Brook Experimental Forest, where numerous other hydrological and environmental indicator data are also being collected as part of the U.S. Forest Service research initiative. In addition to groundwater levels, more stream gaging is necessary to understand the interconnection between groundwater and surface water. In particular, the effect of changes in groundwater levels on the amount of baseflow to small streams is hard to predict since most measured surface water flow data have been collected on rivers that have large, i.e., greater than 50 square miles, drainage areas (see also Chapter 2 – Rivers).

Water Well Board and Well Completion Reports

In 1984 the state of New Hampshire established the Water Well Board and began licensing water well contractors and water well pump installers and requiring the submission of a well completion report for every new water supply well constructed. The well completion reports include information on the total depth of the well, the depth to bedrock, the static water level, and the measured yield. Well records are important for mapping the geology of the state, defining aquifers, and determining the distribution of well yields. They also help well owners with making repairs or improvements to wells. Recently, more accurate data on well location, use, and geologic conditions are required, which will improve the utility of the well information.

Water Quality Data

A great deal of water quality information is currently collected for public water systems under the federal Safe Drinking Water Act. For systems using untreated water from wells, this provides groundwater quality information. Although there is no clear federal or state jurisdiction over testing of private wells, DES has developed a recommended testing schedule for homeowners and many homeowners turn to DES and commercial laboratories for analysis of samples from private wells. While the private well data resulting from these tests are confidential, regional summaries of these data, together with public water supply water quality data, can help scientists understand the condition of New Hampshire's groundwater. Similarly, data collected at waste sites statewide could be mined to provide information on groundwater in some areas of the state.

4.3 Current Management and Protection

Groundwater is a valuable resource for drinking water supply, so some of the relevant regulations and management efforts are outlined in Chapter 7 – Water Use and Conservation and Chapter 8 – Drinking Water. There are also siting criteria for many types of potential contamination sources that are regulated at the local and state levels. Only a few of the most direct programs for groundwater protection are described below.

4.3.1 Quality-Based Regulations and Programs

Source Water Protection Program

The Drinking Water Source Protection Program provides regulatory and non-regulatory tools to protect groundwater and both new and existing sources of public drinking water. The program, within DES's Drinking Water and Groundwater Bureau, provides technical and financial assistance, training, and guidance materials to water suppliers, municipalities, and others regarding all aspects of preventing groundwater contamination. The SWP Program is revising its Source Water Protection Strategy in cooperation with the SB 155 Groundwater Commission and other stakeholders, and plans to have the new strategy complete by spring 2009.

Municipal Groundwater Protection Ordinances

Recognizing that some groundwater resources are highly vulnerable to contamination, or of very high value, or both, and that state siting restrictions for certain high-risk land uses are not sufficient by themselves to protect these resources, many New Hampshire municipalities have adopted groundwater protection ordinances. Most of these ordinances involve land use restrictions over high-yielding stratified-drift aquifers, and have been adopted since the state's aquifers were first mapped in the 1970s and 1980s. Many have been revised over time to reflect more current stratified drift aquifer maps. At least 75 New Hampshire municipalities now have groundwater protection ordinances, 70 of which restrict land uses to protect stratified-drift aquifers, public water supply wells, or both. DES and the New Hampshire Office of Energy and Planning have collaborated on a model groundwater protection ordinance, which has been adopted by approximately 21 of those municipalities (NHDES & NHOEP, 2006).

Groundwater Discharge Permitting and Registration Program

The DES Groundwater Discharge Permitting and Registration Program promotes proper treatment and disposal of wastewater onto or into the ground and implements federal regulations pertaining to underground disposal of non-hazardous fluids other than domestic wastewater, i.e., Class V underground injection wells under the federal Safe Drinking Water Act. The purpose of the program is to prevent and eliminate groundwater contamination that is caused by the improper disposal of waste and wastewater containing solvents, petroleum products, and other industrial and commercial wastes. Any discharge of non-domestic wastewater containing regulated substances requires a groundwater discharge permit and the best available treatment technology, and must meet ambient groundwater quality standards at the boundary of the groundwater discharge zone. Any discharge of domestic wastewater that exceeds 20,000 gallons per day requires a groundwater discharge permit. A discharge of a non-domestic wastewater that does not contain a regulated substance must be registered.

Groundwater Remediation Programs

There are a number of state and federal programs that require the cleanup or containment of contaminated groundwater. These include the Superfund, Leaking Underground Storage Tanks, and Hazardous Waste Cleanup programs. These programs aim to return impaired groundwater to a clean and usable condition.

4.3.2 Quantity-Based Regulations and Programs

Large Groundwater Withdrawal Permitting

In 1998 two state laws, the Groundwater Protection Act and the Safe Drinking Water Act, were amended to ensure that undesirable impacts to water users and water resources from new large groundwater withdrawals are identified and addressed. Any groundwater withdrawal from a new well having a maximum withdrawal of 57,600 gallons or more over any 24-hour period is considered to be a large groundwater withdrawal. New large groundwater withdrawals undergo a comprehensive analysis and testing program in order to study the possible impacts of the withdrawal. New large withdrawals cannot be approved unless it is demonstrated that no unmitigated adverse impacts will occur.

Rewrite of the Alteration of Terrain Rules

The new Alteration of Terrain rules (effective January 1, 2009) represent an important shift in policy for stormwater management at new medium and large developments. While engineered stormwater infiltration structures are discouraged under the old rules, the new rules require infiltration of a prescribed volume of stormwater. This will help to achieve better treatment and minimize alterations to the natural hydrology. The rules also include requirements for well setbacks, stormwater pretreatment, and prohibitions on infiltrating stormwater from certain sites to help avoid the possible contamination of groundwater.

Groundwater Commission

The Groundwater Commission was created in 2003, pursuant to Senate Bill 155, in response to concerns regarding New Hampshire's laws and regulations for groundwater withdrawals. The commission has been extended twice with a current expiration date of 2010. It is comprised of 21 stakeholders including legislators, regulators, water users, environmental advocates and citizens. The purpose of the commission is to find ways to clarify the hierarchy of water uses, bring a balanced approach to water use amongst various sectors (residential, public, industrial, commercial, agricultural, energy, recreational), and improve the current process for the reasonable and efficient use of new water sources (Figure 4-8). The commission's work and accomplishments are summarized each year in an annual report (Commission to Study Issues Relative to Groundwater Withdrawals, 2007).

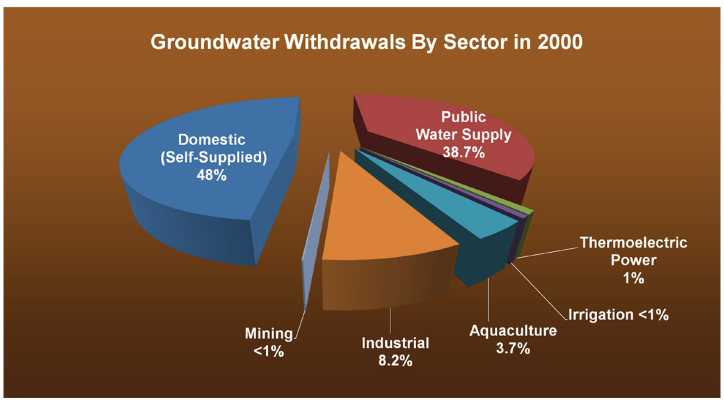


Figure 4-8. While domestic and public water supplies are the most common uses of groundwater, wells withdraw water for several other purposes in New Hampshire. *Source Data: Hutson et al., 2004.*

Expanded Groundwater Level Monitoring Initiative

Work is currently underway to develop a bedrock aquifer monitoring network. At present, only one of the wells in the state's limited groundwater level monitoring network monitors groundwater conditions in bedrock (Figure 4-9). Resources have been obtained to expand this to 10 wells. Wells in the Seacoast Region will be especially important for monitoring the level of salt water near inland aquifers. Maintaining a long-term water level monitoring network will require dedicated funding sources. Options for funding sources are currently being identified and assessed by the Groundwater Commission.

Seacoast Groundwater Availability Assessment

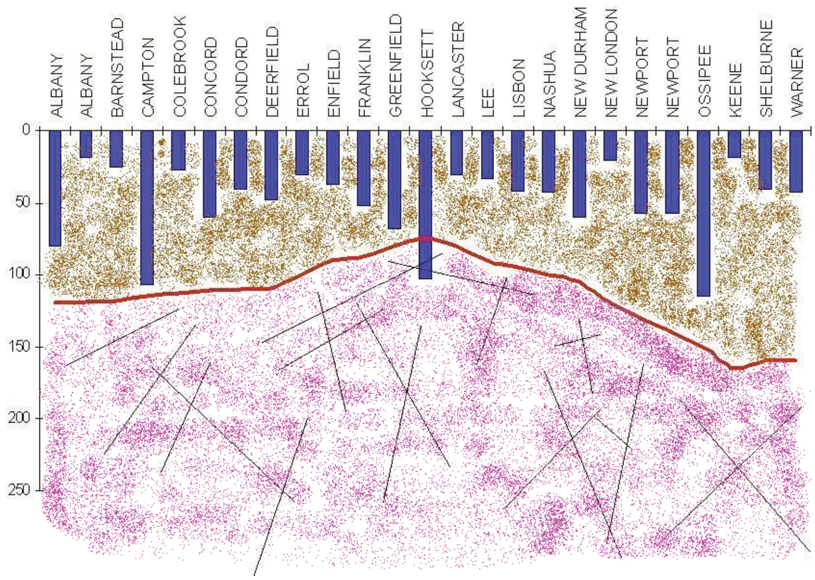


Figure 4-9. Only one of the 22 wells in the state's groundwater level monitoring network is a bedrock well. ***Source: Modified from Wunsch, 2006.***

Concerns about landscape development driven by economic and population growth in the Seacoast Region of the state and increasing reliance on groundwater withdrawals spurred an intense study on water use and the hydrogeology of the Seacoast Region. The study included the development of the following information for 42 seacoast communities (NHDES, 2008a).

- Updated seamless map of the surficial geology that can be used to assist in refining the location of aquifers.
- Estimate of water use for 2003 and projected water use (withdrawals, transfers, and discharges) for 2017 and 2025.
- A database linked to a Geographic Information System that provides records of wells and soil borings that have been installed in the region over the last several decades. This information can be used to provide information such as depth to bedrock, aquifer properties, and water level information to support projects and studies throughout the region.
- A map showing potential high and low recharge areas that can be used with supplemental data to assist with ensuring groundwater recharge is preserved as land development and land conservation decisions are made.

As part of the project, a groundwater model is being developed for the area of the Seacoast surrounding Great Bay and adjacent to the ocean. The model will assesses various scenarios including the impacts of climate change, increased groundwater withdrawals, establishment of more impervious surfaces and various wastewater disposal management options. The impacts to river flow, groundwater elevations and the salt water/freshwater interface will all be assessed as part of the model.

Artificial Recharge Guidance

Where existing sources are inadequate to meet growing demand or where yields are limited due to reduced recharge, artificial recharge is likely to be viewed as an option to increase or maintain well yield. The town of Newmarket, for example, recently completed the permitting process that will enable the town to discharge raw river water on the land surface to recharge the Newmarket Plains aquifer. The city of Dover has used a similar artificial recharge system to supplement its water supply for 20 years. In Dover, during the months between November and May when the river water levels are at their highest, water is pumped to a gravel pit and the water then infiltrates into the aquifer, increasing the available storage for use in the high demand summer months. Prompted by the Newmarket proposal, DES has developed guidance documents for artificially recharging aquifers and for discharging treated wastewater to land surfaces for infiltration or irrigation purposes (NHDES, 2006; NHDES 2007b). While artificial recharge projects are driven by quantity concerns, DES's review of such projects typically focuses on groundwater quality concerns.

4.4 Stakeholder Recommendations

This section contains key recommendations that have been developed in concert with a group of volunteer stakeholders that have reviewed and contributed to this chapter.

4.4.1 Improved Monitoring to Support Protection

In order to understand the impacts of land use change, water withdrawals, and climate change, more data on both groundwater levels and surface water resources are needed. Recent studies such as the seacoast groundwater availability assessment and the in-stream flow studies for the Lamprey and Souhegan rivers (see Chapter 2 - Rivers and Streams, Section 2.3.4) have helped set a stage for sustainable management, but such studies are expensive and limited in their geographic scope. As undeveloped groundwater resources available for water supply become increasingly scarce, this information will be crucial for planning in the future. Although groundwater is the supporting base for many surface water resources, its lack of visibility makes trends impossible to perceive without a more consistent and extensive monitoring network. More water level monitoring is required statewide in order to determine historical and current trends and to project changes in the future. Associating the effects of land use, water use, and altered hydrology with certain changes evident in groundwater or the intrinsically linked surface waters will help us predict and avoid future, detrimental impacts to New Hampshire's water resources.

4.4.2 Increased Municipal Land Use Controls to Protect Groundwater Quality and Quantity

Land use decisions, which are largely under the control of local planning and zoning boards, are critical in either protecting groundwater or placing it at risk for contamination or depletion. The protection of groundwater resources, therefore, depends on the ability of planning and zoning boards to make well-informed decisions that balance groundwater protection goals with other local goals such as economic development. In some areas, regional approaches involving multiple communities may be the best option for effective groundwater protection.

Simply restricting development is not always the most feasible or advantageous solution because of existing land uses, competing economic development goals, or other community goals that are inconsistent with stringent land use restrictions. Local land use boards need to consider the full range of approaches to protecting groundwater, from land conservation and land use restrictions (zoning) to better site and facility design and management. Consideration of low impact development techniques explained in Chapter 10 – Stormwater is also needed.

The tension between groundwater protection and economic development goals is particularly acute, for example, where transportation corridors or valuable sand and gravel deposits coincide with valley-bottom stratified-drift aquifer deposits. In such situations, local land use boards need access to expert assistance in order to understand the resources at risk, the nature of the hazards posed by certain land uses, and the range of approaches available to address those hazards. Only then can communities responsibly weigh resource protection alternatives against other community needs.

While the needed expertise and training are available from DES, regional planning commissions, and consultants, the available resources fall short in some respects. For example, while wellhead protection areas and stratified-drift aquifers have been mapped statewide, the accuracy of the mapping is not sufficient in many areas for communities to use on a stand-alone basis to define areas subject to land use restrictions. An increasing number of communities recognize the need to refine this mapping, but the resources are not available on either the local or state level to conduct the required work. While municipalities have the ability to incorporate provisions in their ordinances to shift the costs of such work to development proponents, they are often reluctant to do so.

At the same time, the effectiveness of groundwater protection measures enacted in some communities is compromised when they are not consistently applied, such as when local zoning boards grant variances to land use restrictions. While the solution to this problem is not quite clear, municipalities would probably do well to ensure that their groundwater protection programs are carefully crafted, frequently reviewed and updated, consistently applied, and well understood by officials as well as the public.

4.4.3 Increased Public Education and Awareness

Increased public education and awareness regarding groundwater is needed in several areas. First, improved public awareness of groundwater would enable citizens to make better informed decisions regarding the protection and management of groundwater on the community level.

Second, improved awareness would enable residents to make more responsible decisions regarding their own use and handling of hazardous substances and other potential pollutants. This would help ensure proper storage, use, and disposal of household chemicals and other pollutants with the potential to contaminate groundwater.

Finally, because the quality of water supplied by private wells is not monitored or regulated by state programs and few municipalities require testing prior to occupancy or real estate transfer, the responsibility for testing and monitoring lies solely in the hands of the water user. Improved awareness of private well issues would enable private well users to make better informed decisions about testing and treating their water supply.

Hazardous Materials in the Home

Gasoline
Motor Oil
Other Automotive Fluids
Auto Batteries
Paint
Paint Thinner
Other Solvents
Pesticides
Cleaning Products
Herbicides

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