

Chapter 3: Groundwater

Goals

Students will understand:

1. The concept of groundwater and aquifers
2. The importance of the Ossipee Aquifer
3. Important local drinking water issues

Background Information

Groundwater makes up about 98% of all the usable fresh water on Earth and is about 60 times as plentiful as fresh water found in lakes and streams. Across the United States, groundwater is the source of drinking water for at least half of the population. In rural areas, this value can be much higher with almost all residents depending on private wells for drinking water. Hidden below the land surface, groundwater is often undervalued or overlooked as an important water resource. However understanding the importance of groundwater both globally and locally and fostering a sense of stewardship for this limited resource will help ensure its protection.

Groundwater

When precipitation falls to the Earth as part of the water cycle, some of it flows along the land surface to streams and lakes, some of it is used by plants, some evaporates and returns to the atmosphere, and some sinks into the ground. Water that seeps into the ground slowly percolates downward due to the forces of gravity and passes through spaces between soil particles until it reaches the water table (Figure 1). From the land surface to the water table is the **unsaturated zone**. The speed at which water

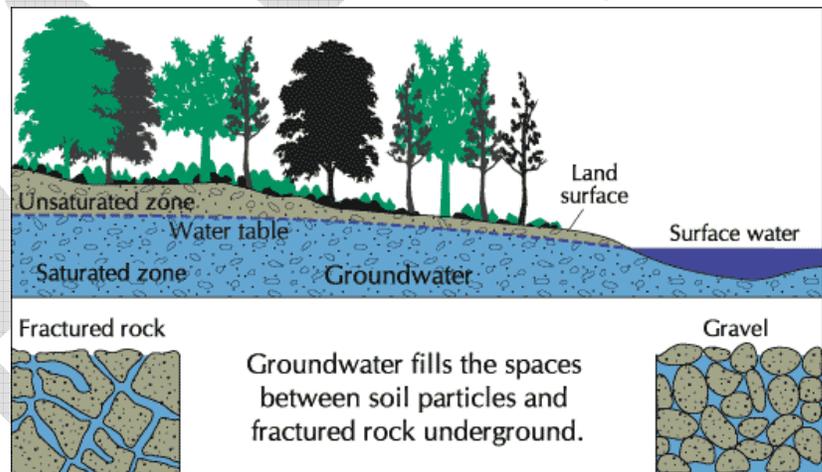


Figure 1. Groundwater diagram (<http://www.who.edu/seagrant/research/ecp/0406.html>).

percolates through the unsaturated zone is dependent on the size and shape of the soil particles, the amount of pore space between the particles, and whether or not the pore spaces are connected. For example, soils that consist primarily of larger sand and gravel particles tend to have larger, interconnected pore spaces that allow water to flow easily and relatively quickly. In contrast, some soils, such as silts and clays, have poorly connected pore spaces and water tends to flow slower.

Below the water table the soil is **saturated**, meaning that all the spaces between the soil particles are filled with water. The top of this saturated zone is the **water table**. The water table may be shallow, which is often the case when it is next to a stream or lake, or deep and may rise or fall depending on many factors (Figure 1, Figure 2). Heavy rains or melting snow may cause the water table to rise, or heavy pumping of groundwater supplies may cause the water table to fall. While water in the unsaturated zone is considered soil moisture, once it reaches the saturated zone it is considered

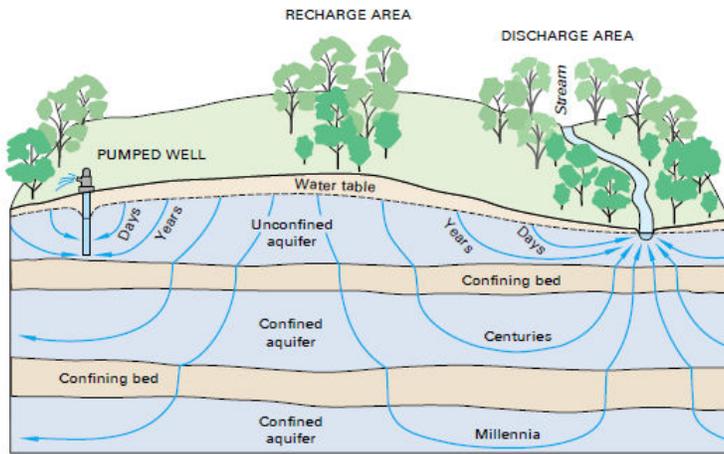


Figure 2. Diagram of groundwater flow patterns, recharge and discharge areas, and confined and unconfined aquifers (Winter 1998).

groundwater. **Groundwater** is the water found below the water table in the saturated zone, where all the spaces between the grains of gravel, sand, silt, clay and cracks within rocks are completely filled with water. Ultimately, it is precipitation that recharges the groundwater supply. The entire land area that contributes precipitation to a groundwater resource is called a **recharge area** (Figure 2).

Watersheds are often divided into primary, secondary, and tertiary aquifer recharge areas. **Primary recharge areas** exist where aquifer materials are exposed at the land surface and where surface

water and runoff directly infiltrate the ground and recharge the aquifer (Figure 3). **Secondary recharge areas** are zones adjacent to the aquifer where surface water and groundwater flow into primary recharge areas (Figure 3). **Tertiary recharge areas** include the rest of the watershed and supply water to streams that flow into primary recharge areas and may or may not recharge the aquifer depending on water levels.

When water reaches the water table and becomes groundwater, it begins to move along with groundwater flow, which tends to follow a downhill or down slope direction. Compared with water in rivers and streams, groundwater moves very slowly, from as little as a couple inches per day in clay to as much as 3-4 feet per day in sand and gravel. Groundwater naturally resurfaces when it intersects with a nearby stream or lake or when it emerges from a hillside as a spring. These places are referred to as **discharge areas**. Drinking water wells are also discharge points and a major pathway that groundwater travels to get back to the land surface. During dry periods, groundwater can recharge streams, rivers, and lakes.

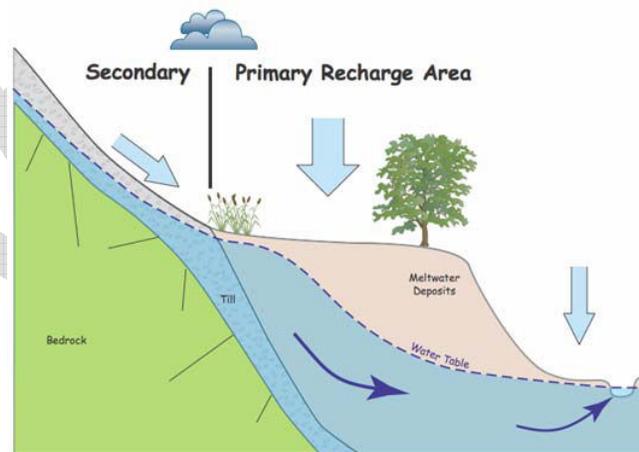


Figure 3. Primary and secondary recharge areas (GMCG 1997).

Aquifer

Within the saturated zone, groundwater flows between and within aquifers. An **aquifer** is a formation within the saturated zone that is capable of yielding significant quantities of water for human use through wells or springs (Figure 2, Figure 4). Groundwater is usually found in these formations, which are often an integral part of the surrounding watershed or basin. Groundwater is widespread, existing virtually everywhere, and therefore aquifers provide a useful spatial boundary for some of the more significant groundwater resources.

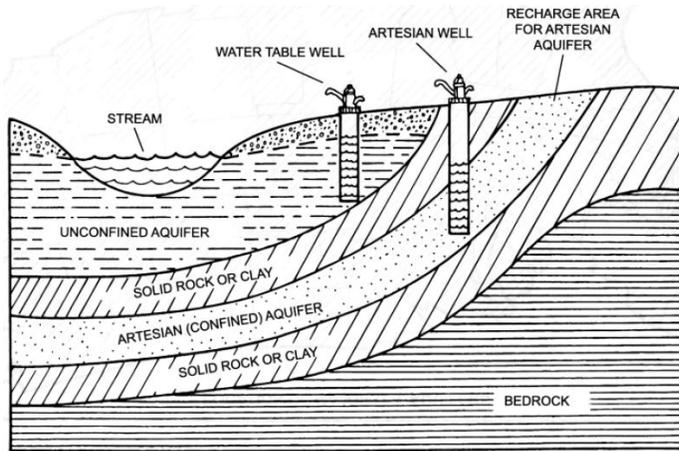


Figure 4. Diagram with an example of a water table well (unconfined aquifer) and an artesian (confined aquifer) well (EPA et al.).

Aquifers can exist in many different formations, but generally they are separated into two categories, confined and unconfined. **Unconfined aquifers** consist of permeable geologic formations, either solid rock or loose sediments that consist of sand, gravel, and clay. Unconfined aquifers may consist of rock debris transported by glaciers, deposited by streams, or deposited in lakes. These aquifers are also known as water table aquifers because they receive recharge directly from the infiltration of rainfall and surface water (Figure 2, Figure 4). Unconfined aquifers that contain well-sorted loose materials can store large quantities of groundwater and are great

sources of water for wells. The Ossipee Aquifer, a stratified drift aquifer, is an example of this type of unconfined aquifer. In contrast, **confined aquifers** are those that are covered by an impermeable or semi-permeable layer of rock, often referred to as a confining layer or bed (Figure 2). Confined aquifers are not directly recharged by precipitation, but will be recharged more slowly through fractures, small cracks, and pore spaces in the confining beds or through small unconfined regions (Figure 4).

Types of Wells

Wells are used to capture groundwater and pump it to the land surface for many purposes including for drinking water, agriculture, industry, etc. There are three main types of wells (dug, driven, and drilled) based on how the well is installed (Figure 5). **Dug wells** are holes in the ground dug by shovel or backhoe. Historically, a dug well was excavated below the water table until incoming water exceeded the digger's bailing rate. The well was then lined with stones, brick, tile, or other material to prevent collapse. It was covered with a cap of wood, stone, or concrete. Dug wells tend to be shallow, typically only 10-30 feet deep, and consequently are at the highest risk of becoming contaminated. While dug wells have been used as a source of residential drinking water for many years, most are remnants of older homes dug before drilling equipment was readily available or when drilling was considered too expensive.

Driven wells are constructed by driving a small diameter pipe into areas with thick sand and gravel deposits where the water table is within 15 feet of the land surface. A screened well point at the end of the pipe is attached before driving to help push the pipe through the soil and ultimately allows water to enter the well while at the same time filtering out sediment. Under appropriate geologic conditions, driven wells can be easy and relatively inexpensive to install and are still common and widely used. Although

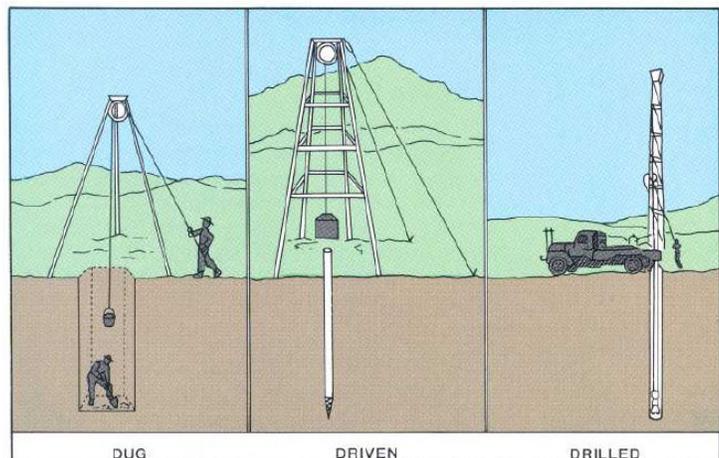


Figure 5. Types of wells (Waller 1994).

driven wells tend to be deeper than dug wells, typically 30-50 feet deep, they are still relatively shallow and are vulnerable to contamination from nearby land uses.

The most common type of well is the drilled well. **Drilled wells** use percussion or rotary drill machines to penetrate about 100-400 feet into the bedrock. In order to be a useful water supply, a drilled well must intersect bedrock fractures containing groundwater. Artesian wells are specific type of drilled well that penetrates a confined aquifer that is under sufficient pressure to raise water levels above the land surface (Figure 4). Because of this natural pressure, artesian wells do not require a pump.

Groundwater Pollution

Groundwater is recharged by precipitation; primarily rain and snow melt. In some areas of the world, people face water shortages because groundwater is used faster than it can be naturally replenished. In other areas, groundwater is susceptible to contamination from human activities on the land surface. In New England, the average depth to the water table ranges between 8-20 feet. Where the unsaturated zone is made up of materials that allow water to flow quickly, such as sand and gravel deposits, pollution from the land surface is a common concern. This is especially true when unconfined aquifers exist below this highly permeable material. Groundwater can be polluted by landfills, septic tanks, leaky underground storage tanks, overuse of fertilizers and pesticides, etc. (Figure 6). Any number of land uses can contaminate groundwater if hazardous materials leak, spill, or are carelessly discarded into and onto the soil. When it rains, water carries these pollutants with it as it percolates through the soil to recharge groundwater, consequently polluting the groundwater resource. The speed in which this

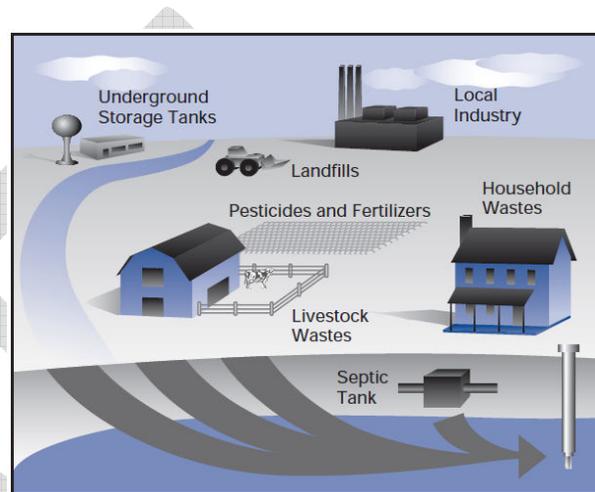


Figure 6. Land use activities that might potentially contaminate a drinking water well (EPA).

Cost of Contamination in Public Water Systems, Case Studies in NH

Water system	Contaminant	Cost of Clean-up
Seabrook, Well #1	VOCs*	\$500,000+
Merrimack Well #6	VOCs	\$1,000,000+
Milford Savage and Keyes Wells	VOCs	\$26,000,000
Peterborough South Well	VOCs	\$16,500,000+
Grantham Village School	Tolulene	\$4200/year
Londonderry South School	Nitrate	\$6700+
Belmont	VOC	\$5000/year
Barrington	VOC	\$45,000
Franklin	VOC	\$40,000

* VOC = Volatile Organic Compounds, typically petroleum or solvents.

Figure 7. This table shows the costs for some of the more serious groundwater contaminated public water systems in New Hampshire (SPNH 1998).

process occurs depends on soil type, the properties of the pollutant, and how often and how much precipitation occurs. If there is a well nearby, that well can then become contaminated with the polluted groundwater. In addition, because many rivers and streams are recharged at least partly by groundwater flow, nearby surface waters may also become contaminated. Once polluted, groundwater is no longer a safe source of drinking water and alternative sources of water will be needed until it

has been cleaned-up. Groundwater remediation is often a very difficult (in some cases impossible) and expensive process that should be avoided. In New Hampshire, clean-up costs for some of the more polluted public drinking water wells range from several thousands to millions of dollars (Figure 7). Limiting the potential sources of groundwater contamination through the use of best management practices is a more cost-effective strategy. **Best management practices (BMPs)** are methods that have been determined to be the most effective, practical means of preventing or reducing pollution.

Ossipee Aquifer

In addition to the many surface water features that exist in the Ossipee Watershed, this region also has a unique groundwater resource. Underlying approximately 22% of watershed, the Ossipee Aquifer is part of the largest and most productive stratified drift aquifer in New Hampshire (Figure 8). Primary, secondary, and tertiary recharge areas for the Ossipee Aquifer are shown in Figure 9. **Stratified drift** is a type of unconfined aquifer that is comprised of layers of sand and gravel deposited by glacial meltwater. Because of the way in which these materials were deposited and the large size of the sand and gravel particles, this aquifer has both a large storage capacity and rapid recharge rates, which allow precipitation or runoff from the land surface to quickly replenish groundwater. The characteristics that make the Ossipee Aquifer very productive also make it very vulnerable to pollution from the land surface. Consequently, land use practices in specific parts of the watershed have the potential to significantly impact the drinking water quality.

Although groundwater quality is generally good in New Hampshire, there are both natural and anthropogenic sources of contamination that are concern for drinking water. Common natural contaminants include iron, manganese, arsenic, and radon. While iron and manganese levels are monitored for aesthetic concerns, the Environmental Protection Agency (EPA) has identified **maximum contaminant levels (MCLs)** for arsenic and radon that are associated with human health risks. Water testing results from public and private wells have shown that drinking water wells that exceed MCLs for arsenic and radon are not uncommon and are more prevalent in bedrock wells. In regards to human influenced sources of pollution, water testing results have demonstrated and continue to demonstrate the increasing impact that land use practices are having on groundwater quality. Volatile organic compounds (VOCs), such as solvents and petroleum constituents, are detected in approximately 5% of groundwater samples. Many household products, including paints, varnishes, waxes, cleaners, disinfectants, and fuel and automotive products, contain VOCs or chemicals that form VOCs when added to water. Furthermore, used oil and gasoline in quantities less than one gallon can contaminate as much as a million gallons of groundwater. As potential carcinogens, VOCs are a significant human health concern. Consequently, the EPA has identified MCLs for 29 different VOCs.

Groundwater samples across New England also show increasing concentrations of sodium and chloride, most likely from road salt application. The potential influence that human actions have on degrading drinking water will only continue to increase with population growth and development pressures. Therefore, it is important to make sure that land use activities limit the amount of pollution that could potentially get into drinking water supplies through the use of BMPs. This is especially important in primary recharge areas where precipitation, which can include pollution from the land surface, is directly replenishing drinking water supplies (Figure 9).

Ossipee Aquifer

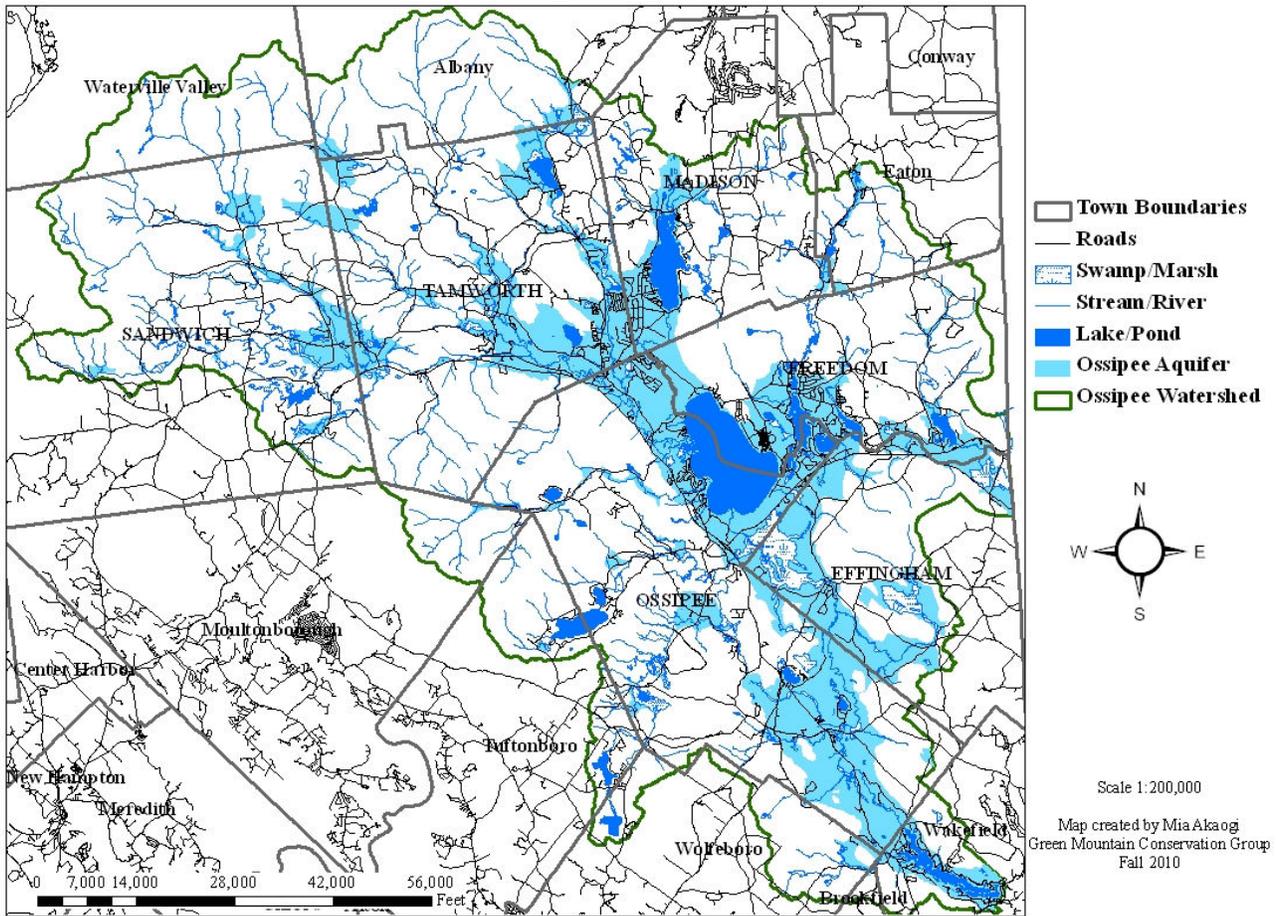


Figure 8. Map of the Ossipee Watershed with the Ossipee Aquifer in light blue.

Ossipee Aquifer Recharge Areas

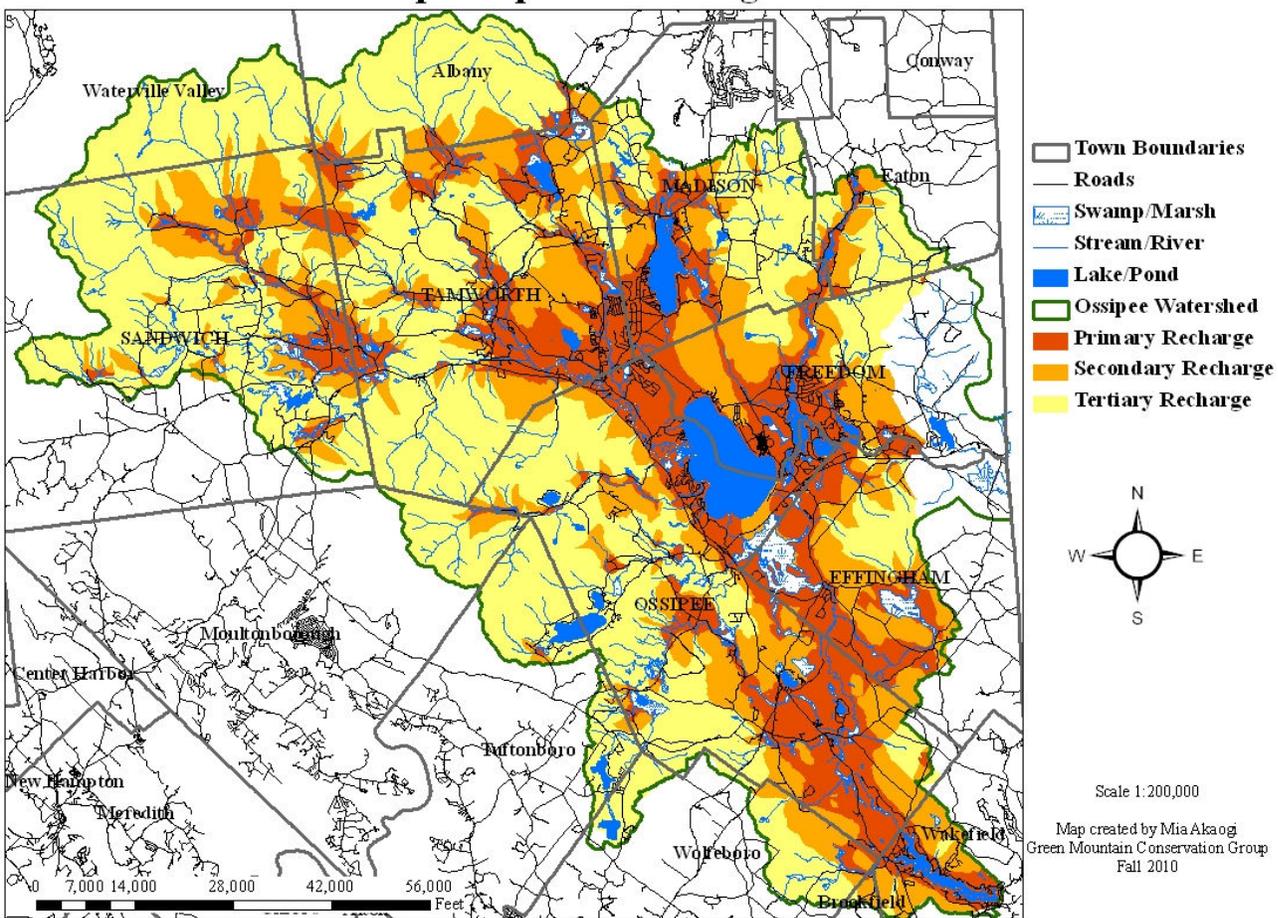


Figure 9. Map of the Ossipee Aquifer with primary, secondary, and tertiary recharge areas.

Indoor Activity

Groundwater Education Through Water Evaluation & Testing (GET WET!)

New Hampshire State Science Standards

- To be completed

Source: Theresa Thornton, GET WET! Executive Director, Senator George J. Mitchell Center for Environmental and Watershed Research, University of Maine.

Summary: GET WET! works with local students and the community to create a long-term groundwater quality database for towns where there is shared use of groundwater resources.

Objectives: Students will develop: 1) an understanding of groundwater concepts, 2) comprehension of the importance of testing well water for nitrates, pH, chloride, conductivity, iron, and hardness, 3) laboratory skills, 4) data analysis and graphing skills using Excel, 5) an ability to interpret Ossipee Watershed maps, 6) internet research capabilities, 7) public presentation skills, and 8) and understanding why conservation and commitment to a healthy environment takes an entire community.

Estimated Time: approximately 4-5, 1 hour class periods

Part I: Introduction to groundwater issues

In Part I of GET WET! students will get an introduction to groundwater, the Ossipee Watershed, local groundwater issues, and the 6 parameters that will be the focus of well water testing.

Materials:

- GET WET! Pre-visit PowerPoint (Workbook CD)
- Ossipee Watershed map with aquifer (available at GMCG office and Workbook CD).
- Appendix A: Description of the 6 parameters (chloride, conductivity, hardness, iron, nitrate, and pH)
- A copy of the Letter, Sampling Procedure, and Private Well Information Sheet for each student (Workbook CD).
- Optional: “Aquifer in a Cup” activity (GET WET! curriculum on Workbook CD or <http://www.groundwater.org/kc/activity2.html>)

Directions:

1. Using information available in the Background Information section of this chapter and the GET WET! PowerPoint presentation, give an introduction to groundwater and the Ossipee Aquifer. The “Aquifer in a Cup” activity can be used to introduce the concepts of groundwater and aquifers.
2. Also provide an introduction to the six parameters that will be a part of well water testing day. An explanation of each parameter is provided in Appendix A.

Optional Extension: Have students divide into 6 groups, each group researching a different parameter. Use worksheet on page 3-7 of Student Workbook. Have students display this information on a poster and present back to the class before well water testing day. If you have a

large class, have other groups research parameters not tested through GET WET! (e.g. lead, bacteria, radon, arsenic, volatile organics, fluoride).

3. Send students home with a 500mL sample bottle and Letter, Sampling Procedure, and Private Well Information Sheet. Give them a deadline for returning full sample bottles (needs to be before water testing day).

Associated Student Workbook Activities:

- Groundwater diagram (page 3-1, 3-2)
- Water Maze (3-3)
- United States Groundwater Use Map (3-4)
- GET WET! Water Testing Parameters (3-7)

Part II: Well water testing

In Part II of GET WET! students will test their own well water for the 6 parameters and enter their well data and GPS coordinates (obtained from Google Maps) into an Excel spreadsheet. This day takes a lot of coordination and will run more smoothly if you have a lot of volunteers to help out. Make sure to have at least one adult at each station. It is possible to get 20-25 students through all the stations in an hour.

Materials:

- For each student:
 - 1 pair gloves
 - goggles
 - clipboard
 - pencil
 - Classroom Sampling Sheet (Workbook CD)
- Paper Towels
- Six testing stations, one for each parameter (chloride, conductivity, hardness, iron, nitrate, pH). Use Classroom Set-up and Station Set-up handouts (Workbook CD)
- Each station should have:
 - 1-2 testing kits (depending on number of students)
 - 2 sets of testing kit directions (Workbook CD)
 - 1 parameter sign (Workbook CD)
 - 1 classroom washing instruction sign (Workbook CD)
 - Distilled water
 - Wastewater bucket
 - Cafeteria tray (optional)
 - Cups/beakers (conductivity & pH stations)
 - Calculators (sodium chloride & hardness stations)
 - Legal pad, sharpie, clock (nitrate station)
- Computer station with at least three computers/laptops that have GET WET! Excel Sheet (Workbook CD) and GoogleMaps.
- Laboratory Guidelines (Workbook CD)

Directions:

1. Set up classroom according to GET WET! Classroom and Station Set-up handouts.
2. Have students work individually or in pairs (if a student forgot his/her water sample or does not have well water)

3. Discuss safety with students. Make sure to cover important information in GET WET! Laboratory Guidelines handout.
4. Have each student grab their water sample, clipboard with sampling sheet, pencil, goggles, and gloves.
5. Divide students, approximately 4 students at each station, and have them rotate as they finish. Keep in mind, some tests take longer than others to complete.

Associated Student Workbook Activities:

- Sampling Sheet (page 3-8)

Part III: Discussion of data

In Part III of GET WET! students will be introduced to simple data analysis concepts, such as mean, median, mode, range, standard deviation, and outliers, and will be taught guidelines on how to create a PowerPoint presentation.

Materials:

- GET WET! Post-visit PowerPoint (Workbook CD)
- Appendix B: Description of mean, median, mode, range, standard deviation, and outliers.
- Appendix C: Guidelines for PowerPoint presentations.

Directions:

1. Using information available in Appendix B, the data collected in Part II, and the GET WET! PowerPoint presentation, introduce students to the concepts of a mean, median, mode, and range. Standard deviation can be covered with upper level students.
2. In addition, discuss sources of data error, the concept of an outlier, and guidelines to creating a PowerPoint presentation found in Appendix C.
3. Prepare students for what they will be doing in Part IV.

Part IV: Data analysis and research

In Part IV students will 1) research groundwater issues in their town and in the Ossipee Watershed, 2) create scatter plot graphs of their data using Excel, and 3) create a PowerPoint presentation that they can present to the community.

Materials:

- Access to computers
- PowerPoint
- Local experts (hydrologist, geologist, municipal planner, engineer, water treatment facility operator, etc.) and/or volunteers to work with students to research specific topics. One adult per group would be ideal, but having several adults jump from group to group is also possible.
- GET WET! handouts with helpful links for researching topics (Workbook CD)
- Create specific topic list with resources using Ossipee or Tamworth Research handouts as examples (Workbook CD)

Directions:

1. Divide students up into groups of 2 or individually and give each a research topic. Examples of how to separate the groups can be found on the Workbook CD (see Examples for Research Days). Topics include hydrology, geology, land use (current and historical), chloride,

- conductivity, hardness, iron, nitrate, pH, other parameters, well testing, well maintenance, world water issues, well types, potential contamination sources, water conservation, etc.
2. Each group will conduct their research and create a few PowerPoint slides for a class presentation.
 3. When each group finishes their slides, compile all the slides to create a class presentation. Examples of the community presentation can be found on the Workbook CD.
 4. Have students practice presenting to other classes or schools.

Associated Student Workbook Activities:

- Ossipee Watershed Map (3-5)
- My Drinking Water Well (page 3-6)

Service Project

GET WET! Community Outreach

- Community Presentation: Organize an evening event and invite parents, town officials, conservation commission members, and the public. Students will present their findings from well water testing and research.
- Newspaper Article: Have students write an article for the local newspaper about their project and what they learned. Include graphs, maps, and photos.

Analysis

Graphing

- Six of the groups will research a specific parameter, calculate mean, median, mode, range, and create a scatter plot graph of the data.

Mapping

- The GET WET! Excel file will have latitude and longitude coordinates for each well and corresponding data results. This information can be mapped using GIS software to show general levels of each parameter across the watershed and in relationship to important features, such as roads or lakes. Examples from 2010 can be found on the Workbook CD.

Extensions

- Organize an educational event or create a brochure or posters for National Ground Water Awareness Week (usually second week in March, check NGWA website <http://www.ngwa.org/>) sponsored by the National Ground Water Association.
- After completing GET WET!, students could host a “Test Your Well” event where interested residents could bring in their well water and the students could teach/help them complete the six tests.
- Attend annual Household Hazardous Waste Day at the Ossipee Town Hall, hand out well water testing kits (available from NH DES), and educate residents about the Ossipee Aquifer.

Assessment Tools

- Explain factors that influence levels of the six parameters (chloride, conductivity, hardness, iron, nitrate, pH) and explain their impact on groundwater and human health in an essay.

- Graph and map data for GET WET! community presentation.
- Compose essay that connects personal actions with their impact on groundwater.
- Student quiz (Appendix D)

Glossary

Anion: An ion with a negative charge (e.g. Cl^- , NO_3^-).

Aquifer: Underground sediments, which can be soil or rock, that are saturated and yield significant quantities of water.

Artesian well: Artesian wells are a specific type of drilled well that penetrate a confined aquifer which is under sufficient pressure to raise water levels above the land surface. Because of this natural pressure, some artesian wells do not require a pump.

Best management practices (BMPs): Structural, nonstructural, and managerial techniques recognized to be the most effective and practical means to reduce surface water and groundwater contamination while still allowing the productive use of resources.

Cation: An ion with a positive charge (e.g. Na^+ , NH_4^+).

Confined aquifer: An aquifer that is bounded above and below by impermeable or semi-permeable layers which are often referred to as a confining layers or beds. Confined aquifers are not directly recharged by precipitation, but will be recharged more slowly through fractures, small cracks, and pore spaces in the confining beds or through small unconfined regions.

Confining layer (confining bed): A layer of material (e.g. rock or clay) that prevents groundwater movement or the rate of movement is extremely slow and keeps the aquifer below it under pressure. This pressure creates springs and helps supply water to wells.

Discharge area: Where groundwater naturally resurfaces when it intersects with surface water, emerges from a hillside as a spring, or is pumped to the land surface through a well.

Drilled well: Wells that use percussion or rotary drill machines to penetrate about 100-400 feet into the bedrock. In order to be a useful water supply, a drilled well must intersect bedrock fractures containing groundwater.

Driven well: Wells that are constructed by driving a small diameter pipe into areas with thick sand and gravel deposits where the water table is within 15 feet of the land surface. A screened well point at the end of the pipe is attached before driving to help push the pipe through the soil and ultimately allows water to enter the well while at the same time filtering out sediment.

Dug well: Holes dug in the ground by shovel or backhoe until incoming water exceeded the digger's bailing rate. The well is lined with stones, brick, tile, or other material to prevent collapse and covered with a cap of wood, stone, or concrete. Dug wells tend to be shallow, typically only 10-30 feet deep.

Groundwater: Water found in spaces between soil particles underground (located in the saturation zone).

Groundwater recharge: Process where precipitation moves through the soil and reaches groundwater, replenishing aquifers.

Impermeable: A material that prevents water from moving through it.

Ion: An atom or a group of atoms that has acquired a net electric charge by gaining or losing one or more electrons.

Maximum contaminant level (MCL): The highest level of a contaminant that the Environmental Protection Agency (EPA) allows in public water systems. This is a legally enforceable standard under the Safe Drinking Water Act and is the maximum amount of a contaminant allowed in drinking water without causing risk to human health.

Mean: The mean is found by adding all the numbers in a data set and then dividing the sum by the total number of numbers. A mean is often called an average.

Median: The median is the middle value in a list of numbers. To find the median, the numbers should be arranged in order from least to greatest.

Mode: The mode is the number that occurs most often within a set of numbers.

Ossipee Aquifer: Stratified drift aquifer that lies underneath the Ossipee Watershed providing drinking water for a majority of the population.

Outlier: An outlier is a value that is numerically distant from the rest of the data. Outliers can be an indication of human error (either in data collection or entry) or equipment error (the kit or meter did not work correctly). However, an outlier could also be a legitimate result and an indication that the well or groundwater sample is unique in comparison to general trends across the town or watershed. It would be important to investigate this outlier further.

Permeable: Porous material that allows water to move freely through it.

Primary recharge area: Areas where aquifer materials are exposed at the land surface and where surface water and runoff directly infiltrate the ground and recharge the aquifer.

Range: The range is the difference between the largest (maximum) and smallest (minimum) number.

Recharge area: The entire land area that contributes precipitation to a groundwater resource.

Remediation: Containment, treatment or removal of contaminated groundwater. This may also include containment, treatment or removal of contaminated soil above the water table.

Saturated zone: The underground area below the water table where all of the spaces between soil and rock material are filled with water. Water found in the saturated zone is called groundwater.

Secondary maximum contaminant level (SMCL): The EPA also sets non-enforceable guidelines for contaminants that may cause cosmetic effects (such as skin and tooth discoloration) or aesthetic

effects (such as taste or odor). Public water systems are not required to adopt these SMCL, but states may choose to adopt and enforce them.

Secondary recharge area: Zones adjacent to the aquifer where surface water and groundwater flow into primary recharge areas.

Standard deviation: A standard deviation is a measure of how spread out the data is. A low standard deviation indicates that the data points tend to be very close to the mean, whereas a high standard deviation indicates that the data is spread out over a large range of values.

Stratified drift aquifer: A type of unconfined aquifer that is comprised of thick layers of sand and gravel deposited by glacial meltwater.

Tertiary recharge area: Zones that supply water to streams that flow into primary recharge areas and may or may not recharge the aquifer depending on water levels.

Unconfined aquifer (water table aquifer): An aquifer made up of permeable geologic formations, either solid rock or loose sediments, which consist of sand, gravel, or clay, in which the upper boundary is the water table. These aquifers are also known as water table aquifers because they receive recharge directly from the infiltration of rainfall and surface water.

Unsaturated zone: The area between the land surface and the water table where some of the spaces between soil particles are filled with water and others are filled with air.

Volatile organic chemicals (VOCs): Many household products, including paints, varnishes, waxes, cleaners, disinfectants, and fuel and automotive products, contain VOCs or chemicals that form VOCs when added to water. VOC contamination of drinking water is a human health concern because many are toxic and known or suspected human carcinogens.

Water pollution: The introduction of any substance that changes the physical, chemical, or biological properties of water and makes it harmful to use.

Water table: The top of the saturated zone, which is also the upper surface for unconfined aquifers. This level varies greatly across the landscape and also varies seasonally depending on the amount of rain and snowmelt.

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Appendix A: Explanation of Six GET WET! Parameters

Chloride

Chloride comes from sodium chloride, NaCl or salt. When dissolved in water, salt separates into its individual ions sodium (Na^+) and (Cl^-). Every water resource contains some sodium and chloride. Chloride found in groundwater can come from at least four sources: 1) marine aerosols near the seacoast, 2) trapped and buried in the soils near sea level through either tidal or geologic changes, 3) road salt, and 4) septic systems.

Typical background levels of Na^+ and Cl^- for pristine locations in New Hampshire are generally less than 20 mgNa/L and 30 mgCl/L. In the immediate seacoast area, elevated levels of Na^+ and Cl^- occur naturally due to the proximity to sea water and salt blown contamination. Seacoast area concentrations typically range up to 75 mgNa/L and 150 mgCl/L. Substantially higher levels of Na^+ and Cl^- tend to imply contamination from human activities, including road salt storage, use of road salts, discharges from water softeners, human or animal waste disposal, leachate from landfills, and other activities.

Both Na^+ and Cl^- cause a taste in water. EPA has identified a concentration of over 250 mg/L of either Na^+ or Cl^- as a concentration which can be expected to impart a salty taste to drinking water. The secondary maximum contaminant level (SMCL) of 250 mg/L is based on aesthetic concerns, and is only advisory in the EPA Safe Drinking Water Act program. However, the EPA has recommended that sodium levels not exceed 20mg/L for those people on a physician-prescribed “no salt diet.” This is the same level recommended by the American Heart Association.

Conductivity

Conductivity is a measure of the ability of water to pass an electrical current and is an indication of the number of ions in a water sample. It is influenced by the presence of ions that have a negative charge such as chloride (Cl^-), nitrate (NO_3^-), sulfate (SO_4^-), and phosphate (PO_4^{3-}) and ions that have a positive charge such as sodium (Na^+), magnesium (Mg^{2+}), calcium (Ca^{2+}), iron (Fe^{2+} , Fe^{3+}), and aluminum (Al^{3+}). Organic compounds like oil, various automotive liquids, alcohol, and sugar do not conduct an electrical current well and therefore have low conductivity when in water. Conductivity does not differentiate between ions and only gives a reading of how much is there. In areas along the seacoast or where road salt is a common groundwater pollutant, conductivity can be used as an indication of sodium chloride levels. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported at 25°C, which is also referred to as specific conductivity.

Conductivity levels in groundwater are influenced primarily by the surrounding geology. Groundwater that flows through areas with granite bedrock, tend to have lower conductivity because granite is composed of materials that do not dissolve into ions easily. However, bedrock with natural iron and manganese deposits and areas with clay soils tend to increase conductivity in groundwater. Due to the predominance of granite in New Hampshire, groundwater has traditionally had low conductivity values. Consequently, sources of elevated and increasing conductivity are typically due to human activities, such as road salting, faulty septic systems, and urban/agriculture runoff. New development in the watershed can alter runoff and groundwater flow patterns and expose new soil and bedrock areas, which may also increase conductivity.

Conductivity is measured in microsiemens per centimeter ($\mu\text{S}/\text{cm}$). There is no health standard for conductivity. However, conductivity levels can often be correlated with sodium and chloride levels because they tend to be the dominant ions in water. Both sodium and chloride have SMCLs identified by the EPA (see above). For reference, distilled (pure) water has conductivity levels in the range of 0.5 to $3\mu\text{S}/\text{cm}$. The conductivity of rivers in the United States generally ranges from 50 to $1500\mu\text{S}/\text{cm}$. In 2010, conductivity values for well water samples tested during the first year of GET WET! in the Ossipee Watershed ranged from 9 to $630\mu\text{S}/\text{cm}$ with an average of approximately $140\mu\text{S}/\text{cm}$. In general, the lower the conductivity the better for drinking water.

Hardness

Hardness is a measure of the amount of dissolved minerals that have a positive electrical charge in drinking water. These positive ions are primarily calcium (Ca^{2+}) and magnesium (Mg^{2+}). Dissolved iron (Fe^{2+} , Fe^{3+}), manganese (Mn^{2+}), and aluminum (Al^{3+}) may also be present, but often make up a small fraction of the total because large amounts of these minerals are not usually found naturally in water. Drinking water that has a high hardness value is considered “hard water” and low hardness is called “soft water”. The values that are associated with these terms are not universally agreed upon but two scales to categorize hardness can be found in Figure 10. Hardness in most groundwater is naturally occurring from the weathering of limestone, sedimentary rock, and calcium bearing minerals. This weathering process is accelerated by acidic water, either natural or from acid rain. In contrast, granite isn’t easily dissolved and therefore areas rich in limestone usually have very hard water whereas those that are mostly granite do not. Hardness can also occur locally in groundwater from chemical and mining industry effluent or excessive application of lime to soil in agricultural areas.

Worded Description	Sanitary Engineers (mg/L as CaCO_3)	Water Conditioning Industry (mg/L as CaCO_3)
soft water	0-75	0-50
somewhat hard water	76 to 150	51-100
hard water	151 to 300	101-150
very hard water	301 and up	151 and up

Figure 10. Two scales for categorizing degrees of hardness (NH DES).

Hardness in drinking water is not known to pose a health risk and is primarily considered an aesthetic water quality factor. The presence of some dissolved minerals in water is typically what gives drinking water its characteristic and pleasant taste. However, at higher concentrations hardness can cause “scale” (mineral buildup in pipes and plumbing fixtures) and reduce the effectiveness of soap for bathing and laundry. Often people with hard water, install a water softener to improve these aesthetic concerns.

Iron

Comprising at least 5% of the Earth’s crust, iron is one of the Earth’s most plentiful resources. Iron is present in the soil and underlying geology, making it a common element in groundwater. Rainwater that percolates through the soil will dissolve iron deposits, causing iron to seep into groundwater. Iron is present in water in two forms: either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. However, when it is exposed to the air, the water turns cloudy and a reddish brown

substance begins to form. When these deposits break loose from water piping, rusty water will flow through the faucet. This sediment is the oxidized or ferric form of iron that will not dissolve in water.

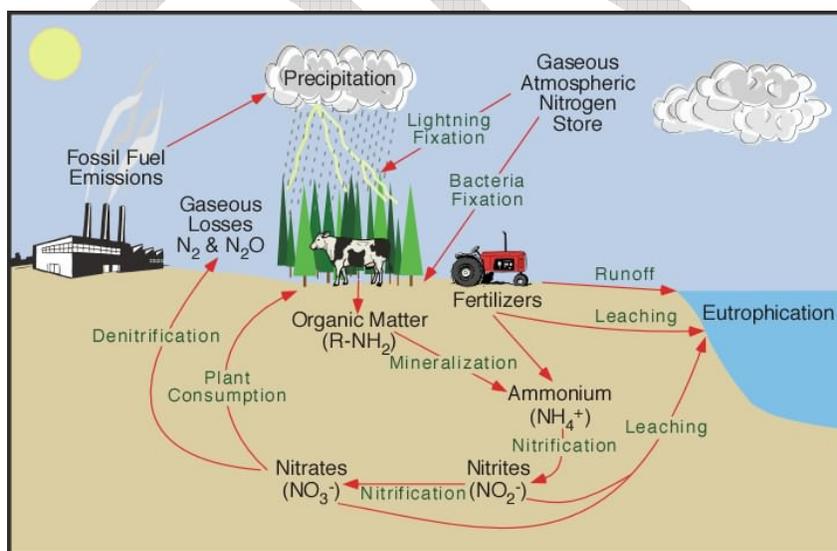
Although common in groundwater, iron is seldom found at concentrations greater than 10mg/L. However, as little as 0.3mg/L iron can cause water to turn a reddish brown color and will leave reddish brown stains on fixtures, dishes, and laundry that are very hard to remove. In addition, the presence of iron in wells often gives rise to the growth of iron bacteria. To survive, the bacteria use the iron, leaving behind a reddish brown or yellow slime that can clog plumbing and cause an offensive odor. This slime is noticeable in the toilet tank when the lid is removed.

Neither dissolved ferrous iron or iron bacteria are hazardous to health, although bacteria in large concentrations can be a health issue. Iron is mostly considered an aesthetic concern because it gives water an unpleasant taste. Iron bacteria are naturally occurring in the soil and will thrive when there is adequate iron to feed on. To address drinking water taste and iron staining, the EPA has set a SMCL for iron at 0.3mg/L.

Nitrate

Nitrogen is used by both plants and animals to carry out many of the functions of life. This element is especially important for plant growth. Nitrogen comprises approximately 78% of the Earth's atmosphere, making it the most abundant atmospheric gas. However, nitrogen gas is largely unavailable to plants and is often a limiting nutrient in the soil. In order to be used by plants, nitrogen needs to be converted to the nitrate form. This conversion is completed by specialized bacteria in the soil. As nitrate, nitrogen is absorbed and used by plants and subsequently by the animals that consume those plants. The breakdown of organic matter returns this nitrogen back into the atmosphere. This process is referred to as the nitrogen cycle (Figure 11).

Nitrate nitrogen can also be converted to nitrite under conditions of low oxygen. Both nitrate and nitrite are soluble in water and can be found in surface waters and groundwater. Nitrate/nitrite concentrations are normally low in New Hampshire but when there are elevated levels in groundwater it is often an indication of fertilizer or septic systems leaching into the ground nearby.



Nitrate concentrations as low as 1-10mg/L may indicate human impacts on groundwater.

High nitrate and nitrite concentrations in drinking water is a health concern for infants (through 6 months of age) and for women during pregnancy. Nitrites are responsible for blue baby syndrome. This condition develops when nitrite binds to oxygen receptor sites on hemoglobin, decreasing oxygen uptake in the blood and giving the skin a bluish appearance. As a result of these health concerns, the EPA has established a

Figure 11. Nitrogen cycle
<http://www.physicalgeography.net/fundamentals/9s.html>.

maximum contaminant level (MCL) for nitrate at 10mg/L and a MCL for nitrite at 1mg/L. Research has shown that concentrations as low as 4mg/L of nitrate can be a health concern. If elevated nitrate/nitrite levels exist in drinking water, there is also concern for bacteria and pesticides/herbicides because these contaminants are associated with fertilizers and animal wastes.

pH

pH is a measure of how acidic or basic water is. Specifically, pH is a measure of the concentration of hydrogen ions (H^+) and hydroxide ions (OH^-) in the water. Acidic solutions have greater numbers of H^+ and basic solutions have greater numbers of OH^- (Figure 12). Pure water has equal amounts of H^+ and OH^- in it. The pH scale ranges from 0 to 14, with 7 indicating a neutral pH (neither acidic nor basic). For example, distilled water has a pH of 7. Basic or alkaline solutions (e.g. bleach and ammonia) have pH values greater than 7 and acidic solutions (e.g. battery acid, lemon juice, vinegar) have pH values less than 7 (Figure 13).

Ion	Strong Acid	Weak Acid	NEUTRAL	Weak Base	Strong Base
H^+	large number of Hydrogens	>	equal number of Hydrogen and Hydroxide ions	>	small number of Hydrogens
OH^-	small number of Hydroxides	<		<	large number of Hydroxides
pH	1		7		14

Figure 12. pH Table (Thornton 2006).

Under normal conditions, rain and snow (the major sources of groundwater recharge) have pH values near 5.6. However, in New England rainfall tends to have a lower pH because of pollution emissions from sources such as coal-fired power plants and car exhaust leading to “acid rain”.

Consequently, the typical pH of rain in the Northeast is closer to 4. Once “acid rain” falls to the ground, some of it infiltrates downward to mix with groundwater and can affect its pH. In addition, the pH of groundwater varies depending on the types of rock and sediments that exist nearby. Groundwater that passes through carbonate-rich rocks (e.g. limestones and marbles) will usually have pH values great than 7 because the acidic water is buffered by the positive ions in these rocks. If there are few carbonate rich rocks in the area (e.g. sandstones, granites, and volcanic rock) then the groundwater will tend to remain acidic. In the Ossipee Watershed, where granite is the

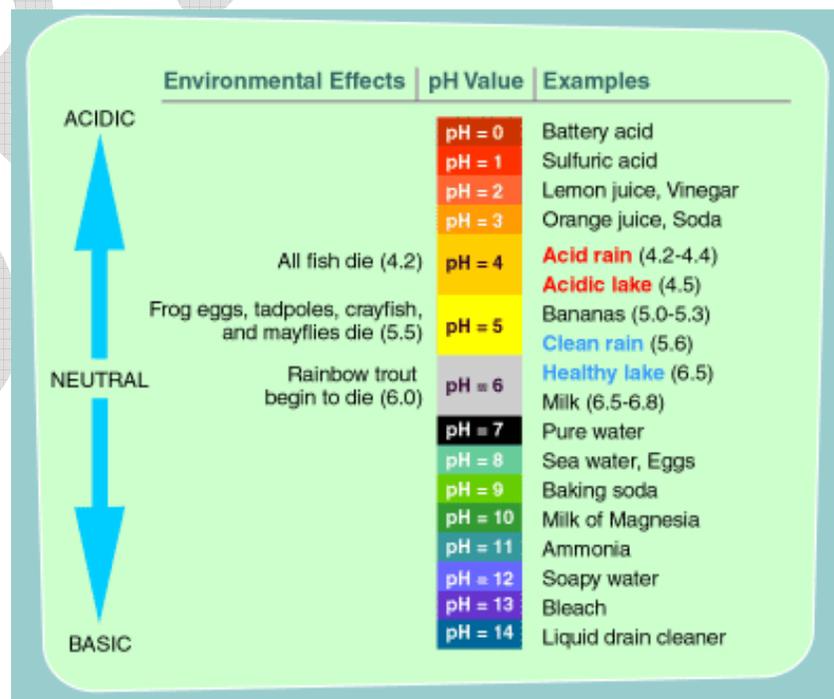


Figure 13. pH scale with common liquids and environmental impacts (http://www.epa.gov/acidrain/education/site_students/phscale.html).

dominant rock type, groundwater tends to reflect the acidity of rainfall.

Water with a low or high pH is not, by itself, harmful to human health. However, even mildly acidic water can dissolve metals (such as lead, copper, and iron) that may be in plumbing pipes and fixtures. These metals are a health concern. Lead pipes should not exist in homes built after 1987, but there are millions of homes where lead is still a potential problem. To address this issue, the EPA has set a SMCL for pH that is 6.5-8.5 for public water systems, which is also a good standard for private well owners. SMCLs are primarily for aesthetic issues, low pH water has a bitter metallic taste and can cause corrosion while high pH water has a slippery feel, soda taste, and can result in a build-up of scale deposits.

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Appendix B: GET WET! Data Analysis

Mean

The mean is found by adding all the numbers and then dividing the sum by the total number of numbers. A mean is commonly referred to as an average.

Median

The median is the middle value in a list of numbers. To find the median, the numbers should be arranged in order from least to greatest.

Mode

The mode is the number that occurs most often.

Range

The range is the difference between the largest (maximum) and smallest (minimum) number.

Outlier

An outlier is a value that is numerically distant from the rest of the data. Outliers can be an indication of human error (either in data collection or entry) or equipment error (the kit or meter did not work correctly). However, an outlier could also be a legitimate result and an indication that the well or groundwater sample is unique in comparison to general trends across the town or watershed. It would be important to investigate this outlier further.

Standard Deviation

The standard deviation is a measure of how spread out the data is. A low standard deviation indicates that the data points tend to be very close to the mean, whereas a high standard deviation indicates that the data is spread out over a large range of values.

Appendix C: Guidelines for PowerPoint presentations

These guidelines are for the GET WET! community presentations but can be used for any presentation where PowerPoint is used. Examples of GET WET! presentations can be found on the website http://www.umaine.edu/waterresearch/outreach/GetWet/State_programs.htm and on the Workbook CD.

General

- Introduce What, Why, and Where
- Present results as graphs or tables
- Use lots of pictures or diagrams
- Wrap-up ideas
 - Tell the audience what you were testing for (6 parameters)
 - Tell the audience why you were testing for those parameters (drinking water health/resource protection)
 - Tell them where the testing takes place including:
 - Habitat types
 - Local geology (glacial)
 - Land use (current?, historical?, potential impacts?)
 - Tell them how you tested the parameters (go through a demonstration of the kits)

Layout

- Choose a simple design from PowerPoint options or pick contrasting colors for background and text (e.g. light color text with dark background or dark text with light background)
- Keep this design consistent throughout the presentation. Don't have every slide a different color and layout; it becomes distracting for the audience.
- Don't use a lot of animation or special effects; they tend to distract the audience.
- Use a lot of images, photos, diagrams, graphs, etc.
- Use as few words as possible to convey message. Avoid paragraphs and full sentences by using bullets and short phrases.
- Keep words large enough (font size 24 and larger is recommended for titles)
- Stick with simple font types. Fonts "with feet" are easier to read in a paragraph (e.g. Times, Garamond). Fonts "without feet" make nice titles (e.g. Arial, Calibri)
- Limit images to 1-3 per page. Too many can be distracting.

Appendix D: Student Quiz

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Chapter 3: Groundwater

Student Quiz

Define the following word.

1. Groundwater: _____

Match the six groundwater parameters with their description in the box.

2. _____ Chloride

3. _____ Conductivity

4. _____ Hardness

5. _____ Iron

6. _____ Nitrate

7. _____ pH

A. Causes water to turn reddish brown when present.

B. Found in salt.

C. A measure of the number of ions in the water sample.

D. A measure of how acidic the water is.

E. A measure of dissolved minerals that have a positive charge.

F. Found in fertilizer and animal waste.

G.

Fill in the blank.

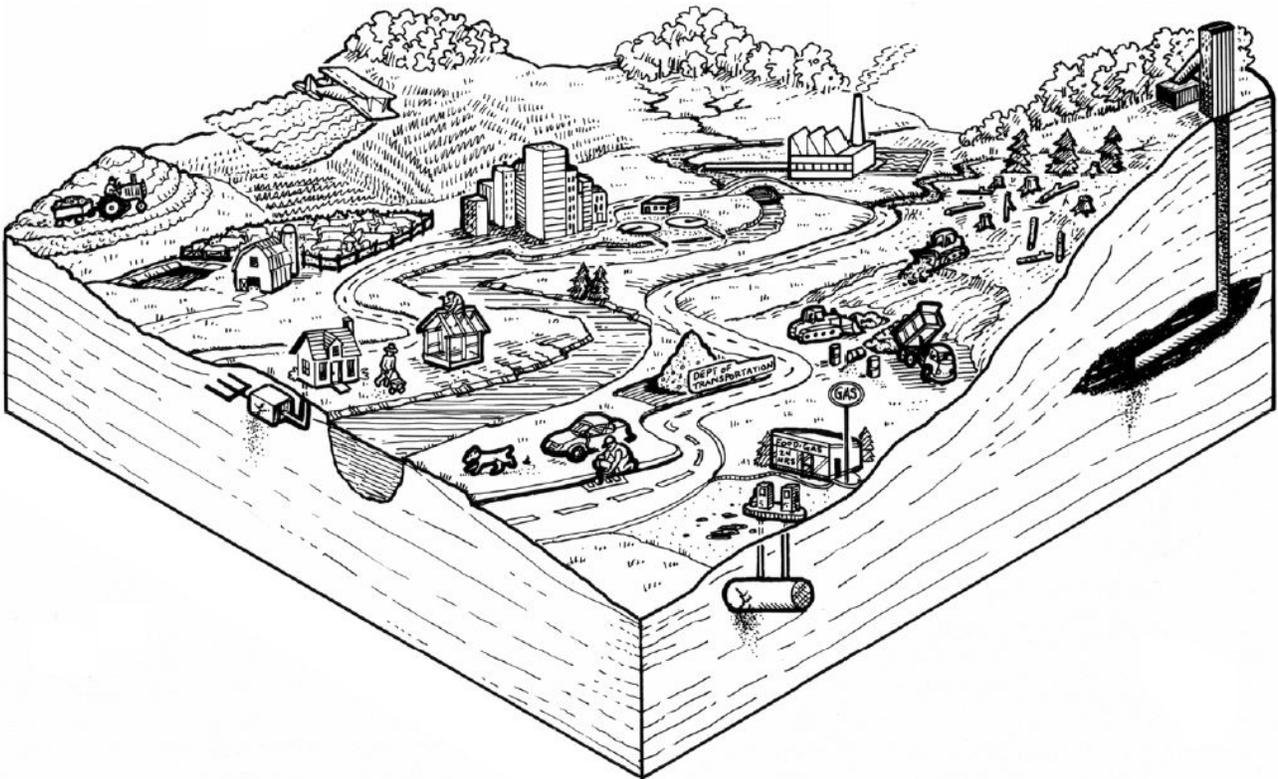
8. What are the three types of wells?

a. _____

b. _____

c. _____

9. Circle 5 potential sources of groundwater pollution in the drawing below.



Describe the 5 pollution sources circled in the drawing above.

- 10. _____
- 11. _____
- 12. _____
- 13. _____
- 14. _____
- 15. _____

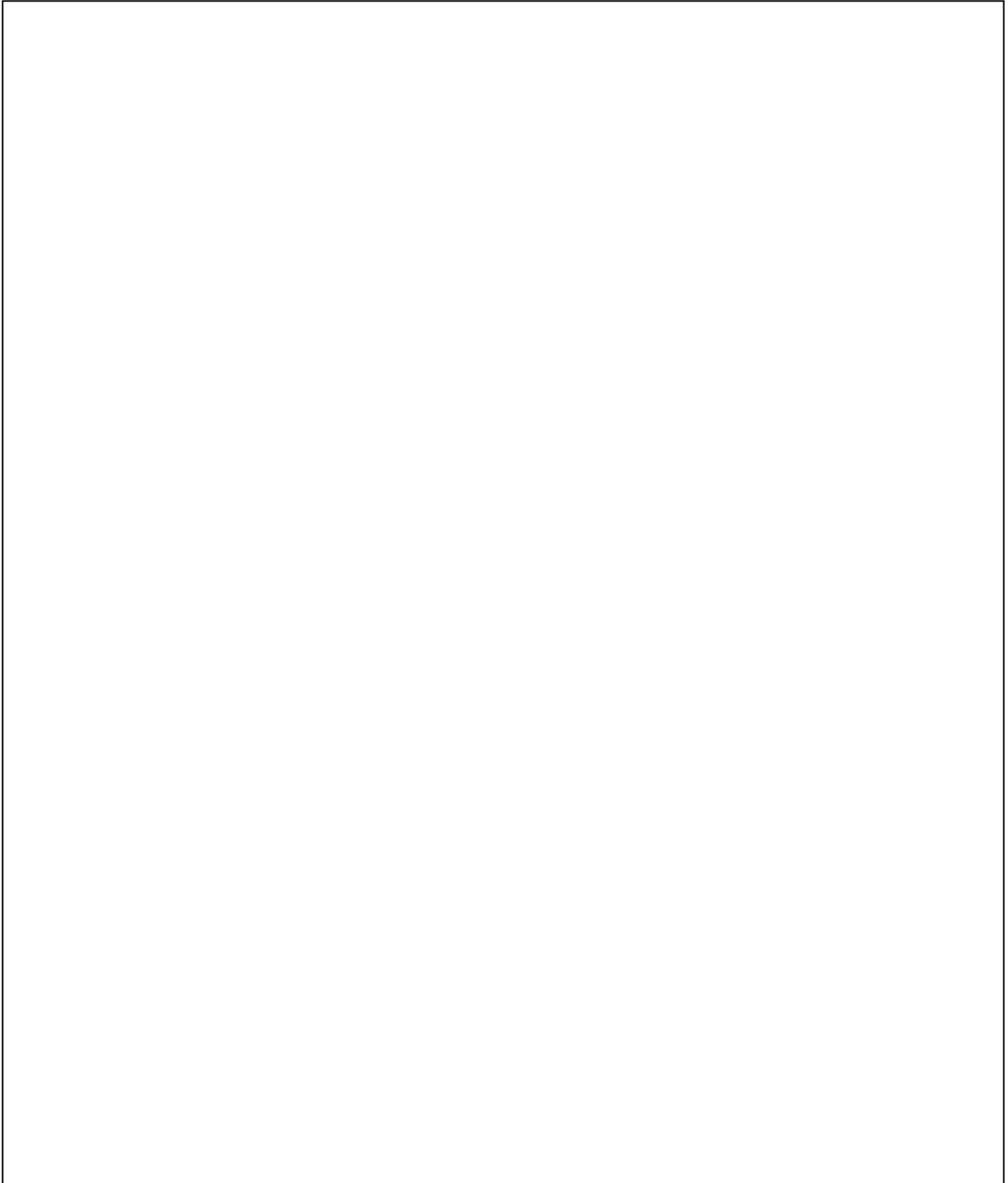
True/False

- 16. _____ Groundwater is in the saturated zone.
- 17. _____ The Ossipee Aquifer is the smallest stratified drift aquifer in New Hampshire.
- 18. _____ Aquifers are in the unsaturated zone.
- 19. _____ Best management practices (BMPs) are methods for preventing or reducing pollution.

20. _____ The water table never changes.

Draw a diagram of groundwater in the box below:

Make sure to label surface water, groundwater, water table, unsaturated zone, and saturated zone.



Chapter 3: Groundwater

Student Quiz Answer Sheet

Define the following word.

1. Groundwater:

Water found below the water table in the saturated zone, where all the spaces between the grains of gravel, sand, silt, clay and cracks within rocks are completely filled with water.

Match the six groundwater parameters with their description in the box.

2. B Chloride

3. C Conductivity

4. E Hardness

5. A Iron

6. F Nitrate

7. D pH

A. Causes water to turn reddish brown when present.

B. Found in salt.

C. A measure of the number of ions in the water sample.

D. A measure of how acidic the water is.

E. A measure of dissolved minerals that have a positive charge.

F. Found in fertilizer and animal waste.

Fill in the blank.

8. What are the three types of wells?

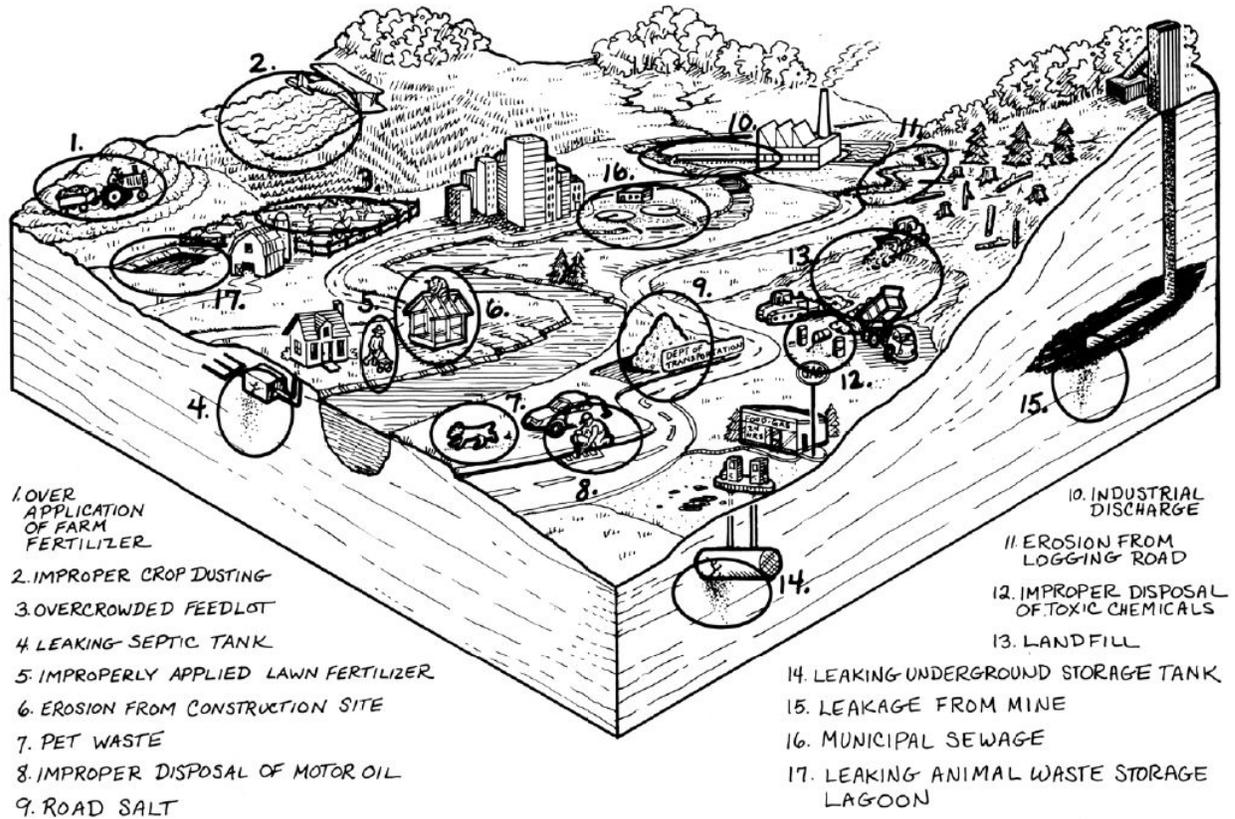
a. dug

b. driven

c. drilled

9. Circle 5 potential sources of groundwater pollution in the drawing below.

Source: Environmental Protection Agency Region 4, Alabama Department of Environmental Regulation, & LEGACY-Partners in Environmental Education. (n.d.) *The Water Sourcebooks*. Retrieved from <http://www.epa.gov/ogwdw000/kids/wsb/>



True/False

16. T Groundwater is in the saturated zone.
17. F The Ossipee Aquifer is the smallest stratified drift aquifer in New Hampshire.
18. F Aquifers are in the unsaturated zone.
19. T Best management practices (BMPs) are methods for preventing or reducing pollution.
20. F The water table never changes.