Dynamics of Groundwater

A Unit Designed for Enduring Understanding

SMT 503, Spring 2005

Introduction

Fresh water is arguably the most important natural resource on the earth. Without it, human life as we know it would cease to exist. Our dependence upon fresh water is often overlooked, especially in industrialized societies such as the United States, where the notion that clean groundwater and surface waters will remain abundant or unaffected seems to persist despite the fact that some areas of this country are experiencing quite severe hydrologic draught, shrinkage, and contamination in various forms. With a growing population, it is becoming increasingly vital that we provide our population with a proper education pertaining to groundwater and its role in the environment as well as civilization if we wish to successfully sustain this important resource for the future.

Earth System Context

Groundwater Systems serve as a valuable component in the earth systems context due to the promotion of the following:

- understanding the role of groundwater in the hydrologic cycle
- understanding the factors controlling groundwater movement such as: permeability, porosity, recharge, discharge, pressure, topography, confining layers, confined vs. unconfined aquifers, and residence time.
- understanding how groundwater movement and alteration affects the environment (erosion, contamination, land subsidence, geothermal activity, etc.)

The above topics are fundamental earth processes. This mini-unit, ***Dynamics of Groundwater,*** is a portion of a larger unit that encompasses earth processes such as the hydrologic cycle, the rock cycle, plate tectonics and erosion. The content in this curriculum is intended for a 9th grade Earth Science class, although it could be used in higher grades as well. The program of assessment activities is best suited for a secondary Honors Earth Science class. Standards that incorporate groundwater concepts are typically listed for grades 5-8, as are listed in the Maine Learning Results, the National Science Education Standards and Science Benchmarks, but such concepts should be emphasized in higher level earth science classes as well.

Groundwater concepts are essential building blocks for the promotion of true understanding of the interaction of earth's dynamic processes and cycles, most notably the hydrologic cycle. Thus, a unit with a concentration on groundwater appropriately complements a broader unit consisting of geologic processes content.

Scope and Sequence

The unit will cover all of the student outcomes in a manner that progresses from the necessary learning of content material and terminology to a more, detailed exploration of groundwater concepts. This will be accomplished by leading the students through a series of activities that will provide students with new skills and knowledge that they will build upon in each ensuing activity, which will enable them to successfully complete each one.

Student Outcomes

The following outcomes are listed from lowest to highest priority according to the Wiggins and McTighe strategy.

Worth Being Familiar With:

Students will encounter the following terminology in content reading and/or discussion and will be familiar with the terms themselves, but will not be required to recall exactly what they mean. These terms are not important factors in acquiring enduring understanding, but may be of some interest to the students.

- Students will be familiar with the term artesian wells and understand that it is associated with groundwater.
- Students will be familiar with the terms caves/karst.
- Students will understand the phenomenon behind the occurrence of geysers.
- Students will be familiar with the term capillary fringe and understand that it is associated with aquifers and the water table.

Important to Know and Do:

Students will be able to (a) define the following terms, (b) use the following terms in diagrammatic form, (c) display understanding of how, when and why these hydrologic characteristics are present, and (d) explain how they are related to, are affected by or affect groundwater movement.

- Students will be able to define characteristics of springs including (a) why and where they occur, and (b) how they are affected by or affect groundwater movement.
- Students will be aware of mineral deposition by groundwater and be able to describe how it occurs and its relationship to everyday life.
- zone of aeration/saturation
- Students will be aware of porosity/permeability alues for types of soils/rocks and will display understanding of their meaning by utilizing them in hydrogeologic problem-solving.
- Students will understand how to read maps of geologic, hydrologic, and topographic nature and learn how to use information from such maps by utilizing them in problem-solving.
- Student will understand the effects of human utilization of groundwater aquifers such as subsidence, saltwater encroachment, and sinkholes.

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Enduring Understanding:

- Students will be able to describe what discharge and recharge mechanisms are with respect to the groundwater system, how they occur, and what environmental factors control or affect their occurrence.
- Students will be able to describe the characteristics of an aquifer and the water table, and be able to correctly diagram and label such characteristics.
- Students will be aware of factors driving groundwater movement such as permeability, porosity, hydraulic head, hydraulic gradient, and display understanding of how these factors affect groundwater movement.
- Students will be aware of and display understanding of the effects of water well withdrawal on aquifers (confined and unconfined) by applying this awareness to real-life scenarios and problems.
- Students will be aware of pollution sources and methods, effects of contamination and display understanding of these issues through comment in class discussion application in class projects.
- Students will expand their group-work, problem-solving, higher level thinking skills and knowledge of how to use a variety of resources.

Essential Questions

1. How important is groundwater as a natural resource?
2. How integral is groundwater to everyday life as we know it?
3. To what extent is groundwater a renewable resource? Is it, in any aspect, a non-renewable resource? Why or why not?
4. Is groundwater an endangered natural resource in the U.S.? In the world? Why or why not?
5. How does the availability and quality of groundwater affect and structure industrialized society? How does it affect natural ecosystems?
6. How significantly do humans impact the availability and quality of groundwater? In what ways?
7. Can humans be better stewards of the land with respect to groundwater? In what ways?

Pre-Requisite Assessment:
Necessary Skills and Knowledge

Answer the following questions to the best of your ability.

1. What is the volume of a cylinder that is 6 ft in length and 3 inches wide?

2. Out of the following statements, which provides the best definition for groundwater?

    a. It is composed of all the water bodies on the ground surface and beneath the ground surface.
    b. It is the collective combination of underground rivers, lakes and streams that are all connected.
    c. It is the water that exists in streams, rivers, lakes bogs and marshes that we see on the earth's surface.
    d. It is composed of all the water beneath the ground surface that exists within layers of soil and rock.

3. A woman decides that she wants to walk from Town A to Town B in as straight of a line as possible, even if she cannot walk on roads. The first day she travels a distance of 11.5 miles. The second day she travels a distance of 4.7 miles, and on the third day she travels 9.9 miles. What is her average rate of travel? At this rate, how many days will it take her to reach Town B, which is a total distance of 72.3 miles from Town B? Show all of your work and units.

4. True or False:

    Fluids move from areas of lower pressure to higher pressure. T F

    Groundwater is not a natural resource. T F

5. Draw a map of your favorite place or that includes your favorite place. Be sure to include the following items:
    a. A compass (direction)

b. Any important geographic or anthropologic (human related) things such as mountains, bodies of water, roads, streets, landmarks, schools, town halls, houses, parks, or anything that is an important aspect of your favorite place.
c. An appropriate scale.
d. A map key, or legend, that will help somebody who is unfamiliar with your place to find their way around. Use symbols, colors, words or numbers in your map key.
e. An obvious, defined area to which your map key applies.

6. Imagine that your map has fallen into the hands of a person who has never been there and decides that it looks like a cool place to go. Create a set of directions that will lead someone who has never been to your favorite place on a tour that includes at least three of its most important features. This can be done on foot, in a car, by boat, or however you wish

to do it, as long as the directions are clear and get the person where they need to go.

7. Contour lines are:
    a. Lines on a map that indicate the direction of wind movement.
    b. Lines on a map that indicate changes in elevation.
    c. Lines on a map that define latitudinal and longitudinal position.
    d. Lines on a map that define changes in horizontal distance.

8. On a table in front of you sits two glasses of water. The glass on the left is full, the glass on the right is only about half full. Which of the following statements is correct?
    a. Water in the bottom of the full glass in under the same pressure are water in the bottom of the half-full glass.
    b. Water in the bottom of the half-full glass in under more pressure than water at the bottom of the full glass.
    c. Water at the top of the full glass is under more pressure than water at the top of the half-full glass.
    d. Water at the bottom of the full glass is under more pressure than water at the bottom of the half-full glass.

Dynamics of Groundwater:

Unit Assessments

The following group of assessments has been developed according to the prioritized outcomes (attached) listed for this unit, *Dynamics of Groundwater*. They are listed in order of suggested implementation, though this can be altered to fit individual classroom goals and resources. The intended audience is a secondary Honors Earth Science class, most likely in 9th or 10th grade.

Assessment 1: What do you know about groundwater?

Time Allotment: 1-2 forty-minute class periods

Day One:

This assessment is intended to be used as an introductory tool, both for the students and the teacher. It will be initiated with a pre-test that covers basic content knowledge, terminology and will ask the student to comment on their views concerning the importance of groundwater to everyday life. The assessment itself will be relatively short and should not take more than 20 minutes to complete, but will be designed to provide the teacher with information about the students' pre-existing knowledge of groundwater properties. Questions will be asked in multiple-choice format with appropriate distracters to help elicit any common misconceptions. The students will be asked to draw a diagram depicting their ideas about groundwater, with the only requirement being that they label their diagram and describe any processes taking place in the diagram. This will be the first question on the pre-test, and will be given separately from the remainder of the test, to avoid (as much as possible) the incorporation of any ideas, terms, or information that the student might 'borrow' from the test itself. The intent is to gain some insight into the students' raw understanding of groundwater before it is introduced in the classroom.

Day One-Day Two:

The second portion of this assessment consists primarily of discourse among the students and the teacher regarding the students' ideas about groundwater. This can be accomplished easily with the use of a few overhead diagrams that show typical environments on the earth in cross section view. Examples might include a typical neighborhood with houses, streets, lawns, parking lots, buildings, businesses, streams, ponds, and any other common feature in a neighborhood. Another might be a rural setting, with various vegetation forms, hills, valleys, rivers, lakes, rocks, swamps. There are many generic figures available that contain such common geographic features, some of which can be found on websites such as USGS and the Maine Geological Survey, as well as many other websites specifically intended to provide education resources for earth science teachers. Teachers could also very easily create their own diagrams, if preferred. It may be useful to provide each student with their own paper copies of the diagrams before initiating classroom discourse, so that they can take a few minutes to translate their own ideas onto paper and use them as a stepping stone into the classroom discussion. The students can keep these diagrams and use them to compare their original ideas about groundwater to their newly acquired and formed ideas at the end of the unit. This will allow the students to gain perspective and be aware of any changes in or refinement to their understanding as the unit evolves.

Once converted into overheard form, the diagrams can be used by the teacher as a venue to transcribe the students' ideas about groundwater into visual depictions. This enables all of the students to *hear* and *see* each other's ideas, especially in the event of discrepant views. The goal is for the class to arrive at a general agreement about what groundwater is in terms of any defining characteristics, as well as identify any geological and/or environmental factors that are thought to affect groundwater in terms of behavior, quality and availability. In doing so, the students are encouraged to think about groundwater in light of their own knowledge as well as other students' ideas and knowledge. This also enables the teacher to better grasp the knowledge level of the students, as well as pick out any prominent misconceptions and misapplied information from the very beginning. This activity is not intended to be didactic in nature, but rather resemble a conversation among the students with the teacher merely recording the information so that everyone can see it. The teacher should only direct the conversation by asking occasional questions to appropriately spark and steer the discourse in the intended direction. Examples of questions that might be asked are listed below.

What is groundwater?
Where do we find it? Is it everywhere? Is there more in some places than others?
How do we know where it is or how much of it there is?
Where does it come from?
Can we see it? What does it look like under the ground? Is it all connected everywhere, or is it separated into different bodies?
How long does it stay?
How do we use it?
Does it move? How does it move, and where does it move to?
Is it in rocks? Is it in soil? Does the type of soil have any affect on groundwater movement? How?
Do we have ways to access groundwater? How?

A classroom discourse fueled by such questions as listed above and accompanied by visual aids will provide the teacher with an initial opportunity to assess the level of understanding and familiarity with the listed outcomes for the unit. The discourse should cover a number, if not all, of the listed outcomes, even if only briefly. This will provide the students with a general overview of topics to be covered in more detail at a later time and at the very least familiarize them with new and/or old terminology and ideas about groundwater.

Assessment 2: Groundwater Worksheet
Time Allotment: This assessment should be completed outside of class.

Note: This assessment is intended for use after appropriate reading of content materials has been completed by the students.
The students will be given a study guide worksheet to complete as they cover the content reading. These questions will cover terminology, definitions, and processes listed in all of the outcome levels. This assessment is intended to ensure that the students read the material and have some working knowledge of important terms and definitions and important relationships before they proceed to later projects. This worksheet resembles many traditional tests, and ideally would cover all levels of Bloom's Taxonomy, with the majority of the questions residing in the lower levels. It is intended to be used by the students as a tool to help them understand and organize the content material, reinforce their familiarity with the content material, as well as require to them to think at a higher level about some of the enduring concepts. This could be accomplished by asking the students to comment on human influence on groundwater quantity and quality and asking

them to discuss their view on this, using information from the content material and/or other sources to support their view.

Students will be asked to show that they are familiar with groundwater terminology by providing correct definitions of terms and in some instances (higher lever thinking questions) describing the appropriate relationships between them. This could be accomplished with sentence completions, matching, or multiple choice questions. They might be asked to provide definitions for a list of terms. Then they might be given a few scenarios where they are required to use those terms to describe what is happening and why. They will answer some basic questions regarding groundwater processes. They will be asked to draw a diagram depicting specific aspects of groundwater movement.

Assessment 3: Groundwater Lab

Day 3:

The school has been fortunate enough to attain the necessary resources required to drill three test wells on the property. These wells are used by the school science classes as a tool to promote better understanding about groundwater and hydrologic processes.

The students will be divided into groups of three for one class period, wherein they will visit the wells and perform some basic measurements. The students will measure the depth of each well, as well as the elevation of the water table. This can be done with a specific instrument that is designed to measure the water level in a well, or it can be done with a 50’ or 100’ measuring tape with a heavy object attached to the end. Once all of the groups have taken measurements in each of the wells, they will be asked to take a few moments to survey the landscape around them. Are they on a hill? Are they on a relatively flat area? Are there any defining geologic characteristics around that are obvious, such as soil type, bedrock outcrops, marshes or streams? Are they in a rural or urban setting? What types of development are nearby? They will be asked to observe such features and draw a basic map depicting what they observe and where it is located in relation to the wells. Distances can be estimated, with the help of the teacher. Some distances could be measured if they are within range of the measuring tapes.

Day 4-5:

After their maps have been completed, the students will return to the classroom, where they will observe a bedrock geology map of the area, as well as a surface geology map of the area and a topographic map. It is likely that the students will need help deciphering the maps, but they are relatively easy to read once the correct geographic location is determined. This will give them more information regarding the type of bedrock and soil that exists in the vicinity of the wells, as well as the geography of the surrounding area. Once this information has been determined, there will be a class discussion regarding what it all means. The maps should all be displayed and discussed. The students will be asked to determine how the soil and rock types of the area might play a role in the water table level and discharge/recharge rates. They will be asked to make an educated guess about the movement of groundwater in the area according to the topography and soil types they observe. After the discussion, they will be asked to write a paragraph describing the soil and rock type of the area, the topography, and how the groundwater movement might be influenced by these factors. Each group will be asked to construct a cross section of a specific defined area that includes at least one of the wells. In this cross section, they will need to include the correct depths of the water table and the

well(s), as well as soil types and approximate depths, bedrock types and approximate depths (approx. depths can be obtained from the maps). The water table will need to be shown appropriately (not as a separate entity). The cross sections should be done in color if colored pencils are available, and they should be drawn to an appropriate scale.
All of the materials should be turned in at the completion of the lab. This includes measurements of the wells, observation maps, cross section and well written paragraph that appropriately ties together all of the information that was obtained regarding soil type, bedrock, water table elevation, and topography.

Inquiry Based Activity: The Water Beneath Us
Day 6-7

Assessment 4: Explore the Water in your Town
Day 8-9
This assessment is an inquiry-based group project, and is designed to incorporate all of the skills and knowledge that the students have attained at this point. It operates mostly at the enduring understanding level, and is designed to both test and promote enduring understanding in that it requires the students to show appropriate levels of understanding and in the process of doing so, they will further their understanding and learning.
Students will build upon the groundwater lab that they have completed. The students will be divided into four groups (or however many groups are feasible). Each group will be given a set of data. The sets of data will correspond to specific area of the town in which the school resides. The data sets will include well logs of wells that have been drilled in the area. These logs typically include soil types, depth to water, depth to bedrock, water flow rate (gpm), and distance from structures, sewers, or water bodies. Any information available regarding water quality will also be provided. Most of the wells will be private wells drilled for use in homes, and there may be information regarding wells drilled on business properties for water monitoring purposes (if available). Well log information and water quality information from private wells can be obtained from the town office and water district.
After completing the groundwater lab, the students are familiar with topography, bedrock geology and surface geology maps. They will again use these maps to complete this project.

1. The students will be required to construct a groundwater contour map for the geographic area that their data covers. The scale will be determined by the teacher and will be the same for all groups. The contours should be as accurate as possible. An example of a groundwater contour map should be provided for reference, and instructions should be given regarding how to construct this type of map.
2. The students will be required to give a general description of the bedrock in the area, the soil type(s), and the topography. They might need to use additional resources such as the internet to find this information in better detail than provided by the maps. Sites to search might be local University Geology Departments, State Geological Survey and USGS. They will be asked to provide written comment on the relationships between these features and whether or not

they see a relationship between these features and their groundwater contour map. They should answer questions such as: Can you pick out any areas that might provide more reliable water sources than others? What features would you look for when drilling a well in order to ensure that the well would supply an adequate amount of water? How would you determine the water quality? What features might affect the quality of water in the well? (think about residence time, soil or bedrock types, contamination)

3. Each student will be required to construct a cross section of a defined but different area within their assigned geographic region. This cross section should have an appropriate scale and include at least two wells and well depths, water table elevation, bedrock elevation (if known), soil type(s), and appropriate topographic features such as hills, swamps, rivers, streams, ponds, etc. All features need to be labeled and their relationships to one another correctly portrayed.
4. The groundwater contour maps from each group will be combined into one map. The class will then discuss the map together and draw any observable conclusions regarding the relationship of the town topography, bedrock and soil types to the groundwater elevations. The discussion can focus on the limitations involved with choosing locations for obtaining adequate water resources, such as unknown information regarding soil, bedrock, water quality and cost feasibility issues associated with obtaining this type of information as well as a productive water source. This might be accomplished with the aid of internet resources, such as drilling company websites and engineering/environmental company websites that give detailed descriptions of these types of real-life projects. Guest speakers (engineers, well-drillers, hydro-geologists) would also be useful tools to engage the student in these types of issues.

Assessment 5: Project H_2O: A Town in Need of Water
Time Allotment: 7, forty-minute class periods
Day 10-17

You have been divided into groups of four. Each group represents a consulting firm that has been asked by the town to provide them with a bid proposal. Your group needs to create a name for its company and provide a proposal for the following scenario.

Due to the rapidly expanding population in your town, the potable water supply is quickly dwindling. The wells presently owned and operated by the town are not providing an adequate supply of water for the growing population, and water shortages have forced the town to implement water bans during the summer and fall months when the water supply is at its lowest. Your company has been hired by the town to research this problem and devise a cost-effective, timely solution for this problem. Your job is to find a prospective location for a new town well(s) that will provide additional, potable water to the town water supply that will alleviate the water shortage problem. The town has allotted a budget of $30,000 dollars to complete this project. Your company has seven days to construct a plan of action and provide the town with a bid for the project. The project includes the following objectives:

1. Choose a location or locations. Provide extensive reasoning for your choice(s) regarding the geologic, hydrologic, and geographic characteristics of the site(s) that render them as logical and sufficient. In other words, in a professional manner, provide the client with any information that you know about the geology, hydrology and soils that make the location suitable for obtaining water. (Use information from well logs, soil and geology maps, topography maps, water quality reports, websites, books.) You may choose to organize this information any way you like, as long as it includes all necessary information and is presented in a logical, understandable manner.

2. Provide the client with the following information:
    1. Estimate the necessary well depth(s). (Think about the volume of the well vs. the amount of water needed.) Give an estimated rate of water flow (gpm- gallons per minute) that is needed to maintain an adequate water supply in the well(s).
    2. Estimate the cost of drilling the well(s) according to soil and bedrock characteristics. (The cost of drilling might differ for soil and bedrock. Use drilling company websites, make phone calls, or other reasonable sources to make this estimate.)
    3. Provide information about potential pollution sources and suggest a plan to the city that would prevent any future contamination problems. Use the aerial photo of the town to accomplish this task by completing the following:
        - Circle any areas that might be considered as contamination sources (consider such things as gas stations, dry cleaners, automobile shops, landfills, highly fertilized areas, mills, manufacturing businesses or any other potential hazardous source).
        - Provide a well-written statement (one page or less), that describes any negative effects these sources might have on the

groundwater and surface water quality in the new well location(s).

- Highlight the locations of the existing town wells and review their proximity to any potential contamination sources. Provide a summary that answers the following questions:
    1. Why were these locations chosen?
    2. What geologic and hydrologic features make these locations desirable?
    3. Are there any nearby possible sources of contamination that the town should be aware of?
    4. What repercussions will the town face if these wells become contaminated?

3. Present your recommendations and estimates to the client and provide them with your final bid. This presentation should be completed within 10 minutes and contain at least one visual that incorporates all important points that you want to make to the client. Remember, your goal is to win the bid by convincing them that your location is the best choice for a new well.

4. Each consultant, on his/her own must provide the client with a well-written, closing statement (at least one full page) that answers the following questions. Back up your statement with concrete examples and information that you have learned during this unit.
   1. How important are public water supply and sewage disposal/treatment systems? Do public sewage disposal systems contribute to the contamination of surface or groundwater supplies? (Think about storm drains, surface water runoff, household chemicals and detergents, pesticides, herbicides, fertilizers.)
   2. How can we be better stewards of our water resources?
   3. Explain your view on the importance of groundwater to our society and rate the importance of this natural resource.

Requirements	**Novice- Underdeveloped** **(Does not meet requirements)**	**Advanced- Developed** **(Meets requirements)**	**Expert- Fully Developed** **(Exceeds requirements)**
Class Participation and Group Contribution **(assessment of individual student participation)**	The student does not participate at all or very minimally at both the class and group level. Verbal and written contribution is absent and/or not useful or thoughtful. The student displays unwillingness or inability to work in a class, group and/or individual setting.	The student contributes in both verbal and written form to class and group activities. Contributions are thoughtful and useful. The student shows willingness and attempts to work in a class, group and individual setting. The student is helpful to others in his/her class and/or group.	The student contributes significantly to class and group work in both verbal and written form. The student offers engaging ideas and suggestions to the class and/or group. The student provides useful information to the class and/or group. Participation significantly contributes to the completion of project goals.
Utilization of Resources **(group assessment)**	Project is not completed with use of provided resources or with very minimal use. Information taken from available resources is applied incorrectly or incoherently, and is not cohesive.	Project is completed with use of provided resources. Information taken from provided resources is applied correctly and is both coherent and cohesive. Not all necessary resources are used.	Project is completed with use of provided resources, as well as additional, appropriate resources sought outside of the classroom. All necessary resources are used. Information taken from provided and additional resources is applied correctly, and is both coherent and cohesive.
Level of Scientific Observation, Calculations and Reasoning **(group assessment)**	Required observations and calculations are not recorded and/or are incoherent, labeled incorrectly. Material lacks organization and structure and is not backed by real scientific resources and reasoning. Units are not used or used incorrectly.	Most required observations and calculations are recorded and labeled. Some calculations may be incorrect. Organization of material is coherent and displays structure and is at least partially backed by sound scientific reasoning. Units are used appropriately, but may be missing in some instances.	All required observations and calculations are recorded and labeled correctly. Organization of material is coherent, displays useful, sound scientific reasoning and structure, and is presented neatly. Units are used appropriately in all required instances.
Final Project Organization, Thoroughness, and level of Completion **(group assessment)**	Project is not complete. Material is not organized, coherent, and does not meet any of the listed goals. Most or all of required materials are missing, not completed, or completed thoughtlessly and/or incorrectly.	Project is almost complete. All required materials are present but may not be fully completed or completed incorrectly. Materials are organized neatly and coherently as well as display cohesiveness and thoughtfulness. Most or all of project goals are met.	Project is complete and meets all of listed goals. All required materials are present and fully completed. Materials are presented neatly and coherently, organized usefully, and display cohesiveness. Project incorporates resources, data beyond those provided in class and displays

			implementation of engaging, higher levels of thought.

Pedagogical Methods and Resources

In order for the students to complete ***Project*** $\boldsymbol{H_2O}$, they will need to use specific resources as well as receive guidance regarding how to use those resources as the project evolves. Much of the decision making will be left to them in terms of how to use their available resources and how they want to present their information. They will be provided with the rubric to help them ascertain whether or not their project is meeting the necessary requirements. There are a number of things that could be done to enhance this project. For example, a guest speaker might elaborate on the structure of public water and sewage systems and their role in a town's infrastructure and vitality. A class discussion regarding the importance of water as a natural resource and in our everyday lives should occur at some point during the project, maybe even before the project. A list of relevant internet sites should be provided as a starting point for the students as they begin their research. This project will expose students to real life problems and frustrations that real scientists face when attempting to utilize our natural resources in the most cost-effective and environmentally sound manner. The project will cover all listed enduring concepts, as well as provide the students with an experience to build upon the following skills:

- mathematical calculations with the additional benefit of real-life applications
- abstract thinking skills
- writing skills
- verbal skills
- group work/team work ethic
- map reading skills
- learning how to utilize and gather available resources
- problem solving

These skills will also be implemented during the inquiry based activity. All of the students will need to enter the class with enough of these skills to build upon, which is what the pre-requisite design instrument will test for.

Most of the pedagogical methods in this unit are embedded in the assessments and inquiry activities themselves. The *Groundwater Lab, Explore the Water in Your Town, and Project* H_20 all require a significant amount of learning to occur during their implementation. The unit will start with the pre-requisites test, as well as the first assessment test and discussion, which will expose the students to terminology, basic concepts and set the stage for the level of thought which will be expected of them throughout the unit. The results of the pre-test and diagram will enable the teacher to better judge the level of content knowledge held by the students, as well as any prevalent misconceptions. The discussion and class diagrams serve as an initial method to focus the class upon a common model of the groundwater system. From that point, the students can be lead into deeper exploration of the concepts that are necessary to construct a proper model of this system. First, this is backed up by some content reading and a basic worksheet in order to ensure that the students have some familiarity with the language and have had an opportunity to observe some diagrams and models that describe the groundwater system. After this has been accomplished, they are ready to begin sharpening their skills that are essential in any science discipline (listed above), by applying them to activities centered around groundwater, such as the groundwater lab, the inquiry-based activity and the major assessment project. Much of the actual teaching in this unit will occur throughout these activities, and in instances when it is necessary to halt activities and initiate discussion in the class regarding issues that need to be clarified or are being approached incorrectly by the students. The teacher needs to be highly observant and listen closely to what is being discussed in the groups as the projects move forward in order to intervene at the appropriate times. The students will need to be prodded to extend their thinking beyond the content material, and this indeed is the most difficult but most important role of the teacher during this unit. This should occur both during discussions as well as in the inquiry-based activities. The content material is important because once they have grasped it, they will be asked to extend their thinking to higher levels that are needed for the final two projects.

Ideally, I would love to have the time to implement all of the activities listed in this unit in a classroom. It is highly probable, however, that they might need to be scaled back due to either time restraints or resource constraints, or a combination of both. I think, however, that it would be possible for a teacher to accumulate over time most of the materials necessary to facilitate all of these activities, and I think that students would certainly attain a higher level of understanding and enduring learning than traditional classroom activities. This is especially true in light of the fact that groundwater is not indexed as a priority in any science standards that I have yet viewed. Yet, it is one of our most important resources and it will only become increasingly vital as our population progresses to ensure that our students have been provided with an education that enables them to better manage this resource that we so greatly depend upon for survival and enjoyable, healthy lives.

Educations standards that are used in the unit are listed below:

Grades 6-8, Science Benchmarks:

- Fresh water, limited in supply, is essential for life and also for most industrial processes. Rivers, lakes, and groundwater can be depleted or polluted, becoming unavailable or unsuitable for life.

Grades 5-8, National Science Education Standards:

- Water, which covers the majority of the earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.
- Water is a solvent. As it passes through the water cycle it dissolves minerals and gases and carries them to the oceans.

Grades 5-8, Maine Learning Results:

Demonstrate factors effecting the flow of groundwater.

The Water Beneath Us

A Subsurface Investigation of Groundwater

To begin our investigation of groundwater, we will start by taking some simple, real-life measurements of groundwater right outside our building and we will begin to answer some questions about what they mean. You will be divided into groups of three and four students. Each group will need to complete all of the activities and questions in the lab, but they do not need to be completed in the order that they are listed. Follow the directions for each activity carefully, and remember to work as a team- which means ask ***each other*** questions when you have them and work together to find a ***logical*** answer.

A. Groundwater level is typically measured relative to elevation above sea level or a distance below the ground surface. Today, we will measure groundwater relative to the distance it is located below the ground surface (bgs). The surface of the water that your instrument will be in contact with is called the **water table,** which is the surface of the **zone of saturation.** We will be using two groundwater wells, one is 20ft deep and the other well is approximately 250ft deep. We will refer to them as the Deep Water Well (DWW) and the Shallow Water Well (SWW).

   1. Estimate the distance below the ground surface (bgs) (in feet) that you think the groundwater is located at. Is it shallow or deep? Is it the same for both wells? Is it different? Why or why not?

   2. Taking turns, each student must take a measurement with the water-level reader in both DWW and SWW and record the real depth below ground surface (bgs) of the

groundwater. (Remember the water-level reader measures in meters, so if you want it in feet, you must convert.) Remember to subtract the height of the well casing from you measurement.

DWW: SWW:

3. Is there a difference in water depth below the surface for the two wells? If so, do you think it is a significant difference? Why or why not?

4. If you measured a difference in the depth of water below the surface, what can you say about the elevation of the water table for each of the wells? Is it the same or is it different? If they are different, which well has a higher elevation?

If your measurements indicate different water-table elevations in each of the wells, then you have just measured what is called **hydraulic head**, which is a difference in elevation between parts of the water table. The slope of the water table between these elevations is called the **hydraulic gradient,** which helps determine the velocity of groundwater movement. A higher hydraulic head means that there is a higher pressure exerted on the column of water in that portion of the water table.

5. What can you say about the difference in hydraulic head between the two wells? Is it large or small?

Where is more pressure being exerted, on the water table in SWW or DWW? Does this tell you anything about the direction the water might flow? (Think about how fluids act under pressure, where do they always want to go?)

What can you say about the hydraulic gradient between the two wells?(Is the slope of the water table between the two wells large or small?)

What does this tell you about the velocity (distance/time) of the water that is moving below you? Is it relatively fast or slow?

Is there anything around you that you can observe that might account for this? (Hint: look at the general topography)

6. From what you have just learned about hydraulic head and hydraulic gradient, what can you say about the groundwater below you? If you could cut a piece out of the earth like a piece of pie and look at the inside, what would all of this water, soil and rock look like? Draw and label a sketch that describes what you think it would look like. Be sure to include the two wells and label the ground surface.

7. Is the water displayed in your sketch open to the surface environment or closed to it? In other words, can water on the surface reach the water below the surface? How?

   Can water from the ground surface reach the water you measured today in the wells? Is the water table beneath you today open or closed to the surface environment? Explain.

If water from the surface reaches the water beneath the surface, then we can consider that the water table below the surface is open to the environment on the surface. This process is called **recharge,** which explains how groundwater is replenished. Water, such as rainwater, seeps downward through the soil to the water table. The collection of water beneath the ground surface that exists within the layers of soil and rock is called an **aquifer.**

8. From what you have observed today, would you consider the aquifer below you to be a confined aquifer (closed to recharge from the direct ground surface) or an unconfined aquifer (open to recharge from the direct ground surface)?

B.

1. Take a moment and think about what would happen if you added a large volume of water to the well. What would happen to the water level in the well? Explain what you think would happen.

2. Each group will now add an object to the well called a **slug.** The slug is easier to put into the well than water and will not disturb the water chemistry. Each slug has a specific volume, so imagine that volume to be a big slug of water that you could dump into the well. The smaller slug will be added to SWW, the larger slug will be added to DWW.

   b. Take a moment and think about what will happen when you add the slug to each of the wells. What will happen to the water level? Explain.

c. **Be ready** to measure the water level below the ground surface (bgs) in each well **directly** after the slug has been added. This will be time 0:00. **Be ready** to take another measurement **1 minute later, and every minute thereafter for the next 5 minutes. This is done most easily by having one person holding the water level reader, one person reading the depth off the reader, and everyone else recording the information.** When you are ready to record the water level directly after and for each minute after you add the slug, you should add the slug to the well.

SWW	Depth (bgs)
0:00	
1:00	
2:00	
3:00	
4:00	
5:00	

DWW	Depth (bgs)
0:00	
1:00	
2:00	
3:00	
4:00	
5:00	

d. Did the water levels change after you added the slug? Why or why not?

e. Did the water levels change during the 5 minutes after you added the slug? Why or why not?

f. If the water levels did change, was it a significant change? Was it a rapid change? Did the water level change at the same rate over the 5-minute time period? Calculate the average rate of change for the five minute span using appropriate units. (i.e., inches/minute, ft/second, ft/minute...)

SWW: DWW:

g. What does this rate mean? Does it tell you anything about soil characteristics, such as permeability? Explain.

h. Imagine the person next to you had a large barrel of illegal pesticides and decided to get rid of them by dumping them on the ground. Where would they go? If they reach the water table of the aquifer beneath you, can you estimate how long it might take them to get there?

If the pesticides reach the water table, can you estimate how far they might travel in 5 days? (think about hydraulic gradient)

i. If we used a large pump to pump out all of the water in the shallow well, what would happen? If we kept pumping for days and days, do you think that the water table level would go down? Why or why not?

k. What happens when people drill shallow wells at their homes and pump the water into their house? Do their wells always keep providing them with water? Do you think that people can affect the level of a water table by withdrawing water from shallow wells? Can you think of any real life instances where this has happened?

C.

In a paragraph, describe some of the factors that you have learned today that help control the movement of groundwater. What can you say about human activities and the possible ways that we might affect aquifers?