Lesson # 3: Groundwater

Driving Question: Where Does Water Come From & Where Does It Go?

Learning Goal:

The groundwater system includes aquifers (rocks formations from which water can be withdrawn for use), springs, and the water table. Water moves underground through pore spaces and cracks in rocks and soil. (MEGOSE HS8, MCF(EH) V.2MS3) A variety of factors affect aquifer/groundwater system characteristics, including rock/sediment type, permeability, depth, and thickness. Aquifers can be either confined (bounded above by impermeable layers) or unconfined (unbounded).

Objectives:

O4 Apply an understanding of permeability to explain the movements of groundwater through confined and unconfined aquifers. (using)

O5 Develop/build models that explain how water moves through a groundwater system and watershed (constructing).

Assessment:

A4 Given a stratigraphic cross-section of a groundwater system, explain how a pollutant will affect different aquifers and wells.

A5 Build a model and explain the movement of water through a watershed and through a groundwater model.

Lesson Purpose:

This lesson explores the question, "Where does water come from?" It connects to lesson two by developing the groundwater portion of the drinking water system. It also engages students in building models, model-based reasoning, and small group work. An important component of this lesson is to develop an understanding of the relationship between groundwater and lakes and rivers. This understanding will be necessary for Lesson #4: Watersheds

Lesson Overview:

Activity Number	Label	Function	Description
3.1	Journal Questions	<u>Elicit Student Ideas</u> / <u>Establishes Purpose</u> - This activity links to lesson 2 by exploring more in-depth where and how we get our water from the ground.	Students respond in journals to daily question. This activity is repeated each day of this lesson, using different questions.
3.2	What Does Water Look Like Underground?	<u>Elicit Student Ideas</u> / <u>Establishes Lesson Purpose</u> - This activity establishes that this lesson will help students understand where Lansing gets its water. The T-Chart elicits student ideas about where water is located underground	Teacher presents question and elicits ideas - Where does Lansing get its water? Students complete the "before side" of a T-chart drawing

Activity Number	**Label**	**Function**	**Description**
3.3	Permeability	Construct Understanding - This activity allows students to build an understanding of permeability. Students will use the knowledge of permeability to understand aquifers (activities 3.4 & 3.5)	Students pour water on gravel and clay to see what happens to the water. Students learn the definition of permeability.
3.4	Aquifers - what are they?	Present Concepts - This activity presents students with concepts they will be exploring more in depth in activity 3.5	Using an overhead, teacher briefly explains what an aquifer is and the difference between confined and unconfined aquifers
3.4RT	*Soak Some Rocks*	*Re-teach Optional Activity- This activity may be useful to demonstrate to students that water really does soak into rocks. It is necessary only if students are having trouble understanding that there are spaces within rocks where water can go.*	*Students find the mass of rocks, soak the rocks overnight, and then find the mass of the rocks the next day. Students should find that the rocks soaked up water and have a greater mass.*
3.5	Building Groundwater Model	Construct Understanding/ Developing Models - This activity engages students in building a model of a groundwater system. It also introduces the idea of a cross-section and illustrates the relationship between a cross-section and a map.	Students build groundwater models, from a given cross-section. The cross section is drawn on 1/2 of a sheet of paper. The top 1/2 of the paper shows a related map. Students can fold the paper in half over the edge of a table to see the relationship between the map and cross-section.
3.6	Exploring the Groundwater Model	Constructing Understanding/ Inquiry Activity - This activity engages students in making observations and looking for patterns in the way water moves through a groundwater system, and how groundwater systems are connected to rivers and lakes.	Students pump water through the groundwater model, making observations and noting patterns of water use. The materials will guide students to examine the connection between surface water and groundwater.

Activity Number	Label	Function	Description
3.7	Well Problem: Where would you put a well?	Formative Assessment/ Model-Based Reasoning - This activity assesses how well students understand the relationship between surface water and groundwater by asking where a well should be drilled.	Given a new map/cross-section, students are asked to suggest a location for a new well and justify their answer based on the features on the map and cross-section.
3.8	What Does It Look Like Under Lansing? Well Log Cross-Section	Apply Understanding/ Developing Models - This activity addresses some of the same concepts learned in activities 3.5 & 3.6. However, it comes at the content from a slightly different angle. It also demonstrates how geologists use data to construct cross-sections, which are also models.	Students use well-log data to construct a x-section of the Lansing area.
3.9	Follow the Water	Apply Understanding/ Model-Based Reasoning - This activity requires students to use the cross-section models to solve problems.	Using the X-section drawn in 3.9, students trace the path of hypothetical water molecules through the groundwater system, given different scenarios. Groups present their ideas on posters to the whole class.
3.9RT	*Tracing Water Paths in Groundwater Models*	*Re-Teach Optional Activity This is an opportunity for students who are not understanding how water moves through groundwater systems to connect the idea of water moving through a cross-section to water moving through the groundwater model.*	*This is a teacher demonstration to help students understand the path that water takes through a groundwater system. The teacher adds dye to a groundwater tank. The students watch the path that the water takes through the system and then draw the path on a cross-section*
3.10	Surface Water or Groundwater? Which is Better?	Return to Lesson Purpose This activity returns to the lesson purpose and explores other options for cities to get drinking water. It also explores the pros- & cons of groundwater vs. surface water.	Students read about where Grand Rapids gets its water and discuss pros and cons of surface water vs. groundwater for a domestic water supply.

Activity Number	Label	Function	Description
3.11	Finish T-Chart	Lesson Assessment - This activity allows students to show what they learned about where water is located underground. It also allows students to compare what they have learned to their original ideas.	Students complete the T-Chart started in activity 3.2.

Preconceptions:
The research literature documents the following student ideas that are not congruent with a scientific understanding of groundwater. This lesson addresses these some of these preconceptions by building on student ideas. The idea is to help students move their understanding towards a more scientific understanding, rather than simply correcting misconceptions. You should be aware of these preconceptions, but it does not mean that all of your students will hold these ideas. It is important for you to elicit your own students' ideas and build on their ideas during this unit.

Common Preconception Visible in Drawings	Desired Goal Conception	Activity that Addresses this Preconception	What to emphasize
1. Groundwater occurs in underground tanks or pipes	Ground water fills spaces between the particles that make up soil and rock.	3.3 - Permeability	Students can see water in the spaces between the gravel grains.
		3.4 Aquifers – What are They?	Teacher introduces the concept of an aquifer. Emphasize where the water is stored in the aquifer (in the cracks and spaces).
		3.4RT Soak Some Rocks	*Students determine whether or not rocks can absorb water.*
		3.5 Building Groundwater Model 3.6 Exploring the Groundwater Model	Students can see water in the spaces between the gravel grains.
2. Groundwater occurs in underground rivers, lakes, or very large open spaces		3.3 - Permeability	Students can see water in the spaces between the gravel grains.
		3.4 Aquifers – What are They?	Teacher introduces the concept of an aquifer. Emphasize where the water is stored in the aquifer (in the cracks and spaces).
		3.4RT Soak Some Rocks	*Students determine whether or not rocks can absorb water.*
		3.5 Building Groundwater Model 3.6 Exploring the Groundwater Model	Students can see water in the spaces between the gravel grains.

Common Preconception Visible in Drawings	Desired Goal Conception	Activity that Addresses this Preconception	What to emphasize
3. Groundwater exists separately from the rest of the water cycle.	The water in the ground is part of the water cycle and is connected to the surface water. Water in the ground is often stored underground for very long periods of time.	3.5 Building Groundwater Model 3.6 Exploring the Groundwater Model	Students should see how the lake and the aquifer are connected – water moves in and out of the lake through the aquifer.
		3.7 Well Problem	Students should recognize that one of the best places to put the well is near the river because the aquifer is being recharged by the water in the river.
		3.8 Well Log Cross-Section	Emphasize that the groundwater table and the river levels are connected
		3.9 Follow the Water	Emphasize that the water can soak into the ground from the river or from water running off any surface.
		3.9RT Tracing Water Paths in Groundwater Models	*Students watch colored dye move through a groundwater system*
4. Once it reaches the water table, groundwater does not move, unless pumped.	Groundwater can move through the pore spaces in the rocks and sediment. Groundwater moves under the influence of gravity, just like water on the surface.	3.5 Building Groundwater Model 3.6 Exploring the Groundwater Model	Students should see how the lake and the aquifer are connected – water moves in and out of the lake through the aquifer.
		3.7 Well Problem	Students should recognize that one of the best places to put the well is near the river because the aquifer is being recharged by the water in the river.
		3.8 Well Log Cross-Section	Emphasize that the groundwater table and the river levels are connected
		3.9 Follow the Water	Emphasize that the water can soak into the ground from the river or from water running off any surface.
		3.9RT Tracing Water Paths in Groundwater Models	*Students watch colored dye move through a groundwater system*

Materials:

Activity Number	**Per Student**	**Per Group**	**Per Class**
3.1	Journals		Journal questions posted on OHP or board
3.2	Student Resources Packet 3.2: T-Chart		
3.3	Student Resources Packet 3.3/3.4	• 1 clear plastic drinking cup filled with gravel • 1 clear plastic drinking cup filled with powdered clay • 1 plastic cup of water • eye dropper or plastic pipette with narrow tip.	
3.4	Student Resources Packet 3.3/3.4	• Same cups as above • eye dropper or plastic pipette with narrow tip.	• Aquifer Overhead • Groundwater System Overhead
3.4RT	*Student Resources Packet 3.4RT*	• *Plastic cup* • *Rock sample* • *Grease pencil* • *Triple-beam balance*	*Group data table on board or OHP (you will need to draw it on the board or OHP)*
3.5	• Student Resources Packet 3.5/3.6 • Groundwater Model Cross-Section & Map	• Modeling tank, stopper & well http://www.mines.edu/outreach/cont_ed/esrc.shtml#pgwm • Gravel • Sand • Clay (powdered) www.wardsci.com 80 V 5719 Stress Clay, 20 lbs.	Teacher Demonstration Model
3.6	• Student Resources Packet 3.5/3.6 • Groundwater Model Cross-Section & Map	Rain cup (plastic cup with holes punched in the bottom) Cup of water	Overhead of the Groundwater Model
3.7	• Student Resources Packet 3.7 • Well Problem Cross-section and Map		• Teacher Demonstration Model • Well Problem Cross-section and Map Overhead
3.8	• Student Resources Packet 3.8 • Blank Cross-Section • Well Logs	Colored pencils	Blank Cross-Section Overhead
3.9	• Student Resources Packet 3.9 • Completed Well-Log Cross-section		Completed Well-Log Cross-Section Overhead

3.9RT	• Student Resources Packet 3.9RT		• Teacher Demonstration Model • Food Coloring • Grease Pencil

Activity Number	Per Student	Per Group	Per Class
3.10	• Student Resources Packet 3.10 • Reading about Grand Rapids water supply		
3.11	• Student Resources Packet 3.11 • T-Charts		

Activity 3.1 Journals (10 minutes)
Function/Rationale:
This activity
1. Allows the teacher time to take roll and complete administrative duties while students enter the room. Students should be expected to complete the journal activity everyday without prompting.
2. Elicits student ideas and previews the new lesson for the day.

Directions
1. Post journal questions on the overhead projector or chalk board. Suggested journal questions.
2. Students should respond individually in their journals to the daily journal questions.
3. Review the questions. Lead a short discussion asking for sample student responses.
4. There will be new journal questions for each day. The following are suggested journal questions. You should adapt the questions to your students' needs and the specific logistics of the lessons. Use the journal questions as opportunities for embedded assessment and re-teaching, if necessary.
5. First Day - Yesterday we learned that some cities get their water from underground. Where does this water come from and how does it get there? *The water comes from rain that soaks into the ground from the surface, including rivers and lakes.*
6. Other potential questions
   A. A city relies on groundwater for its drinking water. It has always assumed that the groundwater aquifer will recharge itself. As the city grows, more streets and parking lots are paved. What might this mean for the aquifer? *The ground surface will become impermeable and the less water will infiltrate.*
   B. How will the flow rate of groundwater in a well compare with the flow rate of water in a river? (faster, slower, the same) Why? *Slower, because the water has to move through tiny pore spaces.*
   C. You have a house along the banks of the Mississippi River. You are going to dig a well for water. The bottom of the river is about 15 feet below the ground surface where you dug your well. Approximately how deep will you have to drill your well to get water? *You have to drill to the level of the water surface of the river.*
   D. Two nearby cities both get their drinking water from groundwater. Quakerville gets its water from an unconfined aquifer and Ramsville gets its water from a confined aquifer. What are the advantages and disadvantages for Quakerville (or Ramsville)? *The unconfined aquifer is shallower, so the city does not have to drill as deeply. However, the water table in the unconfined could be unstable and he unconfined aquifer could be more susceptible to pollution.*
   E. Cleveland gets its drinking water from Lake Erie. What would be the advantages and disadvantages of getting drinking water from the surface, rather than the ground? *If the*

surface water is nearby, it may be cheaper to take the water from the lake rather than the ground. However, the lake could possibly be more susceptible to pollution.

Embedded Assessment Suggestion:
Daily journals provide some useful assessment that can be used to monitor students' progress and difficulties with understanding the content. Moreover, since the data are collected daily, they provide opportunities for you to take corrective action when students are having difficulties.

Activity 3.2: What Does Water Look Like Underground? (10 minutes)
Function/Rationale:
1. Elicits Student Ideas - The T-Chart elicits student ideas about where water is located underground
2. Establishes Lesson Purpose - This activity establishes that this lesson will help students understand where Lansing gets its water.

Directions:
1. Explain to students that the city of Lansing gets is water from wells that take water from underground. Ask students, "What does it look like underground? Where is the water?"
2. Have students share a few responses with the class to help students begin thinking about their own answers.
3. Distribute "Before & After" T-Charts.
4. Direct each student to draw a picture of where they think the water is underground. Have students label the important parts of their pictures.
5. Collect all pictures (make sure the students put their names on the sheets as you will return these later). The "After" part of the T-Chart will be completed at the end of lesson (Activity 3.11).

Embedded Assessment Suggestions
1. Examine the T-charts for preconceptions and also be alert to the discourse in groups while students are at work.
2. Do not worry about correcting scientifically incorrect ideas yet. As you work through the lesson, be aware of the preconceptions students have and take advantage of opportunities to help students build more scientifically-acceptable ideas.
3. Refer to the table in the preconceptions section. Depending on what the student drawings show, you may decide to emphasize certain aspects of these activities to help your students build more scientifically-acceptable ideas.

Activity 3.3: Permeability (10 - 15 minutes)
Function/Rationale:
1. Construct Understanding - This activity allows students to build an understanding of the relative meaning of permeable and impermeable. Students will use this understanding to understand aquifers (activities 3.4 & 3.5)

Directions:
1. Before the class period, place 1 cup of gravel, 1 cup of clay, and 1 cup of water on each table.
2. Have students pour half of the cup of water onto the gravel and the other half of the water onto the powdered clay.
3. Have students observe where the water goes in each cup and record their observations.
4. Define **permeability** - how easily water moves through the pore spaces. Permeability is relative. Gravel has a greater permeability than sand. Clay and shale have a very low permeability, to the point that for practical purposes, they are **impermeable**.

5. If necessary provide the following analogy: Imagine a room filled with beach balls. How much space is between the beach balls? Would water flow through these spaces easily? We would say this room is permeable. Now imagine a room filled with golf balls. How much space is between the golf balls? It would be harder for the water to flow through the golf balls. We would say this room is less permeable than the room with beach balls. Finally, imagine a room filled with ball bearings. There is still space between the ball bearings, but they are very, very tiny. It would be much harder, and take much longer for the water to flow through the ball bearings than the beach balls. We would say the ball bearing room is almost impermeable.
6. Note: Students may have trouble understanding later that rocks are impermeable in the short-term, but permeable in the long-term. Given enough time, rocks like sandstone are permeable. That is why we have aquifers in sandstone. However, during a rainstorm, water falling on rock will not soak in very much; most will run-off. So, permeability is also relative to time.
7. Introduce the term **infiltrate** - to soak in.

Group Work Suggestions

1. Remind students to share their ideas before writing their answers on their papers.

Embedded Assessment Suggestions

1. Examine student drawings to compare the quality of student observations with their responses to the questions. If students are not making careful drawings, consider modeling how to make careful observations and records of observations.
2. Examine definitions to determine if students are recording the definitions of permeable and impermeable correctly. Students will be using these concepts in later activities and need to understand these concepts in order to apply them.
3. As you move among the groups of students at work, ask them to describe what is meant by *impermeable* and *permeable*.
4. If students are having difficulties with understanding permeable and impermeable, consider doing activity 3.4RT.
5. Sometimes students will understand that gravel and sand have spaces for water, but will not believe that sandstone or other solid rocks have spaces for water. In this case, consider doing activity 3.4RT.

Activity 3.4: Aquifers - What Are They? (5 minutes)

Function/Rationale:

1. Present Concepts - This activity presents students with concepts they will be exploring more in depth in activity 3.5

Directions:

1. Explain that an aquifer is a layer of rock or sediment that is permeable enough to allow large quantities of water to soak into it and allow water to be pumped or flow out of it for use (by people).
2. Have students work in groups to use their eye dropper or pipette try to pull water out of the cup with gravel and water and out of the cup with clay and water. Students should easily be able to pull water out of the spaces between the grains of gravel, but will not be able to get water out of the clay.
3. Use the overhead transparency of the Aquifer to discuss where water is stored underground. Where is the water stored?
4. Point out the following features and have students provide the explanations.
   A. Aquifer
   B. Water Table

5. Use the Groundwater System Overhead to develop the idea of a groundwater system. Point out the following features:
   A. Unconfined aquifer – aquifer that is open to the surface; that is, there are no confining layers above it. There may be another unconfined aquifer above it, but no confining layers.
   B. Confining layers – A layer that is impermeable and prevents water from soaking through into layers below.
   C. Confined aquifer – An aquifer that is below a confining layer.
   D. Water table – The top of the saturated zone. Below the water table, all of the pore spaces are filled with water. Above the water table, water may infiltrate down, but all of the pore spaces are not filled. The water table is the level in the well where we way we “hit water”.
   E. Location of water table relative to the river – The water table is usually the same elevation as the water in a river or lake.
   F. Spring – Where groundwater exits the ground onto the surface.

Embedded Assessment Suggestions
1. Evaluate student definitions of aquifer. Either use the overheads or create new drawings to re-teach the concept of aquifers.
2. Sometimes students will understand that gravel and sand have spaces for water, but will not believe that sandstone or other solid rocks have spaces for water. In this case, consider doing activity 3.4RT.

Activity 3.4RT: Soak Some Rocks (Optional Re-teach Activity) (15 minutes on each of 2 days)
Function/Rationale:
1. Use this activity to show that permeability is relative. While it is true that hard surfaces such as surfaces made of rocks are impermeable in the short-term and cause water to run-off, in the longer-term, rocks have spaces that can hold water. Students may recognize the apparent contradiction; this activity may help them resolve that conflict.
2. This is also an inquiry activity. Students will collect data to answer a question

Directions
1. Ask the class, "But what about rocks? We saw in our models that there are spaces in sand and gravel that hold water, but what if the ground is made of rocks? Can there still be water in the rocks?”
2. Have students write their answer to the preview question in their Student Resource Packets. "Where is the water in rocks?"
3. Ask students how they might find out if rocks hold water. Call on a few students for answers and have students write a response in the Student Resource Packets.
4. Explain that one way to find out would be to find the mass of the rock and then soak the rock in water. It is important that students understand the purpose for finding the mass of the rocks; otherwise this activity does not achieve its function in helping students understand that rocks hold water. Students should understand that they are testing to find out if after soaking the rock, the rock has more mass. If it does, then the rock soaked up some water into the tiny spaces in the rock. Refer back to the beach ball analogy, if necessary.
5. Allow one student from each group to choose a rock.

6. Have each group find the mass of their rock and record it in the Student Resource Packet and on a table on a white board. Be sure students find the mass of the rock without the plastic cup. You may need to remind students of proper lab procedures.

Group #	Mass of Dry Rock	Mass of Wet Rock

7. Have each group label a plastic cup with their group name, using a grease pencil or some other way of marking the cups. Each group should fill the cup with water, place their rock in the cup, and leave the cup overnight.
8. As an alternative, you may wish to have one student volunteer to record the mass of one rock. The entire class can record the results on the table in their Student Resource Packet. This alternative may make it easier to monitor how well students use the balance, ensure that student results are accurate, and ensure that the activity reinforces the concept that some rocks have small spaces where some water may soak in.
9. On the following day (or longer, depending on the schedule), have students find the mass of their soaked rocks. Be sure students find the mass of the rocks without the cups.
10. Have record the mass on the white board and in their Student Resource Packet.
11. Have students answer the questions in their Student Resource Packet.
12. Review with students what their findings mean.

Embedded Assessment Suggestions

1. Student answers will guide you in how well students understand that water could be in pores and cracks in the rocks.
2. If students are having difficulty, you may re-address this problem in activities 3.5 & 3.6. When you get to these activities, have students draw a picture of where the water is in the model. The picture should show the water between the rock and sand particles.

Activity 3.5: Building Groundwater Model (30 minutes)

Function/Rationale:

1) Developing Models – This activity engages students in actually building a model of a groundwater system. They will use this model in activity 3.6 to understand how water flows through groundwater systems.
2) This is a group activity. Students will work together to construct their model and their understanding of groundwater systems.
3) This activity introduces the idea of cross-section and illustrates the relationship between a cross-section and a map.

Preparation:

1) Before class, build a teacher demonstration model. This model should not be the same as the model the students will build. You will use this model to introduce the idea of a model.
2) Label the following features on the teacher demonstration model using either sticky-notes, mailing labels, or grease pencil
   A) Confining layer (clay layer)
   B) Confined aquifer (below clay layer)
   C) Unconfined aquifer (above clay layer)
3) You will also use this teacher demonstration model in activity 3.6 to help students who are having trouble.

Directions:

1) Introduce to students the concept of a model. Use the teacher groundwater model to explain what a model is. Explain that scientists build models to help them understand ideas and things they may not be able to see directly. Models also help scientists play

with variables to see how things work. Students will be building groundwater models to see how groundwater systems work.

2) Demonstrate for students how to fold the Groundwater Model Plan.
   A) Fold the Groundwater Model plan in half along the line.
   B) Unfold the paper so that it makes a 90 degree bend. Hold the side labeled “map” horizontally and the side labeled “cross-section” vertically.
   C) Explain that the vertical side is like looking at the ground from the side through a window. It shows the layers underground. This is called the cross-section view. The horizontal side is what is on top of the ground. It is called the map view.
3) Explain that students will build a model in their Groundwater Model tanks that looks just like the drawing of the cross-section. Hints (from student pages):
   A) Insert the stopper tightly into the hole in the plastic tank.
   B) Put the well in first, next to a side of the tank so that you can see it through the tank wall.
   C) Pour the sand layer into the tank.
   D) Use a cup to pour just enough water into the tank to fill up the sand. There should be no water standing on top of the sand. The sand should just be wet.
   E) Pour in the rest of the sediments in layers carefully and evenly. Don’t mix the sediments.

Group Suggestions

1. Help students work together to build the model. Remind them that everyone should contribute.
2. If necessary, you may decide to assign roles to groups. For example: Materials Managers get the materials for the group, Checkers make sure the group is putting the materials into the model so that the model matches the paper cross-section. Other group members could be assigned a layer to put into the model, if necessary. However, it may be that groups can work these roles out for themselves.

Activity 3.6: Exploring the Groundwater Model (15 – 30 minutes)

Function/Rationale:

1. This activity engages students in making observations and looking for patterns in the way water moves through a groundwater system.
2. Students construct an understanding of how groundwater systems are connected to rivers and lakes.
3. The whole-class discussion allows the teacher to get a gauge of the class understanding.
4. The student-drawing and labeling on the cross-section serves as an embedded assessment of individual and whole-class progress on understanding groundwater systems.

Directions:

1. Have students follow the materials to add water and pump water through their models.
2. Students should complete the cross-section of the Groundwater Model Plan by labeling the following features:
   A. Confining layer (clay layer)
   B. Confined aquifer (below clay layer)
   C. Unconfined aquifer (above clay layer)
   D. Top of the water table (∇)
   E. Arrows that show the flow of water from the rain through to the well.
3. Hold a whole-class discussion. Ask the following questions. Have students provide answers. You may use the overhead of the Groundwater Model Plan to facilitate the discussion

A. How does the water get into the unconfined aquifer? *Because there are no impermeable layers above it, water can infiltrate into the ground. Where it collects is the aquifer.*
B. What is a confined aquifer? *A confined aquifer is under an impermeable confining layer.*
C. What is a spring? *A spring is where the groundwater intersects the ground surface and spills out onto the surface.*
D. How does the water get into the confined aquifer? *Water takes a very long time to fill a confined aquifer. The confining layers are relatively impermeable, but given a long enough time, water will eventually infiltrate through it. Water can also fill a confined aquifer from the side.*
E. What is the relationship between the river and the water table? *The river and the water table are at the same level.*

Group Suggestions
1. Remind students to help each other with completing labeling of the Groundwater Model Plan.
2. Remind students that they will be grading themselves on their group work.
3. Provide guiding suggestions to groups that are not working well together.

Embedded Assessment Suggestions
1. During construction of the groundwater systems, offer guidance. Ask guiding questions as necessary to make sure students understand how and why their systems work. Check that students understand that water infiltrates into the aquifers from above or from lakes and streams. Check that students understand that water moves at different rates, depending on the size of the spaces (permeability). Check that students understand that clay layers are impermeable (usually). Also check understanding of the terms water table, saturated, and unsaturated. Take the opportunity to help students understand the aquifer concepts if they are having trouble.
2. You may want to consider having students label their models before labeling their Groundwater Model Plan. Use sticky-notes, mailing labels, or grease pencils to have students label their groundwater models with the following features.
   A. Confining layer (clay layer)
   B. Confined aquifer (below clay layer)
   C. Unconfined aquifer (above clay layer)
3. After students build the model aquifers to examine where water is held in aquifers, spot check student descriptions and drawings. This check will give you an idea of how much you need to emphasize the drawings on the overhead transparency to show water in pore spaces and cracks.
   Note: Some students may think that underground water is stored in tanks. You may be able to confront this alternative conception by asking students how the water would get into the tanks. Show students that the water can soak into the ground through pores, but water cannot soak into a tank. If, however, students believe that groundwater is stored in underground rivers, lakes, and caverns, acknowledge that in special circumstances, this will happen. In areas with limestone, a unique type of rock that dissolves slowly in water, large underground caves may develop. Sometimes, these underground caves are filled or partially filled with water. This situation does exist in places like Kentucky, Ohio, Florida, and in some areas of Michigan. However, in most places, including Lansing, the groundwater exists in the pore spaces and tiny cracks in the rocks.
4. During the group discussion, monitor the types of answers you are receiving. If students are having trouble answering questions, consider using a teacher-built demonstration model to demonstrate important relationships from the questions to individual groups or to the entire class.

5. Evaluate group work evaluations for students' conceptions of how well their groups are working. Consider providing feedback and guidance to the class about what parts of their group work is going well and what they can do to address their own concerns.

Activity 3.7: Where Would You Put A Well? (20 minutes)
Function/Rationale:
1. This activity serves as a formative assessment for how well individual students understand the relationship between surface water and groundwater.
2. Students use model-based reasoning skills to solve a problem.

Preparation:
1. Build another demonstration model. This model should match the map and cross-section designed for this activity. (See Student Resources).

Directions:
1. Provide students with a map/cross-section.
2. Introduce the activity by showing the demonstration model to the class. Explain the task.
3. Remind students that they are to complete the first part of this activity (steps 1 – 5) individually. Students may share their answers after they complete step 5.
4. If students decide to change their answers, they must do it in a different color (do not erase) and explain why they changed their minds and why the new location is better.
5. Remind students how to fold the map/cross-section, like they did in activity 3.4.
6. Have students read the directions and use the information on the cross-section and map to determine where to locate a well.
7. Students must write out the justification for their choice for well location.
   Student Directions

1. You own all of the land in the picture. You need to drill a well for water for your house. You do not want to take the water directly from the river because the river water is not as clean as the groundwater.
2. Examine the picture of the cross-section below. Label the following features:
   A. Unconfined aquifer(s)
   B. Confined aquifer(s)
   C. Confining layer(s)
3. Remember, it costs about $9 per foot to drill a well. So, you don't want to have to spend too much money, but you also want to make sure you have enough water for your house.
4. Decide where would be the best place to drill the well so that you will have water all year long. Draw in your well. Be sure to show how deep your well should go.
5. Justify your well location below. Explain
   A. Why you chose to put it where you did.
   B. Why you drew it as deep as you did.
6. Share your answers with your group members.
7. If you decide to change your answer, draw in a second well in a different color from the first well. Be sure to use a key to identify which well was your first well and which well was you second well.
8. Justify your change below. Explain why you changed your well location and why the new location is better.

Formative/Embedded Assessment
1. The best location for a well in this cross section is near the river, below the first confining layer. Here, the aquifer will be recharged by the river. A student could put the well above the first confining layer, but there is less surface area to fill the aquifer, this aquifer is fairly shallow, and the recharge area is partially covered with a road (Cherry Lane).

2. After you have assigned this problem and students have turned in their answers, you should go over the problem with the students. Ask students for their answers and justifications. An overhead is provided.
3. Refer to the teaching demonstration model to help explain potential solutions to the students.

Activity 3.8: What Does It Look Like Under Lansing? Well Log Cross – Section (50 minutes)

Function/Rationale:

1. This activity addresses some of the same concepts learned in activities 3.5 & 3.6. However, it comes at the content from a slightly different angle.
2. This activity also demonstrates how geologists use data to construct cross-sections, which are also models.

Directions

1. Have students answer the pre-view question in their packets.
   Preview Question: How do we know it looks like under Lansing?
2. Ask for several student answers to the pre-view question.
3. Explain in detail how to construct the cross-section. Suggested explanation:
   Today we are going to make a cross-section that shows what it looks like under Lansing. You are going to use data from Driller's Reports. Whenever drillers drill a well, they must take careful notes of the types of soil and rocks that they drill through. They record what they drilled through, how thick it was, and how deep it was. These records are then filed with the state government (Department of Environmental Quality in Michigan), where they become part of the public record.
4. Place the Ingham County Cross-Section on the overhead. Explain the cross-section. Suggested Explanation:
   A. Locate Well #1 on the Cross Section. Note that the top of the cross-section represents the surface of the ground. Find the Grand River and the Red Cedar River. The long columns represent wells. You will add in what the drillers found in each well and then make a hypothesis about what exists between the wells.
   B. Note that along the left side is the elevation marking. Along the sides of each well are the depth markings. We will be using the depth markings for each well when we draw in the layers.
5. Place the Driller's Record on the Overhead. Explain how to read a Driller's Record. Suggested explanation:
   Look at the Driller's Record for Well #1. The "Formation" column tells you what the driller found. The "Thickness of Stratum" column tells you how thick the layer was. The "Depth to Bottom of Stratum" tells you how deep the layer went underground.
6. Demonstrate step-by-step how to mark the layers in Well #1 using the data from the Driller's Record and the appropriate symbol from the key. Be sure to mark the water table.
7. Have students complete Wells #2, and #3. Students may work together, but each student must turn in her/his own packet.
8. Have students connect the layers. This becomes an estimate or a hypothesis about the underground structure between the wells. Note that layers in the Glacial Aquifer pinch out or become thinner as you move across the county.
9. Have students label the aquifers.
10. Have students answer the questions.
    A. How many aquifers are under Lansing? (*four - Glacial Aquifer, Saginaw Aquifer*, *Bayport Aquifer, Marshall Aquifer*
    B. List the confined and unconfined aquifers.
       a. Unconfined: *Glacial Aquifer & Saginaw Aquifer*
       b. Confined: - *Parma Bayport Aquifer & Marshall Aquifer*

C. How does the water get into the Glacial Aquifer? How does the water get into the Saginaw Aquifer? *(Water soaks into the Glacial Aquifer from rain and snow that falls on the surface of the ground and from water in rivers and lakes that all soaks (infiltrates) into the ground. This water continues to flow downward into the Saginaw Aquifer.)*

D. How are the Grand River and the Red Cedar River connected to the groundwater system? *(Water soaks into the ground through the river bed. The river is the surface expression of groundwater).*

E. If you were drilling a well for your own house in the same location as Well #3, how deep would you go? Why? Remember, it costs about $9/foot to drill a well. *(Make sure students can justify their answers. One possible answer could be as follows: Because drilling is expensive people probably do not want to have to go too deep. However, going only to the top of the clay layer would make the well very shallow and therefore possible susceptible to running dry during droughts. The clay layer will not yield much water because of its low permeability. Therefore, one would probably want to drill into the glacial gravels below. A well of about 150 feet might be safe. To be really sure, go to 200 feet into the Grand River & Saginaw Sandstone. However, this option will be more expensive.*

F. How have your ideas changed about what it looks like under Lansing?

11. Whole Class Closure
    A. Use the completed cross-section to help students see what the completed cross-section should look like.
    B. Choose several of the group questions to ask the whole class. Review as necessary

Group Management Suggestions

1. Check group grades and reasons. If there is a large discrepancy between your impressions of students' group work and their grades, be sure to address it the next day. You may consider holding a class discussion about what is going well, what needs work, and why.

Embedded Assessment Suggestions:

1. Check that students understand how to read the Driller's Record and make the well logs and cross-sections.
    A. Check that students are using the "depth to bottom" column to mark off the bottom of each layer in the wells.
    B. Make sure students are using the proper symbols for each layer. You might have them add the symbols to the Driller's Record so that they have a match between the Driller's Record and the Cross-Section.
    C. You may need to provide students guidance in constructing the cross-sections because two of the units pinch out.
2. Check to find out if students are getting the idea that some layers are aquifers and some are not. Suggested questions are listed below. Review as necessary.
    A. Which layers are not aquifers? *(Saginaw Confining Shale, Michigan Confining Shale) Shales are relatively impermeable compared to glacial sediment and sandstones.*
    B. Do these layers contain water? *Yes. However, the time that it takes water to move through these layers is so long that it is not possible to pump water out of these layers to use for drinking. The definition of "aquifer" is that an aquifer is a layer of water from which people can pump water for economic use. Shale layers usually do not fit this definition.*
    C. Why are they not aquifers? *(It is not possible to get the water out of these layers. Shales are made of clay-size particles. Clay is relatively impermeable and does not allow water to flow through it easily. Refer students back to Activity 3.3 when they poured the water onto the clay and the gravel.*

Activity 3.9: Follow a Water Molecule (20 – 30 minutes)

Function/Rationale:

1. This activity requires students to use the cross-section models to solve problems. Students use data taken from the cross-section to answer a question.
2. This activity begins as an individual activity, but provides students opportunities to share and explain ideas to others and then modify their original answers based on feedback from peers.
3. It will be important for students to have strong understanding of groundwater systems in order to understand how pollution travels through groundwater (lesson 5). This activity provides an opportunity to check on students' understanding in preparation for future lessons.

Directions

1. Students should use the same cross-section model that they completed in activity 3.8. You may decide to provide a copy of the completed cross-section for students who did not complete the cross-section model.
2. Using an overhead of the completed cross-section, model for students how to use a colored pencil to trace the path of a water molecule as it moves through the system. Begin the modeling at point Y.
3. Have students use a different color to trace the path of a water molecule beginning at point Z.
4. Students must explain their decision making process to another person in their group. Students record the name of the person to whom they provided the explanation.
5. After each partner has explained their path choice, students should then provide each other with feedback as to whether or not they agree with their partner and why.
6. Using a second colored pencil, students may make changes in their water path. Remind students not to erase the original path, but to change it using the new color.
7. Finally, have students write a few sentences about why they changed their path.

Group/Partner Work Suggestions

1. Remind students that by sharing ideas, they are helping others learn.
2. Model what it means for two students to help each other but not do the work for the other person.

Embedded Assessment Suggestions

1. Examine whether or not students are understanding:
    a. The connections between groundwater and surface water.
        i. You may ask individual students to explain why they drew the path that they did.
        ii. Ask student where the water from the river goes. *Some of it soaks into the ground.*
        iii. Ask students how water gets into the river. *Some comes from runoff from the surface, but some also soaks out through the ground.*
    b. The influence of permeable and impermeable layers
        i. Does water soak through the shale layers? *Yes, very, very slowly compared to how quickly it soaks through glacial sediment and sandstone.*
        ii. When water meets and impermeable layer, what will happen? *Some of the water will soak into the impermeable layer very, very slowly. Most of the water will pool on top of the impermeable layer or move sideways through the layer on top.*
2. If students are not demonstrating understanding of the above concepts, consider doing activity 3.9RT

Activity 3.9RT: Tracing Water Paths in Groundwater Models (15 minutes)
Function/Rationale:
1. This is an opportunity for students who are not understanding how water moves through groundwater systems to connect the idea of water moving through a cross-section to water moving through the groundwater model.

Preparations
1. Have access to the teacher demonstration model of the Ground Water Model (Activity 3.5/3.6) Alternative: Build a new model.
2. Do not allow students to use their own models for this activity because they will be using their models for the lesson 5. This activity adds food coloring dyes to the models and will render the models unusable for lesson 5.
3. You may choose to do this activity with just a small group of students who had trouble with activity 3.9.

Directions
1. This is a whole-class or group activity. You may have to have students gather around closely.
2. Have students identify the following features of the model. Use a grease pencil to label the features as the students identify them,
   A. Confining layers
   B. Unconfined aquifer
   C. Confined aquifer
3. Have students draw a picture of the groundwater model. Note, when students originally did this activity, they built their model from a drawing. It may have been a few days since they built the model. This time, have students draw the contents of the model without referring to the original drawing. Students should include the labels in their drawings.
4. Add some food coloring to the ground water model. As the food coloring moves through the tank, follow the leading front of the dye with a grease pencil, tracing the path of the dye onto the tank.
5. Have students draw the same path onto their drawings.
6. Discuss with students why the colored dye took the path that it did.
7. Have students explain the path in words on their papers.

Embedded Assessment Suggestions
1. Pay attention to student reasoning as they draw their water molecule paths. Questions you might ask include:
   A. Tell the story of the colored dye. Why does it take this path?
   B. Why did you draw this path going into this layer?
   C. What happens here? (Where the dye encounters an impermeable layer)
2. If students are still struggling, consider modeling the process again, narrating the path of the dye yourself out loud so that students can follow along.

Activity 3.10: Surface Water or Groundwater? Which is Better? (15 - 20 minutes)
Function/Rationale:
1. This activity returns to the lesson purpose and explores other options for cities to get drinking water.
2. It also explores the pros- & cons of groundwater vs. surface water.

Directions:
1. Have students read the paragraphs about where the city of Grand Rapids gets its water. Students may either read individually or in groups.

2. Have students work in small groups to discuss the pros and cons of surface water vs. groundwater for domestic water supply.

Suggested pros & cons

Groundwater Pros		**Groundwater Cons**	
Reason	Initials	Reason	Initials
1 May be cheaper to drill than to pipe water from a large supply of water a long way away.		1 Groundwater is not replenished quickly – therefore you use up the water fast.	
2 Groundwater may be of higher quality than surface water		2 It may be expensive to pump groundwater from very deep sources.	
3 Groundwater may be readily available		3 It may be contaminated with either natural or human-introduced toxic pollutants.	
4 Groundwater supplies are not affected by droughts		4 Groundwater may be too deep to access economically	
Surface Water Pros		**Surface Water Cons**	
Reason	Initials	Reason	Initials
1 Surface water may be readily available nearby		1 Nearest supply of surface water may not be enough to supply a large city	
2 Surface water may be replenished faster than groundwater		2 Surface water may have bacterial contamination or sediment and litter pollution.	
3 It may be cheaper to pipe water in from close distances than to drill and pump water from deep aquifers		3 Surface water may have to be piped a long way to the city.	
4 Surface water could be of higher quality than groundwater.		4 Surface water supplies may be susceptible to shortages during droughts.	

3. Use a large group discussion format to have each group share their pros & cons. Make a list of the pros & cons on the board or overhead.
4. Have students each answer question #6 in the student packet: Why do you think Lansing uses groundwater and Grand Rapids uses surface water for drinking water supplies?

Group Work Suggestions

1. Remind students that everyone must share their ideas. Groups are to make a list of pros & cons and initial each person's contributions.
2. During whole class discussion, have one person from each group nominate either a pro or a con for the class list. Go around the room and ask each group for a nomination. Ask students to explain the reason for their nomination.

Embedded Assessment Suggestions

1. Assess how well students are developing their pro & con lists. Students may need some guidance to get them going.
2. You may need to provide students with additional information and examples for them to develop pros and cons.
3. Check to be sure that students are using reasons to support their opinions in question #6. You may need to provide a model for the type of response that you would like them to produce.

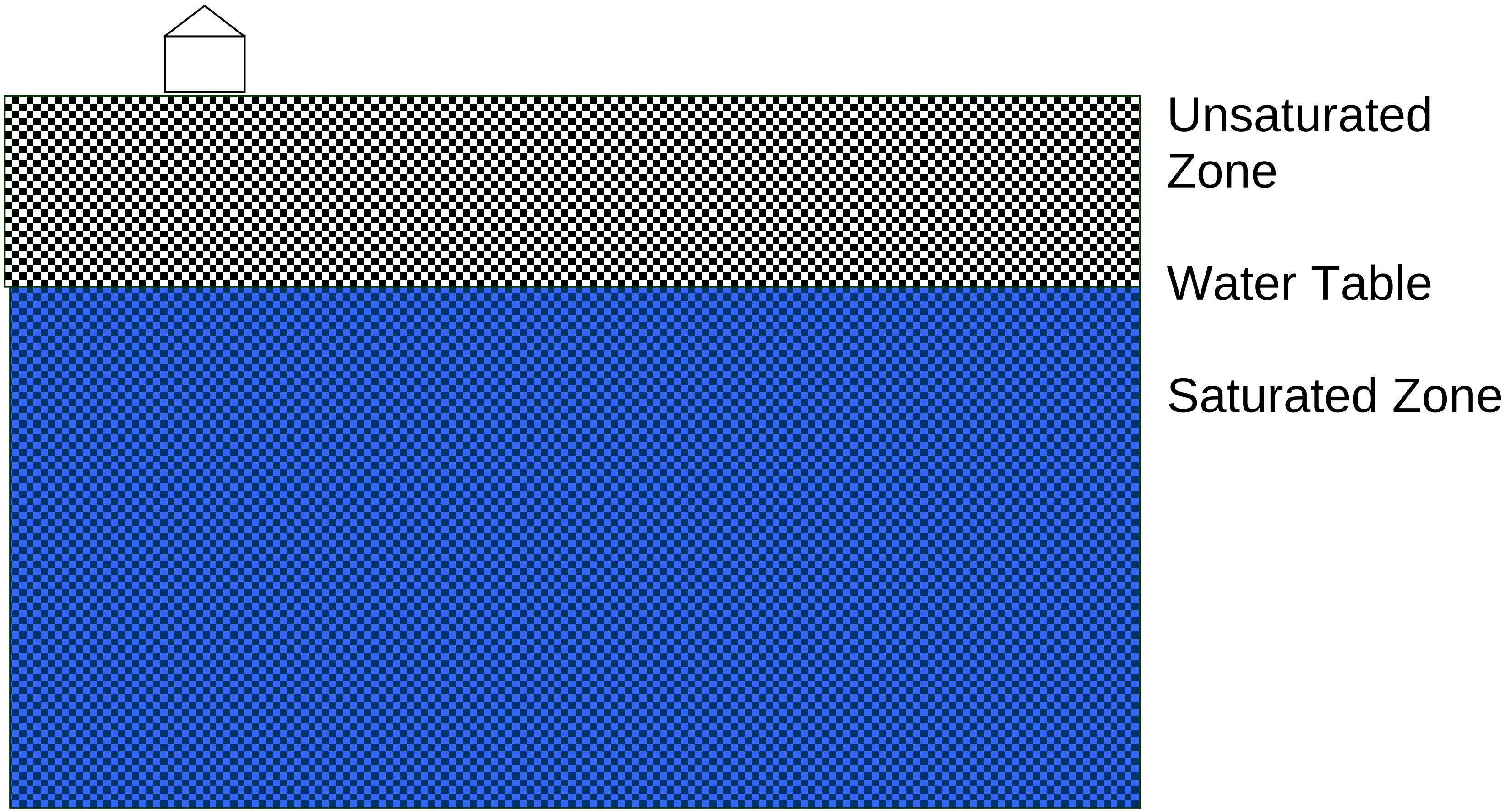
Activity 3.11: Finish T-Chart (10 minutes)
Function/Rationale:
1. This activity allows students to show what they learned about where water is located underground.
2. This activity also allows students to compare what they have learned to their original ideas.
Directions:
1. Re-distribute the "Before & After" T-Charts.
2. Have students draw the picture of what water looks like underground in the "After" side.
3. Have students write 5 complete sentences on the back summarizing what they learned about aquifers. Students should do this activity as homework if there is no time left in class.

Embedded Assessment Suggestions
1. Examine students' responses to see how their ideas have changed. Also, read the paragraphs to see how well students are aware of their own ideas. You may need to coach them on thinking about how their ideas have changed.

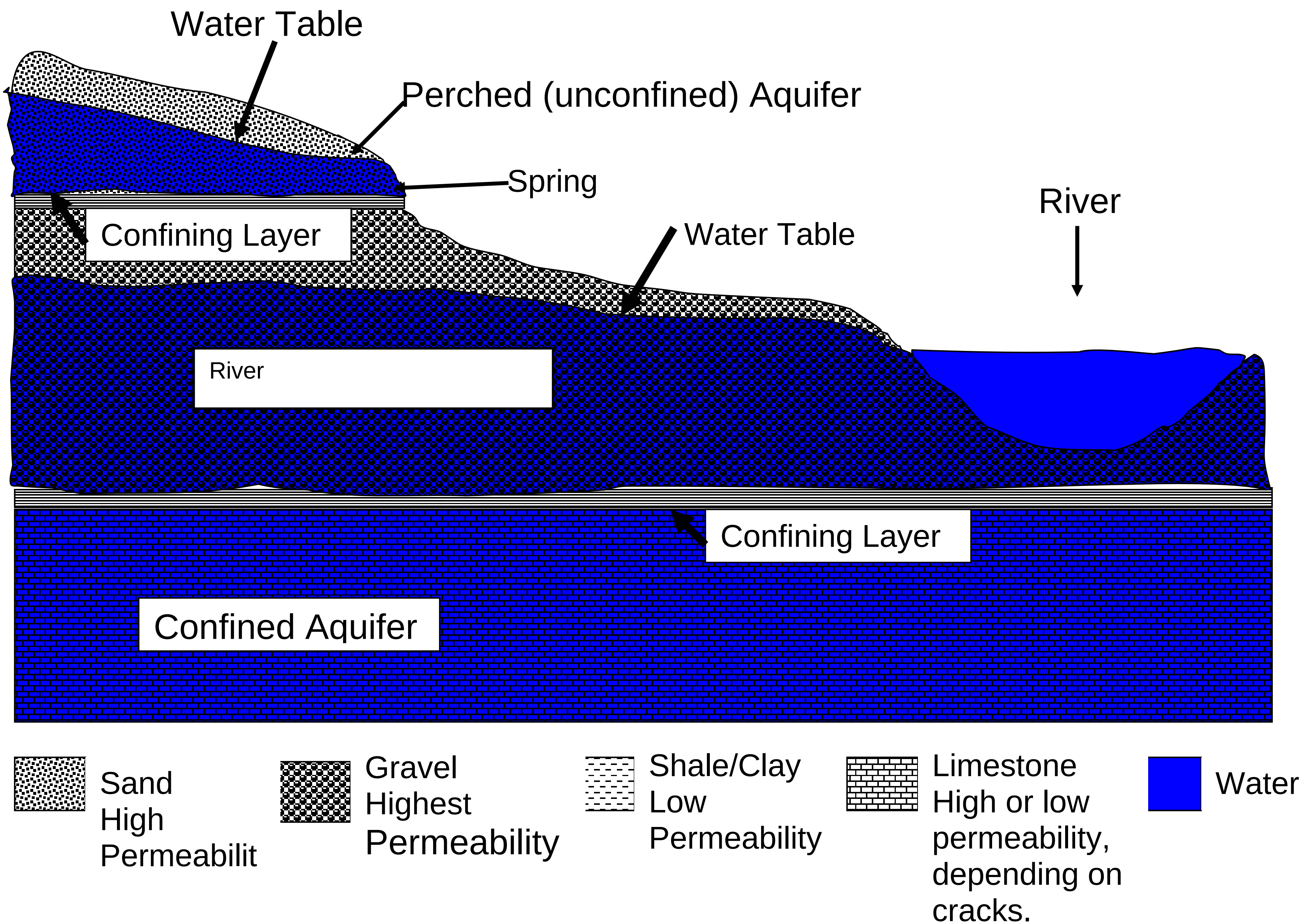
Activity 3.4 Aquifer Overhead

Aquifer

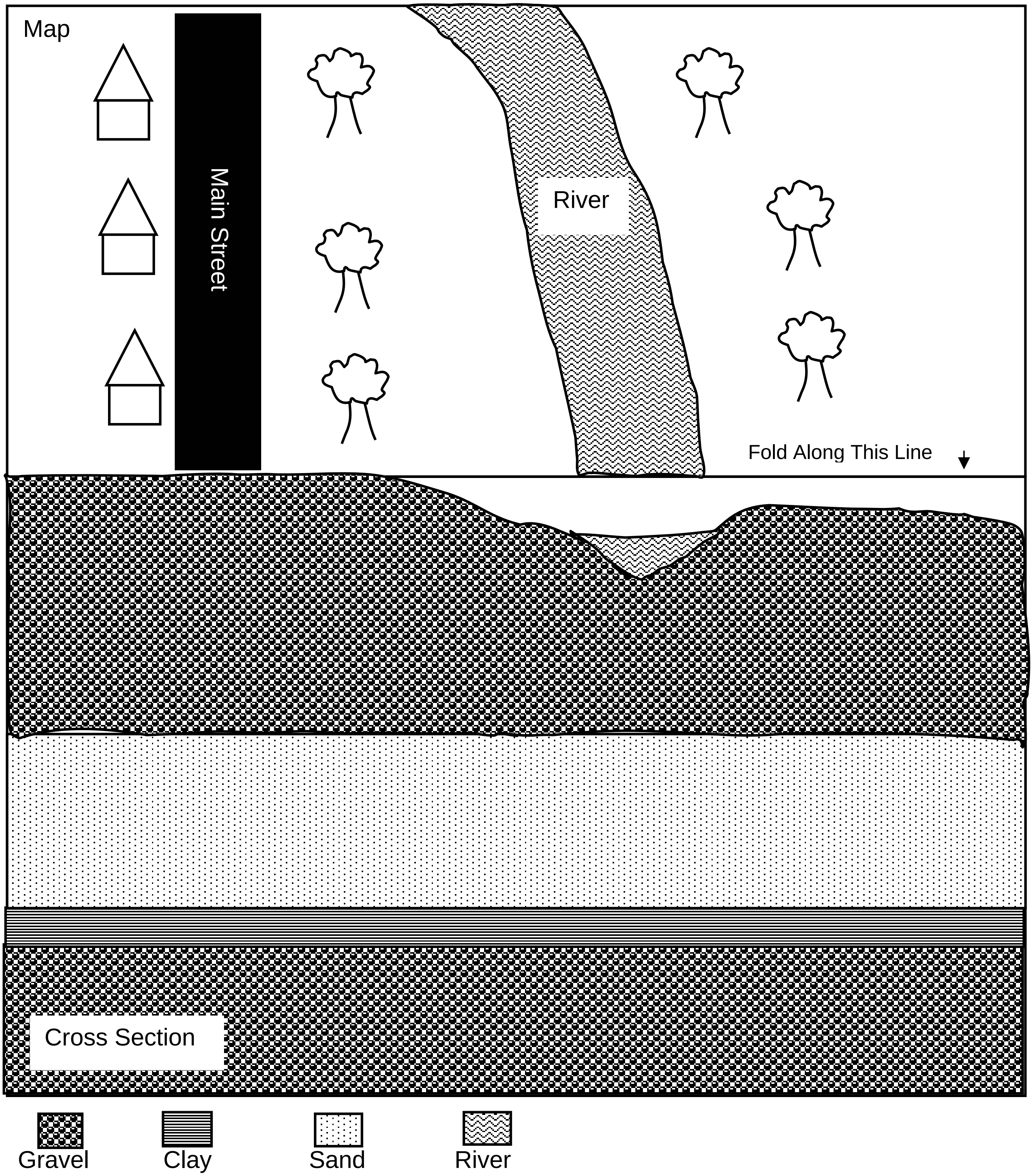
Rock, soil, or sediment that contains water that can be removed for use by pumping or natural flow.



Activity 3.4 Groundwater System Overview



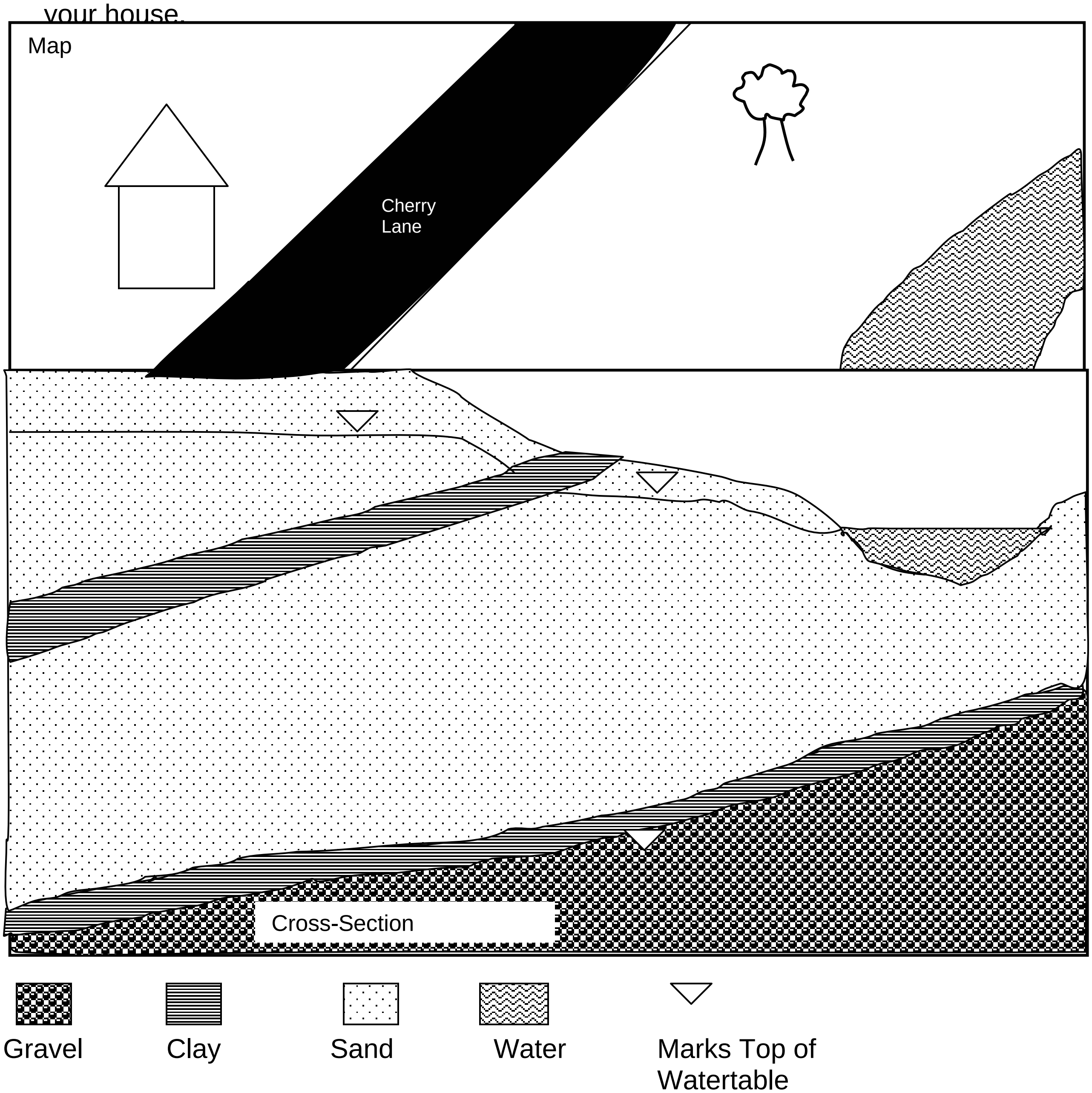
3.5/3.6 Groundwater Model Plan



Activity 3.7: Well Problem

Directions

1. You own all of the land in the picture. You need to drill a well for water for your house. You do not want to take the water directly from the river because the river water is not as clean as the groundwater.
2. Examine the picture of the cross-section below. Decide where would be the best place to drill the well so that you will have water all year long.
3. Remember, it costs about $9 per foot to drill a well. So, you don't want to have to spend too much money, but you also want to make sure you have enough water for your house.



Activity 3.8 Overhead

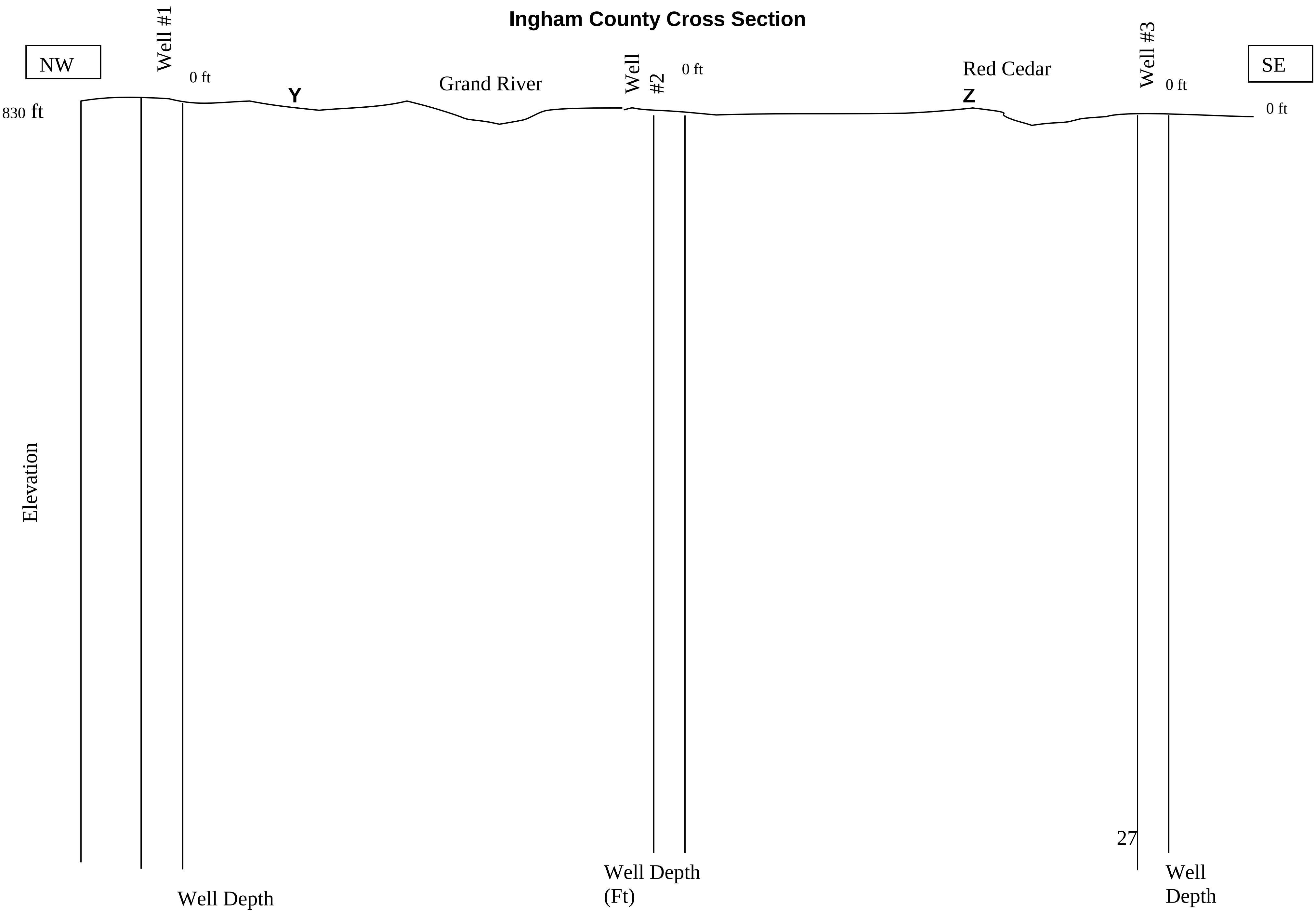
Driller's Records

Well #1

Formation	Thickness of Stratum	Depth to Bottom of Stratum
Glacial Coarse Sand (Glacial Aquifer)	50 ft	50 ft
Glacial Fine Sand (Glacial Aquifer)	50 ft	100 ft
Glacial Gravel (Glacial Aquifer)	200 ft	300 ft
Grand River & Saginaw Sandstone (Saginaw Aquifer	100 ft	400 ft
Saginaw Confining Shale	50 ft	450 ft
Bayport Limestone (Parma-Bayport Aquifer)	100 ft	550 ft
Michigan Confining Shale	50 ft	600 ft
Marshall Sandstone (Marshall Aquifer)	End	

Water Level **20 feet**

Ingham County Cross Section



Name:____Hour: _____________

Lesson # 3: Groundwater

Activity 3.2: What Does Water Look Like Underground?

Purpose: In order to understand where water comes from, we have to be able to imagine what it looks like underground. Where is the water underground? What does it look like down there?

Direction: Participate in the whole class discussion. On the "Before and After" T chart, draw a picture of where you think water is located underground. If there is water underground, what does it look like and how is it stored? Hand in this page.

Before	After

Name:____Hour: _____________

Lesson # 3: Groundwater

Purpose: How do sediments (gravel, sand, clay) store water? Is it easier to get water out of gravel or sand?

Activity 3.3: Permeability

1. Work as a group to complete the following steps
   A. Pour 1/2 of the water into the cup of gravel.
   B. Pour the other 1/2 of the water into the cup of powdered clay.
   C. Observe what happens to the water.
2. Draw a picture of your observations in the table. Draw your own picture.

Gravel	Powdered Clay

3. As a group, decide on a definition for permeability. Write your group definition here.
   ____

____

As a group, answer questions 4 & 5

4. Based on what your observations, which material is more permeable? Why?
   ____

____

5. Which material is almost impermeable? Why?

____

____

Activity 3.4 Aquifers - What are They?

1. Work as a group to complete the following steps and answer the questions.
   A. Use an eye dropper to try to get some of the water out of the cup with the gravel.
   B. Use an eye dropper to try to get some of the water out of the cup with the clay.

Student Resources Lesson #3 Groundwater

Name:____Hour: ______________

2. Which cup (gravel or powdered clay) could you get the water out into the eye dropper? Why?

____

____

What is an aquifer?

____

____

Name:____Hour: _____________

Lesson # 3: Groundwater

Activity 3.4RT: Soak Some Rocks

Purpose: But what about rocks? We saw in our models that there are spaces in sand and gravel that hold water, but what if the ground is made of rocks? Can there still be water in the rocks?

Directions

Where is the water in rocks?

____

____

Directions

6. Choose one rock for your group.
7. How might you find out if this rock could hold water?

____

____

8. One way to find out would be to find the mass of the rock and then soak the rock in water. Be sure to find the mass of the rock by itself, not with the cup. Record you data in the table below and on the white board or chalkboard.

Mass Before Soaking	Mass After Soaking

9. Label a plastic cup with your group names. Fill the cup with water. Gently place the rock in the cup of water. Soak the rock overnight.
10. Remove your rock from the cup.
11. Find its mass. Record it in the table above and on the white board or chalk board.
12. Did the mass change?____________
13. What does this finding mean?

____

____

Name:____Hour: ______________

Lesson # 3: Groundwater

Purpose: Models help scientists understand complex ideas. Sometimes, models help scientists understand things they cannot see. In the next two activities, you will build a model of a groundwater system and see what we can learn from the model.

Activity 3.5 Building Groundwater Model

1. Fold the Groundwater Model plan in half along the line.
2. Unfold the paper so that it makes a 90 degree bend. Hold the side labeled “map” horizontally and the side labeled “cross-section” vertically.
3. The vertical side is like looking at the ground from the side through a window. It shows the layers underground. This is called the cross-section view. The horizontal side is what is on top of the ground. It is called the map view.
4. Construct the groundwater system pictured in the cross-section of the Groundwater Model Plan. Hint
   A. Insert the stopper tightly into the hole in the plastic tank.
   B. Put the well in first, next to a side of the tank so that you can see it through the tank wall.
   C. Pour the sand layer into the tank.
   D. Use a cup to pour just enough water into the tank to fill up the sand. There should be no water standing on top of the sand. The sand should just be wet.
   E. Pour in the rest of the sediments in layers carefully and evenly. Don’t mix the sediments.
5. When you are done, the model should look like the one pictured in the cross-section. The map-view picture represents what the ground looks like on top.

Activity 3.6 Exploring the Groundwater Model

1. Use the cup with holes in it as the “rain cup”.
2. Hold the rain cup over the top of the model.
3. Slowly pour water into the rain cup so that it sprinkles into the model. Stop pouring water after the water has filled within 1 inch of the top of the top layer of the model.
4. Observe carefully where the water goes.
5. Label the following features on the Groundwater Model Plan
   A. The unconfined aquifer
   B. The confined aquifer
   C. The confining layer
   D. The top of the water table - draw a line across the entire cross-section to mark the top of the water table and label it "water table". You can also use an upside down triangle to mark the water table (∇).
6. Use arrows on the cross-section view of the Groundwater Model Plan to show the path of the water from the rain.
7. Use your cross-section to answer the questions in the whole-class discussion.

TURN THIS PAGE OVER

Name:____Hour: _____________

8. After you have finished working with your model and cleaned up your work area, evaluate your group work today.
   A. Write one thing your group did really well today.

   ____

   ____

   B. Write one thing your group needs to work on tomorrow

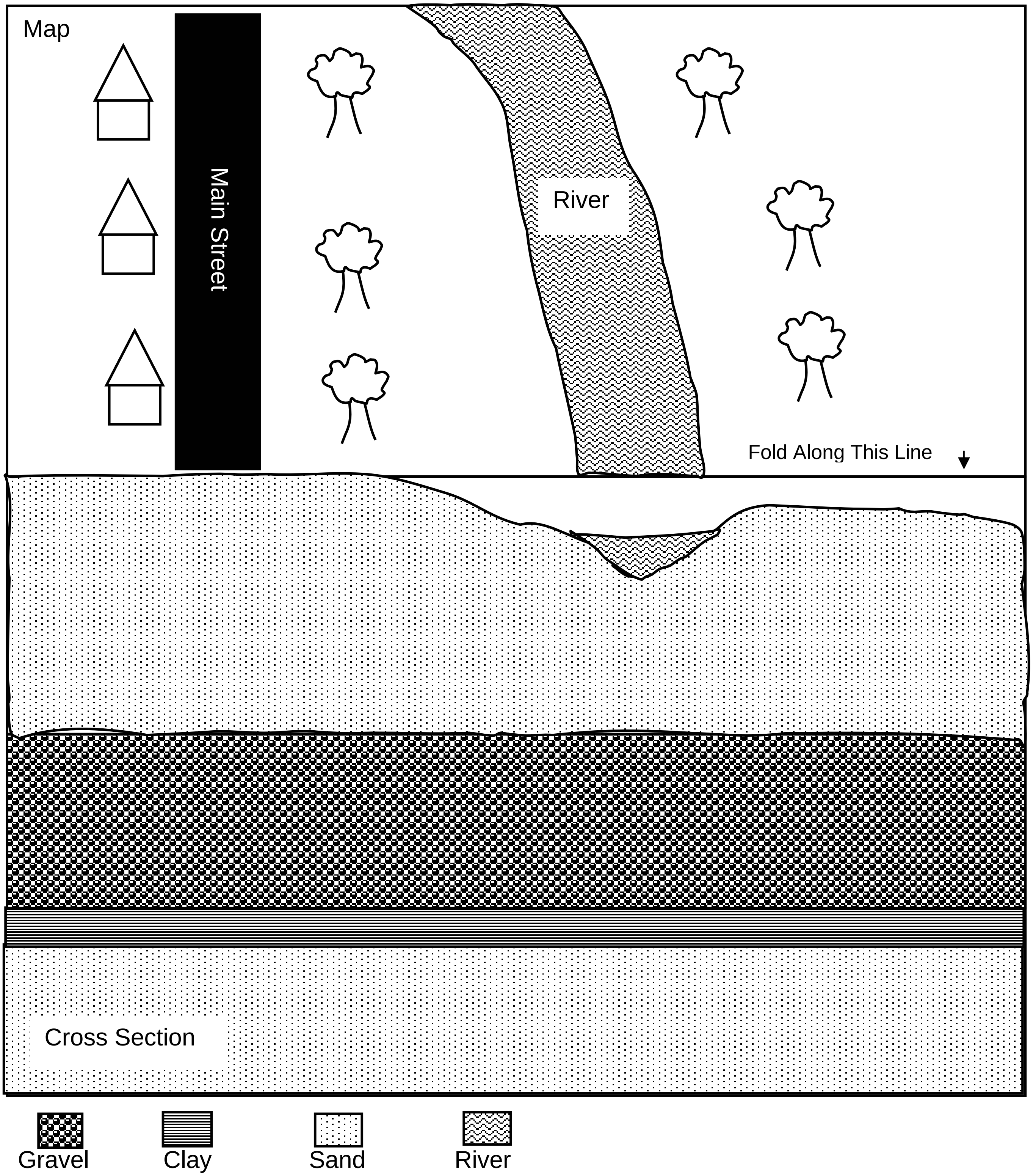
   ____

   ____

Name:____Hour: _____________

Lesson # 3: Groundwater

3.5/3.6 Groundwater Model Plan



Name:____Hour: ______________

Lesson # 3: Groundwater

Activity 3.7: Well Problem

Purpose: Understanding how groundwater systems work is important for helping people figure out where to put their wells.

Directions

1. You own all of the land in the picture. You need to drill a well for water for your house. You do not want to take the water directly from the river because the river water is not as clean as the groundwater.
2. Examine the picture of the cross-section below. Label the following features:
   A. Unconfined aquifer(s)
   B. Confined aquifer(s)
   C. Confining layer(s)
3. Remember, it costs about $9 per foot to drill a well. So, you don't want to have to spend too much money, but you also want to make sure you have enough water for your house.
4. Decide where would be the best place to drill the well so that you will have water all year long. Draw in your well. Be sure to show how deep your well should go.
5. Justify your well location below. Explain
   A. Why you chose to put it where you did.
   B. Why you drew it as deep as you did.

____

____

____

____

____

6. Share your answers with your group members.
7. If you decide to change your answer, draw in a second well <u>in a different color</u> from the first well (do not erase your first well). Be sure to use a key to identify which well was your first well and which well was you second well.
8. Justify your change below. Explain why you changed your well location and why the new location is better.

____

____

____

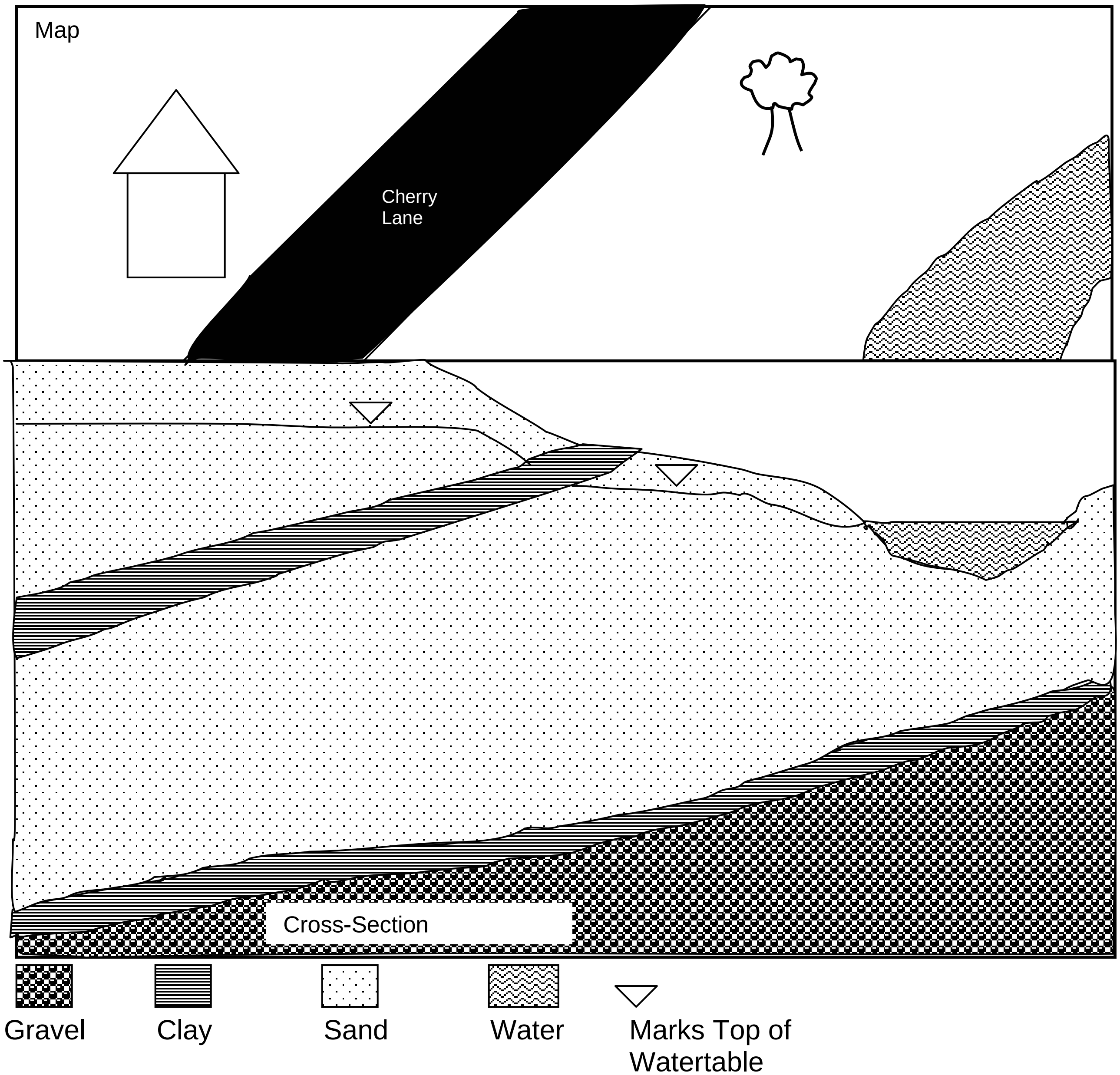
____

____

Name:____Hour: _____________

A. Lesson # 3: Groundwater

Activity 3.7 Well Problem Cross-Section & Map



Name:____Hour: _____________

Lesson # 3: Groundwater

Activity 3.8: What Does It Look Like Under Lansing? Well Log Cross – Section

Purpose: Models work well if we already know what it looks like underground. But how do scientists figure out what it looks like in the first place?

Preview Question

How do we know what it looks like under Lansing?

____

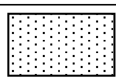
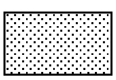
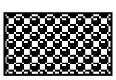
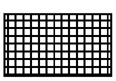
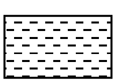
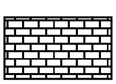
____

____

Directions

1. Locate Well #1 on the Ingham Cross Section Sheet
2. Read Driller's Report for Well #1
3. Fill in the Well Log for Well #1 on the Ingham County Cross Section, using the information in the Driller's Report and the correct symbols from the key.
4. Mark the top of the water table with a small triangle ▽
5. Repeat steps 1 - 3 for Wells #2 & #3.
6. Connect units across the wells. Be sure to fill in the units with the correct symbols from the key.

Key:

Symbol	Sediment or Rock Type	Relative Permeability
	Course Sand	Permeable
	Fine Sand	Permeable
	Gravel	Very Permeable
	Sandstone	Because the sand is cemented together as hard rock, this layer is less permeable than just sand, but it is still more permeable than clay or shale
	Shale	This is a very fine-grained rock. It is impermeable
	Limestone	This rock has lots of cracks in it that hold water and is about as permeable as sandstone
	Clay	Impermeable

Name:____Hour: _____________

7. Label the Sands and Gravels "Glacial Aquifer". Label the Grand River and Saginaw Sandstone "Saginaw Aquifer". Label the Bayport Limestone "Parma-Bayport Aquifer". Label the Marshall Sandstone "Marshall Aquifer".
8. Answer the Group Questions

Group Questions

You may use your group to help you answer the following questions. These questions refer to the completed cross section you just completed.

3. How many aquifers are under Lansing? ________

4. List the unconfined aquifers. List the confined aquifers.

Unconfined: ____

Confined:____

5. How does the water get into the Glacial Aquifer? How does the water get into the Saginaw Aquifer?

____

____

6. How are the Grand River and the Red Cedar River connected to the groundwater system?

____

____

7. If you were drilling a well for your own house in the same location as Well #3, how deep would you go? Why? Remember, it costs about $9/foot to drill a well.

____

____

8. How have your ideas changed about what it looks like under Lansing?

____

____

9. Grade your group work today. Then explain why you gave your group that grade. Consider how well people shared ideas, whether or not everyone participated, and how well you helped each other learn.

   Group Grade: ___________

Reason____

____

Name:____Hour: _____________

Activity 3.8 Driller's Records

Well #1

Formation	Thickness of Stratum	Depth to Bottom of Stratum
Glacial Coarse Sand (Glacial Aquifer)	50 ft	50 ft
Glacial Fine Sand (Glacial Aquifer)	50 ft	100 ft
Glacial Gravel (Glacial Aquifer)	200 ft	300 ft
Grand River & Saginaw Sandstone (Saginaw Aquifer	100 ft	400 ft
Saginaw Confining Shale	50 ft	450 ft
Bayport Limestone (Parma-Bayport Aquifer)	100 ft	550 ft
Michigan Confining Shale	50 ft	600 ft
Marshall Sandstone (Marshall Aquifer)	End	

Water Level **<u>20 feet</u>**

Well #2

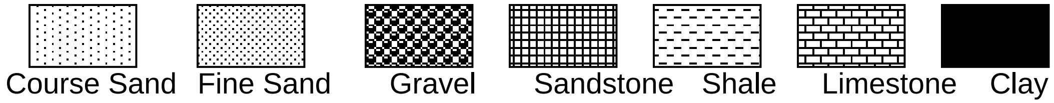
Formation	Thickness of Stratum	Depth to Bottom of Stratum
Glacial Coarse Sand (Glacial Aquifer)	200 ft	200 ft
Glacial Gravel (Glacial Aquifer)	200 ft	400 ft
Grand River & Saginaw Sandstone(Saginaw Aquifer	100 ft	500 ft
Saginaw Confining Shale	50 ft	550 ft
Bayport Limestone (Parma-Bayport Aquifer)	150 ft	700 ft
Michigan Confining Shale	50 ft	750 ft
Marshall Sandstone (Marshall Aquifer)	End	

Water Level **<u>15 feet</u>**

Well #3

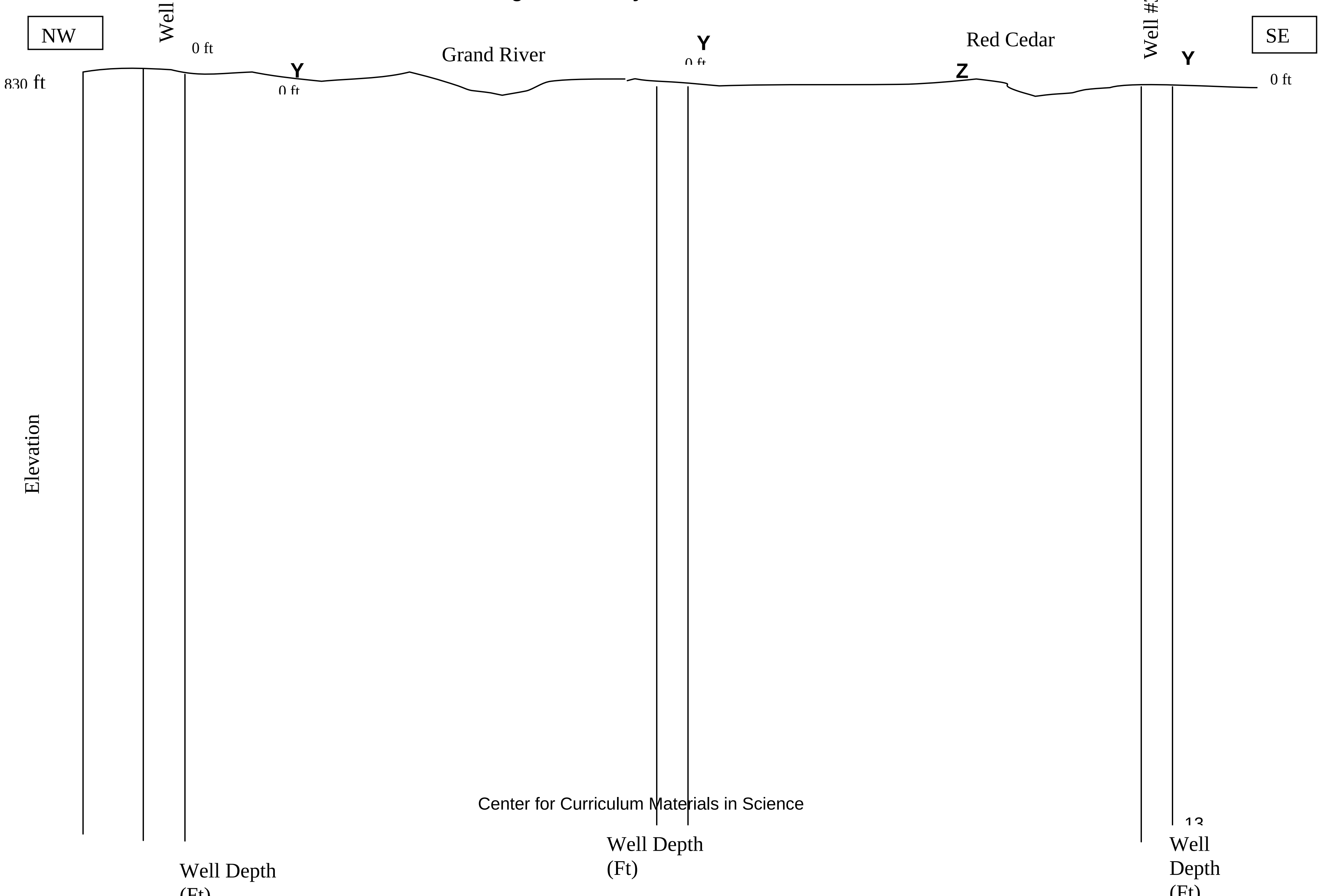
Formation	Thickness of Stratum	Depth to Bottom of Stratum
Glacial Coarse Sand (Glacial Aquifer)	50 ft	50 ft
Glacial Clay (Glacial Aquifer)	50 ft	100 ft
Glacial Gravel (Glacial Aquifer)	50 ft	150 ft
Grand River & Saginaw Sandstone(Saginaw Aquifer	300 ft	450 ft
Saginaw Confining Shale	50 ft	500 ft
Bayport Limestone (Parma-Bayport Aquifer)	100 ft	600 ft
Michigan Confining Shale	50 ft	650 ft
Marshall Sandstone (Marshall Aquifer)	End	

Water Level **<u>20 feet</u>**



Name:_________________________ Per____

Ingham County Cross Section



Name:____Hour: _____________

Lesson # 3: Groundwater

Activity 3.9: Follow the Water

Purpose: Your cross-section is another type of model, built from data obtained from wells. You can use it to help understand how water travels through groundwater systems. This becomes important if you need to be able to predict where pollution might go underground.

Directions

1. Imagine that you drop some colored dye into the water system. Watch as your teacher models how to trace the dye through the water system.
2. Using a colored pencil, trace the pathway that some colored dye might take through the water system if it started at point Z. Consider run-off, permeable layers, aquifers, wells, and impermeable layers.
3. Choose another person in your group to be your partner. Write the name of your partner: ____________________
4. Compare your pathway with the pathway that your partner drew. If you disagree with the pathway that your partner drew, give your reasons for your pathway, and listen to their explanation for their pathway.
5. You do not have to have the same pathway as your partner. However, if you learned something from your partner, you may change your pathway. Be sure to use a <u>different color</u> to show the changed pathway of your water molecule. Include a key to show which color represents your first pathway and which color represents your second pathway.
6. In the space below, explain the pathway that your colored dye took and why.

____

____

____

____

____

7. What did you learn from your partner?

____

____

8. What did your partner learn from you?

____

____

Name:____Hour: _____________

Lesson # 3: Groundwater

Activity 3.9RT: Tracing Water Paths in Groundwater Models

Purpose: Sometimes it is easier to think about the path of water through a groundwater system if you can see it.

Directions:

1. Watch your teacher and participate in the class discussion.
2. Make a drawing of the groundwater model. Include the labels of the confining layers, confined aquifers, and unconfined aquifers.

3. Watch the path of the colored dye as it moves through the groundwater model.
4. Trace the path of the colored dye on your drawing.
5. Explain why the colored dye followed the pathway that it took.

____

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____

____

____

____

Name:____Hour: _____________

Lesson # 3: Groundwater

Activity 3.10: Surface Water or Groundwater? Which is Better?

Purpose: You have seen that Lansing gets its water from underground. However, not every town or city gets its water from groundwater. Why does Lansing get its water from groundwater and other cities take their water from lakes and rivers?

Directions:

1. Read the paragraphs below. You may either read the paragraphs by yourself, or as a group.

Lansing

Lansing and the surrounding areas get their water supply from the groundwater. The Lansing Board of Water and Light has several large well fields with a total of 128 wells that that pull water from the Saginaw Aquifer. The Saginaw aquifer is about 400 feet deep and is not in direct contact with the Earth's surface. Lansing pumps nearly 20 million gallons of water from the Saginaw aquifer per day.

The quality of the water in the Saginaw Aquifer is generally very good. However, the aquifer is vulnerable to contamination from activities on the surface. There is some pollution in the aquifer that resulted from spills of chemicals at the Motorwheel Plant in Lansing. The Lansing Board of Water and Light is using some of its wells to pull the contaminated water out of the ground and prevent it from moving towards the drinking water wells. So far, the Board of Water and Light has been able to keep the pollution from the Motorwheel Plant from affecting the drinking water.

The water from the wells is pumped to a water conditioning plant where it is treated for drinking. The Board of Water and Light does not have to do much to the water to make it drinkable. It removes some of the naturally-occuring minerals that make the water hard (hardness makes it difficult for soap to lather in the shower and leaves rings in sinks and spots on drinking glasses). Chlorine is added to disinfect the water and fluoride is added to protect your teeth. Then the water is distributed through the city water system to homes and businesses.

Grand Rapids

The City of Grand Rapids and its surrounding suburbs get their drinking water from Lake Michigan. Lake Michigan is about 35 miles away from Grand Rapids. Using a system of transmission pipelines, the water is pumped to Grand Rapids. Grand Rapids has over 1200 miles of pipeline to bring the water from Lake Michigan and distribute it to all of the people in the city.

Water from Lake Michigan is treated in the Lake Michigan Filtration Plant. The water in Lake Michigan is some of the highest quality surface water in the world. However, it is still vulnerable to pollution from the cities on the lake and run-off from rivers. In the Lake Michigan Filtration Plant, the water is clarified, fluoridated, and chlorinated. During clarification, any floating solids in the water are removed. Fluoride is added to protect teeth, and chlorine is added to disinfect the water. Then the water is distributed through the city water system to homes and businesses.

Student Resources Lesson #3 Groundwater

Name:____Hour: _____________

2. As a group, make a list of the pros (positive reasons) and cons (negative reasons) for using groundwater for drinking water supplies. Go around the group so that each person adds one reason to the lists.
3. Write the initials of the person who added each reason. You should have the same number of reasons (across both columns together) as you have people in your group.

Groundwater Pros		**Groundwater Cons**	
Reason	Initials	Reason	Initials
1		1	
2		2	
3		3	
4		4	

4. As a group, make a list of the pros (positive reasons) and cons (negative reasons) for using surface water for drinking water supplies. Go around the group so that each person adds one reason to the lists.
5. Write the initials of the person who added each reason. You should have the same number of reasons (across both columns together) as you have people in your group.

Surface Water Pros		**Surface Water Cons**	
Reason	Initials	Reason	Initials
1		1	
2		2	
3		3	
4		4	

6. Answer the following question as a group. Remember to allow everyone to contribute ideas. Use the ideas to develop the best answer.

Why do you think Lansing uses groundwater and Grand Rapids uses surface water for drinking water supplies? Be sure to give reasons for your answers.

____

____

____

____

Grade your group and justify your grade

____

____