Lab 11: Groundwater

Materials:

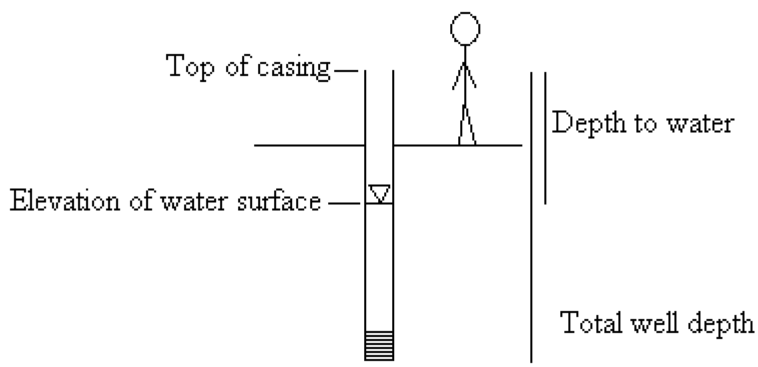
- Two water level meters in 2109 – these have to be shared; coordinate with the other TA(s) teaching with you; instructions on their use are also on the cart
- Rulers
- Extra copies of consulting map
- Data request forms (take 4 per group – if this stack is running low, please make copies or let Katherine know)

Before class

- Might want to let students know to wear shoes comfortable for walking down to Rocky Branch

Suggestions

- Check to see that students did the preclass activity but let them hold on to it until the end of lab, as there is a follow up question
- Ask students to report out what why they think it is important to study water
- Split class into three or four groups
- Ask students what a well looks like
- "Does anyone here grow up using well water at their house?"
    - 52% of North Carolina's population depends upon ground water for its drinking water supply.
- Draw a picture of a well on the board and talk about exactly what students are going to be measuring (p. 2)



Out in the field, p. 2

- Open one of the wells and show students how to take measurements with the water meter
- Explain how they should rotate between the wells
- Warn students wearing glasses to hold on to them when they look into the well
- Measurements should be made as accurately as possible
    - Make two runs and use an average
- Show students outcrop, if there's time – you can also do this with your class if another section is currently at the wells

Activity: Interpreting Groundwater Data, p. 3-4

- Students will have much smaller contour lines for completing the three point problem than are given in their appendix

- "Where is the creek in relation to these wells?"
- Rocky Branch is a gaining stream, and the flow direction is ~northeast
- Make the connection that hydrograph in 2e is the same one from the Streams lab

Activity: Groundwater Consulting Case, p. 5-7

- With their budget, students can request up to 13 TPH tests
- Each group should turn in one final map
- Make sure students understand everything that is required of them (bottom of p. 5)
    - "How would you know the direction of groundwater movement? How is that similar to what we did at Rocky Branch?"
- Pass out 4 data request forms to each group
- Student groups will fill out a data request form and bring it to you. Use your key to fill in the requested information. Fill out the TPH measurement if requested.
- Play groundwater battleship!
- Some TA questions might include –
    - "What might impact how fast the contaminant (TPH) is moving?"
        - Can show examples of rocks from around labs with different porosities and permeabilities
        - Demonstrate porosity by filling a plastic cup with sand and water
    - "What is your strategy for picking well locations?"
    - "North Carolina has spent more than $441 million to clean up pollution from private tank leaks since it set up a fund in the late 1980s... But the state has a backlog of more than 6,500 locations that will take another 25 years to get to..." http://www.newsobserver.com/2009/11/24/208269/leaky-tanks-drain-states-money.html#ixzz1559k1C98
    - Private insurance for tank owners sounds like a good idea to Robert Hodge, a Rowan County farmer and feed-store operator whose drinking water was contaminated by a neighboring gas station. Hodge endured a years-long ordeal after greasy, smelly water started flowing from his faucets around 2000 and the state declared it unfit to drink. "You would turn on the faucet and you could smell it," Hodge said. "And then it was brown." The owner of the gas station paid for a new drinking well, but a lawsuit from Hodge was dismissed because a judge said too much time had passed between when the gas tanks were pulled from the ground in the late 1980s and when Hodge filed for damages.
        - Why did it take 20 years for the contamination from the gas station to get to Robert Hodge's house?
        - Connection between geology and the real world

End of class

- Remind students that final is coming up
    - We will be offering review sessions
- Give students the post-lab assessment. They are allowed to use their labs, but work must be done individually.
- Collect one group report and all prelabs

Lab 11: Groundwater

Walk from Jordan down Morrill Drive. You will pass Warren Carroll Drive on your right. Get your group on the right side of the road and turn in down the steps seen below.

The steps are located at the red circle. Walk down the greenway to the blue circle, where the path splits.

You can see the **rough** positions of the wells below. RB-1 and 2 are right next to each other. Remember that we are not using RB-2 for our exercise. RB-3 is just behind a large sign describing the Rocky Branch Greenway. (You have to walk off the path to get to it.) RB-4 is up the hill on the right, and is accessible from the path.

If you keep walking back in the woods a short distance from RB-3, you will find an outcrop. Throughout the larger outcrop, several well-defined joints are visible. You can use these to talk about how groundwater moves through rocks to get to our wells.

Since this is our last lab, this is a nice place to do a quick review with students. This is also useful if you are waiting for another lab section to finish using the wells.

- Lab 1, Scientific Method: Make some observations about this outcrop. How do you think it got exposed? (Make predictions.)
- Lab 3 & 4, Minerals and Rocks: There is a large quartz vein in the rock in the foreground. The large outcrop is metamorphic. Students should be able to pick out places with foliations.
- Lab 6, Weathering: There are several places where you can easily pull away chunks of rock to examine more closely. What factors could have caused this outcrop to weather at different rates?
- Lab 7, Geologic Time: The rock in the foreground has a really cool looking quartz vein illustrating a cross-cutting relationship.
- Lab 8, Structure: Ask students to estimate the strike and dip of various points on the formation
- Lab 9, Earthquakes: Show students where you can see different parts of the rock were originally together, but have been moved along joints. Can be related to the recurrence interval problem.

I'm sure there are more connections that you can think of, but this is a good place to start! ☺

Name (print and sign): ____

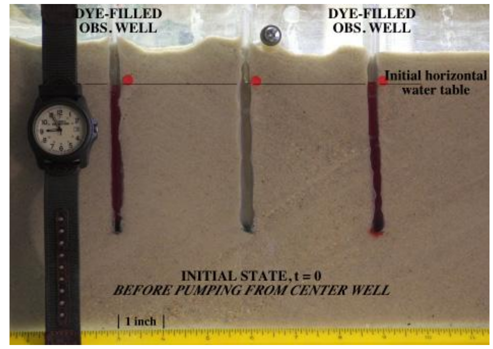
Lab 11: Groundwater

Pre-lab Activity: Underground flow

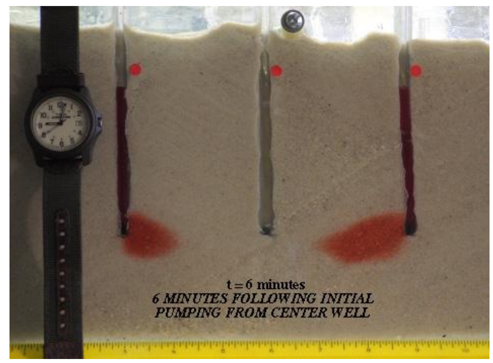
(4 pts). Due at the beginning of lab.

The pictures to the right depict a groundwater flow model filled with sand and three “wells”. These models, for example, are useful to illustrate how contaminants may spread from a leaking oil pipeline. The left and right wells are filled with dye to illustrate groundwater flow direction. The dye was drawn out of the center well at regular intervals. Use these images and what you’ve learned over this semester to answer the questions below.

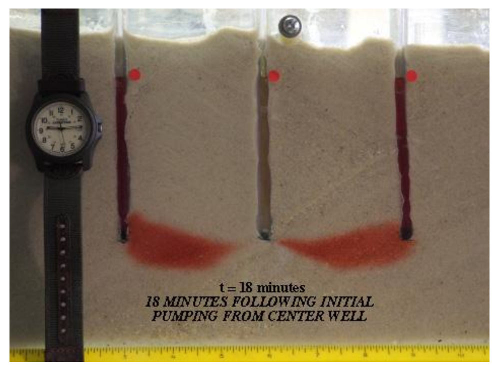
At time 0: Before pumping begins.



At 6 minutes: The dye has migrated nearly halfway to the center well.



At 18 minutes: The dye has reached the center well.



1. What might the dye represent?

2. Describe in words how the dyed water from the two observation wells moves through the system.

3. It takes the dye from each well 18 minutes to move the 3 inches to the center well. Calculate the rate of groundwater flow in a) inches/minute and b) meters/second (Note: 1 foot = 0.3048 meters).

4. A typical velocity found for Rocky Branch in Lab 10 is approximately 0.07 meters/second. Why do you think the velocities for surface water and groundwater differ so drastically?

5. The sediment in the model is sand. Imagine that we had used clay (smaller grain size) instead. Make a prediction: How would the rate of groundwater movement be affected?

   a. It would increase b. It would decrease c. It would stay the same

Name (print and sign): ____

Purpose

The main goal of this exercise is to learn how to determine the depth to groundwater and the direction of groundwater flow for three locations along Rocky Branch on the NCSU campus. In addition, you will participate in a hypothetical consulting exercise that replicates the role of a professional geologist seeking to delineate the threat of groundwater pollution.

Objectives: When you have completed this lab you should be able to:

1. Measure the elevation of the water surface in a subsurface well.
2. Determine the direction of groundwater flow using data from multiple wells.
3. Characterize the relationship between groundwater flow and flow within a neighboring creek.
4. Use well data to interpret the extent of a pollution plume.

<u>Materials:</u>
You will need the following items to complete this exercise:

- Water level meter, flashlights
- Ruler, calculator

<u>Sources</u>:
Hydrogeology consulting exercise was created by Karen Kortz, Community College of Rhode Island.

Activity: Groundwater data collection

The wells you will examine were drilled near Rocky Branch on the east side of campus. Walk down Morrill Drive and turn right onto the path on the south side of Rocky Branch. Walk along the creek until you come to well RB-1.

1. You will be assigned to different 3-5 person teams to measure the distance "down to water" in each well (the vertical distance from the top edge of the PVC casing down to the water level). Each team will start at a different well and move from one well to the next so that each team will measure down-to-water in three wells. BE CAREFUL NOT TO DROP ANYTHING DOWN THE WELLS.

a. Your instructor will open the well casings. Shine a flashlight down the well so that you can see the top of the water level. Take care to not drop the flashlight down the well (use the wrist strap if it has one). Read the total depth of the well from the well plates on the black post beside each well.

b. To measure depth to water level, turn the sensitivity dial on the water level meter fully clockwise and lower the metal probe down until you hear a loud beep. You are measuring the depth to the water from the top of the PVC casing. Make a couple of repeat runs in each well and record to the nearest mm. Dry off the probe and return the meter to its starting position. Convert any measurements in feet and inches to meters and centimeters and enter the data in the table below. [**4 pts**]

c. Calculate the elevation of the water surface by subtracting the depth to water from the elevation of the PVC casing. The tops of the PVC casings have been surveyed and tied in to absolute elevation with a local benchmark, so the elevations of the tops of the casings are relative to sea level. The elevations of the top of the casing in the three wells are as follows: RB-1 100.4 meters, RB-3 101.6 meters, RB-4 102.1 meters. [**4 pts**]

Well	Total well depth (feet)	Elevation at top of PVC casing (meters)	Depth to water from PVC casing (feet/meters)	Elevation of water surface (meters)
RB-1				
RB-3				
RB-4				

(Note: 1 meter = 3.281 feet; 1 foot = 0.305 meters)

Activity: Interpreting Groundwater Data

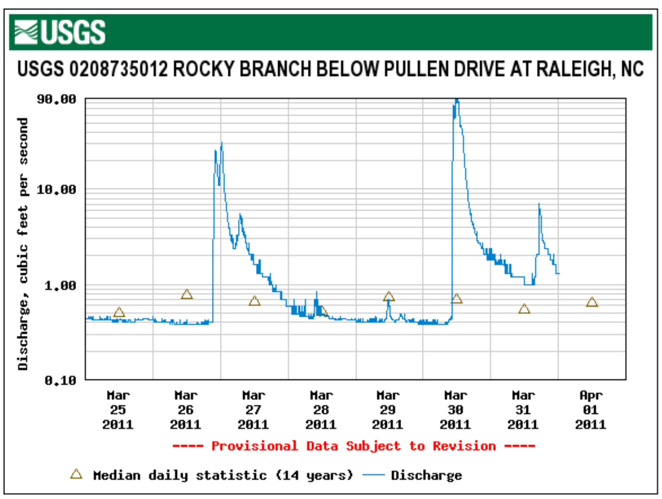
Use the map of the Rocky Branch well locations on the next page to find the flow direction of the water table.

2. Follow the instructions in the Appendix to complete the three point problem necessary to solve the problem.
   a. Draw and label the stream and path on the map to orient yourself. [**2 pts**]
   b. Draw and label the groundwater contours for the surface of the water table directly on the map. [**6 pts**]
   c. Add an arrow to show the direction of groundwater flow. [**2 pts**]
   d. Groundwater may be flowing into the stream (water table slopes toward the stream), a situation known as a gaining stream. Alternatively, your data may show a water table that slopes away from the stream, indicating that water may be flowing from the stream into the groundwater system (losing stream). On the basis of your data, is Rocky Branch a gaining stream or losing stream (circle)? [**2 pts**]

      Gaining stream Losing stream

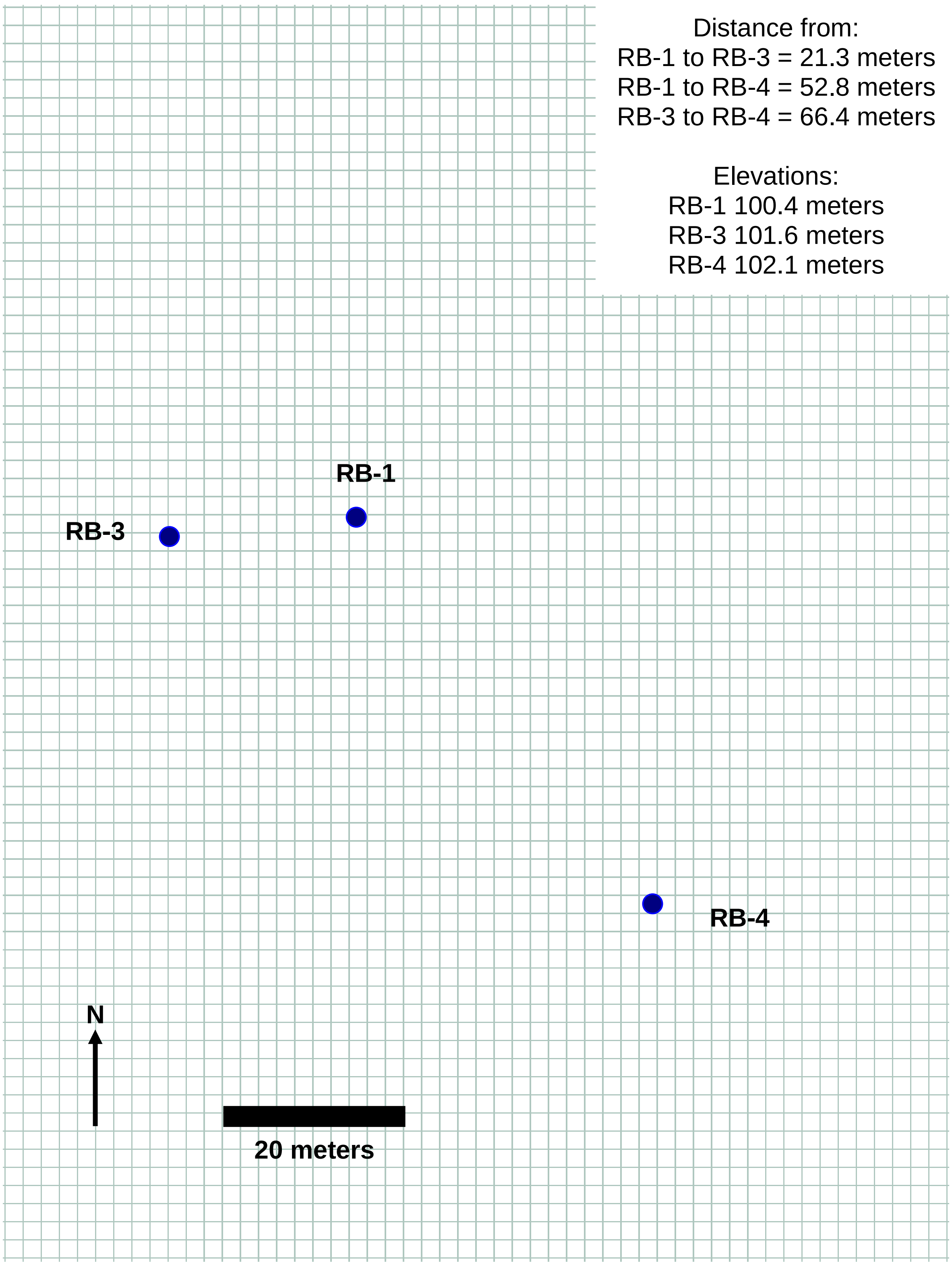
   e. Estimate the direction of slope of the water table surface (direction of groundwater flow). [**3 pts**]

      Flow direction = ________________



   f. Looking at a recent hydrograph for Rocky Branch, how do you now account for the base flow in the creek that rarely falls below 0.4 cubic feet per second? [**3 pts**]

Map of Rocky Branch well locations



Activity: Groundwater Consulting Case

A local college learns that the level of heating oil in one of their underground storage tanks is lower than would be expected. They do not know how long this has been the case. They perform a tightness test on the tank and lines that leave it and discover that there is a leak in the system. They need to hire an environmental consulting firm to determine the extent of the leak and how to clean it up.

Your group is the group they hire. You need to first drill wells near the tank to determine if the tank actually leaked into the groundwater. Then, if there is a leak, you will need to figure out the extent of the leak by drilling more wells. For each well, you measure the elevation of the water table. You can also send the water samples to a lab for them to test for the Total Petroleum Hydrocarbons (TPH).

TPH Value Interpretation	
less than 200 ppb	Clean
between 200 and 20,000 ppb	Contaminated
more than 20,000 ppb	Very Contaminated

The company hires you for a total budget of **$6500**.

- It will cost you $1500 to write the final report for the company.
- It costs $1000 to drill 4 wells, and this includes measuring the elevation of groundwater.
- Because you hire the driller for a day, you need to drill 4 wells at a time.
- The TPH test costs $75 for each sample, and there is no daily limit.

Once your group determines the locations of the wells you want to drill, present your drill requests to your instructor. The instructor will give you the elevation of the water table in the wells. If you want to perform the TPH test, the instructor will give you the results for your wells. The TPH test can be done at any time for the wells you drill.

After determining the extent of the leak (while staying within your budget) you need to prepare a report for the college which hired you. Your report will include a colored map showing:

- the extent of the leak (be sure to 'fill in the gaps' so your map shows where you interpret the entire leak to be, not just where you have measured it) [**5 pts**]
- arrows showing the direction of groundwater (contamination) movement [**2 pts**]
- locations of wells [**2 pts**]
- ground water contours [**2 pts**]
- table showing the data collected along with the budget (next page). [**4 pts**]

Upon completion of this exercise, return to the pre-lab and answer question 1d.

Final Report Data Table and Budget

Drilling Day 1					
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Total Cost Day 1:					

Drilling Day 2					
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Total Cost Day 2:					

Drilling Day 3					
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Total Cost Day 3:					

Drilling Day 4					
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Well location:		Water Table Level (m):		TPH Test Results:	
Total Cost Day 4:					
Final Report Cost:					
Overall Total Cost:					

Company Name: ___________________________________

Final Report Map

<table>
<tr><th></th><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th><th>F</th><th>G</th><th>H</th><th>I</th><th>J</th><th>K</th><th>L</th></tr>
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<tr><td>8</td><td></td><td></td><td></td><td></td><td></td><td colspan="2">TANK</td><td></td><td></td><td></td><td></td><td></td></tr>
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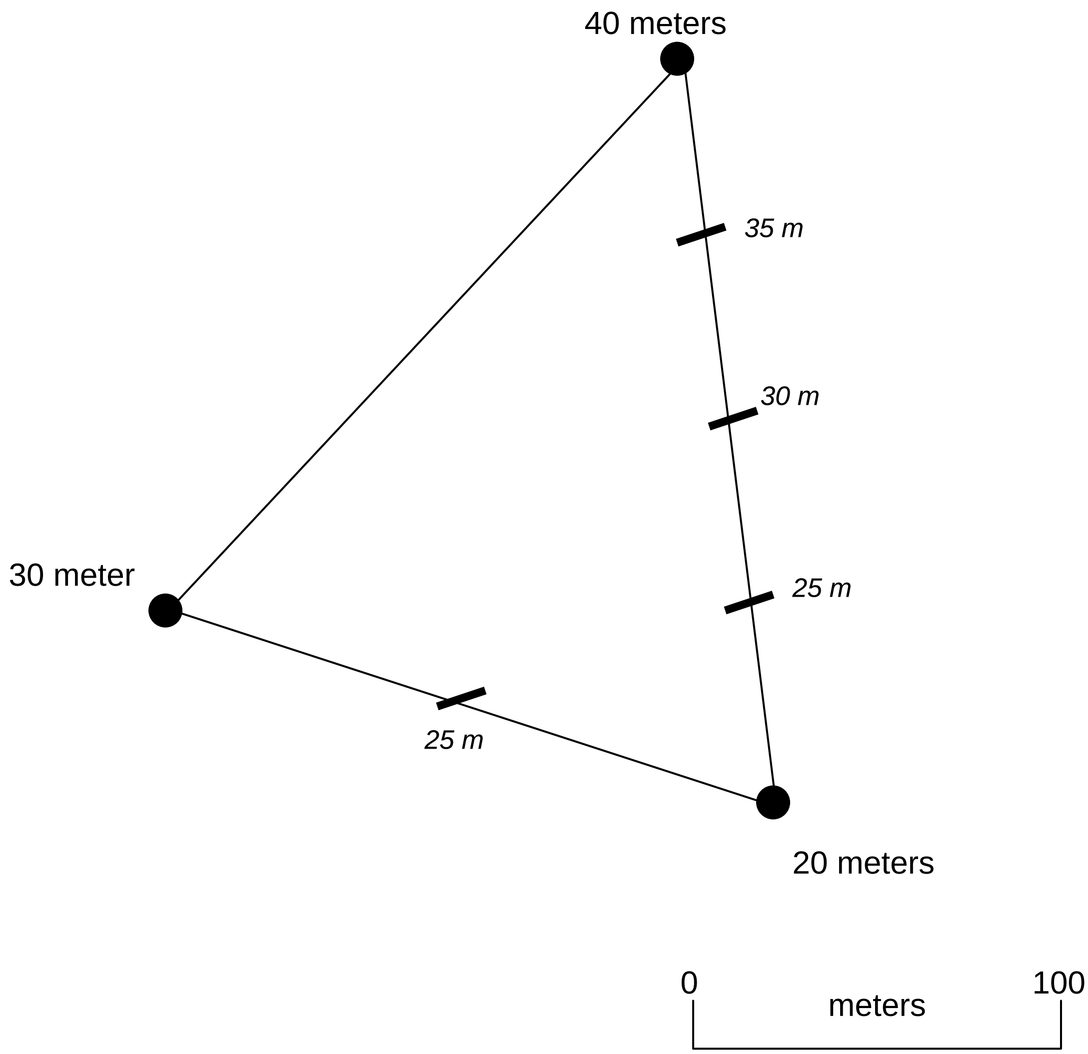
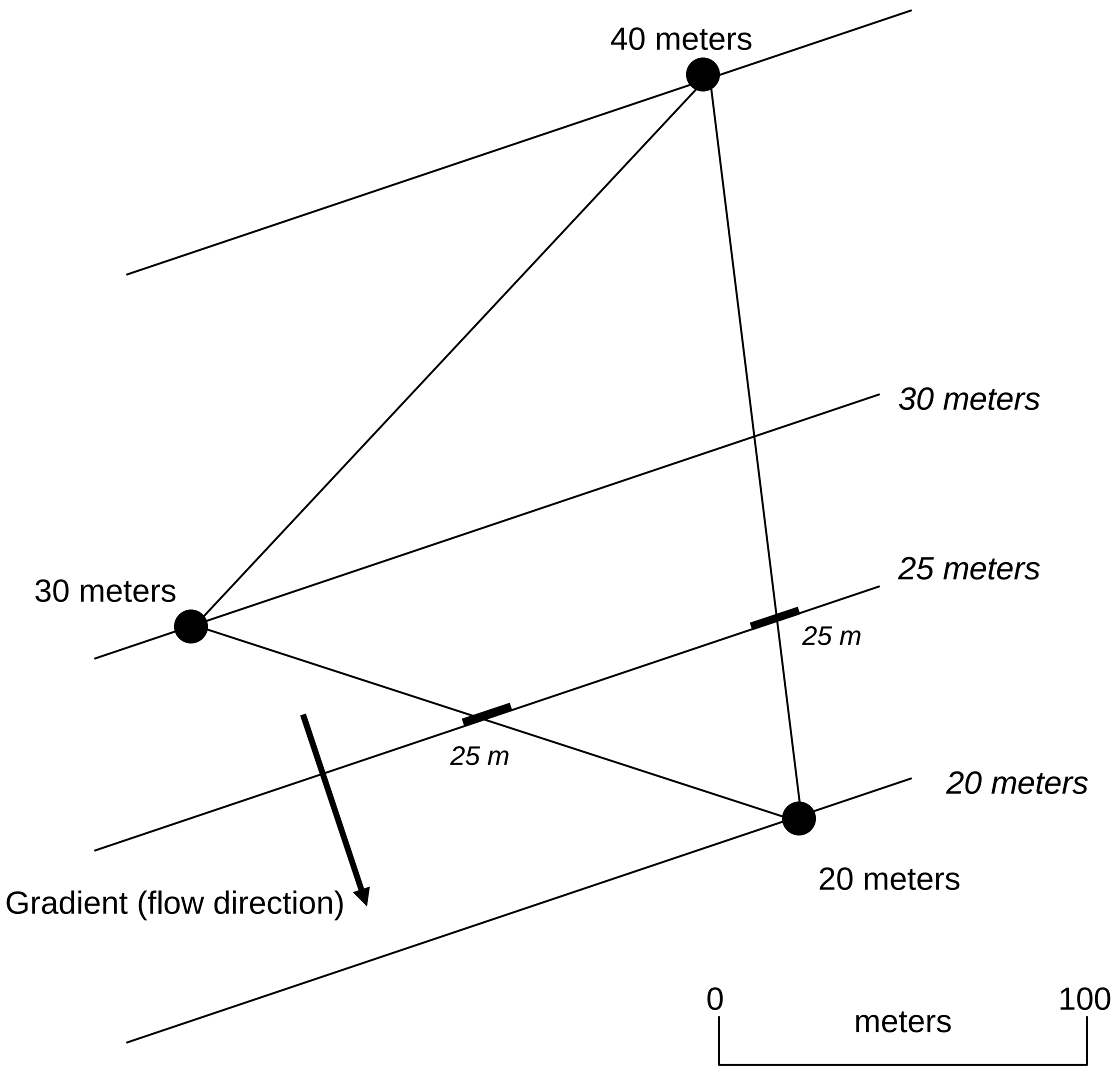
<tr><td>15</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Appendix: How to estimate the gradient of the water table

1. Plot the relative locations of water levels in three wells (in this example at 20, 30, 40 meters). Be careful to calculate accurate elevations (do not plot depths below surface). Your values will be much closer together.
2. Draw a triangle between the three locations.
3. Divide the sides of the triangle between the lowest and highest elevation and lowest and middle elevations. Divide them into roughly equal elevations; ideally the elevations should be in intervals that are appropriate for your particular situation (e.g., 1 meter, 0.1 meter, 0.01 meter).



4. Sketch a line that connects the middle elevation with an equal elevation between the low and high points. A line between these two points is a (structure) contour on top of the surface you are mapping.
5. You should be able to sketch other structure contours parallel to this line between other points on the map (see below).
6. These lines show the elevation of the water table. Water flows from higher elevations toward lower elevations and flows perpendicular to the orientation of the contour lines (see below).



Name (print and sign): ____

Postclass Assessment (5 pts). Complete on your own. You may use your lab for reference.

1. A groundwater consulting company has created a grid showing <u>depth to water</u> (NOT elevation) values in feet below a flat ground surface.

17	13	12	13	13
13	**A**	8	7	6
5	4	3	4	5
10	**C**	7	**B**	9
13	14	13	15	17

↑ **N**

a) What is the direction of groundwater flow at point A? (2 pts)

b) What is the direction of groundwater flow at point B? (2 pts)

c) Make a prediction. What do you think the depth to water value might be at point C? (1 pt)

Data Request Form

Company Name: ______________________________

Well Location (e.g. A-1)	**Results: Water Table Level** (meters above sea level)	**Do you want the TPH test?** (may be requested later)	**Results: Total TPH** (ppb)

Data Request Form

Company Name: ______________________________

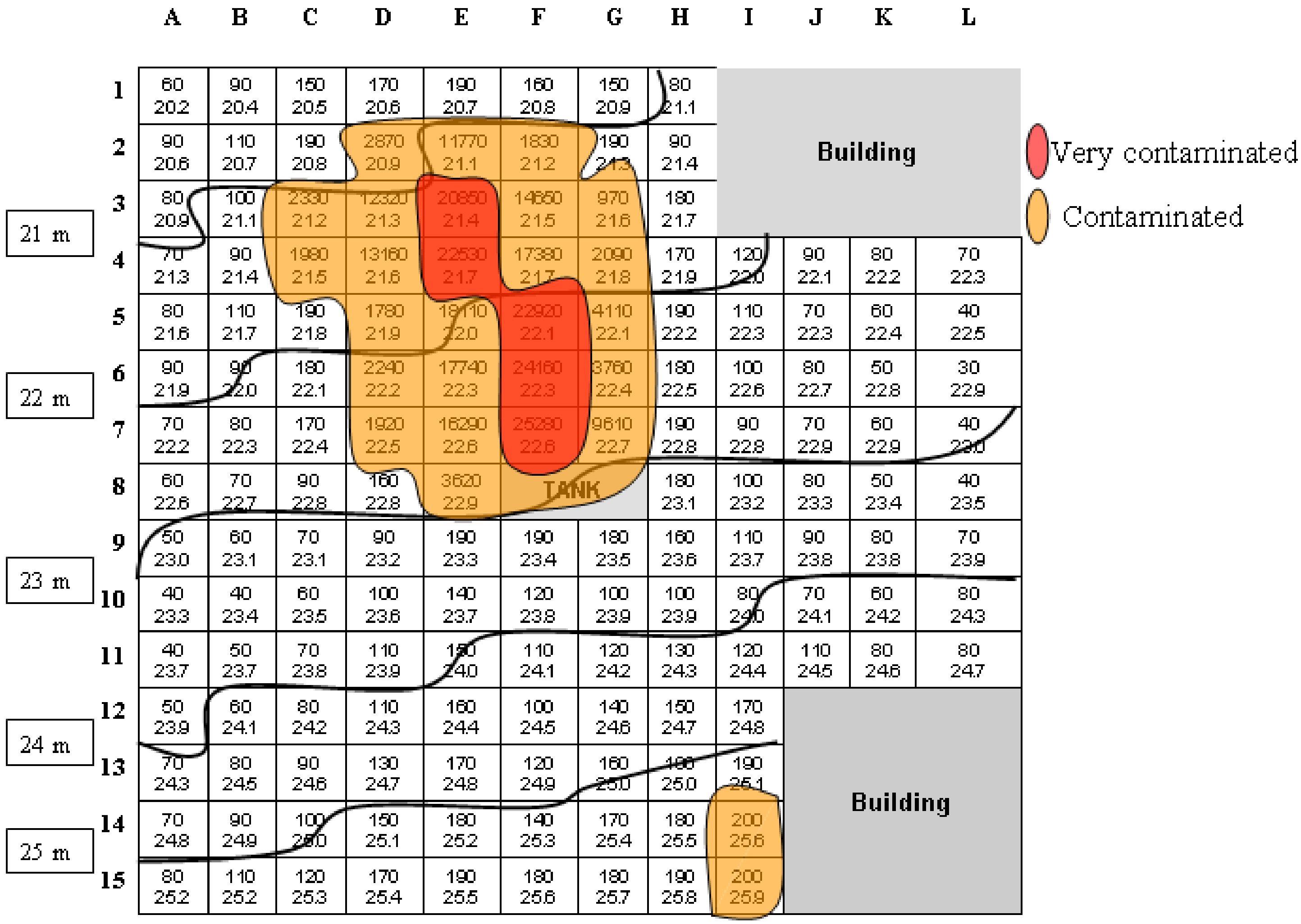
Well Location (e.g. A-1)	**Results: Water Table Level** (meters above sea level)	**Do you want the TPH test?** (may be requested later)	**Results: Total TPH** (ppb)

Data Request Form

Company Name: ______________________________

Well Location (e.g. A-1)	**Results: Water Table Level** (meters above sea level)	**Do you want the TPH test?** (may be requested later)	**Results: Total TPH** (ppb)

	A	B	C	D	E	F	G	H	I	J	K	L
1	60 20.2	90 20.4	150 20.5	170 20.6	190 20.7	160 20.8	150 20.9	80 21.1				
2	90 20.6	110 20.7	190 20.8	2870 20.9	11770 21.1	1830 21.2	190 21.3	90 21.4		Building		
3	80 20.9	100 21.1	2330 21.2	12320 21.3	20850 21.4	14650 21.5	970 21.6	180 21.7				
4	70 21.3	90 21.4	1980 21.5	13160 21.6	22530 21.7	17380 21.7	2090 21.8	170 21.9	120 22.0	90 22.1	80 22.2	70 22.3
5	80 21.6	110 21.7	190 21.8	1780 21.9	18110 22.0	22920 22.1	4110 22.1	190 22.2	110 22.3	70 22.3	60 22.4	40 22.5
6	90 21.9	90 22.0	180 22.1	2240 22.2	17740 22.3	24160 22.3	3760 22.4	180 22.5	100 22.6	80 22.7	50 22.8	30 22.9
7	70 22.2	80 22.3	170 22.4	1920 22.5	16290 22.6	25280 22.6	9610 22.7	190 22.8	90 22.8	70 22.9	60 22.9	40 23.0
8	60 22.6	70 22.7	90 22.8	160 22.8	3620 22.9	TANK		180 23.1	100 23.2	80 23.3	50 23.4	40 23.5
9	50 23.0	60 23.1	70 23.1	90 23.2	190 23.3	190 23.4	180 23.5	160 23.6	110 23.7	90 23.8	80 23.8	70 23.9
10	40 23.3	40 23.4	60 23.5	100 23.6	140 23.7	120 23.8	100 23.9	100 23.9	80 24.0	70 24.1	60 24.2	80 24.3
11	40 23.7	50 23.7	70 23.8	110 23.9	150 24.0	110 24.1	120 24.2	130 24.3	120 24.4	110 24.5	80 24.6	80 24.7
12	50 23.9	60 24.1	80 24.2	110 24.3	160 24.4	100 24.5	140 24.6	150 24.7	170 24.8			
13	70 24.3	80 24.5	90 24.6	130 24.7	170 24.8	120 24.9	160 25.0	180 25.0	190 25.1		Building	
14	70 24.8	90 24.9	100 25.0	150 25.1	180 25.2	140 25.3	170 25.4	180 25.5	200 25.6			
15	80 25.2	110 25.2	120 25.3	170 25.4	190 25.5	180 25.6	180 25.7	190 25.8	200 25.9			



A B C D E F G H I J K L
1 60 20.2 | 90 20.4 | 150 20.5 | 170 20.6 | 190 20.7 | 160 20.8 | 150 20.9 | 80 21.1
2 90 20.6 | 110 20.7 | 190 20.8 | 2870 20.9 | 11770 21.1 | 1830 21.2 | 190 21.3 | 90 21.4
3 80 20.9 | 100 21.1 | 2330 21.2 | 12320 21.3 | 20850 21.4 | 14650 21.5 | 970 21.6 | 180 21.7
4 70 21.3 | 90 21.4 | 1980 21.5 | 13160 21.6 | 22530 21.7 | 17380 21.7 | 2090 21.8 | 170 21.9 | 120 22.0 | 90 22.1 | 80 22.2 | 70 22.3
5 80 21.6 | 110 21.7 | 190 21.8 | 1780 21.9 | 18110 22.0 | 22920 22.1 | 4110 22.1 | 190 22.2 | 110 22.3 | 70 22.3 | 60 22.4 | 40 22.5
6 90 21.9 | 90 22.0 | 180 22.1 | 2240 22.2 | 17740 22.3 | 24160 22.3 | 3760 22.4 | 180 22.5 | 100 22.6 | 80 22.7 | 50 22.8 | 30 22.9
7 70 22.2 | 80 22.3 | 170 22.4 | 1920 22.5 | 16290 22.6 | 25280 22.6 | 9610 22.7 | 190 22.8 | 90 22.8 | 70 22.9 | 60 22.9 | 40 23.0
8 60 22.6 | 70 22.7 | 90 22.8 | 160 22.8 | 3620 22.9 | TANK | 180 23.1 | 100 23.2 | 80 23.3 | 50 23.4 | 40 23.5
9 50 23.0 | 60 23.1 | 70 23.1 | 90 23.2 | 190 23.3 | 190 23.4 | 180 23.5 | 160 23.6 | 110 23.7 | 90 23.8 | 80 23.8 | 70 23.9
10 40 23.3 | 40 23.4 | 60 23.5 | 100 23.6 | 140 23.7 | 120 23.8 | 100 23.9 | 100 23.9 | 80 24.0 | 70 24.1 | 60 24.2 | 80 24.3
11 40 23.7 | 50 23.7 | 70 23.8 | 110 23.9 | 150 24.0 | 110 24.1 | 120 24.2 | 130 24.3 | 120 24.4 | 110 24.5 | 80 24.6 | 80 24.7
12 50 23.9 | 60 24.1 | 80 24.2 | 110 24.3 | 160 24.4 | 100 24.5 | 140 24.6 | 150 24.7 | 170 24.8
13 70 24.3 | 80 24.5 | 90 24.6 | 130 24.7 | 170 24.8 | 120 24.9 | 160 25.0 | 180 25.0 | 190 25.1
14 70 24.8 | 90 24.9 | 100 25.0 | 150 25.1 | 180 25.2 | 140 25.3 | 170 25.4 | 180 25.5 | 200 25.6
15 80 25.2 | 110 25.2 | 120 25.3 | 170 25.4 | 190 25.5 | 180 25.6 | 180 25.7 | 190 25.8 | 200 25.9
Building
Building
21 m
22 m
23 m
24 m
25 m
Very contaminated
Contaminated