CE40460: Groundwater Hydrology

Homework 2 – The Hydrologic Cycle

Due: October 2, 2018

Problem 1 - Wells are located at locations (x,y)=(0,0), (5,15) and (10,10) and the respective head at each well is 80,90 and 100. All units are in meters.

(i) Assume the aquifer is confined. Using the graphical three point method, calculate the direction of flow and draw some lines of constant head (Be careful that your graph is to scale as this is a requirement for this to work).

(ii) Now analytically calculate the head distribution and check if your predicted direction of flow is the same as with the graphical method.

(iii) Now, if the aquifer is unconfined, repeat the calculation. What changes?

Problem 2 - Given the data set below create a plot of well locations (x and y only) using any method you like (e.g. Matlab, Excel or by hand), then label each point with the appropriate hydraulic head and finally contour the data (by hand is fine, although if you can figure out how to do it with Matlab that is fine too – this is not straightforward – You may want to look up *Surface plot of nonuniform data* – this will be useful for problem 6 relating to your field data also). Is there evidence of the regional flow direction? Is there evidence of wells that have inappropriate hydraulic heads? If so, any ideas on why that might be?

X (East is positive X) in Feet	Y (North is positive Y) in feet	Hydraulic Head (feet)
0	123	130.64
13	540	131.99
48	22	130.58
56	321	131.66
101	111	131.28
208	679	133.31
255	314	132.71
297	220	132.36
321	543	133.63
342	119	132.28
451	440	134.04
541	256	134.09
567	12	133.24
599	431	134.53
605	337	134.57
632	709	135.73
675	229	134.40
700	109	134.02
710	334	135.79
750	402	135.20

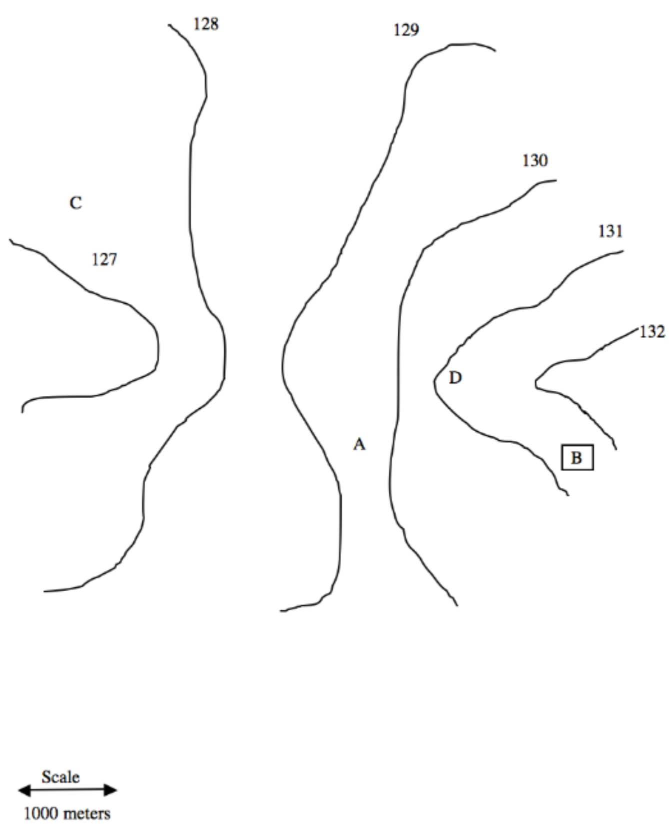
Problem 3 - Shown below is an areal view of a portion of a confined aquifer (that is, this is the view of the horizontal plane of the aquifer). Assume that the aquifer is much larger than the region shown. The contour lines shown were derived from head measurements in a series of observation wells. The measured head is given in units of meters above mean sea level. Assume that there is only horizontal flow in this aquifer and that flow is at steady state.

a) Estimate (by hand or any means you like) the direction and magnitude of the hydraulic gradient at point A.

b) You are told that there has historically been contaminants in the aquifer within the box around point B. If you assume that the aquifer is isotropic and homogeneous, draw a sketch (on the diagram) of the region of the aquifer which might be impacted by that contamination.

c) Under the assumptions given above, where are the likely recharge and discharge areas for this aquifer system?

d) Argue whether or not it is likely that any portion of the water entering the aquifer in the vicinity of point D will eventually arrive at point C.



Problem 4 (parts of this are not straightforward – do not wait until last day to do)

You are working in the aquifer system shown below. Assume that the system is at steady state. Assume that the aquifer is confined and of constant vertical thickness of 22 meters. Assume further that the lakes extend for a considerable distance in/out of the page and that the water levels in the lakes are constant over time. Assume perfect hydraulic connection between the lakes and the aquifer (so that there is no head loss as the water flows from a lake into the aquifer or from the aquifer into a lake). Note that the vertical scale is extremely exaggerated here. The total distance between the lakes is 500m (**i.e. the arrowed line is not a scale**). Take x=0 as the left boundary.

Consider the following two cases:

(i) The system is isotropic and the hydraulic conductivity K is homogeneous.

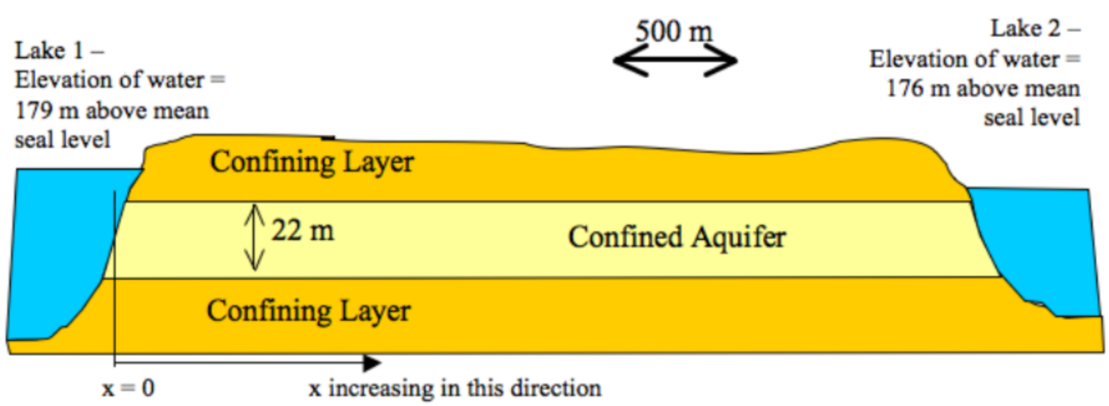
(ii) The system is isotropic, but K varies as follows: $K(x) = Ax+B$ where x is the distance (in meters) from the left end of the aquifer in the diagram.

For each of these cases

(a) derive an expression for the hydraulic head as a function of x within the aquifer – i.e. derive a mathematical expression for each case (do not plug specific numbers in).

(b) per unit meter into the page, how much total flow (m^3/yr) is moving through this aquifer (watch the time units!). Assume for case (i) $K = 1 \times 10^{-6}$ m/s and case (ii) $K(x) = 1 \times 10^{-6} * (1000+x)$ m/s

(C) **Conceptual Question:** If you had recharge (i.e. a leaky upper confining layer) into the aquifer, how might the presence of heterogeneity affect the location of a groundwater divide if it were to exist (i.e. shift it to the right/left)? Explain using your physical intuition and using any analysis you can.



Problem 5

Consider the diagram below. Due to infiltration from the storage pond, water infiltrates into the subsurface, passes vertically through the upper (unconfined) aquifer, and vertically through the upper confining layer. Due to regional flow, the flux in the upper confined aquifer follows an essentially horizontal route towards the east. Flux also enters this aquifer through the lower confining layer. Several wells are drilled within this system. The rate of infiltration from the pond is 0.2 meters per day. The hydraulic conductivity of the upper aquifer is 0.01 cm/sec. The conductivity of both confining layers is 10^{-5} cm/s. The conductivity of the upper confined aquifer is 0.1 cm/s. The conductivity of the lower confined aquifer is unknown.

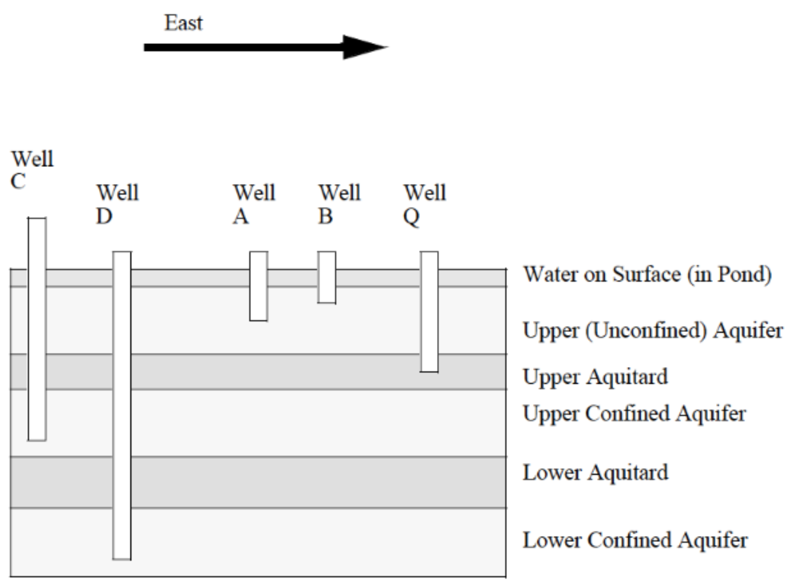
ASSUME THAT THE WELLS PROVIDE MEASURES OF HYDRAULIC HEAD ONLY AT THE BASE OF THE WELL.

Consider wells A and B. Assume that the base of these wells is separated by 10 meters.

a) If you were to compare the water levels in these two wells, which well would have the higher water level?

b) What is the difference in water level in these 2 wells? Provide your answer in centimeters.

c) Which well has the higher water level, well A or Well Q?

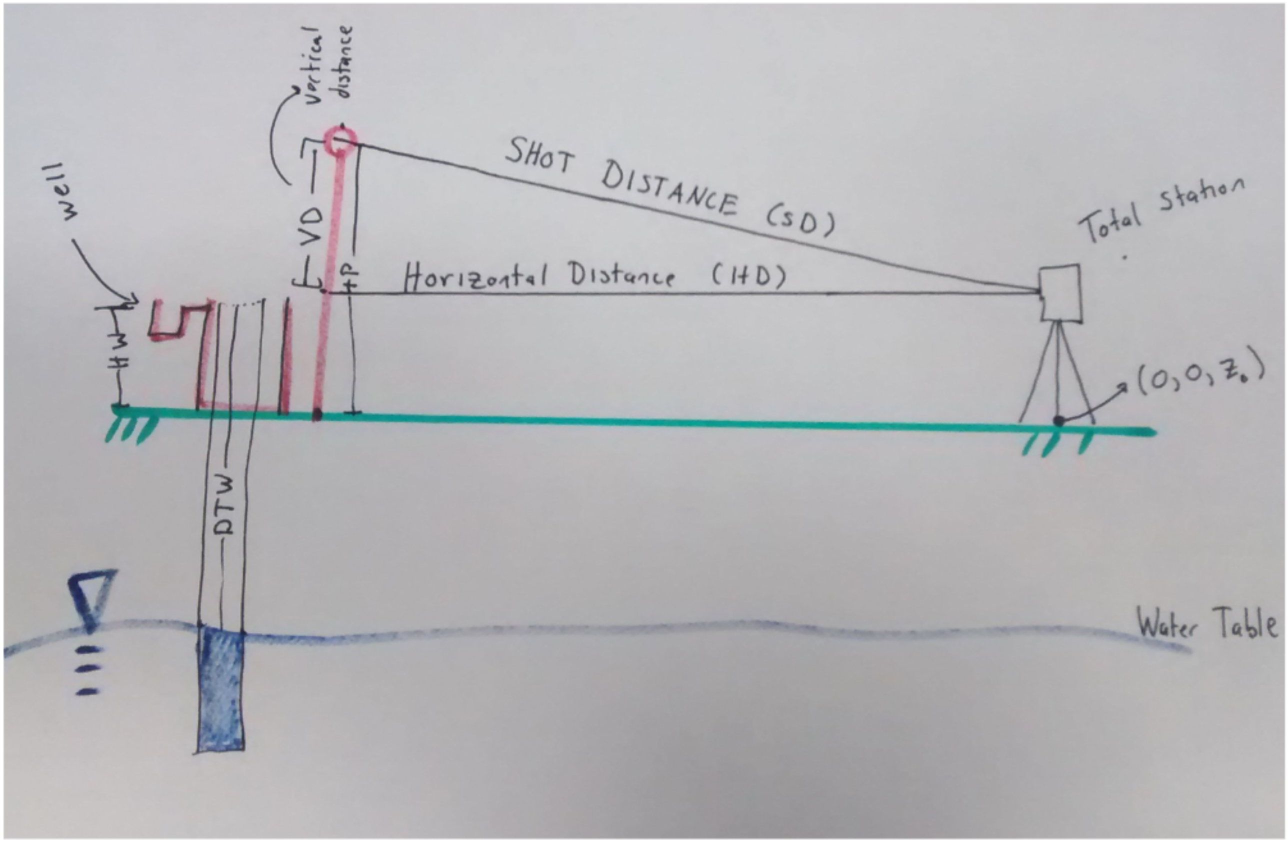


Problem 6 (This can be turned in later than the rest of the homework, but must be turned in before midterm break).

Using the data that you collected on your field trip draw a contour map of the head at the field site and from it see if you can infer a direction of flow.

Also, is there any evidence of vertical flow?

See the notes below for help interpreting the total station data.



Total Station Set-Up and Use:

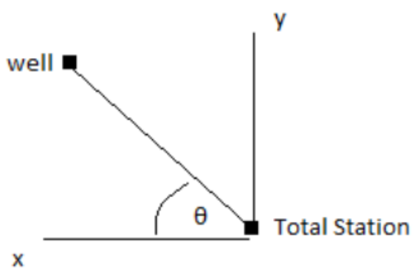
1. Set up tripod on a flat location; secure Total Station (TS) to tripod via screw on top of tripod
2. Use height adjustment dials at the bottom of TS to level TS (bubble should be in center of circle)
3. Measure height of TS from ground (markers located on TS sides)
4. Insert battery on TS side (pins on battery face down)
5. Turn on TS and Press PRG (program)
6. Use Compass to find North, rotate TS northward
7. Zero the TS by pressing 0SET, waiting for 0SET to flash, and press 0SET again
8. Optional: Change units of distance measurements. Click the X in top right of TS screen, press Config, Change Units

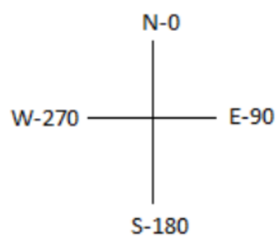
Take Distance and Angle Measurements in Well Field:

1. One Student should take Prism and stand next to well. Prism should be leveled
2. Set Prism height above all nearby vegetation (about 6ft)
3. Point TS to Prism and then lock TS
4. Focus TS, and use fine tune dials to point TS directly at Prism. Note when looking through the scope a bulls-eye should be visible, if not visible turn dial located on scope
5. When Prism is in bulls-eye, Press Measure button and retrieve Vertical/Horizontal/ Shot distances, and Horizontal/Vertical angles.

Coordinate Calculations

To find x,y coordinates of wells use cos/sin of angle *Horizontal distance
E.g.





Horizontal Angle = 290, HD =Horizontal Distance
Since we are in quadrant 4: θ = Horizontal Angle -270= 290-270 =20
$x = HD*\cos(\theta)$, $y=HD*\sin(\theta)$
*Note: If you are in quadrant 3 ($180<HA<270$); $\theta=270-HA$

Find height of ground relative to Total Station
See Diagram Above:

- Choose z0 as the height of the ground at the Total Station (z0 can be any value and is the height relative to an arbitrary datum)
- Find the height of the Prism relative to z0, h_p.
    - h_p= z0+ height of Total Station + Vertical Distance
    - h_p= z0+ TS + VD
- Then the ground level at well is the height of the prism relative to z0 minus the length of the prism
    - $z_{well} = h_p - HP$, where HP is the height from the ground to prism

Now we have x,y,z coordinates for each well

Determine the water Table Level

1. Measure the height from the surface to the top of the well
2. Lower the water level meter into the well until a beep is heard. Record the distance from the top of the well to water table. Repeat for accuracy.

Calculation for Water Table height relative to z0:

- Water Table = height of ground level at well + well height – distance from well top to water table
    - Water Table = z_{well} + HW – DWT: HW is well height, DWT, distance to Water table