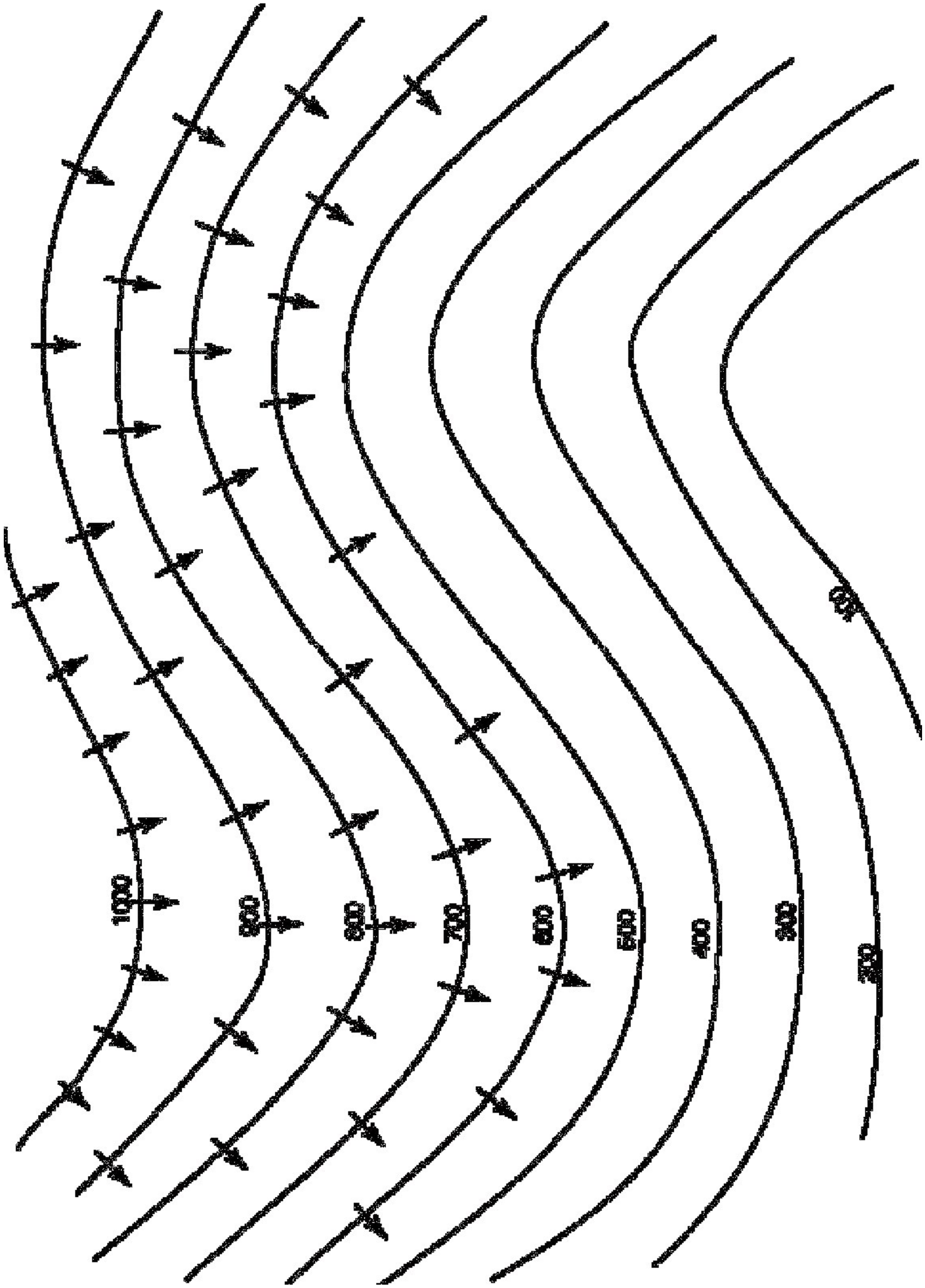
Lab: Contouring and Computing Groundwater Flow

Practice drawing flow lines indicating the direction of groundwater flow on the hypothetical water table contour map on the next page. The short arrows show the exact direction of groundwater flow as it crosses the contour lines. Notice that the arrows are always perpendicular to the contour lines.

1. Draw the first flow line beginning at the 1000 ft. contour label. You must curve the flow line to the right in order to keep crossing lower contours at right angles. You may want to draw additional short arrows at right angles to the 500, 400, 300, 200, and 100 ft. contour lines to help you see the direction of flow before you draw the flow line. If you draw the flow line correctly, it will end up close to the 100 ft. contour label.

2. Draw other flow lines beginning to the left and to the right of the 1000 ft. contour label. Check with the lab instructor to make sure you have drawn the flow lines correctly.


1000
900
800
700
600
500
400
300
200

Groundwater Flow Calculations

The hydraulic gradient ($\frac{h_1 - h_2}{\text{distance}}$) is the difference in water level per unit of distance in a given direction. It can be measured directly from water level maps in feet per foot or feet per mile. It is the slope of the water table surface or of the potentiometric surface.

By using water level maps in conjunction with topographic maps, the depth to the water table or the potentiometric surface can be determined. This depth will vary with time depending on the season and the amount of recharge supplied by precipitation infiltrating the aquifer and the amount of discharge by pumping and by natural outflow to springs and streams. If discharge exceeds the rate of recharge to the aquifer, the water level in the aquifer will decline, and some wells could become dry.

The rate of groundwater flow generally ranges from 5ft/day to 5 ft/year. It is usually less than 1 ft/day, but velocities greater than 400 ft/day have been measured. Groundwater velocity (V) depends on hydraulic conductivity (K), the hydraulic gradient ($\frac{h_1 - h_2}{\text{distance}}$) and the effective porosity (n_e). The following formula is used to determine groundwater velocity in ft/day, where n_e is unitless and given as a decimal (i.e., 10 percent = 0.10), and hydraulic gradient is in ft/ft.

$$V\left(\frac{\text{ft}}{\text{day}}\right) = \frac{K\left(\frac{\text{ft}}{\text{day}}\right)\frac{h_1 - h_2}{\text{distance}}\left(\frac{\text{ft}}{\text{ft}}\right)}{n_e}$$

Knowing the amount of groundwater moving in an aquifer under a property may be of interest for resource development. The quantity of groundwater (Q), in cubic feet per day (ft^3/day) or cubic feet per second (cfs), that passes through a cross-sectional area of an aquifer can be determined by means of Darcy's Law:

$$Q\left(\frac{\text{ft}^3}{\text{day}}\right) = K\left(\frac{\text{ft}}{\text{day}}\right)A\left(\text{ft}^2\right)\frac{h_1 - h_2}{\text{distance}}\left(\frac{\text{ft}}{\text{ft}}\right)$$

where A, the cross-sectional area through which flow occurs in ft^2, is equal to the width of the aquifer times its saturated thickness. Darcy's Law shows that the quantity of flow increases with an increase in K, A, or hydraulic gradient.

These two equations, for the velocity and quantity of groundwater flow, are useful for estimating the movement and potential availability of water in an aquifer.

For the groundwater problems, use the map provided.

1. Calculate the average water table gradient or slope ($\frac{h_1 - h_2}{\text{distance}}$) along the western flow line between the 200 ft contour and the 50 ft contour. Give your answer in ft/ft (round-off to two decimal places) and in ft/mi (round-off to two decimal places). Show your work; use units.

2. If the limestone aquifer near the floodplain in the western part of the map is 30 ft thick and has a porosity of 10%, how much water is stored in a 0.1 mile by 0.1 mile area of the aquifer? Give your answer in cubic feet and gallons (round-off to the nearest gallon). Show your work; use units.

   Conversion: 1 ft^3 = 7.48 gallons

3. Calculate the average groundwater velocity in the vicinity of the western flow line given the hydraulic conductivity (K) of the aquifer = 150 ft/day and the effective porosity (n_e) = 5%. Show your work; use units or suffer dire consequences.

4. On the map, construct a groundwater flow line downslope from each of sites A, B, and C.

5. If gasoline were spilled at B, would it discharge with groundwater directly into the ocean?

6. If gasoline were spilled at C, would it discharge with groundwater directly into the ocean? If not, where would it discharge directly?

7. If gasoline were spilled at A, where would it eventually discharge? Think carefully.

8. In the eastern part of the aquifer, at and down gradient from B, the hydraulic conductivity (K) is 100 ft/day and the effective porosity (n_e) is 30%. Calculate the average velocity along the flow line from B. First you must calculate the hydraulic gradient (slope of the water table) for the flow line from B. It may or may not be equal to the hydraulic gradient you already calculated in question #1. Show your work; use units.

9. If the velocity of the groundwater is assumed to also represent the movement of the contaminant, what is the time required for gasoline spilled at site B to travel to the end of the flow path? First you must measure the distance between point B and the end of the flow path. Round-off distance in feet to one decimal place, round-off time in days to whole days, and round-off years to one decimal place. Follow directions, show your work; use units.

10. Using Darcy's Law, what is the quantity (Q) of groundwater flowing horizontally through a 2 ft by 2 ft square of an aquifer with K = 180 ft/day and a hydraulic gradient of 1 ft/1000 ft? Show your work; use units.

11. What is the elevation of the ground surface at E?