Lab 13: Groundwater -- Water Supplies at Peril

Introduction

Although hidden from view, groundwater like surface water moves under the influence of gravity. Knowing how groundwater moves is important because it helps identify areas were groundwater is recharged and the possible path of contaminants. In more recent times, the movement of groundwater has been important in determining responsibility for polluting groundwater supplies.

Groundwater pumped from wells is important for growing this field of corn.

Groundwater Zones

Near the surface, there are three possible combinations of air and water.

Areation

In the **zone of aeration (unsaturated zone)**, which is closest to the surface, all the voids are filled with air and there is little or no water in the voids. The only water occurs as a thin film on the soil and sediment particles

Capillary Fringe

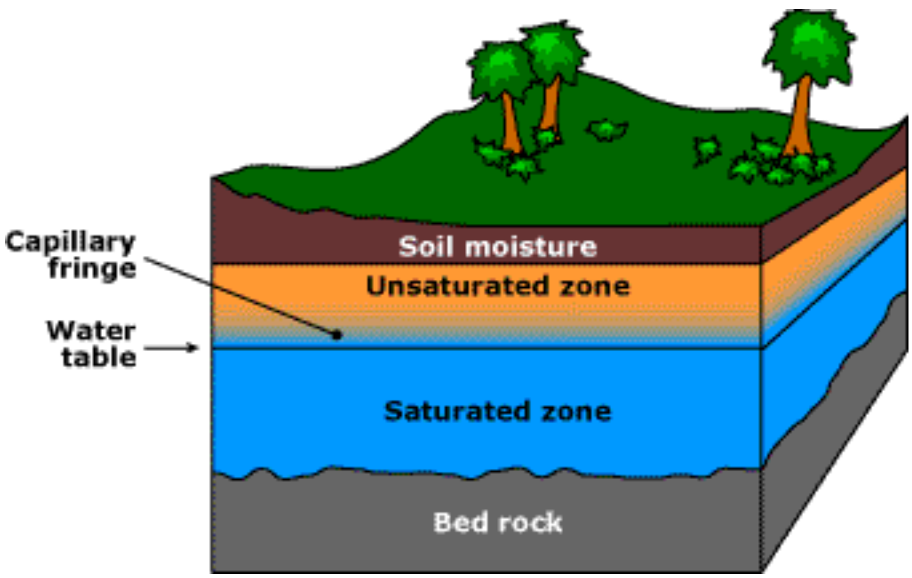
Below the zone of areation is the **capillary fringe**. Here water occurs only as a boundary layer on the solid sedimentary grains. Surface tension draws the water up and keeps it tightly bound to the mineral grains. Regardless of the porosity of the unit, this water does not flow.

Saturation

At the base of the capillary fringe is the **zone of saturation (saturated zone)**. In this region, the voids are completely filled with water. The water is, however, distributed between two different environments: the same boundary layer that occurs along the surface of the sedimentary particles and the rest of the voids between the sediment grains. As in the capillary fringe, the water in the boundary layer cannot move freely. Thus, pumping removes only the water in the voids.

Water Table

The surface that marks the top of the zone of saturation is the **water table**. The depth of the water table varies seasonally and spatially. During periods of drought, the top of the water table moves down, whereas it rises when rainfall is plentiful. In general, it also mimics the surface topography. That is, it is high underneath ridges and low below valleys.

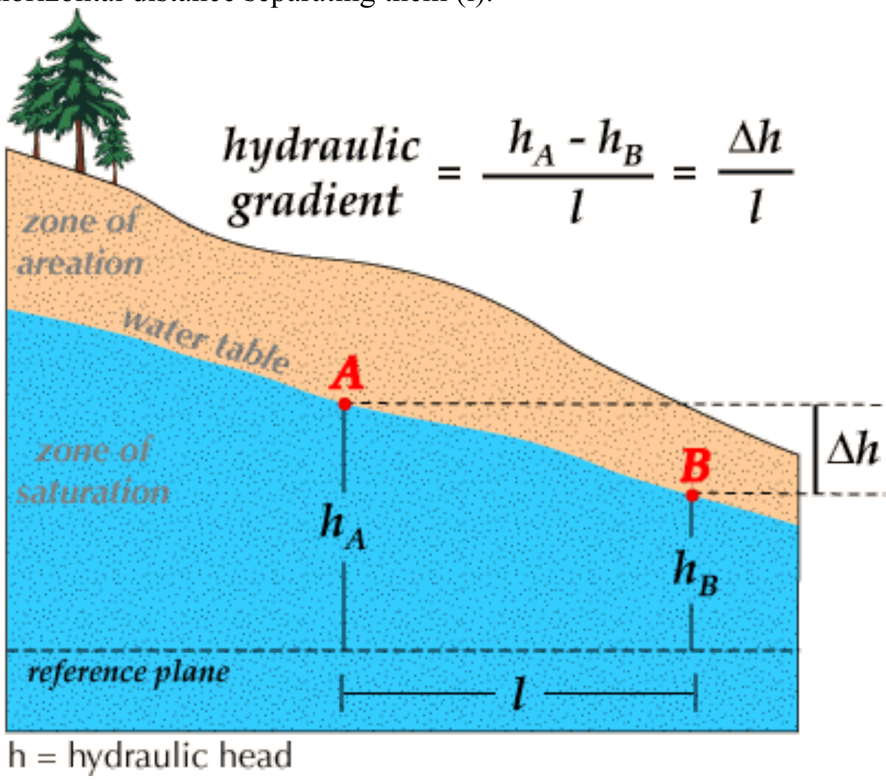


Hydraulic Gradient

In the subsurface, water flows from high regions to low regions just like on the surface. In addition, the steeper the gradient between two regions, the faster the water flows. For topographic maps, we get a feeling for how steep a given surface is from the slope. The equivalent term for groundwater is the **hydraulic gradient**.

Definition

Hydraulic gradient is calculated between two points on the water table. For example, the hydraulic gradient between points A and B on the diagram below is the ratio of the difference in elevation, or head, between the two points (delta h) divided by the horizontal distance separating them (l).



Hydraulic gradient is the ratio of a distance to a distance so mathematically it is a dimensionless number, just like slope. However, it is often difficult to visualize the steepness of the water table by looking at a number without units. Thus, hydraulic gradient is commonly expressed using two different length units. Thus, we typically express hydraulic gradient as cm/m or m/km.

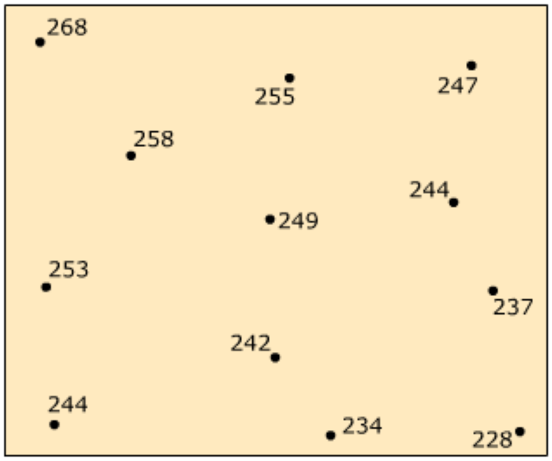
Flow at Water Table

Like water on the Earth's surface, groundwater flows under the influence of gravity. For water at the water table, flow is from high elevation, i.e. high head, to lower areas, i.e. low head. Determining flow direction on the water table surface is simply a matter of determining the shape of the water table.

Mapping the Water Table

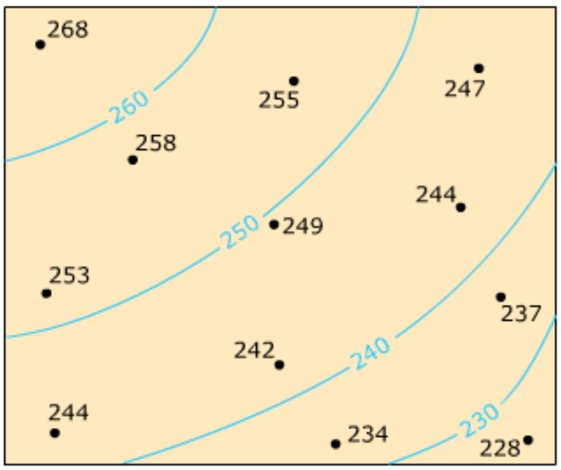
Mapping a region's water table is very similar to constructing a topographic map. The first step is to find the elevation of the water table at a variety of points. This is most easily done by measuring the elevation of water in pre-existing wells in the area. The location of the wells and their respective water table elevations are then plotted on a map of the region.

map view



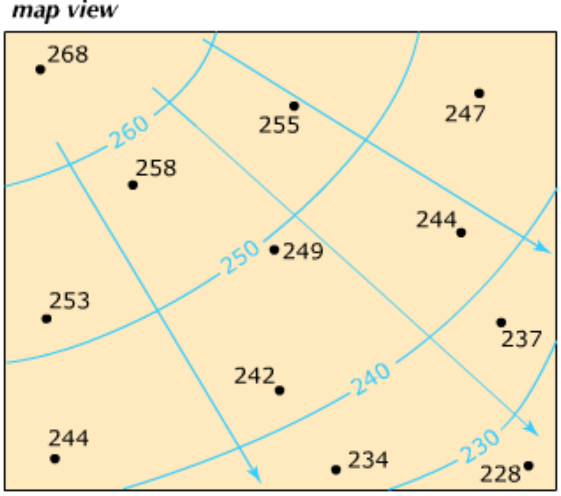
water table elevation (MSL) in well

map view



water table contours

map view



water table flow lines

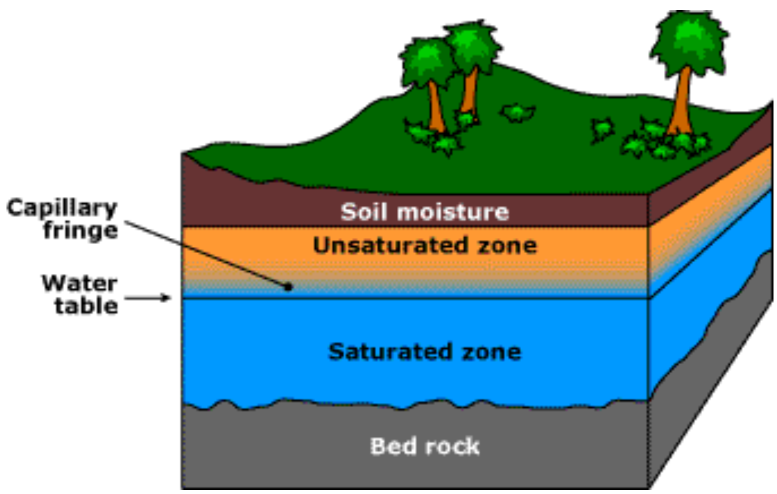
The next step is to determine the contour interval for the water table. Once the contour interval is established, contours are simply drawn around the wells using the same techniques for a topographic map.

Flow Direction

Once the water table has been mapped and a contour map of it drawn, determining groundwater flow lines is a simply, straightforward process. Flow lines always cross water table contours at right angles. Thus, flow lines can be drawn from any point using this simple technique.

Cone of Depression

In addition to naturally caused variations, the height of the water table fluctuates with groundwater pumping. As water is withdrawn, the water table is lowered in the vicinity of the well and a cone of depression forms. The shape of the cone is determined, in large part, by the permeability of the aquifer. In low-permeability aquifers, the cone is narrow and deep because water flows slowly to the well from surrounding areas. In this case, pumping may cause the cone of depression to fall below the well's depth, causing it to dry up. Pumping in highly permeable aquifers produces very broad, shallow cones of depression because water readily flows to the wells. When a large number of wells are drilled into the same aquifer, their cones of depression may overlap, causing a regional lowering of the water table.



The zones of water underground.

Change

When depth to the water table is plotted against time, the drawdown associated with pumping defines a characteristic shape. Initially, the water table drops rapidly. As pumping continues, the rate of fall slows until a stable condition is achieved. If pumping is halted, the height of the water table may recover. The rate of recovery depends on the permeability of the aquifer and the water supply. Recovery is rapid in aquifers of high permeability because water flows readily to the well. When permeability is low, recovery will take much longer.

Reference

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