Chapter 12

Hydraulic Conductivity

Hydraulic conductivity is a term that is used when describing hydrogeologic units. It is a way to quantify or describe the permeability of a rock or sediment. Breaking the term down, the first part, hydraulic, refers to fluid. Most people are familiar with the basic concepts of hydraulic tools or hydraulic brakes. These are mechanisms that use the movement of a fluid to produce some action. In the case of hydraulic conductivity, this refers to the movement of water. The second part, conductivity, refers to the ease of some action to occur. The opposite of conductivity is resistivity.

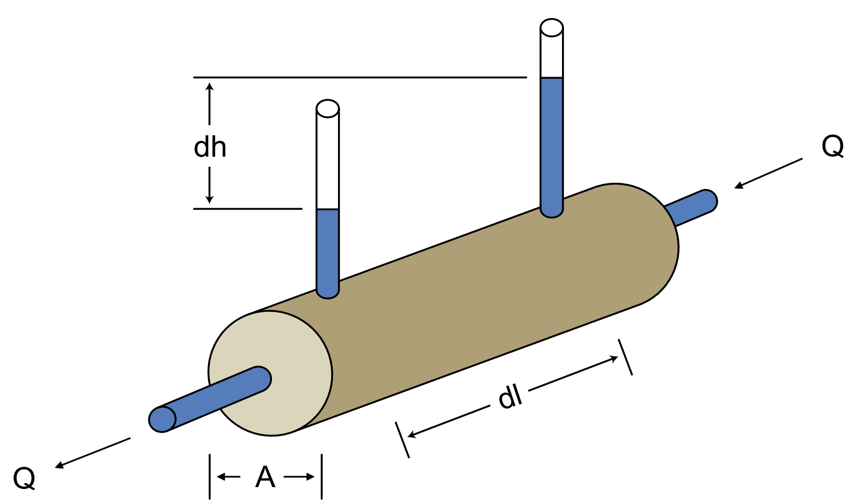
Thinking in terms of electricity, the more conductive something may be, the easier it is for electric current to pass through it (metal is very conductive, whereas wood and plastic are not). In terms of water, conductance is the ability for a fluid to move through a medium, such as a rock or sediment. Therefore, hydraulic conductivity is the measure of how water passes through a geologic material.

Now for some history. The term was introduced by a French engineer named Henry Darcy back in 1856. Darcy was looking at different geologic materials and trying to determine which ones would be best suited for filtering the water used by the city of Dijon. He thought there should be a way to quantify the different permeabilities of these sands and gravels. He took a bunch of samples of sediments he collected in the areas around Dijon and brought them back to his lab. He set up an experiment where he put the sediments in long tubes and ran water through each of them. Then, he measured the time it took for the water to move through each sample and he found that he could get similar results for the same sediment each time he did the experiment. The result was that Henry Darcy assigned numbers to the sediments that quantified how conductive each was to water movement.

The overlying principle for ground-water flow is what is now referred to as Darcy's Law. Darcy's Law is the equation:

$$Q = -K\,A\,dh/dl$$

Where Q is the discharge, K is the hydraulic conductivity, A is the cross-sectional area of the flow, and dh/dl is the hydraulic gradient. This equation can be visualized by looking at the illustration below:



In this illustration, Q shows the water going into and out of the tube, A is the cross-sectional area of flow (equals πr^2), dh is the difference between water levels (head) in the two observation tubes (analogous to wells), and dl is the distance between the two observation tubes. The large tube is filled with aquifer material, such as sand or gravel. By measuring the parameters shown, the hydraulic conductivity can be calculated.

Hydraulic conductivity is expressed as a measure of length versus time. For example, hydraulic conductivity might be shown as a number in feet per day. Or the number could be meters per second. Many different units of numbers can be used, but all relate to the same value of hydraulic conductivity. In a general sense, the number can be used to visualize how quickly water can move through a material.

Two other factors can affect hydraulic conductivity: viscosity and density. Viscosity is a term for the ease of a fluid to flow. For example, pancake syrup is pretty viscous compared to water. If a bottle of pancake syrup is heated, it certainly will flow much easier than it will when it is cold. This shows that the viscosity is related to temperature. In ground water, the temperature of the water can make a difference on how quickly it moves through the rocks and sediments. Therefore, the hydraulic conductivity can be altered by the temperature (changing the viscosity of the water).

Density is a measure of the weight of something per volume. With water, the more dissolved constituents in the water, the higher the density. As one can imagine, seawater is much denser than freshwater. As density increases, the ease of movement of water through the rock or sediment decreases. Therefore, density also can alter the hydraulic conductivity of a material.

When thinking about hydraulic conductivity as a measure of permeability, it can generally be concluded that rocks and sediments with large pore spaces will have larger hydraulic conductivities than those with very small pores. For example, in looking at sediments, clay (very small particles packed close together) has a range of hydraulic conductivities of about 0.000001 to 0.001 feet per day. Sand, on the other hand, has a much larger range of hydraulic conductivities, usually about 1 to 100 feet per day. Gravel can be quite large, at about 10 to 1,000 feet per day. Hydraulic conductivities can have a wide range for each type of rock or sediment, and the larger the pore openings, the greater the value of hydraulic conductivity.