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1. water flow equations

### Darcy’s Law

where is volume of water discharged, is the saturated hydraulic conductivity, is the hydraulic gradient, and is the cross-sectional area through which the water flows.

### Buckingham-Darcy

where is volume of water discharged, is the hydraulic conductivity, which varies as a function of the hydraulic head, is the hydraulic gradient, and is the cross-sectional area through which the water flows.

### Richards

where is the water content as a function of head, t is the time interval over which the flow occurs, is the hydraulic conductivity as a function of hydraulic head, is elevation above a reference point, and is a source or sink function describing additions or subtractions of water from the system, such as plant roots.

### Comparison of the 3 equations

Darcy’s Law is the simplest solution for water flow. This equation was originally developed through empirical column tests by H. Darcy. I believe that his findings were later validated by the Navier-Stokes equations, which are a more general set of expressions treating fluid flow.

Darcy’s Law assumes that the flux of water is constant and that the soil is fully saturated. All pressures are either zero or positive. The hydraulic conductivity is constant throughout the area of interest.

The Buckingham equation extends/modifies Darcy’s Law to work for unsaturated conditions. The major difference is that hydraulic head is no longer constant. However, the equation still assumes a constant flux of water through the profile. In an unsaturated soil, the water is held under tension or suction. Therefore, some pressures will be negative. The conductivity will be lower as water content decreases because the cross-sectional area through which the water can flow becomes smaller.

The Richards equation is the most complete of the three but also the most complex. This equation does not assume constant flux - the water flux varies as a function of both time and space, and so does the conductivity.

When we can safely assume that the soil is saturated (for example, below the water table), Darcy’s Law is applicable. The Buckingham equation can be applied for unsaturated conditions if the boundary conditions are held constant so that the flux density does not vary with time or space. In reality this is an unrealistic assumption for most soils, especially at the surface where temperature, vapor pressure, and the presence of free water all affect the boundary condition. The Richards equation should be used when the flow is transient, and the intitial and boundary conditions are known.