Mixing oil and water: Reinforcing groundwater concepts through comparisons with petroleum migration

Instructor Notes

Basic Rules for Brainstorming:
1. everyone must participate
2. no criticism or evaluation of volunteered ideas is allowed
3. no idea is too wild or too outrageous
4. piggy-backing or building off of other ideas is encouraged

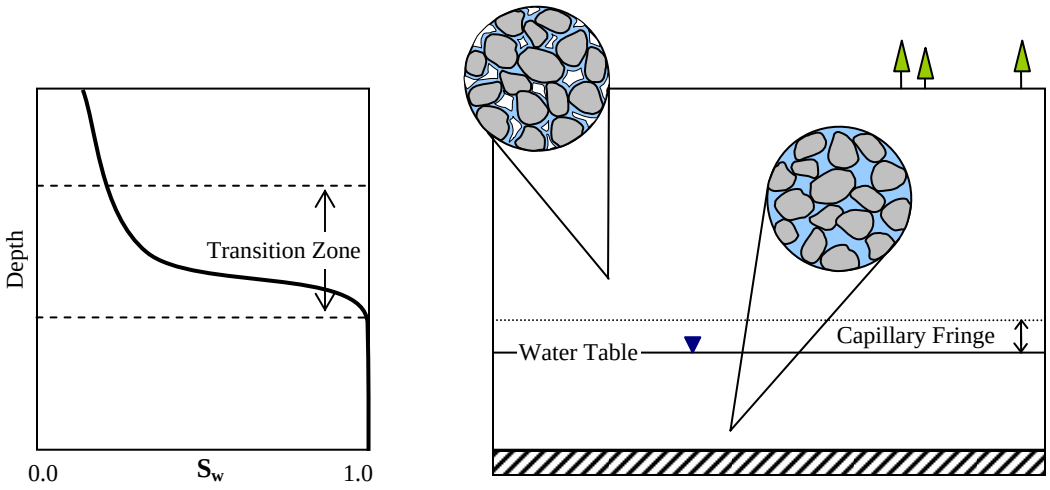
Modified form of Darcy's Law (applicable for fluids other than water):

$$q = \frac{kk_r}{\mu}\left[\frac{\partial P}{\partial s} - 0.433\gamma\cos(\alpha)\right]$$

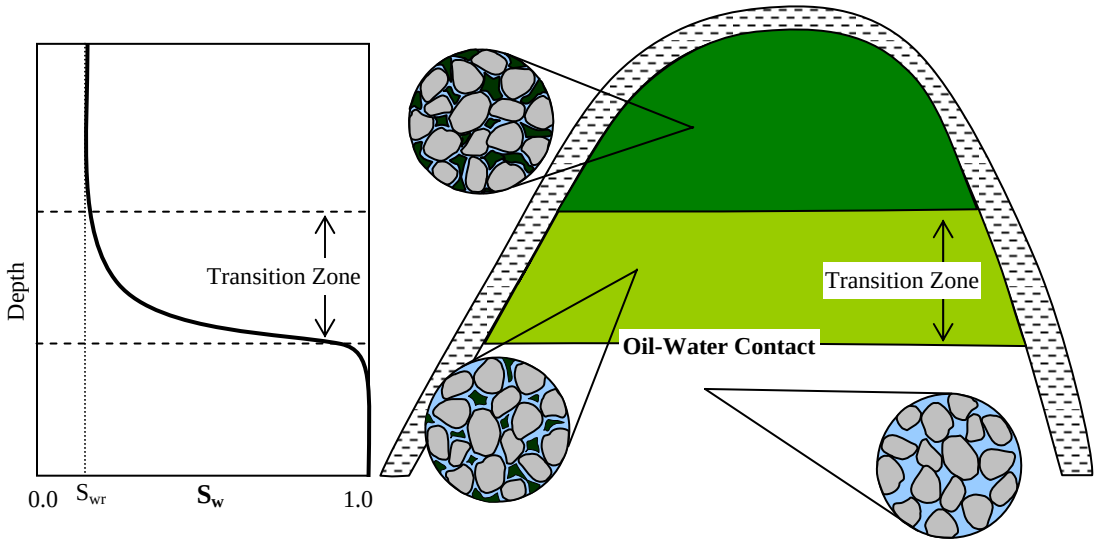
Where:
q = specific discharge or Darcy velocity
k = intrinsic permeability
k_r = relative permeability
P = pressure (psia)
s = distance along the flowpath (ft)
γ = fluid specific gravity (relative to water)
α = angle measured counterclockwise from the downward vertical to the positive s direction
0.433 = water density (psi/ft)

The driving force consists of the pressure gradient ($\delta P/\delta s$) and the hydraulic or gravitational gradient ($0.433\gamma\cos(\alpha)$). Hydraulic gradients arise from the density differences between oil and water (or gas and oil and water). If flow paths are physically constrained (for instance, along a dipping bedding plane), a geometric correction must be made to the hydraulic gradient. Although fluid pressures in a reservoir are generally quite high, pressure *gradients* can be small and comparable in magnitude to hydraulic gradients. Considerable variability can occur, however, depending on whether natural gas caps are present and whether the oil reservoir pressures have been depleted.

Conceptual saturation models for unconfined aquifers and oil reservoirs:

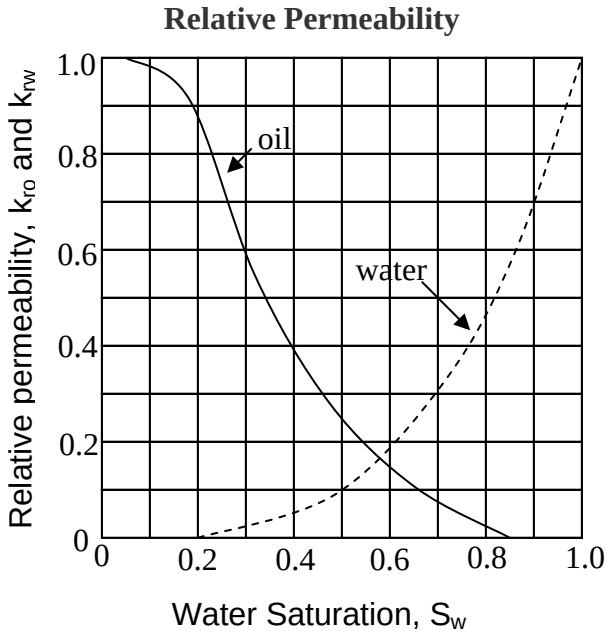


Generalized saturation profile for a homogeneous unconfined aquifer. Insets depict pore spaces that are partially saturated by air and water, or totally saturated with water below the water table.



Generalized saturation profile for a homogeneous, water wet oil reservoir in a simple anticlinal trap.

The oil-water contact is defined as the lowest elevation from which oil can be produced. Below the oil-water contact, only 100% water can be produced. A zone of transitional saturations is found above the oil-water contact, from which an increasing proportion of oil can be produced with decreasing depth until the residual (irreducible) water saturation, S_{wr}, is reached. Above this elevation, oil is the only mobile phase and 100% oil production occurs.



Oil and water relative permeability curves for an oil wet reservoir system (after Craft, Hawkins, and Terry, 1991). At 50% water saturation, the relative permeability to water is approximately 10% and the relative permeability to oil is approximately 25%. Oil permeability is favored because it occupies the center of the pore spaces in a water wet reservoir.