How does groundwater flow ?

February 26, 2002

TOC

Definitions

- Unconfined Aquifer
- Confined Aquifer
- Water Table
- Piezometric surface
- Ground water well
- Piezometer
- Pumping well

Unconfined aquifer

- No confining layer at the top of the groundwater. Groundwater levels are free to rise or fall

Confined aquifer

- A layer of water bearing material that is sandwiched between two layers of much less conductivity (aquicludes or aquitards)

Semi-confined aquifer

- Confined aquifer that is “leaky”. Aquitards are not impermeable.

Water Table

- Top of an unconfined aquifer where pressure is equal to the atmospheric pressure ($p = 0$)

- Also known as phreatic surface or free surface

Piezometric Surface

- The surface obtained by connecting equilibrium water levels in piezometers penetrating the confined aquifer

Groundwater well

- Measures the level of the water table

Piezometer

- Measures the level of the piezometric surface (or, in other words, measures the pressure at a point in a confined or semi confined aquifer)

Pumping Well

- Well used to pump water from a confined or unconfined aquifer to the surface. Can be screened over multiple depths, and pump from multiple aquifers

Definitions

- Transmissivity
- Storativity
- Specific Yield
- Safe Yield

Transmissivity

- Hydraulic Conductivity * Thickness of Aquifer
- K * B = T

Specific Storage

- Volume of water that a unit volume [of a porous medium] releases from (or takes into) storage when the pressure head in the unit volume [of a porous medium] changes a unit amount

- Also known as the storage coefficient in a confined aquifer

Specific Yield

- Also known as ‘storativity’ or ‘storage coefficient’ in unconfined aquifer

- Ratio of the volume of water that drains by gravity to the total volume of the porous media

Safe Yield

- Economic term: Sustainable levels of water extraction…

How does groundwater flow?

- ➲ Darcy: Hydraulic Gradient

- ➲ Velocity vs Flux

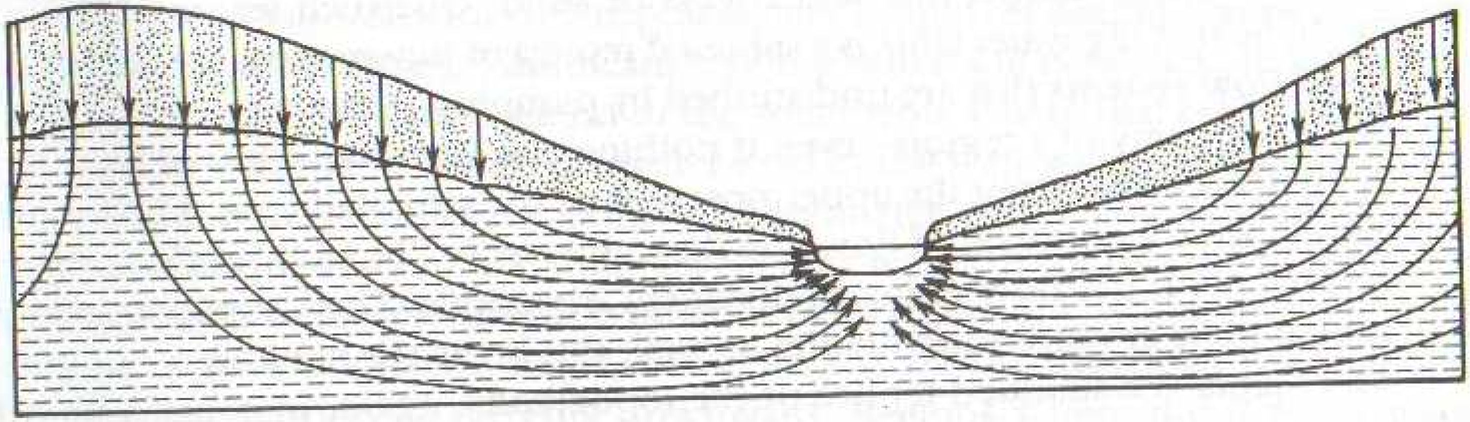


Figure 7.2
Diagrammatic section illustrating ground water flow in a watershed (from King, 1899).

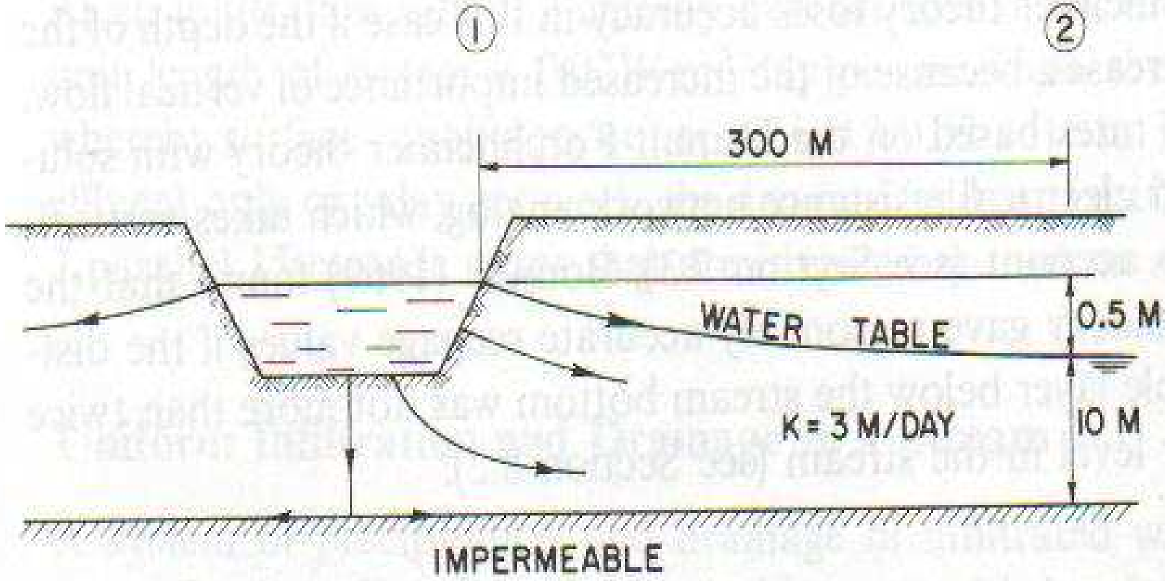


Figure 3.7 Seepage from stream in unconfined aquifer with impermeable layer at relatively shallow depth.

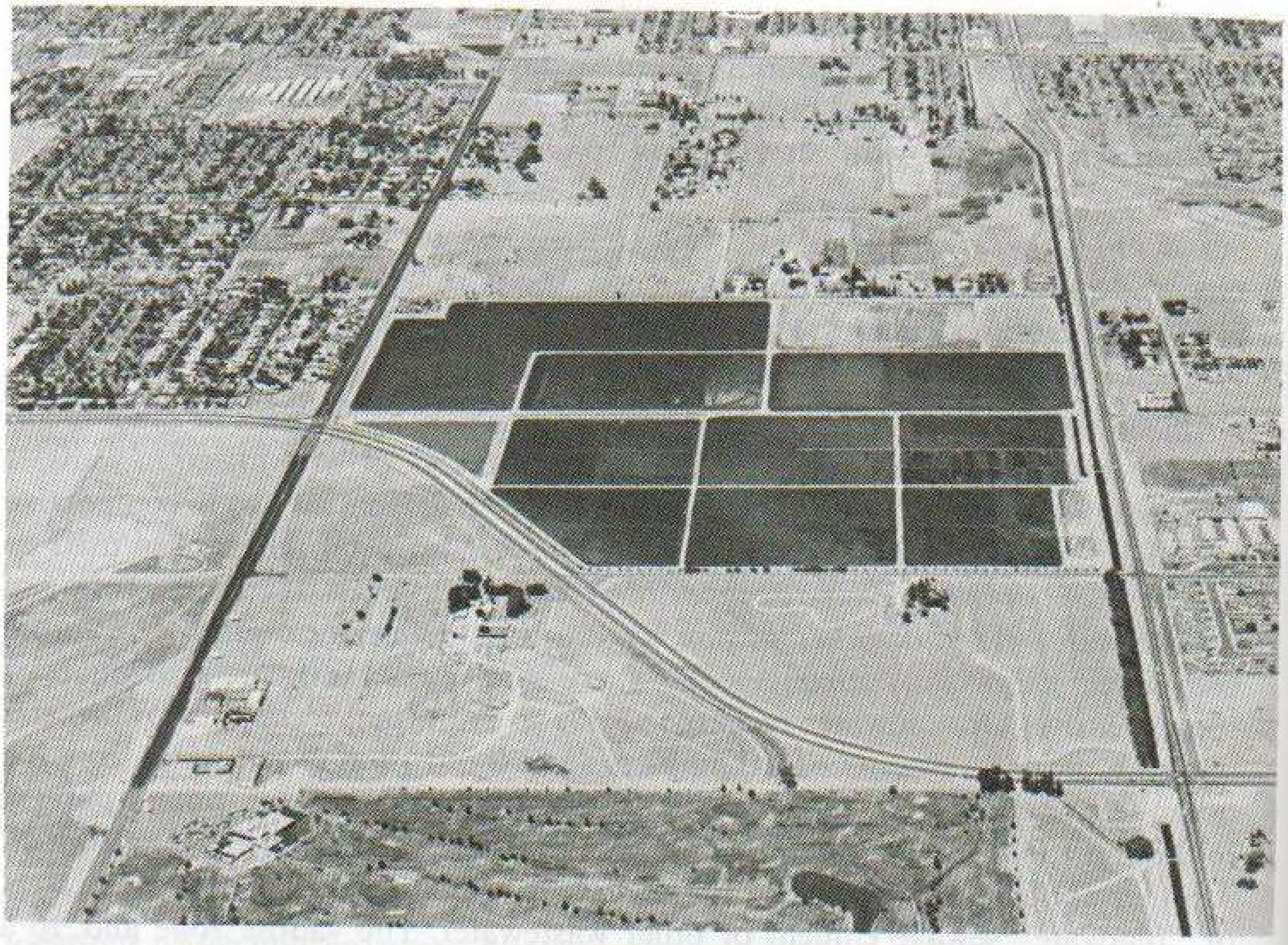


Figure 8.16 Leaky-Acres groundwater recharge project in Fresno, California. *(Photograph courtesy of U.S. Department of Agriculture.)*

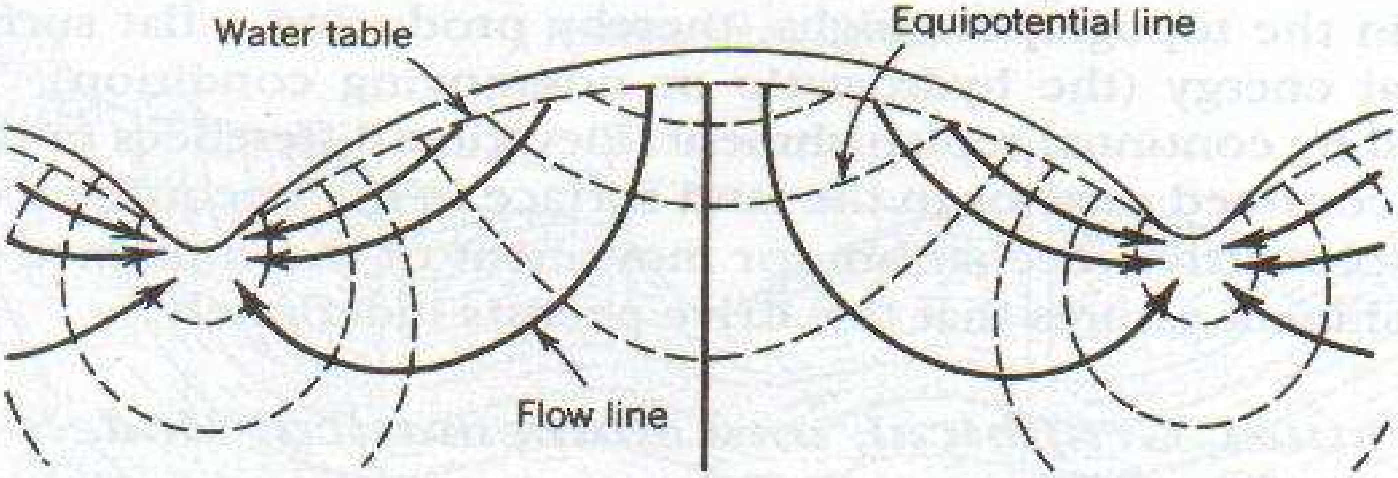


Figure 7.3
Topographically controlled flow pattern (from Hubbert, 1940). Reprinted by permission of the Journal of Geology, University of Chicago Press. Copyright © 1940.

Wells and well screening

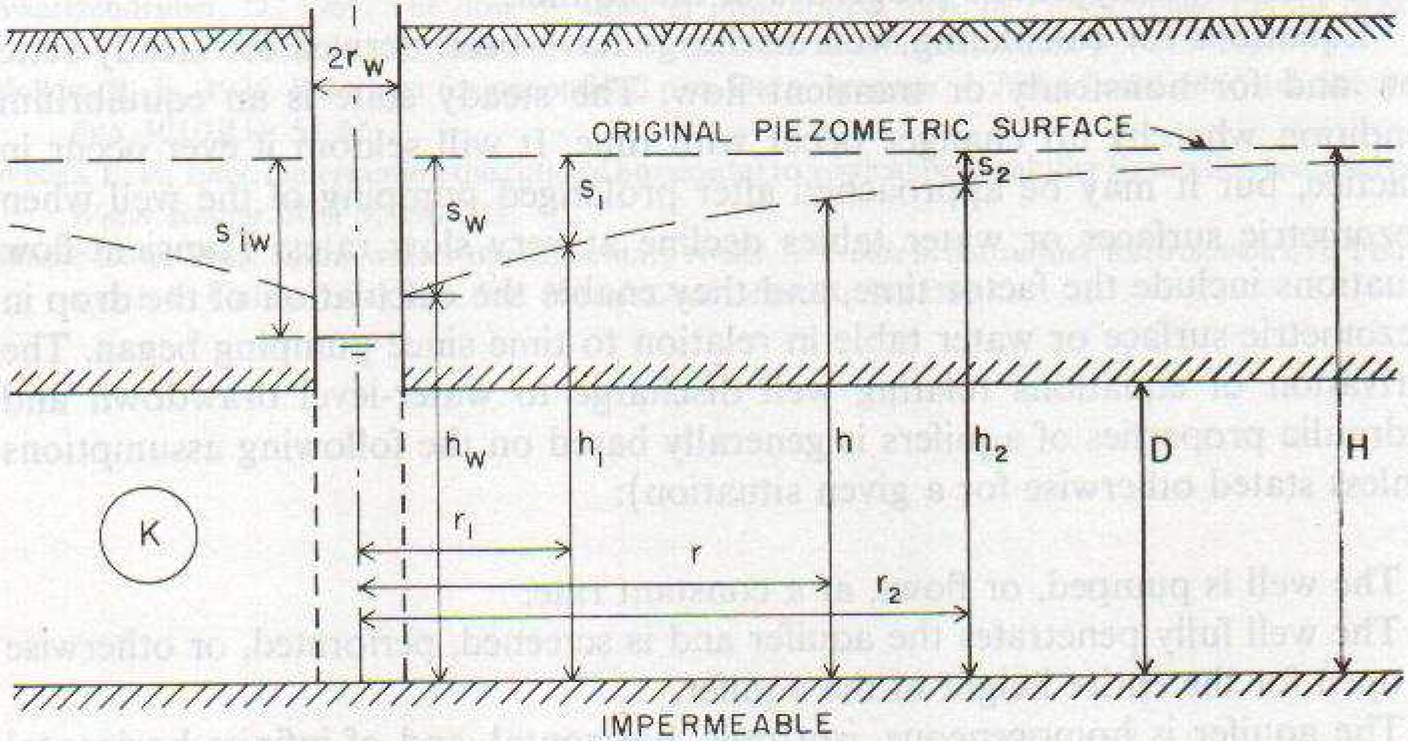
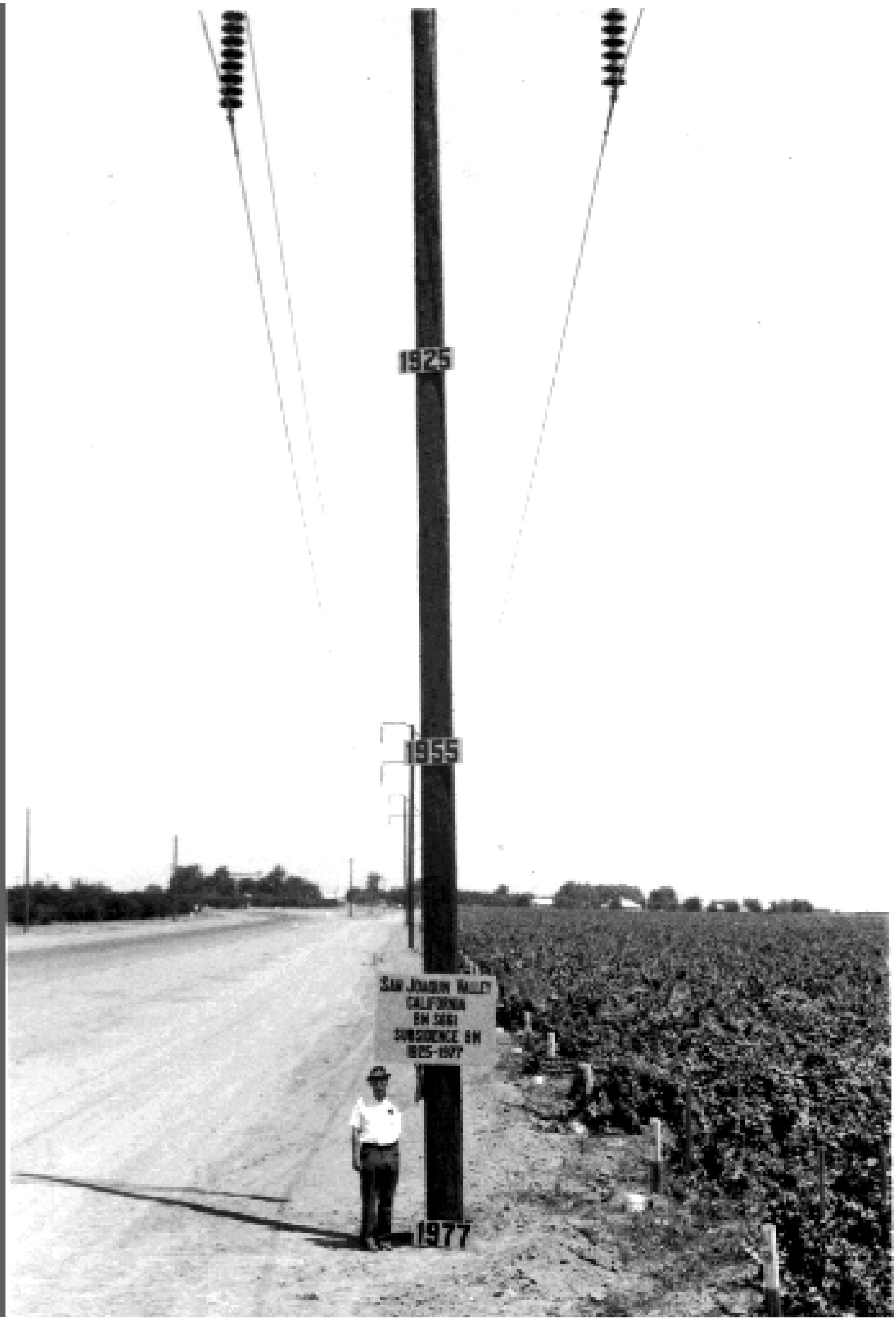


Figure 4.1 Geometry and symbols for pumped well in confined aquifer.


1925
1955
SAN JOAQUIN VALLEY
CALIFORNIA
SUBSIDENCE BM
1977

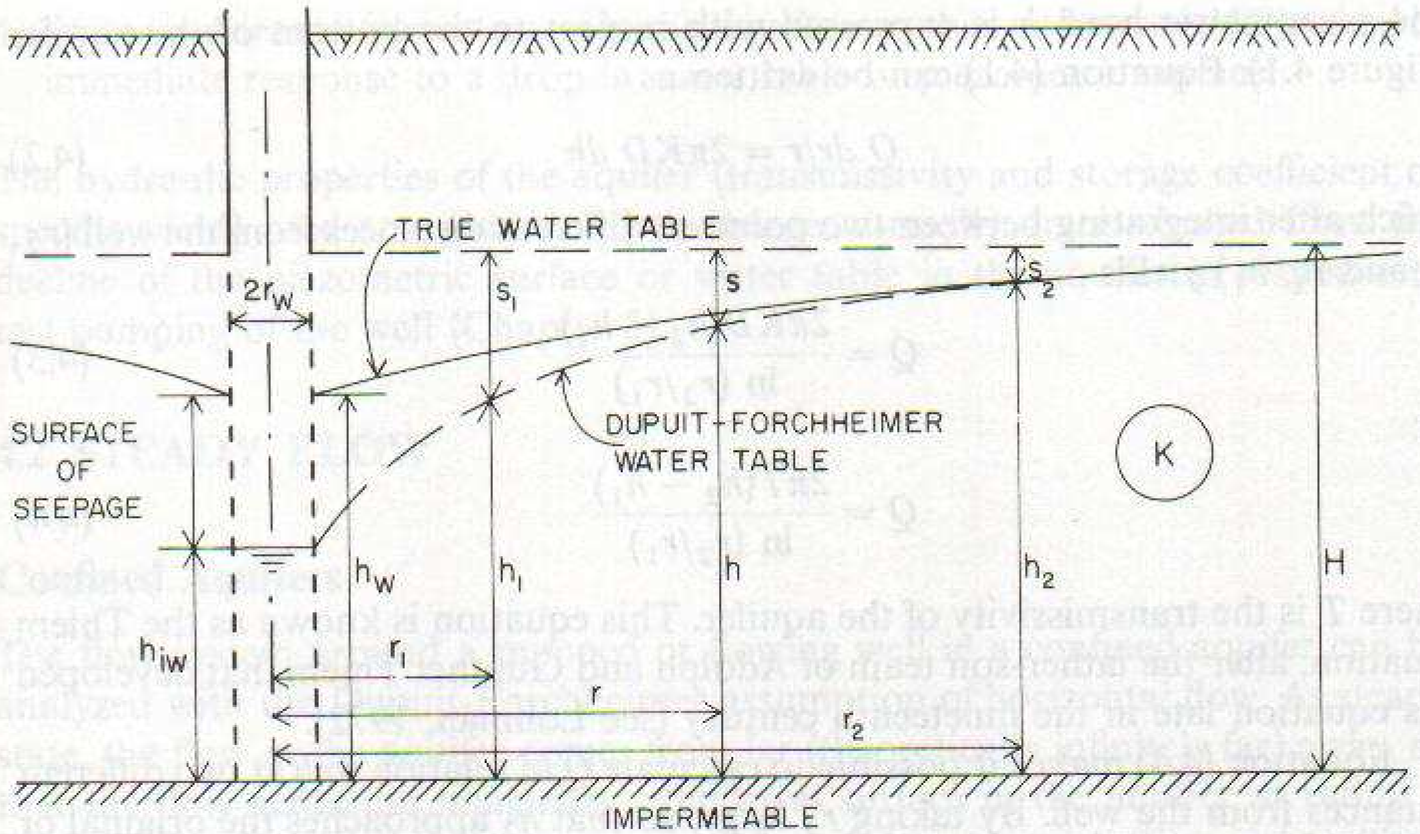


Figure 4.2 Geometry and symbols for pumped well in unconfined aquifer.

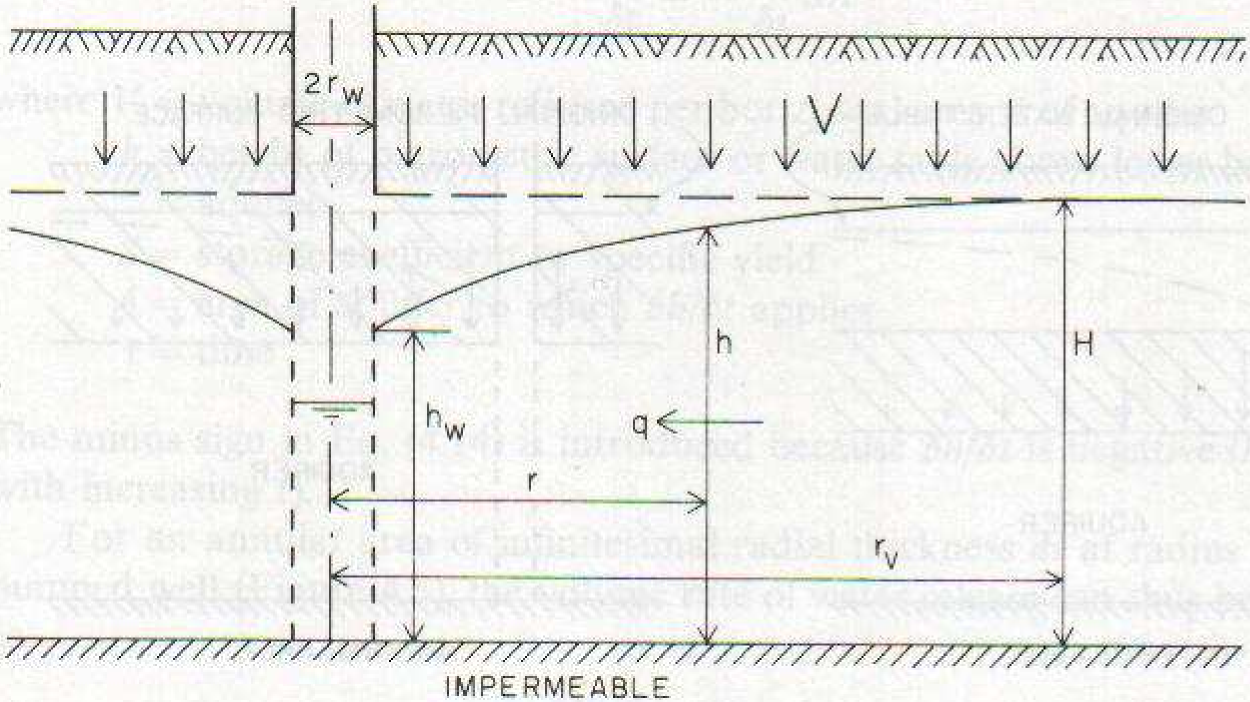


Figure 4.3 Pumped well in unconfined aquifer in equilibrium with vertical recharge.

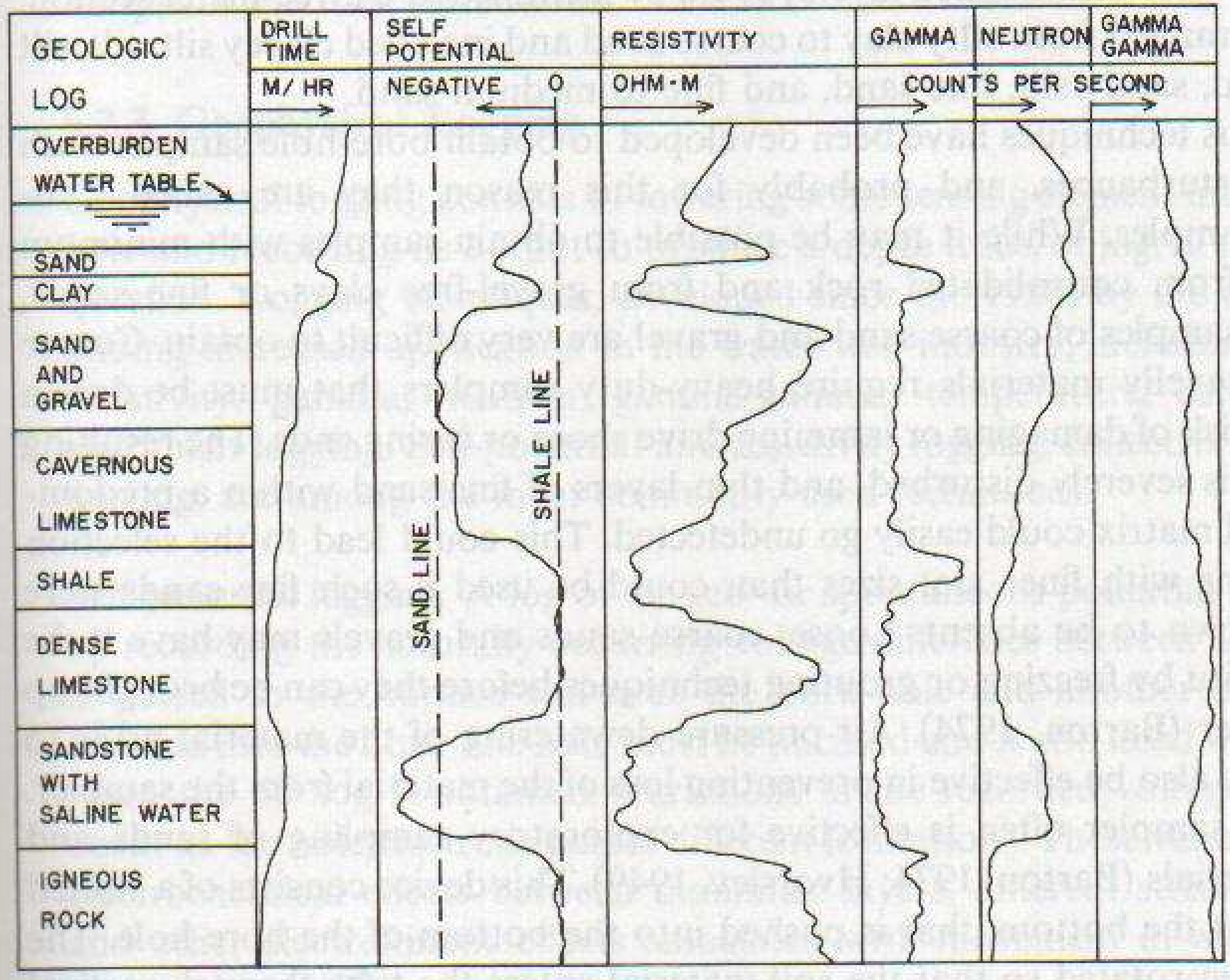


Figure 6.5 Hypothetical driller's and geophysical logs.

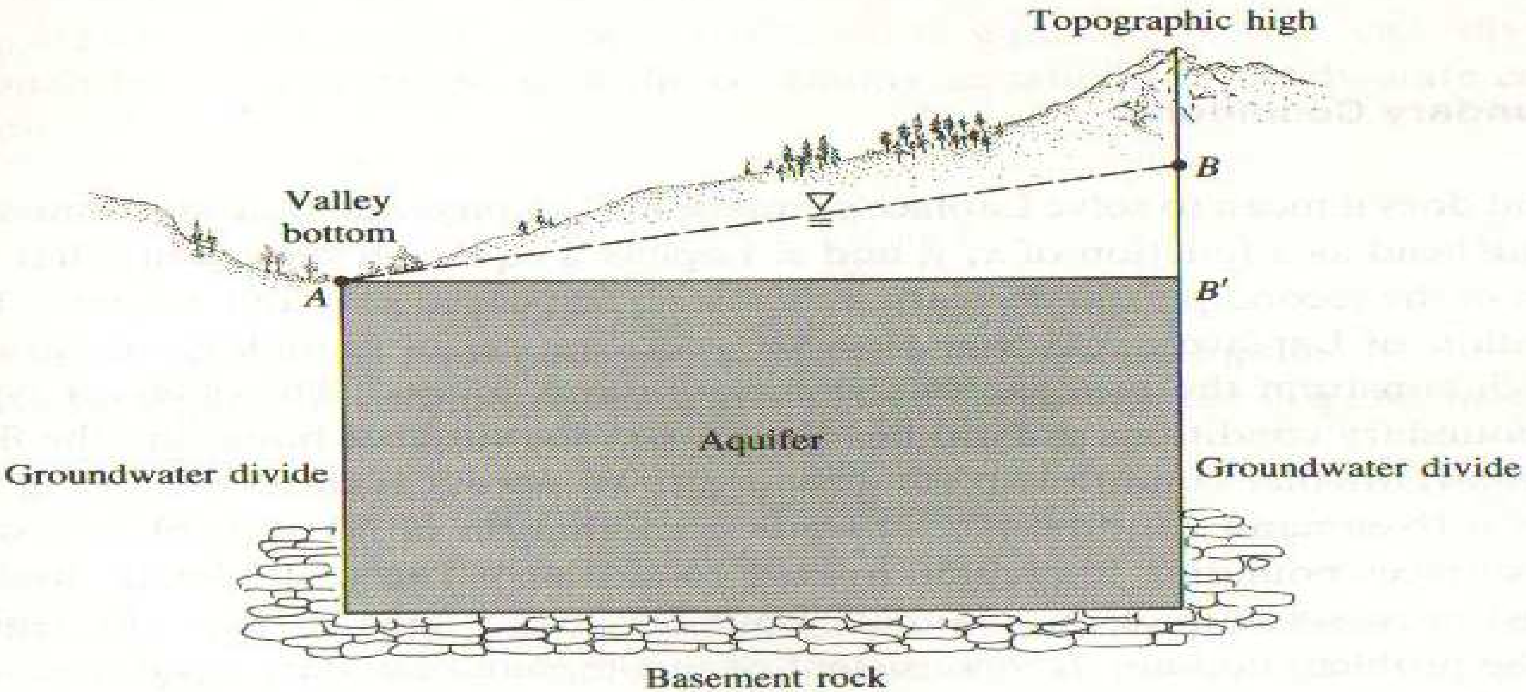


Figure 1.6
Schematic representation of the boundaries of a two-dimensional regional groundwater flow system.

Continuum ... Remember this ?

$$-\left(\frac{\partial \boldsymbol{q}_x}{\partial \boldsymbol{x}}+\frac{\partial \boldsymbol{q}_y}{\partial \boldsymbol{y}}+\frac{\partial \boldsymbol{q}_z}{\partial \boldsymbol{z}}\right)=\mathbf{0}$$

OR

$$\frac{\partial q_x}{\partial x}+\frac{\partial q_y}{\partial y}+\frac{\partial q_z}{\partial z}=0$$

Combine with Darcy

$$0 = \frac{\partial}{\partial x}\left(K_x \frac{\partial H}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial H}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial H}{\partial z}\right)$$

$$0 = \frac{\partial^2 H}{\partial x^2} + \frac{\partial^2 H}{\partial y^2} + \frac{\partial^2 H}{\partial z^2}$$

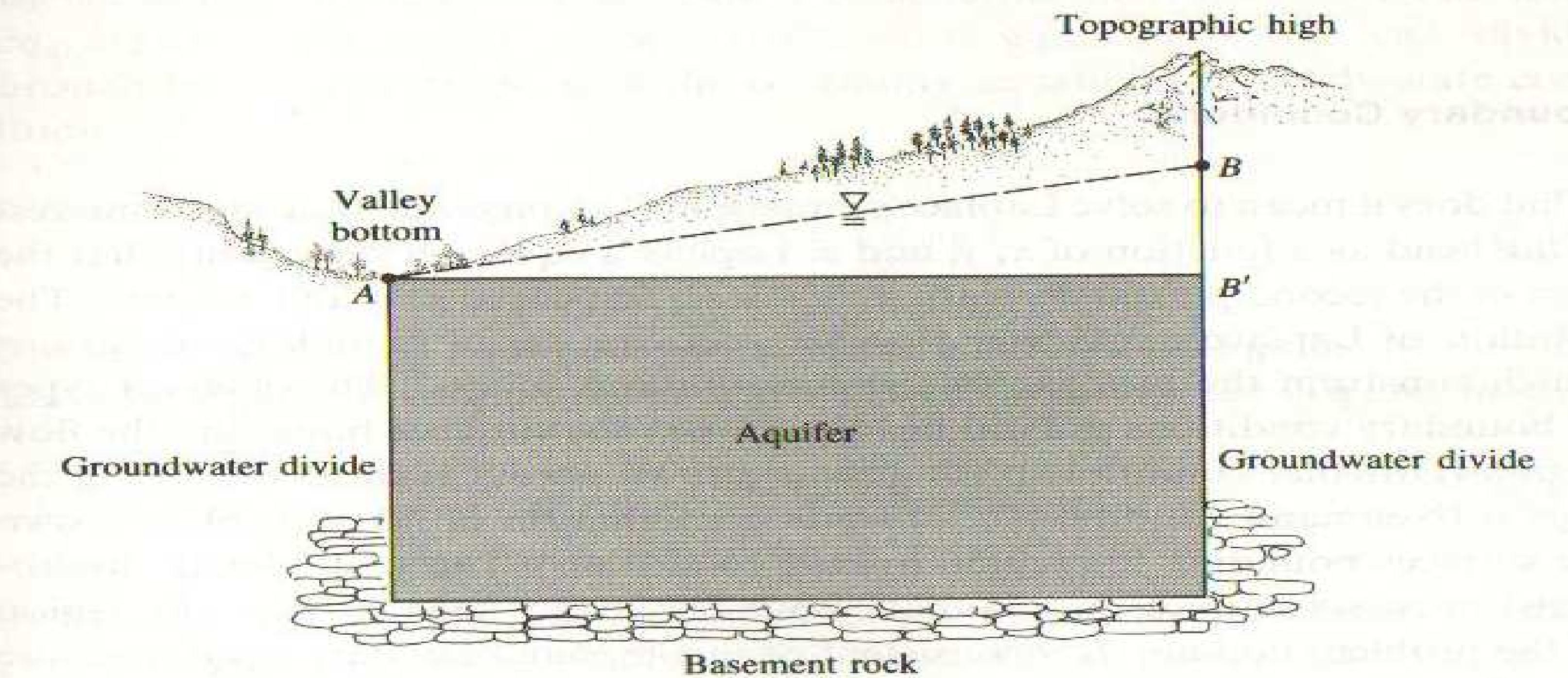


Figure 1.6

Schematic representation of the boundaries of a two-dimensional regional groundwater flow system.

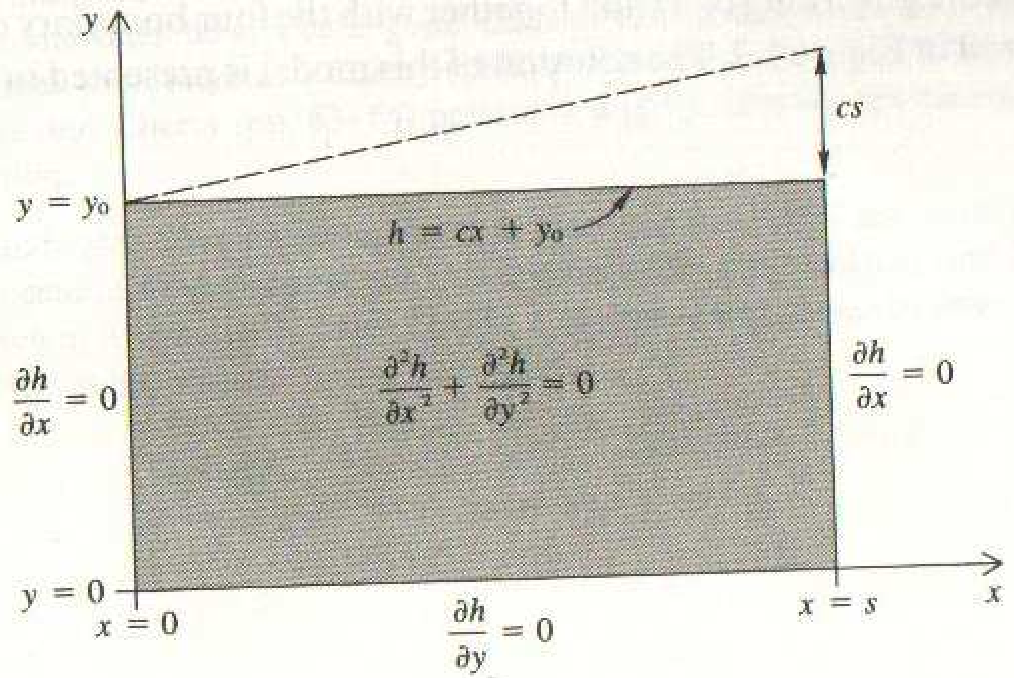


Figure 1.7
Mathematical model of the regional groundwater flow system shown in Figure 1.6.

Boundary Conditions

- No flow boundary
- Dirichlet boundary
  - Head is known for surfaces bounding the flow region
- Neumann boundary
  - Flow is known across surface bounding the region
- Combined head/flow knowledge