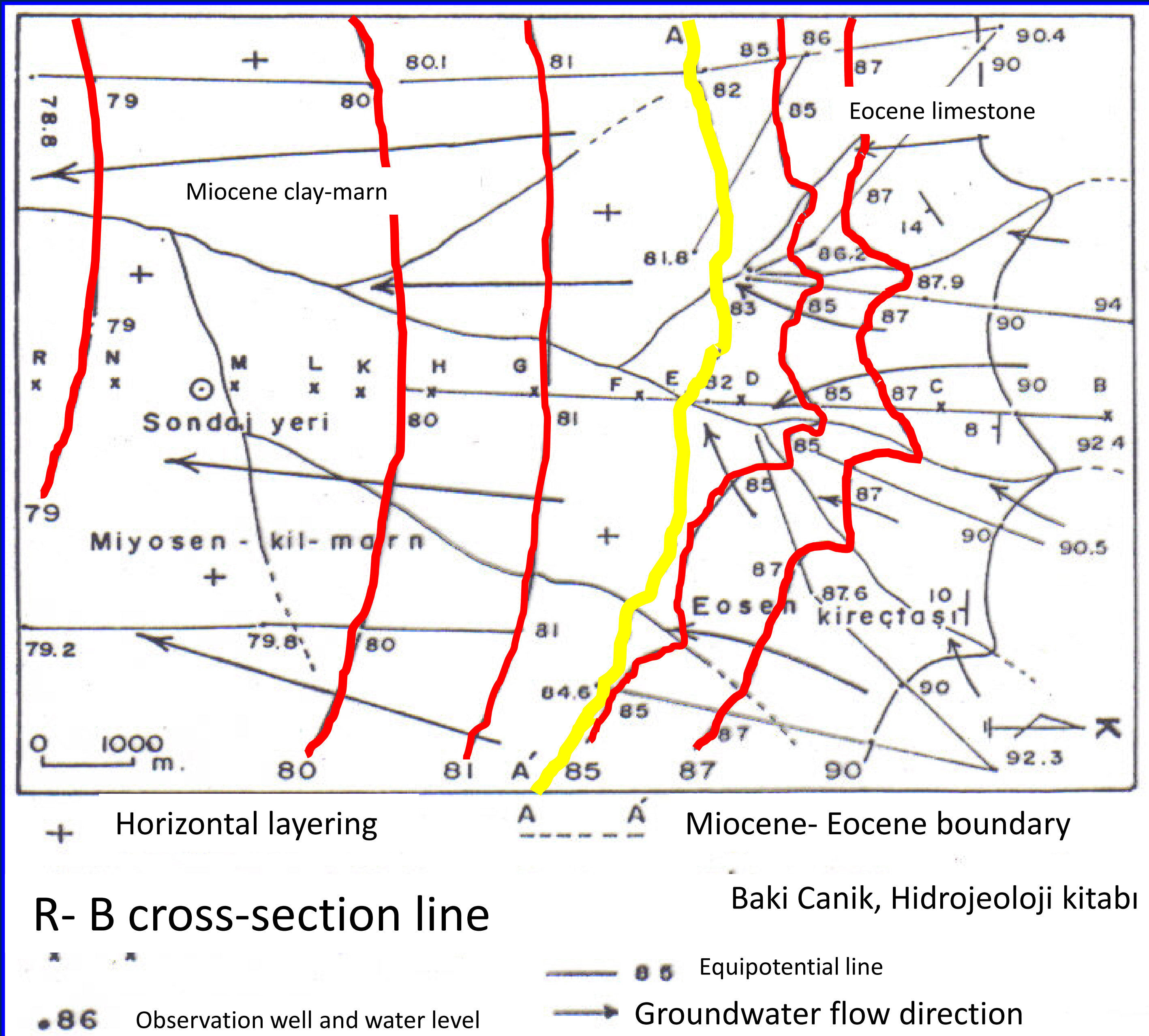
Water Level Meters

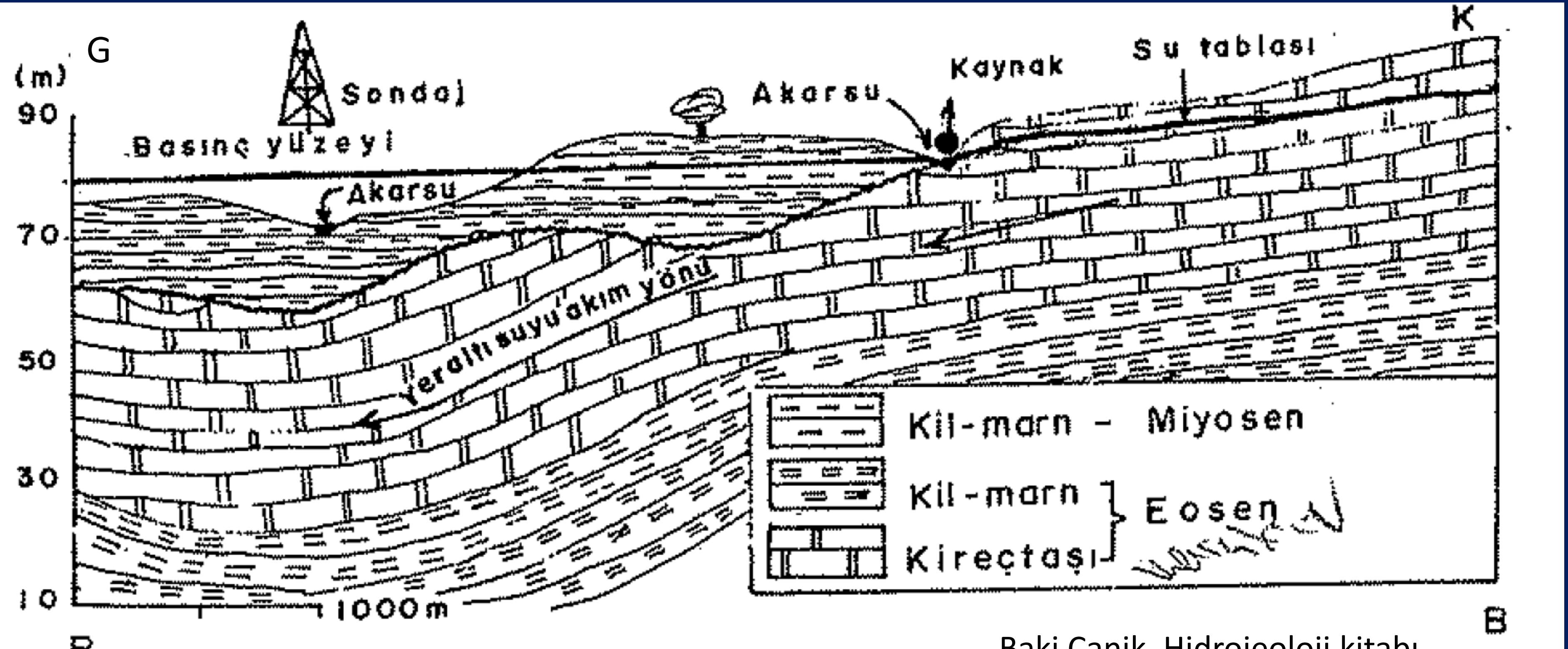


Unconfined aquifer?
Confined aquifer?

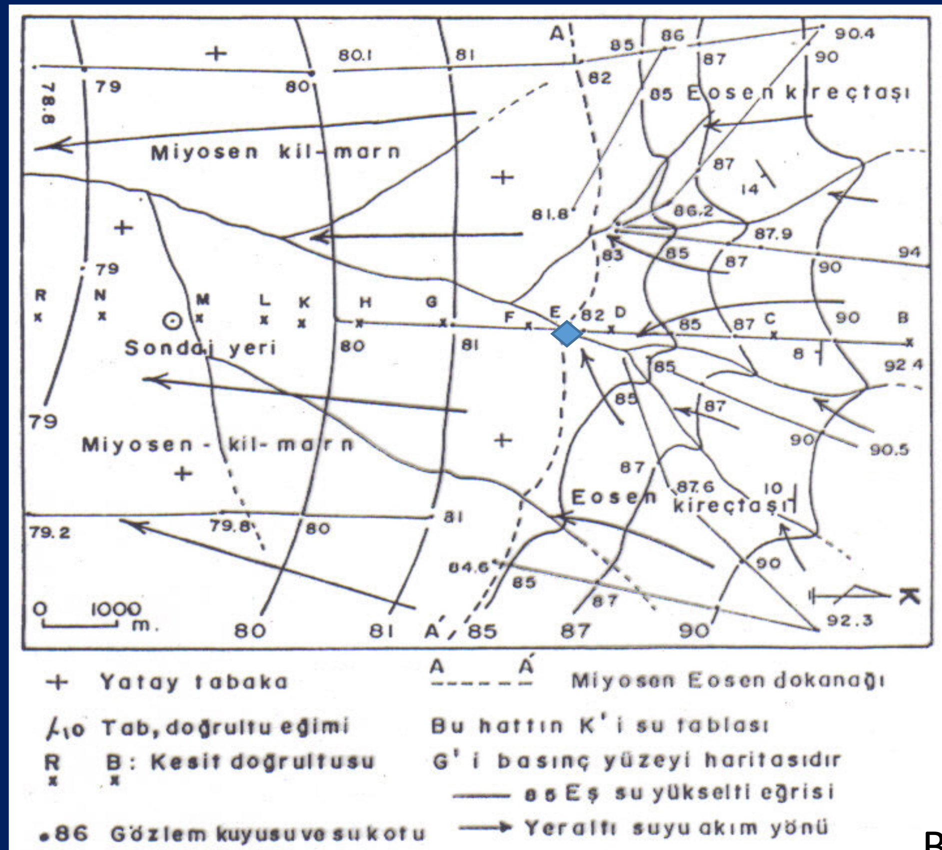
Water table and piezometric level maps

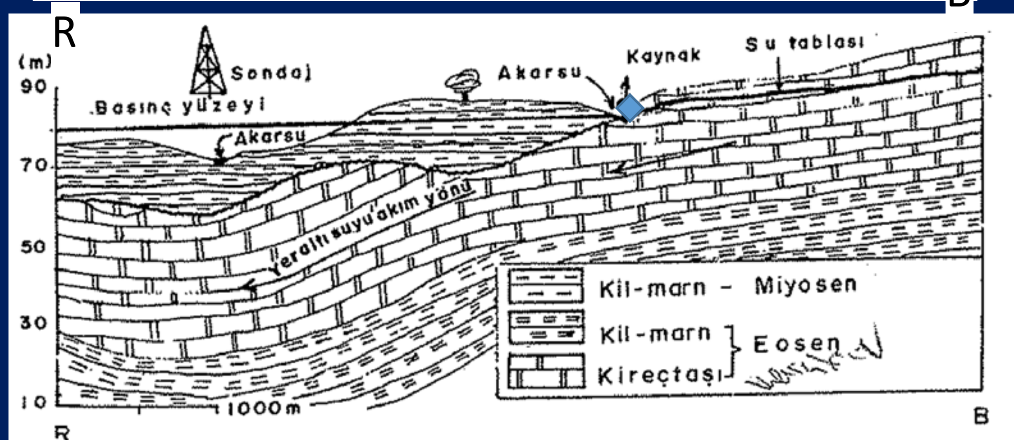
Hydrogeological Cross-section

Hydrogeological cross-sections are different from regular geologic cross-sections because they contain hydrologic and hydrodynamic structures like springs, water table or piezometric surface levels, groundwater flow directions.



Baki Canik, Hidrojeoloji kitabı


Eosen kireçtaşı
Miyosen kil-marn
Sondaj yeri
Miyosen - kil-marn
Eosen kireçtaşı
0 1000 m.
Yatay tabaka
Tab, doğrultu eğimi
R B: Kesit doğrultusu
•86 Gözlem kuyusu ve su kotu
A A' Miyosen Eosen dokanağı
Bu hattın K'i su tablası
G'i basınç yüzeyi haritasıdır
86 Eş su yükselti eğrisi
Yeraltı suyu akım yönü
B

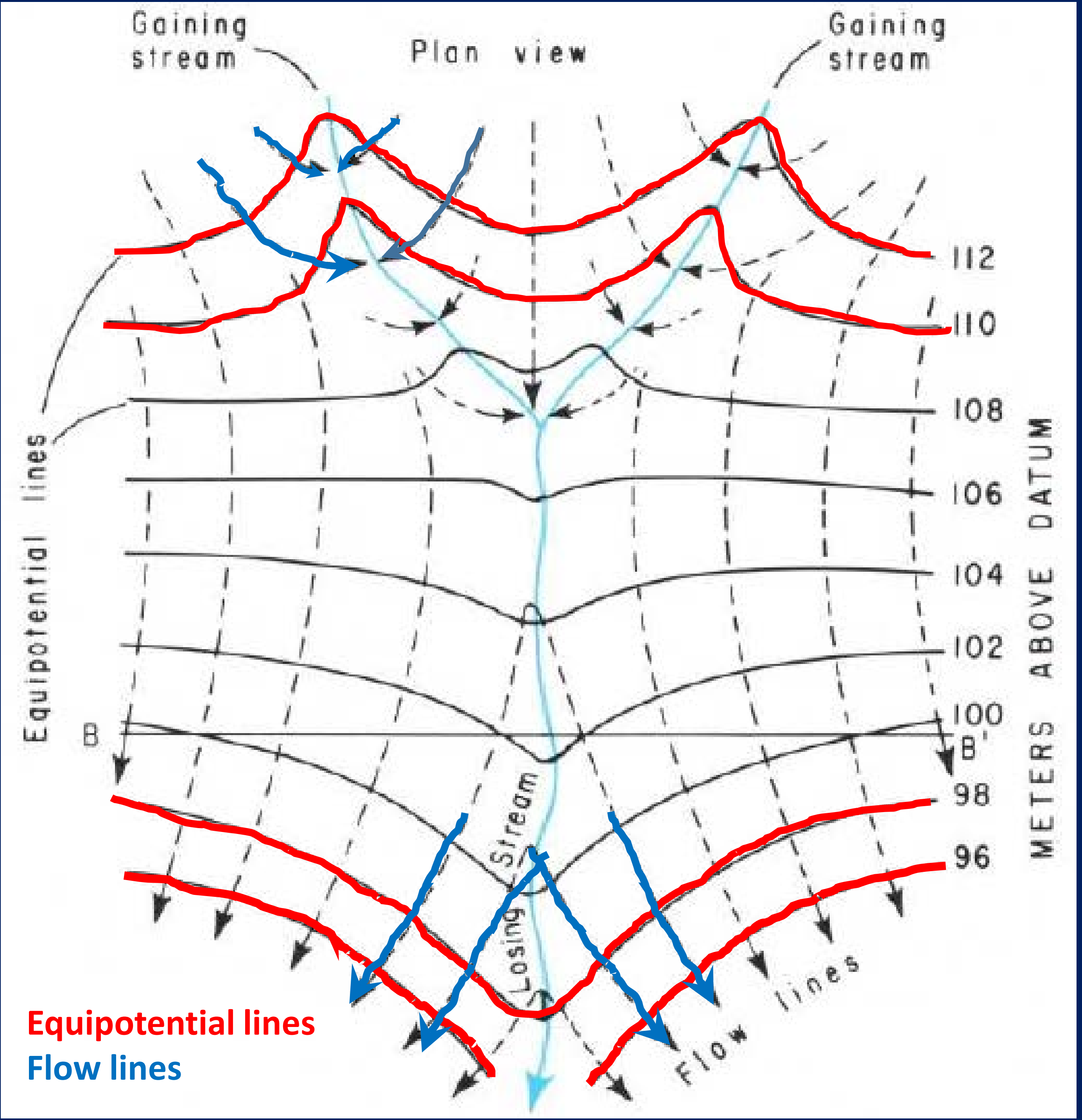

R
(m)
Sondaj
Basınç yüzeyi
Akarsu
Akarsu
Kaynak
Su tablası
Yeraltı suyu akım yönü
1000m
Kil-marn - Miyosen
Kil-marn
Kireçtaşı
Eosen
R
B

Streamflow and groundwater

When a stream channel is in direct contact with an unconfined aquifer, the stream may recharge the groundwater or receive discharge from the groundwater, depending on the relative levels.

A gaining stream is one receiving groundwater discharge

A losing stream is one recharging groundwater



Gaining stream
Plan view
Gaining stream
112
110
108
106
104
102
100
98
96
METERS ABOVE DATUM
Equipotential lines
B
B'
Stream
Losing
Flow lines
Equipotential lines
Flow lines

If contours are located apart, hydraulic gradient is low, hydraulic conductivity is high

Characteristics	**Change**	**Hydraulic gradient (i)**	**Distance between equipotential lines**
Hydraulic conductivity (K)	Increase	Decreases	Increases
	Decrease	Increases	Decreases
Discharge (Q)	Increase	Increases	Decreases
	Decrease	Decreases	Increases
Cross-sectional area (A)	Broadens	Decreases	Increases
	Narrows	Increases	Decreases

$$\frac{K_1}{K_2} = \frac{i_2}{i_1}$$

DARCY'S LAW IN THREE DIMENSIONS

In 3-D flow, hydraulic head is a function of all three-space coordinates, i.e., h=h(x, y, z). In three dimensions, specific discharge is a vector with components q_x, q_y and q_z. For an isotropic medium,

$$q_x = -K\frac{\partial h}{\partial x}, \qquad q_y = -K\frac{\partial h}{\partial y}, \qquad q_z = -K\frac{\partial h}{\partial z}$$

In vector notation: $\vec{q} = -K\nabla h$ where $\nabla h = \text{gradient vector of the head} = \left(\frac{\partial h}{\partial x}\vec{i} + \frac{\partial h}{\partial y}\vec{j} + \frac{\partial h}{\partial z}\vec{k}\right)$

$\vec{i}, \vec{j}, \vec{k}$ are unit vectors in x, y and z coordinate directions, respectively.

$$\begin{bmatrix} q_x \\ q_y \\ q_z \end{bmatrix} = -\begin{bmatrix} K_{xx} & K_{xy} & K_{xz} \\ K_{yx} & K_{yy} & K_{yz} \\ K_{zx} & K_{zy} & K_{zz} \end{bmatrix} \begin{bmatrix} \partial h/\partial x \\ \partial h/\partial y \\ \partial h/\partial z \end{bmatrix}$$

Hydraulic conductivity tensor

3-D linear parabolic partial differential equation, the solution of which yields h(x, y, z, t) in a heterogeneous, anisotropic, confined aquifer.

$$\frac{\partial}{\partial x}\left(K_x \frac{\partial h}{\partial x}\right) + \frac{\partial}{\partial y}\left(K_y \frac{\partial h}{\partial y}\right) + \frac{\partial}{\partial z}\left(K_z \frac{\partial h}{\partial z}\right) = S_s \frac{\partial h}{\partial t}$$

For homogeneous but anisotropic aquifer

$$K_x\left(\frac{\partial^2 h}{\partial x^2}\right) + K_y\left(\frac{\partial^2 h}{\partial y^2}\right) + K_z\left(\frac{\partial^2 h}{\partial z^2}\right) = S_s \frac{\partial h}{\partial t} \quad = \quad \frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} + \frac{\partial^2 h}{\partial z^2} = \frac{S_s}{K}\frac{\partial h}{\partial t}$$

For horizontal flow (x, y)

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = \frac{S_s b}{K b}\frac{\partial h}{\partial t} = \frac{S}{T}\frac{\partial h}{\partial t}$$

Laplace’s Equation- solution of which gives h= h(x,y,z) in an isotropic and homogenous confined aquifer

For steady-state flow homogeneous and isotropic aquifer

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

In a unconfined aquifer, gradient of the water table is not constant; it increases in the flow direction.
To derive an equation of flow in an unconfined aquifer Dupuit assumptions should be accepted.

1) Hydraulic gradient is equal to the slope of the water table
2) For small water table slopes, the flow lines are horizontal and the equipotential lines are vertical (i.e. Horizontal flow).