Geotechnical Engineering–I

BSc Civil Engineering – 4th Semester

Lecture # 23

24-Apr-2015

by

Dr. Muhammad Irfan

Assistant Professor

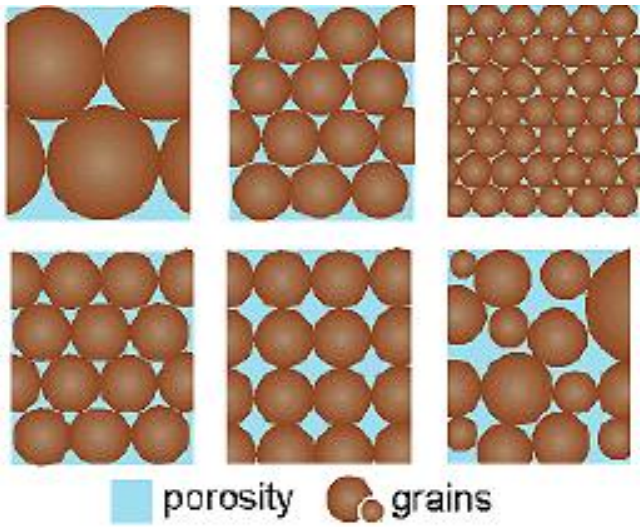
Civil Engg. Dept. – UET Lahore

Email: mirfan1@msn.com

Lecture Handouts: https://groups.google.com/d/forum/geotec-1

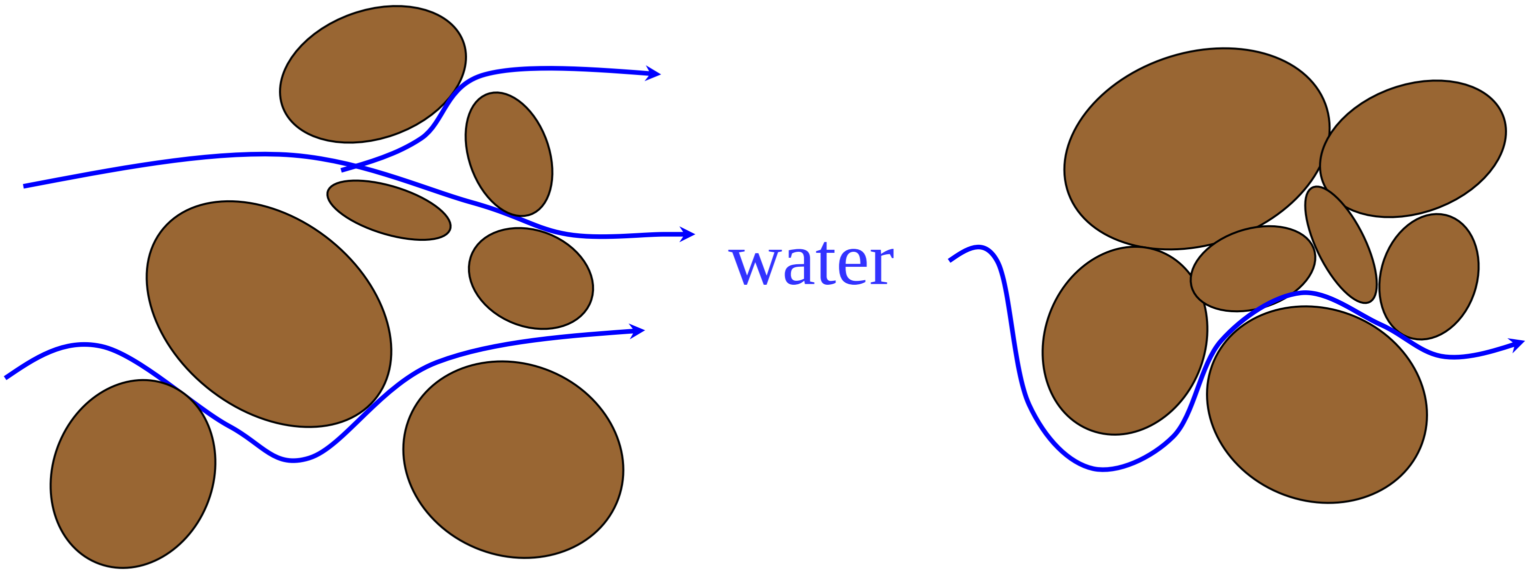
SOIL PERMEABILITY

A measure of soil's ability to permit water to flow through its pores/voids.



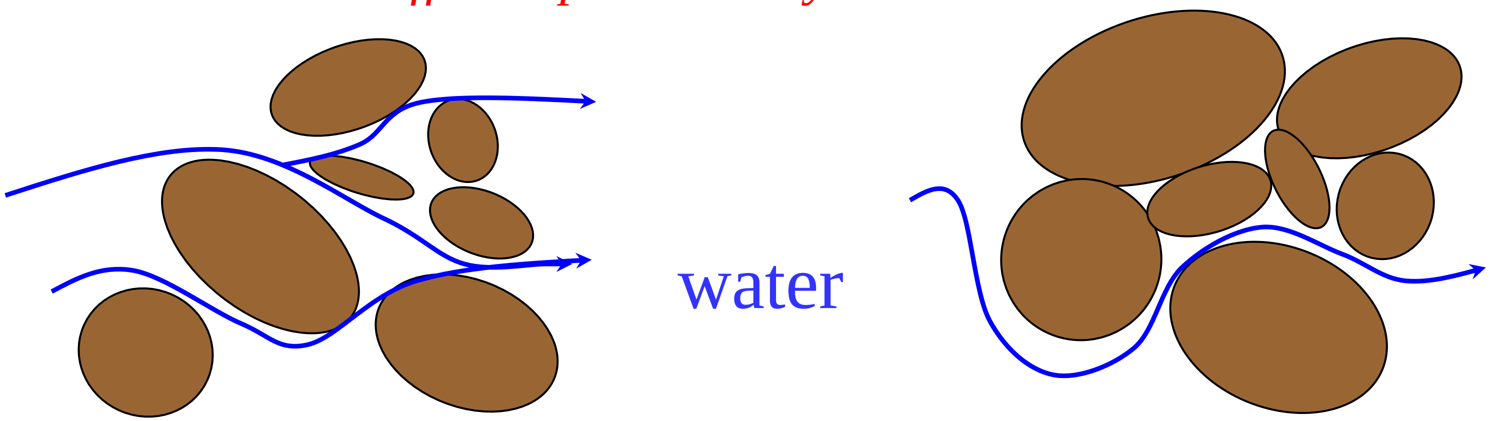
How does water flow through soil?

- Soils → solid particles with *interconnected voids*
- water flows from point of *high energy to* point of *low energy*



SOIL PERMEABILITY

Different soils have *different permeability*.



Loose Soil

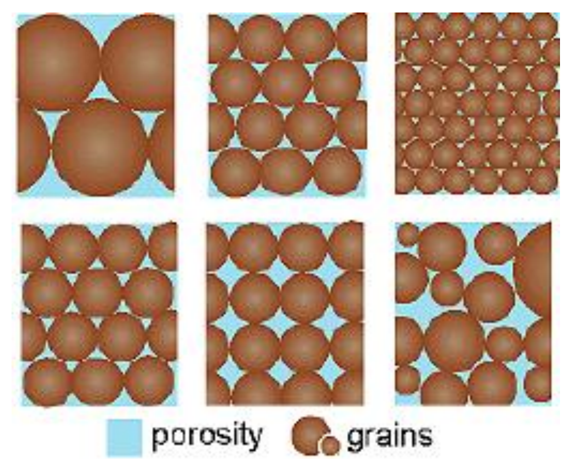
Easy to flow → *high permeability*

Dense Soil

Difficult to flow → *low permeability*

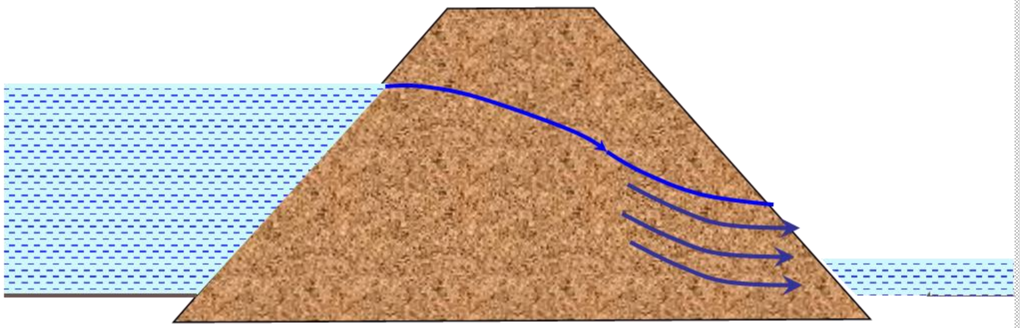
Coarse-grained soils → *high* permeability

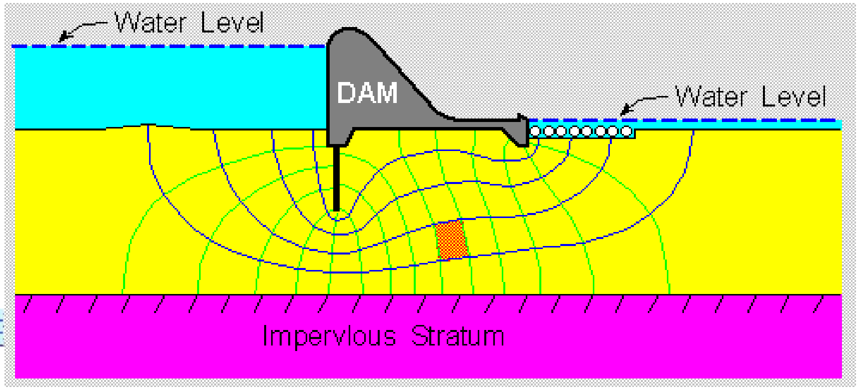
Fine-grained soils → *low* permeability



PERMEABILITY – Importance

- influences the *rate of settlement* under applied loads
- design of *earth dams*
- *soil filters*
- *stability* of slopes and retaining structures
- Underground *water flow*
- *Wells/aquifers*

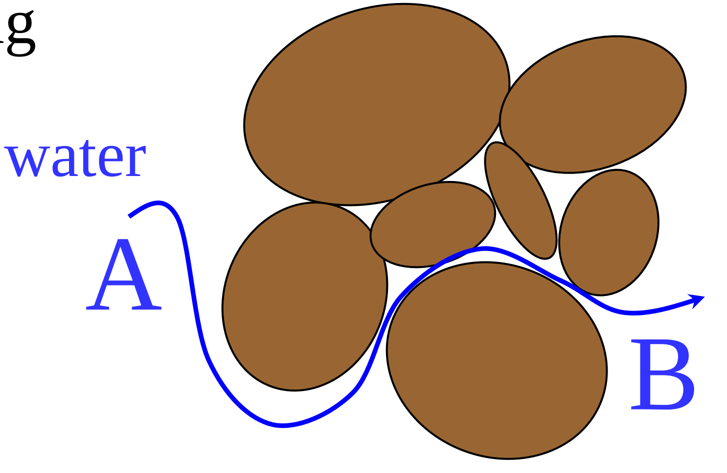




Why does the water flow?

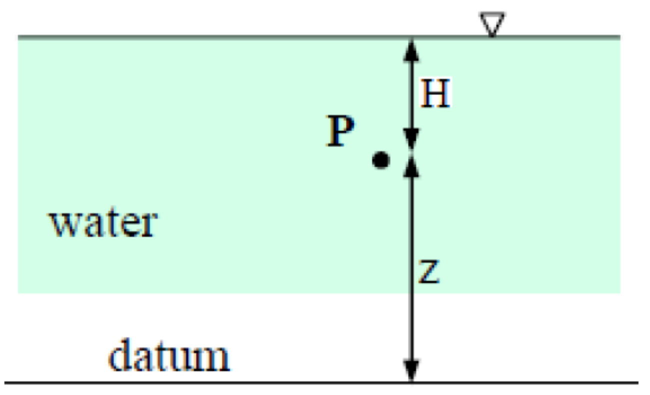
Because the energy at A is higher B

- Energy is dissipated in overcoming the *soil resistance*
- Causing *head loss*



Bernoulli's Equation

The total head at any point in water under motion is the summation of *pressure*, *velocity* and *elevation heads*.



$$h = \frac{p}{\gamma_m} + \frac{v^2}{2g} + z$$

Pressure Head	Velocity Head	Elevation Head

Velocity of flow through soils → extremely small

Velocity head can be ignored

$$h = \frac{p}{\gamma_m} + z$$

- h: total head (m)
- p: water pressure (Pa)
- v: velocity of water (m/s)
- z: elevation head (m)

Bernoulli's Equation

The total head at any point in water under motion is the summation of *pressure*, *velocity* and *elevation heads*.

Total head at A:

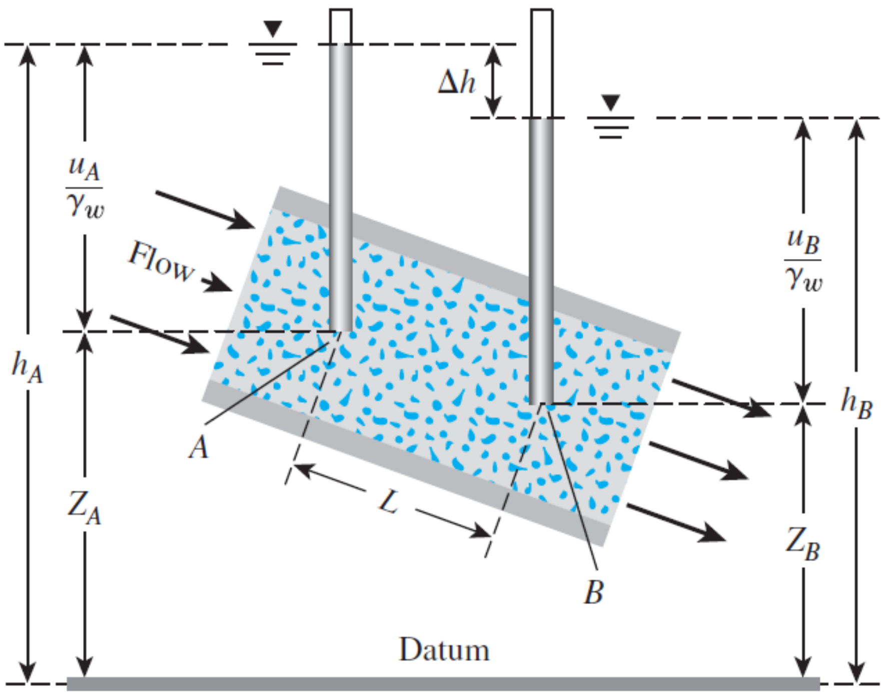
$$h_A = \frac{p_A}{\gamma_w} + z_A$$

Total head at B:

$$h_B = \frac{p_B}{\gamma_w} + z_B$$

Head loss between A & B:

$$\Delta h = h_A - h_B = \left(\frac{p_A}{\gamma_w} + z_A\right) - \left(\frac{p_B}{\gamma_w} + z_B\right)$$



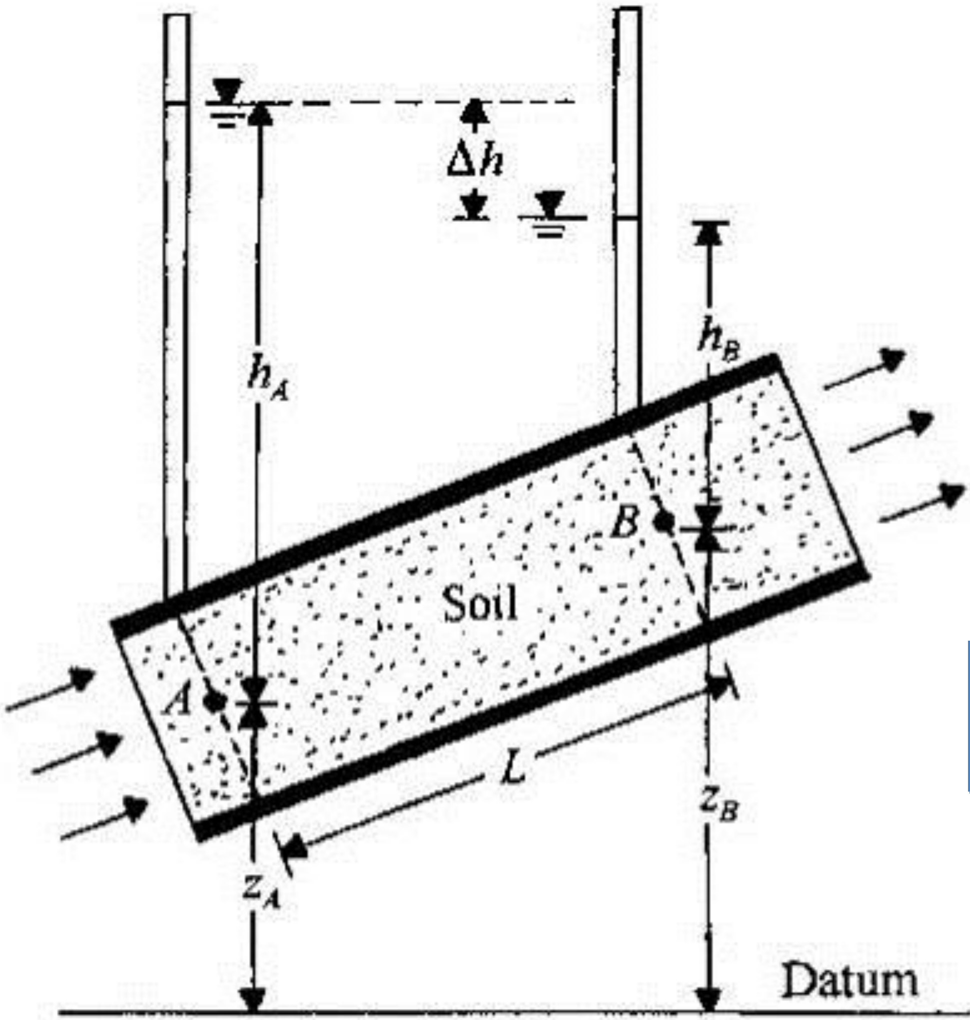
Head loss expressed in non-dimensional form:

$$i = \frac{\Delta h}{L}$$

i: hydraulic gradient

L: distance between points A and B

Bernoulli's Equation



Tricky case!!

Remember always to look at total head

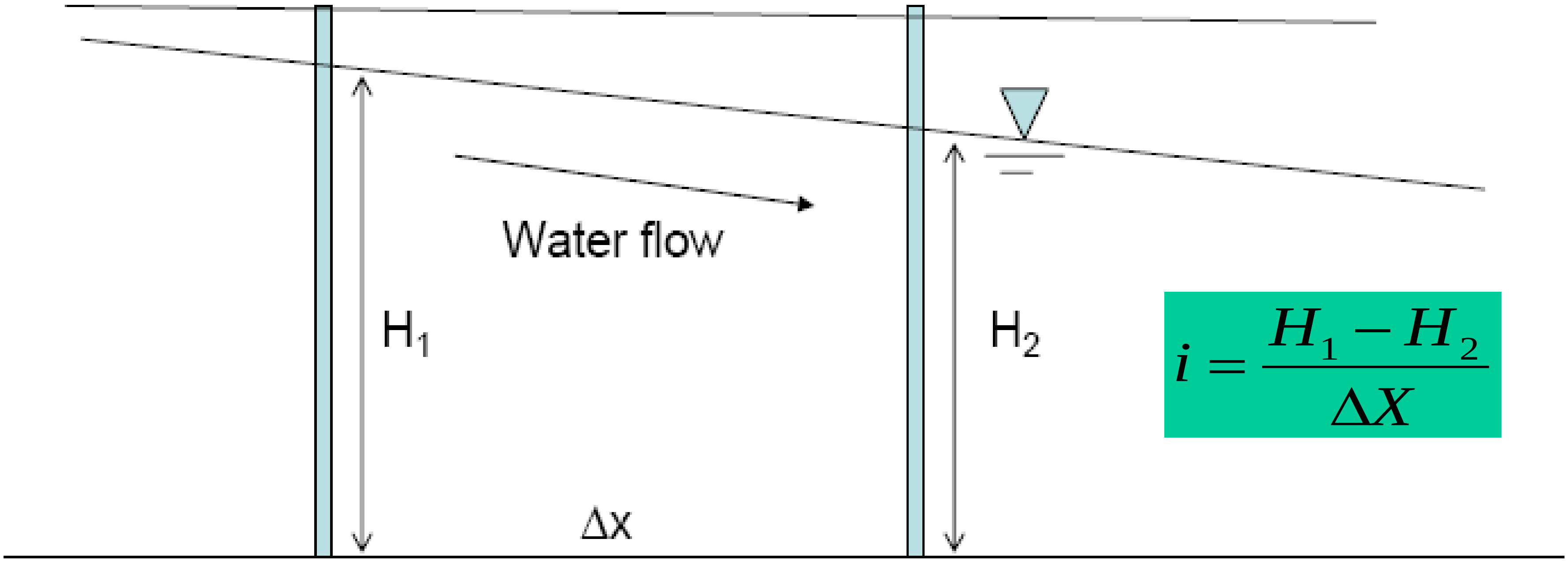
$$i = \frac{\Delta h}{L}$$

i: hydraulic gradient

L: distance between points A and B

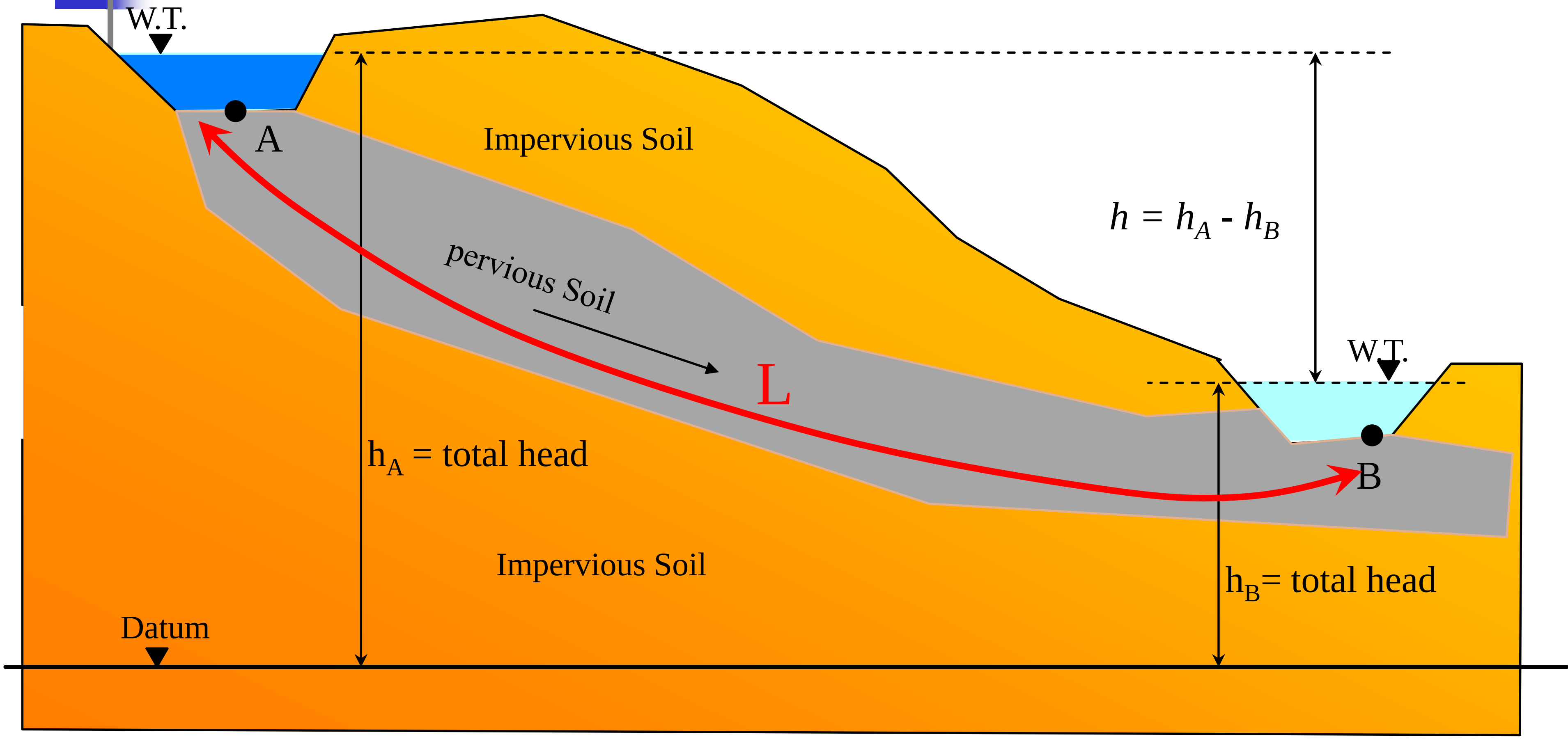
HYDRAULIC GRADIENT

In the *field*, gradient/slope of the head is the *head difference over the distance* separating the 2 wells.



$$i = \frac{H_1 - H_2}{\Delta X}$$

HYDRAULIC GRADIENT



$$i = \frac{(h_A - h_B)}{L} = \frac{\Delta h}{L}$$

Darcy's Law

Henry Darcy in 1856

The *velocity of flow* through soil is proportional to *hydraulic gradient*

$v \propto i$

$v = k \cdot i$

v = discharge velocity
(i.e., the *quantity of water* flowing in *unit time* through a *unit cross-sectional area* of soil)

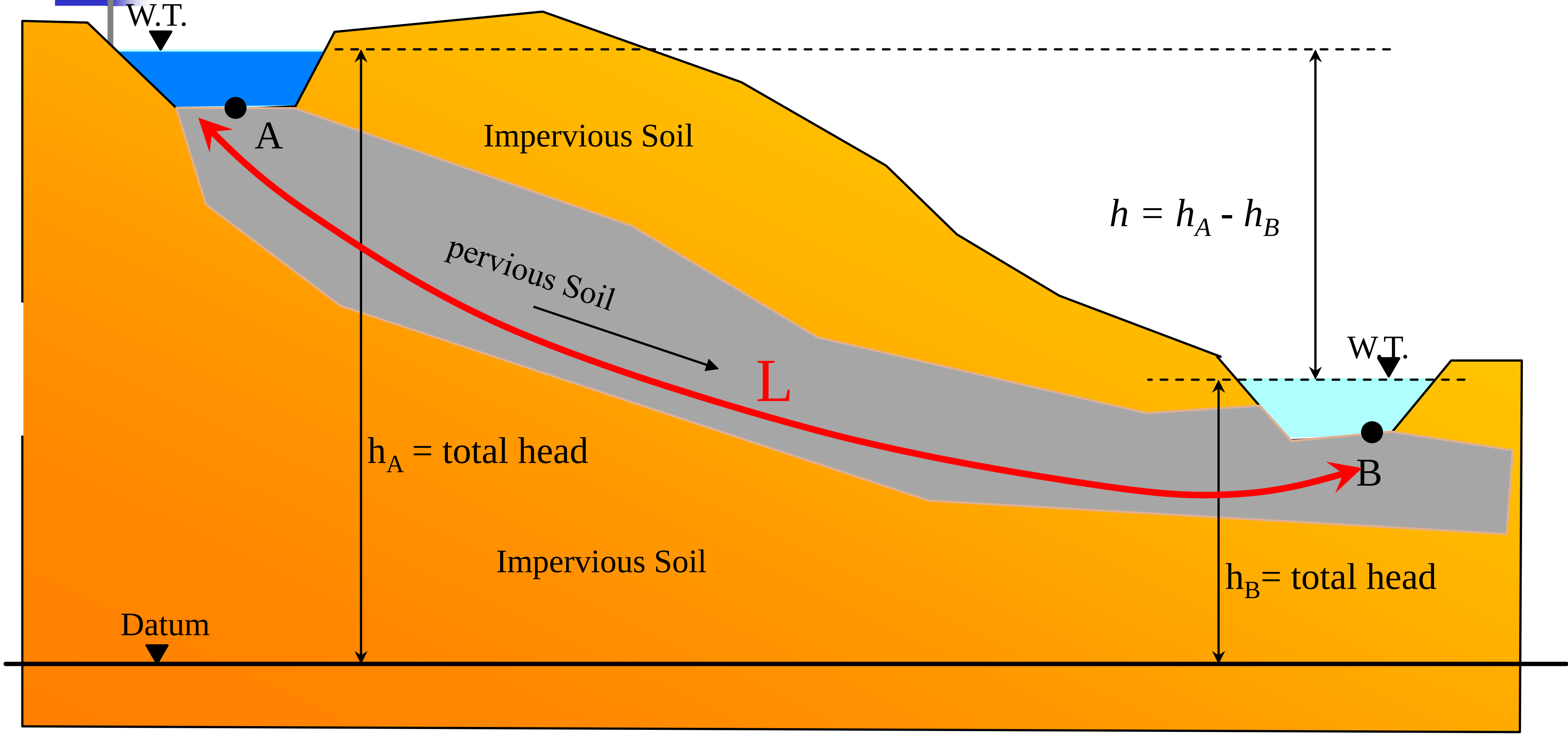
k = hydraulic conductivity (has units of L/T)

i = hydraulic gradient = h/L

Then the *quantity of water* flowing through the soil *per unit time* is

$$Discharge = Q = v.\,A = k\,(h/L).\,A$$

WATER FLOW THROUGH SOILS



$$i = \frac{(h_A - h_B)}{L} = \frac{\Delta h}{L} \Rightarrow Q = k \cdot i \cdot A = k \cdot \frac{\Delta h}{\mathrm{L}} \cdot A$$

WATER FLOW THROUGH SOILS

$$Q = k \cdot i \cdot A = k \cdot \frac{\Delta h}{L} \cdot A$$

To determine the quantity of flow, two parameters are needed

* k = hydraulic conductivity *(how permeable is the soil medium)*
* i = hydraulic gradient *(how large is the driving head)*

Determination of '*k*'

1- Laboratory Testing → [constant head test & falling head test]

2- Field Testing → [pumping from wells]

3- Empirical Equations

Determination of '*i*'

1- from the head loss and geometry

2- flow nets

Seepage Velocity (v_s) & Superficial Velocity (v)

Darcy's law

$$v = k \cdot i$$

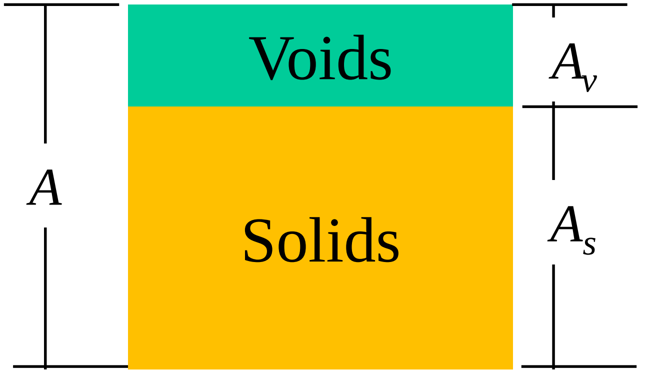
v = velocity of flow

Superficial velocity/Average velocity (v) → Average velocity of flow through soil

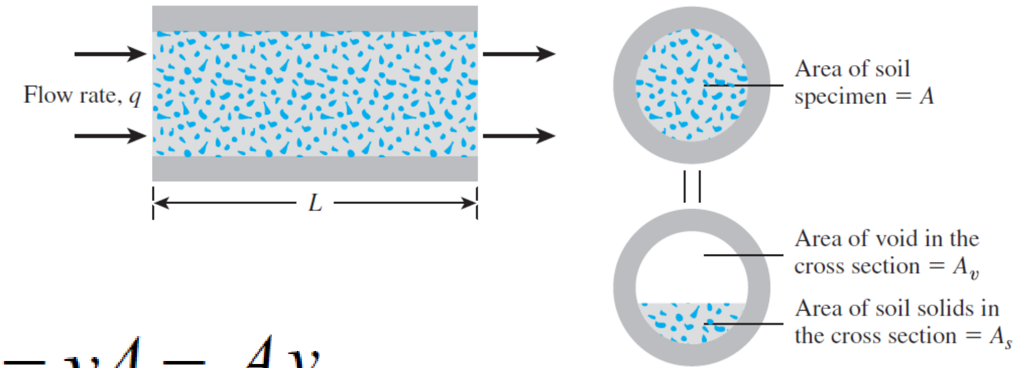
Seepage velocity/Actual velocity (v_S) → velocity of flow through voids only

$$v_S > v$$

$$v = n \cdot v_S$$



Seepage Velocity (v_s) & Superficial Velocity (v)



v = Average velocity/Superficial velocity

v_S = Seepage velocity/Actual flow velocity

$$q = vA = A_v v_s$$

$$q = v(A_v + A_s) = A_v v_s$$

$$v_s = \frac{v(A_v + A_s)}{A_v} = \frac{v(A_v + A_s)L}{A_v L} = \frac{v(V_v + V_s)}{V_v}$$

$$v_s = v\left[\frac{1 + \left(\frac{V_v}{V_s}\right)}{\frac{V_v}{V_s}}\right] = v\left(\frac{1+e}{e}\right) = \frac{v}{n}$$

$$v = n.\, v_S$$

Soil Classification w.r.t Permeability

Relative Permeability	*k* value (cm/sec)	Typical Soil
Highly permeable	1×10^{-1}	Gravel and sand
Medium permeable	10^{-1} - 10^{-3}	Sand with fines
Low permeable	10^{-3} - 10^{-5}	Silts and silty sand
Very low permeable	10^{-5} - 10^{-7}	Fine silts
Very very low permeable/Impermeable	$< 10^{-7}$	Clay

CONCLUDED