Permeability and Seepage (cont'd)

Duration = 18 minutes

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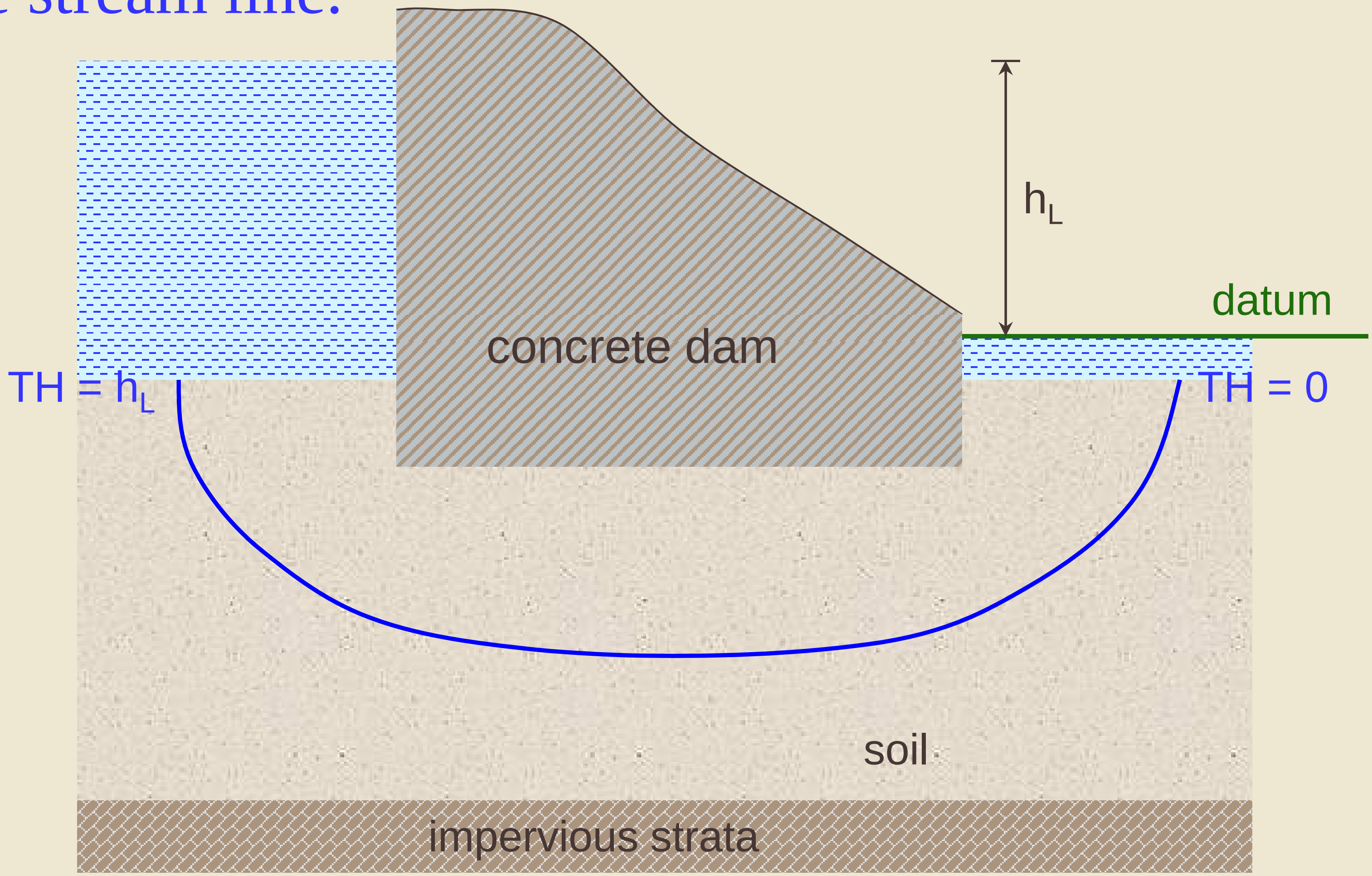
Seepage Terminology

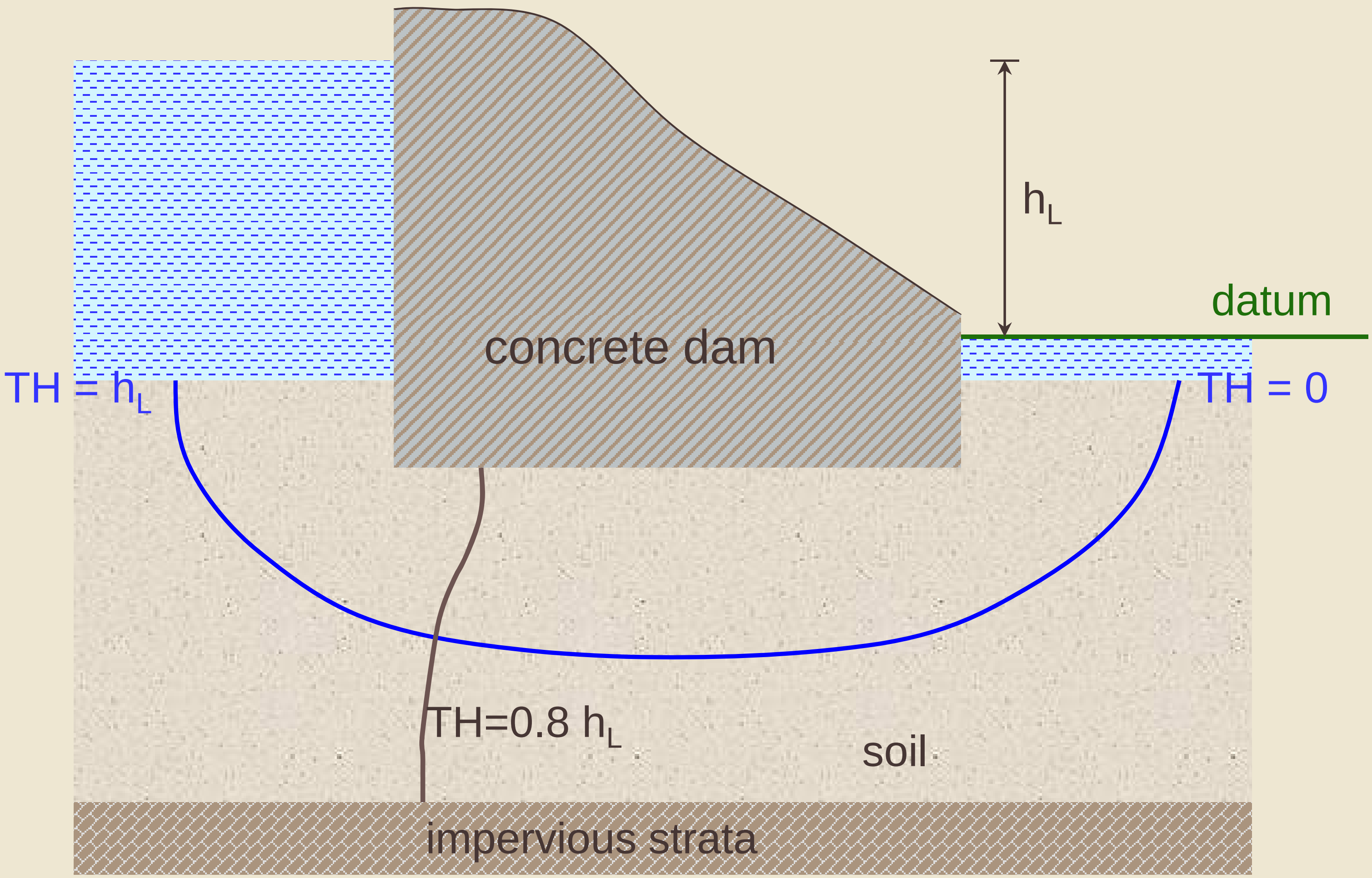
Stream line is simply the path of a water molecule.

From upstream to downstream, total head steadily decreases along the stream line.



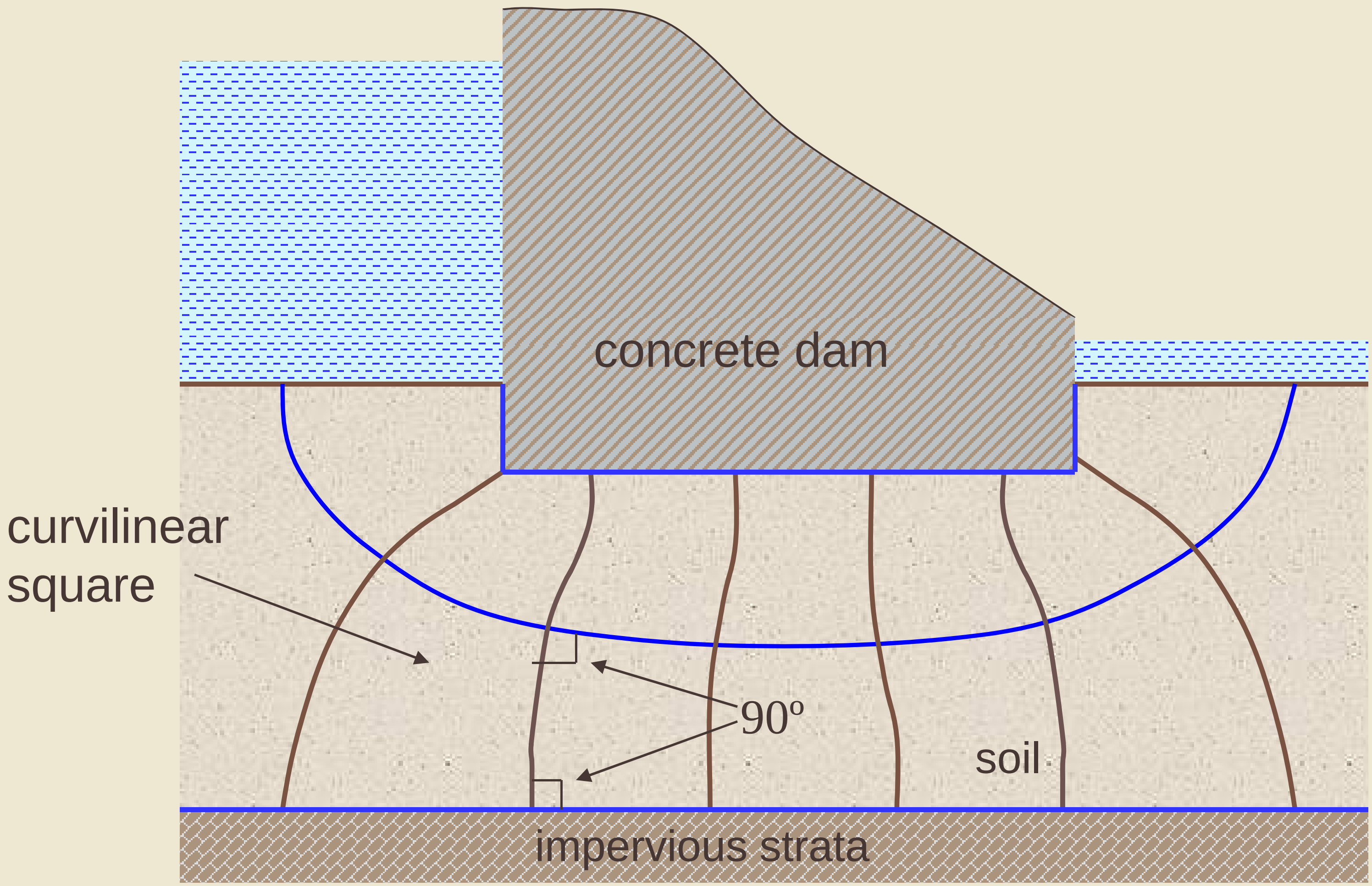
Seepage Terminology

<u>Equipotential line</u> is simply a contour of constant total head.



Flownet

A network of selected stream lines and equipotential lines.



Quantity of Seepage (Q)

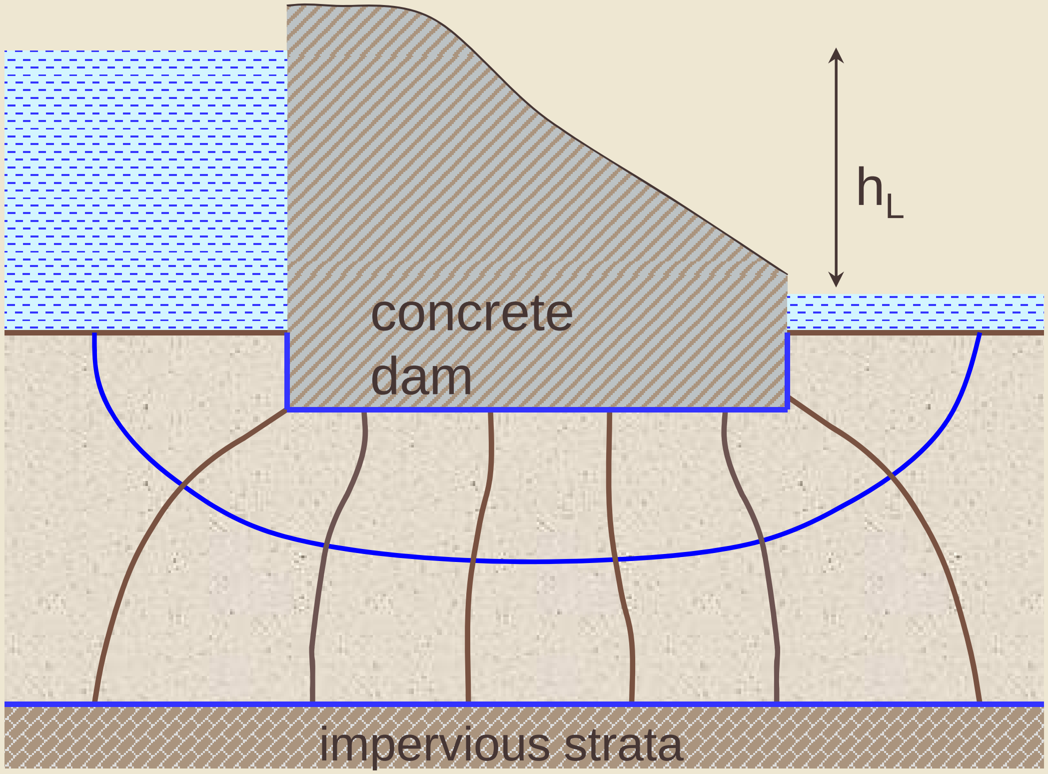
$$Q = k h_L \frac{N_f}{N_d}$$

# of flow channels

….per unit length normal to the plane

# of equipotential drops

head loss from upstream to downstream



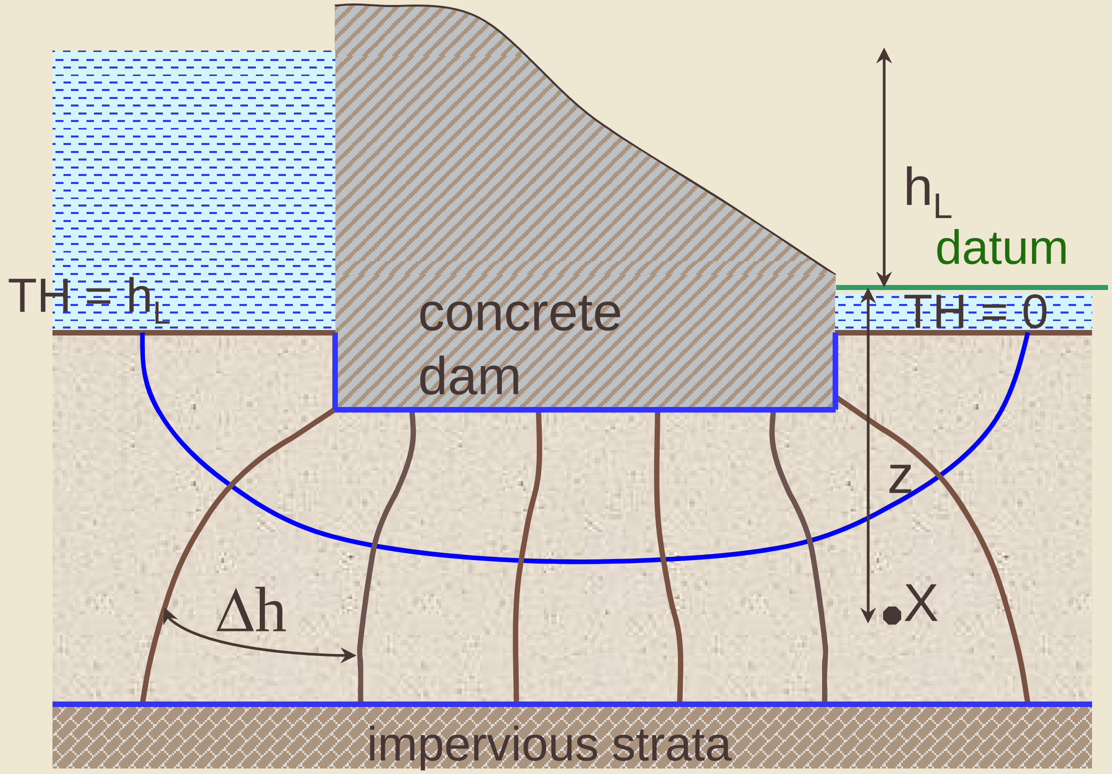
Heads at a Point X

Total head = h_L - # of drops from upstream x Δh

Elevation head = -z

Pressure head = Total head – Elevation head

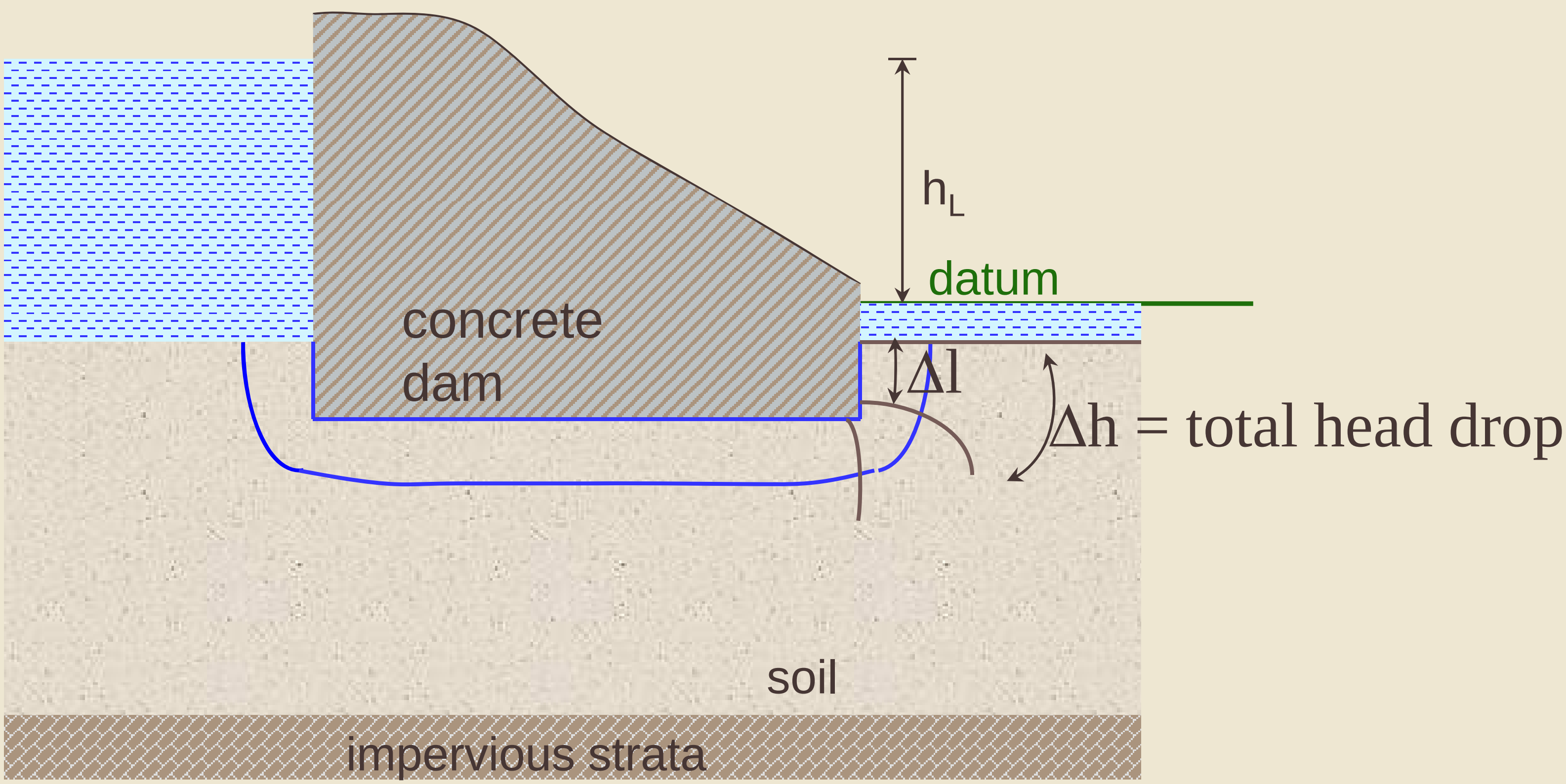
$$= \frac{h_L}{N_d}$$



*Piping in **Granular** Soils*

At the downstream, near the dam,

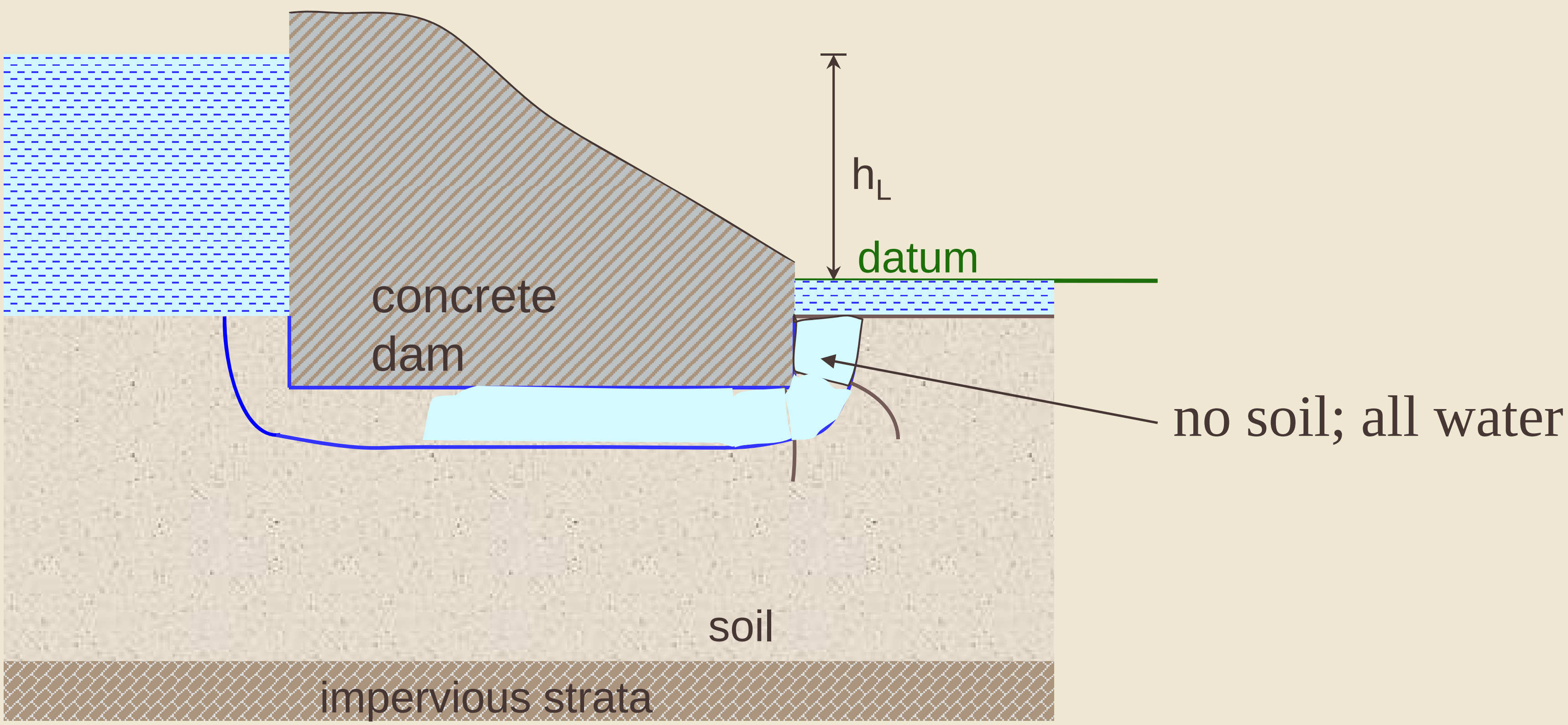
the exit hydraulic gradient $i_{exit} = \dfrac{\Delta h}{\Delta l}$



*Piping in **Granular** Soils*

If i_{exit} exceeds the critical hydraulic gradient (i_c), firstly the soil grains at exit get washed away.

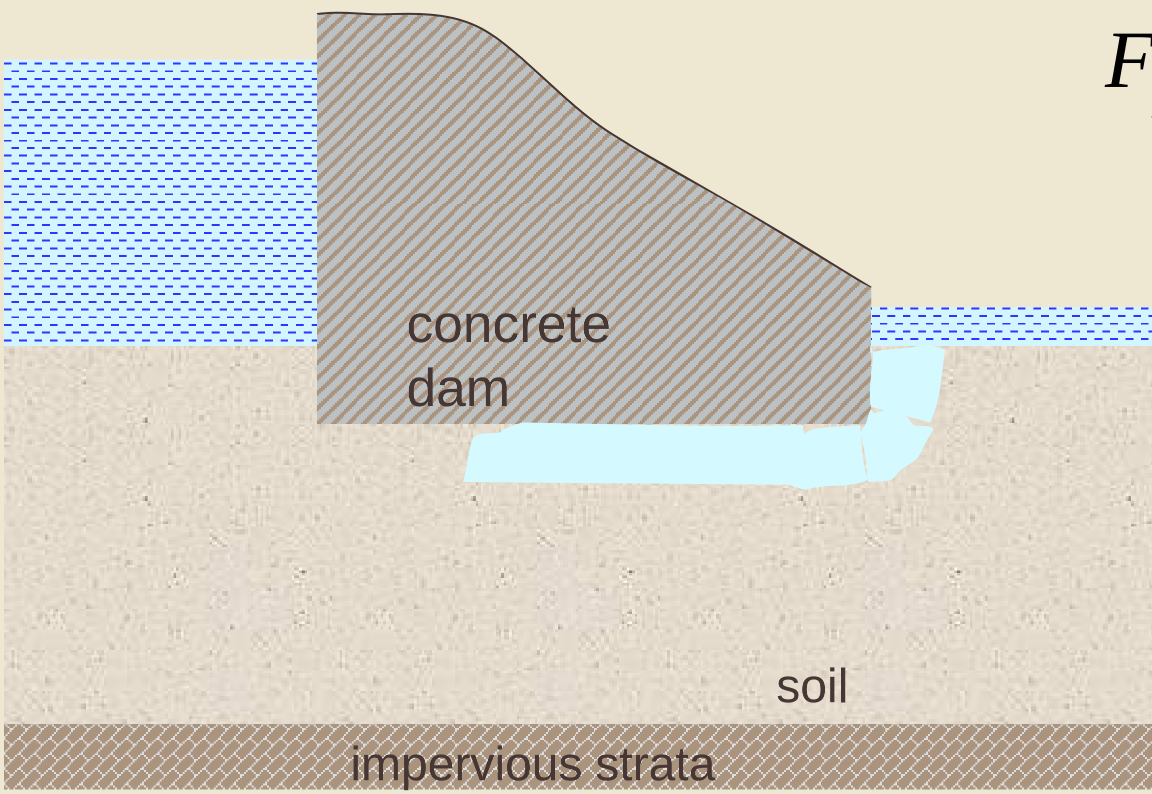
This phenomenon progresses towards the upstream, forming a free passage of water ("pipe").



*Piping in **Granular** Soils*

Piping is a very serious problem. It leads to downstream flooding which can result in loss of lives.

Therefore, provide adequate safety factor against piping.



$$F_{piping} = \frac{i_c}{i_{exit}}$$

typically 3 or more

Piping Failures

Piping Failures

Baldwin Hills Dam after it failed by piping in 1963. The failure occurred when a concentrated leak developed along a crack in the embankment, eroding the embankment fill and forming this crevasse. An alarm was raised about four hours before the failure and thousands of people were evacuated from the area below the dam. The flood that resulted when the dam failed and the reservoir was released caused several millions of dollars in damage.

Filters

Used for:

- facilitating drainage
- preventing fines from being washed away

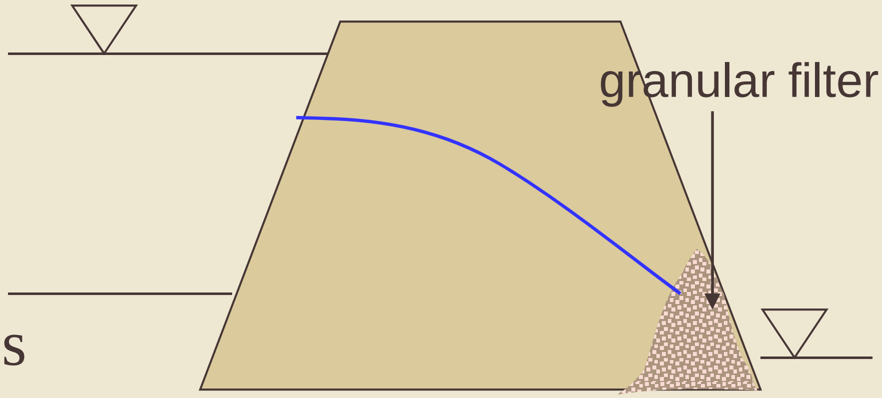
Used in:

- earth dams
- retaining walls

Filter Materials:

- granular soils
- geotextiless

Granular Filter Design



<u>Two major criteria:</u>

(a) **Retention** Criteria

- to prevent washing out of fines

∴ Filter grains must not be too coarse

(b) **Permeability** Criteria

- to facilitate drainage and thus avoid build-up of pore pressures

∴ Filter grains must not be too fine

Granular Filter Design

Retention criteria:

$D_{15,\ filter} < 5\ D_{85,\ soil}$

average filter pore size

Permeability criteria:

$D_{15,\ filter} > 4\ D_{15,\ soil}$

- after Terzaghi & Peck (1967)

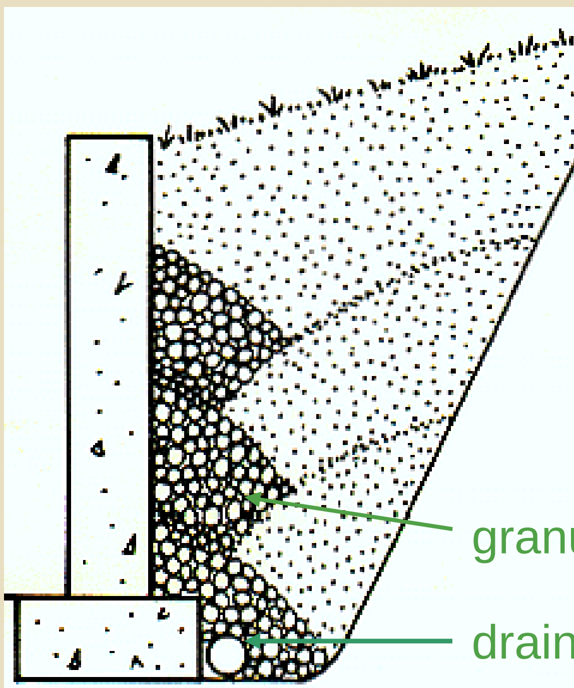
$D_{15,\ filter} < 20\ D_{15,\ soil}$

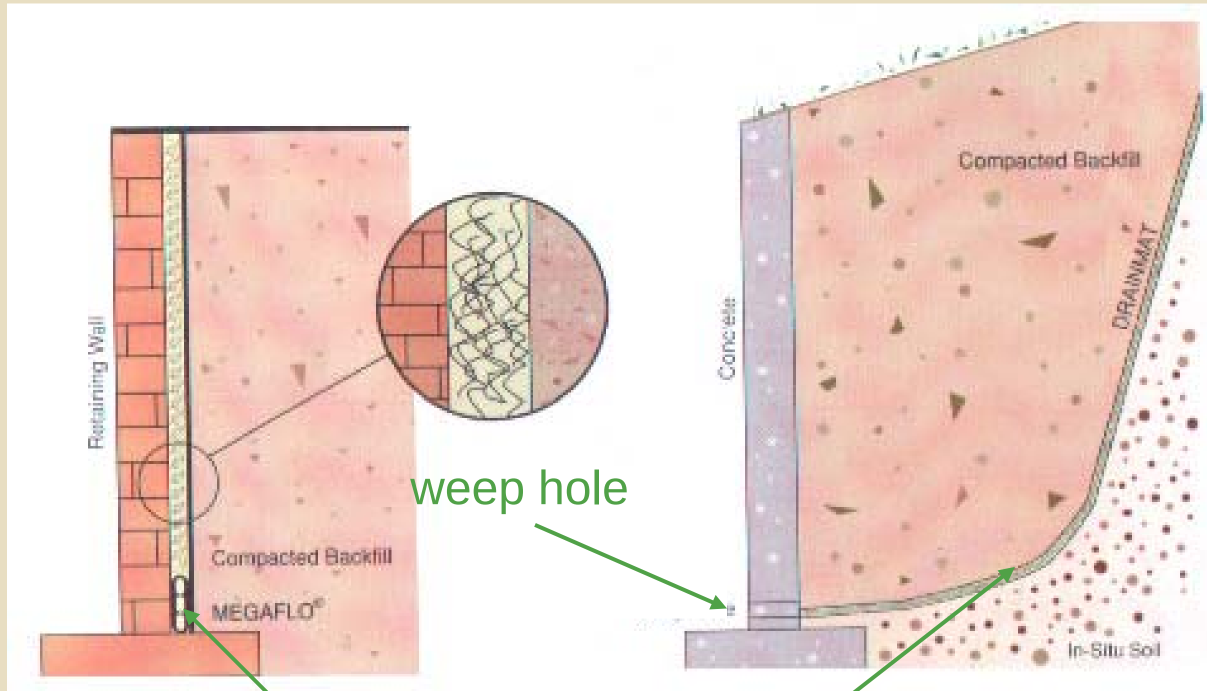
$D_{50,\ filter} < 25\ D_{50,\ soil}$

- after US Navy (1971)

GSD Curves for the soil and filter must be parallel

Drainage Provisions in Retaining Walls





weep hole

geosynthetics

granular soil

drain pipe

Summary

- Total head = Elevation head + Pressure head
- Unit of permeability is m/s, cm/s, m/day..
- Total head decreases along a stream line.
- When flow in the soil is upward, the effective stress decreases and pore water pressure increases.
- When flow in the soil is downward, the effective stress increases and pore water pressure decreases.

Summary

- In granular soils with upward flow, when $\boldsymbol{i} = \boldsymbol{i_c}$ ➔ $\boldsymbol{\sigma'} = 0$ …..Quick condition.

- Critical hydraulic gradient $\boldsymbol{i_c} = \gamma'/\gamma_w$

- Flow rate $Q = kh_L \dfrac{N_f}{N_d}$

- $F_{piping} = \dfrac{i_c}{i_{exit}}$