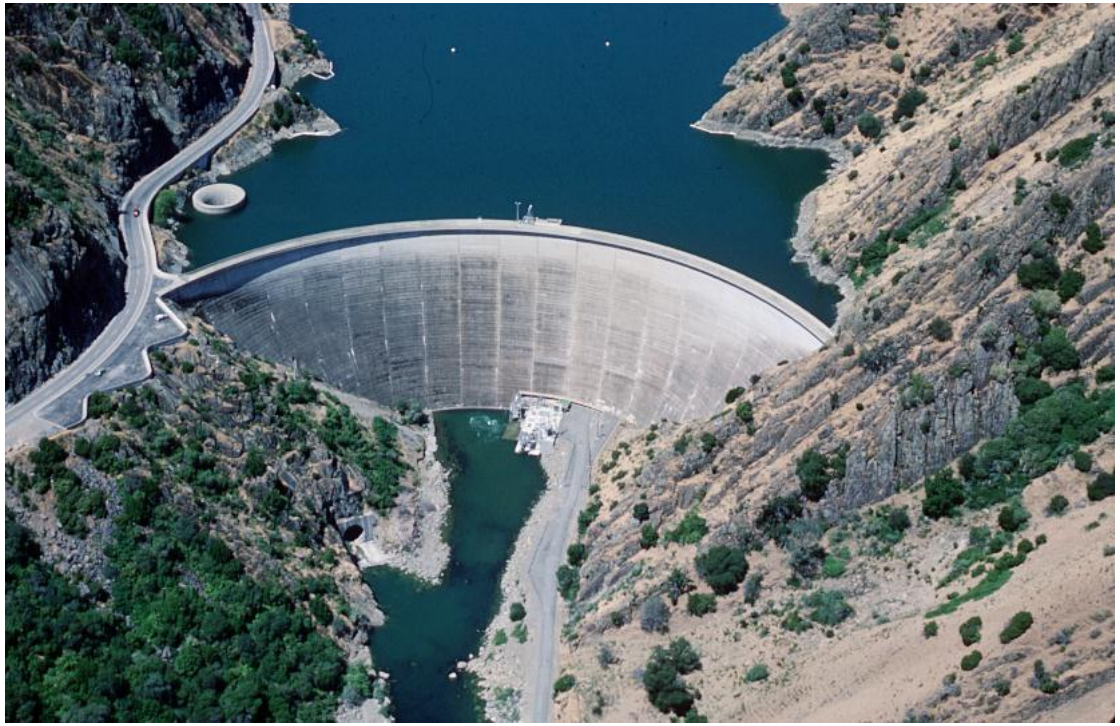
Discontinuities in Dam Engineering

Dams

What is a Dam?

- is a solid barrier constructed at a suitable location across river valley to store flowing water.



Dams.....contd.

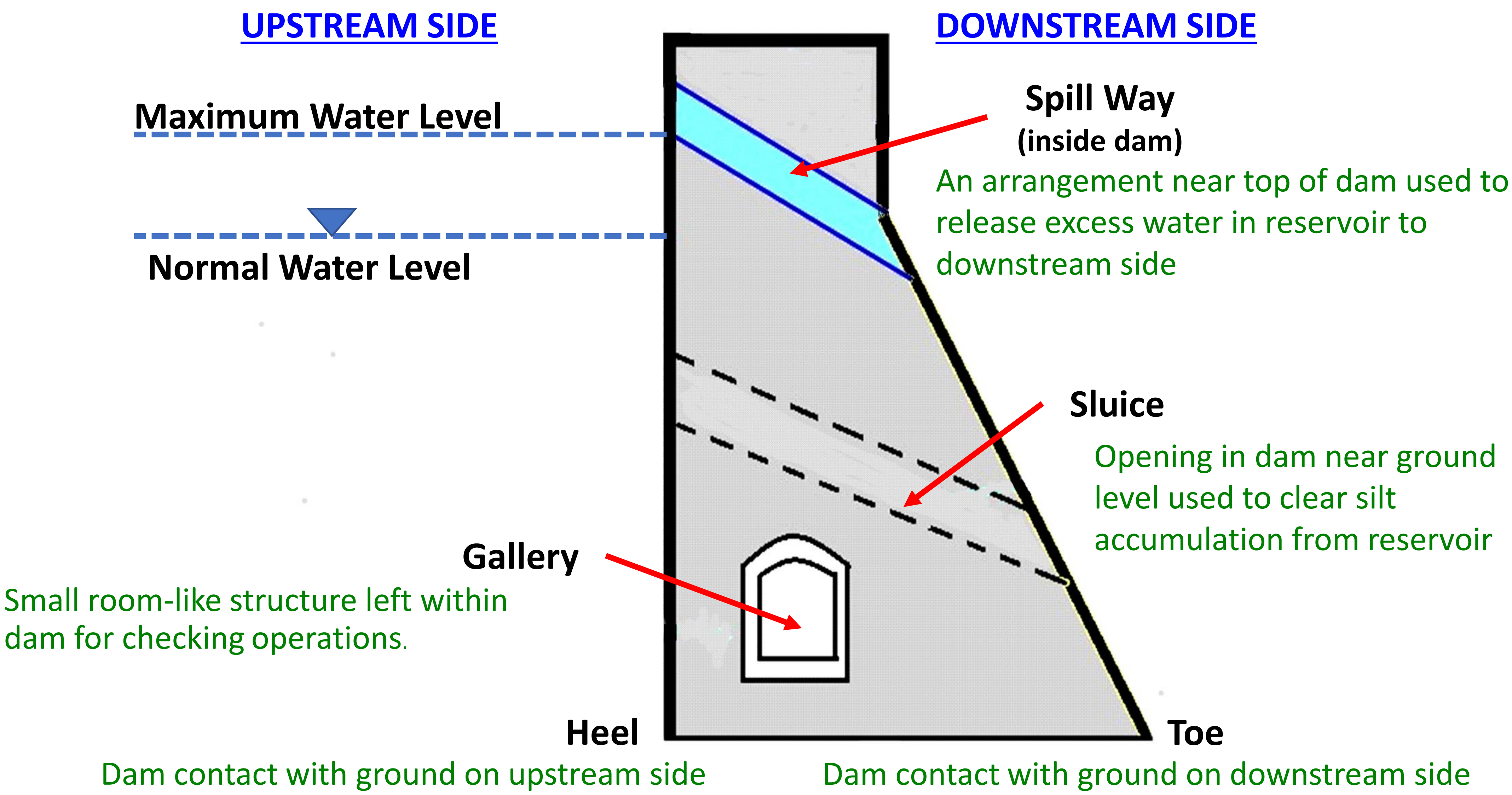
- There is no unique way to retain water, hence, the many different shapes/sizes for dams:
  - some are **tall** and **thin**, while
  - others are **short** and **thick**.

Dams.....contd.

are utilized for:

- Gathering drinking water for people → Water Supply
- Helping farmers bring water to their farms → Irrigation
- Helping create electricity from water → Hydroelectricity
- Keeping areas from flooding → Flood Control
- Creating lakes for people to swim in & sail on → Recreation, Navigation

Structure of a Dam



Forces acting on a Dam Structure

Dam design involves:

- ➢ determination of various forces likely to act on structure,
- ➢ study of nature of these forces.

In our region, dams are generally subjected to:

a) **Water pressure**

b) Self-weight of the dam.

c) Earthquake forces

d) Silt pressure

e) Wave pressure

Forces are considered to **act per unit length of dam**.

Forces acting on a Dam Structure.....contd.

Water pressure – usually subdivided into:

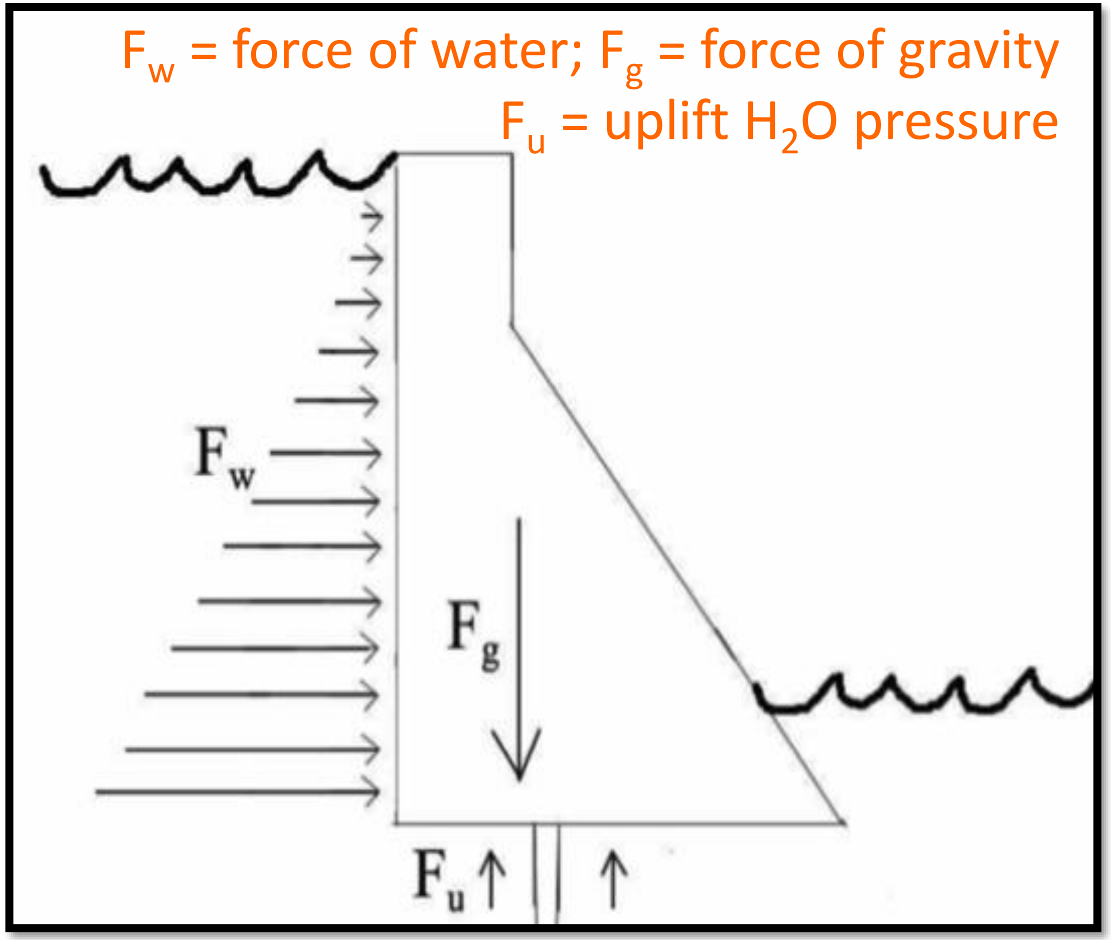
1. **External water pressure –** pressure of water on upstream face of dam and involves two cases;

Forces acting on a Dam Structure.....contd.

i) Where upstream face of dam is vertical, with very low water on downstream side of dam:

- when full, reservoir contains enormous amount of water, while on downstream side, water level will be very low.

- Due to this difference in water levels, reservoir water attempts to leak through rocks of dam with considerable pressure and emerge on downstream side.



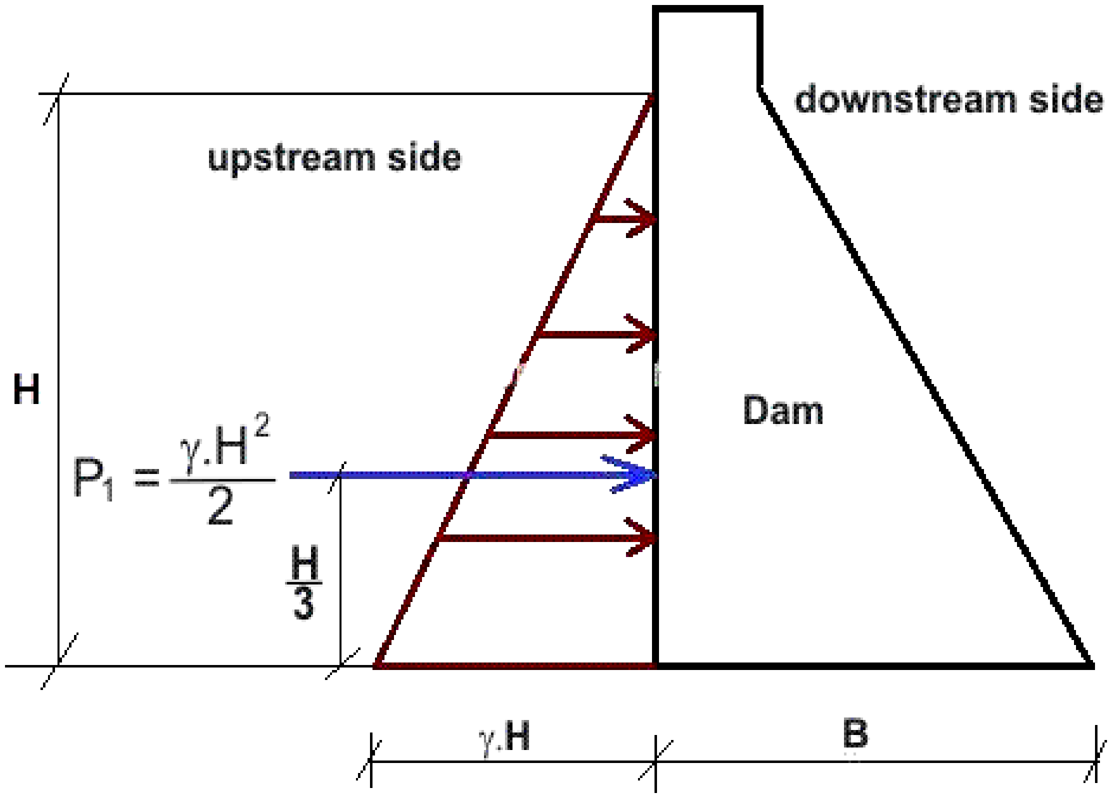
Forces acting on a Dam Structure.....contd.

Total pressure is in horizontal direction:

- ➢ acts on upstream face @ **H/3** from bottom
- ➢ Pressure diagram is triangular, and total pressure, **P = (γ.H²) / 2**

Where;

- γ ≡ specific weight of water (kN m⁻³) H ≡ height, up to which water is stored (m)

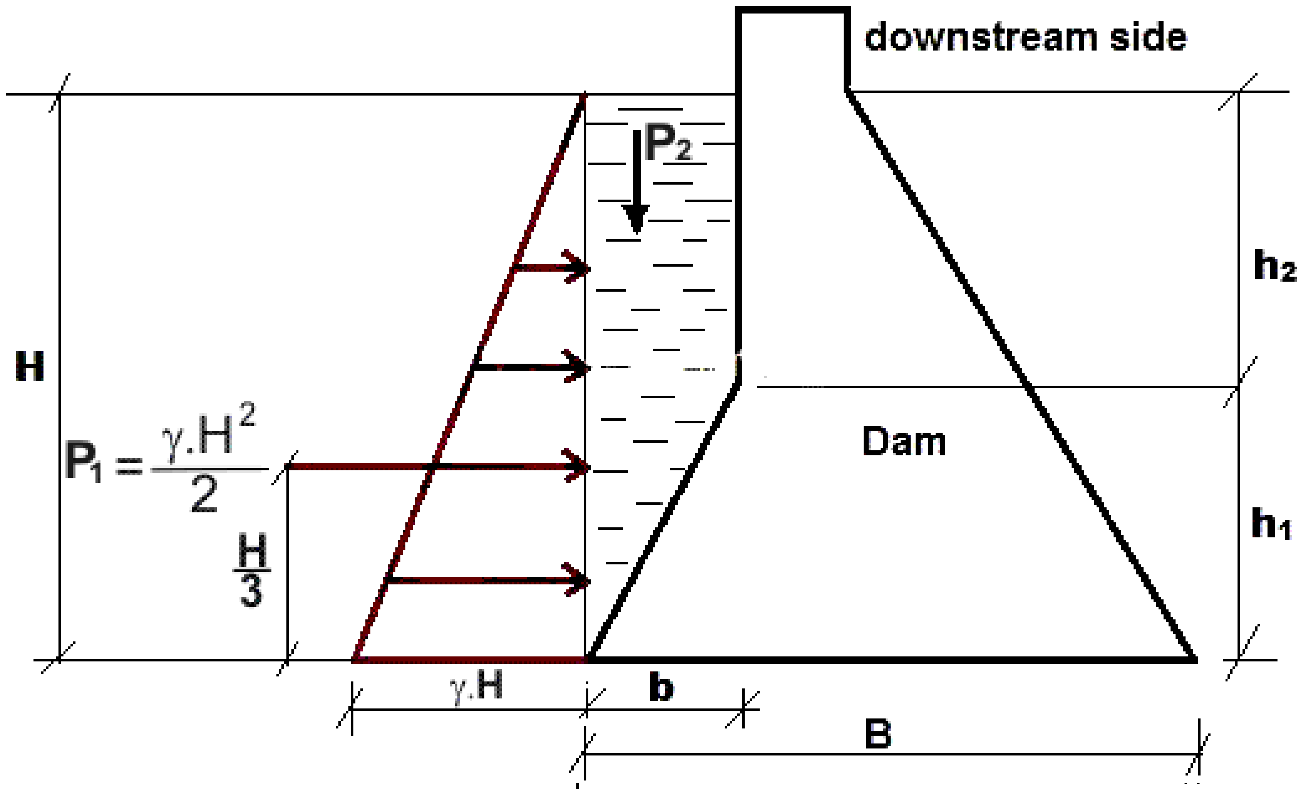


Forces acting on a Dam Structure.....contd.

ii) Where upstream face is with batter, with low or no water on downstream side

In addition to the horizontal water pressure P_1:

- there is **vertical water pressure** due to **water column resting on upstream sloping side**.
- vertical pressure $\mathbf{P_2}$ acts on length **'b'** portion of base, given by:



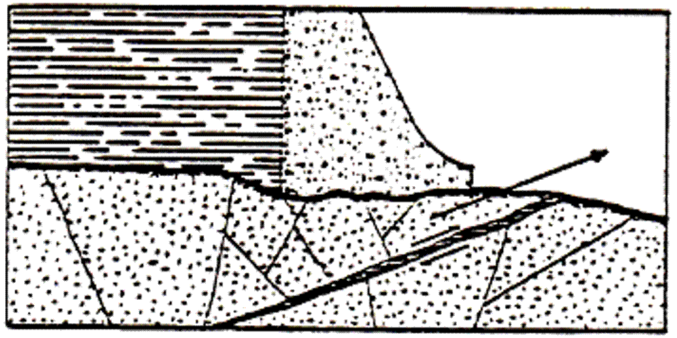
$$P_2 = (b * h_2 * \gamma) + \left(\frac{1}{2} b * h_1 * \gamma\right)$$

…and acts through centre of gravity of water column resting on sloping upstream face.

Forces acting on a Dam Structure.....contd.

Water stored on upstream side of dam creates a head of water equal to height, up to which water is stored

This water :



Fault/shear zones

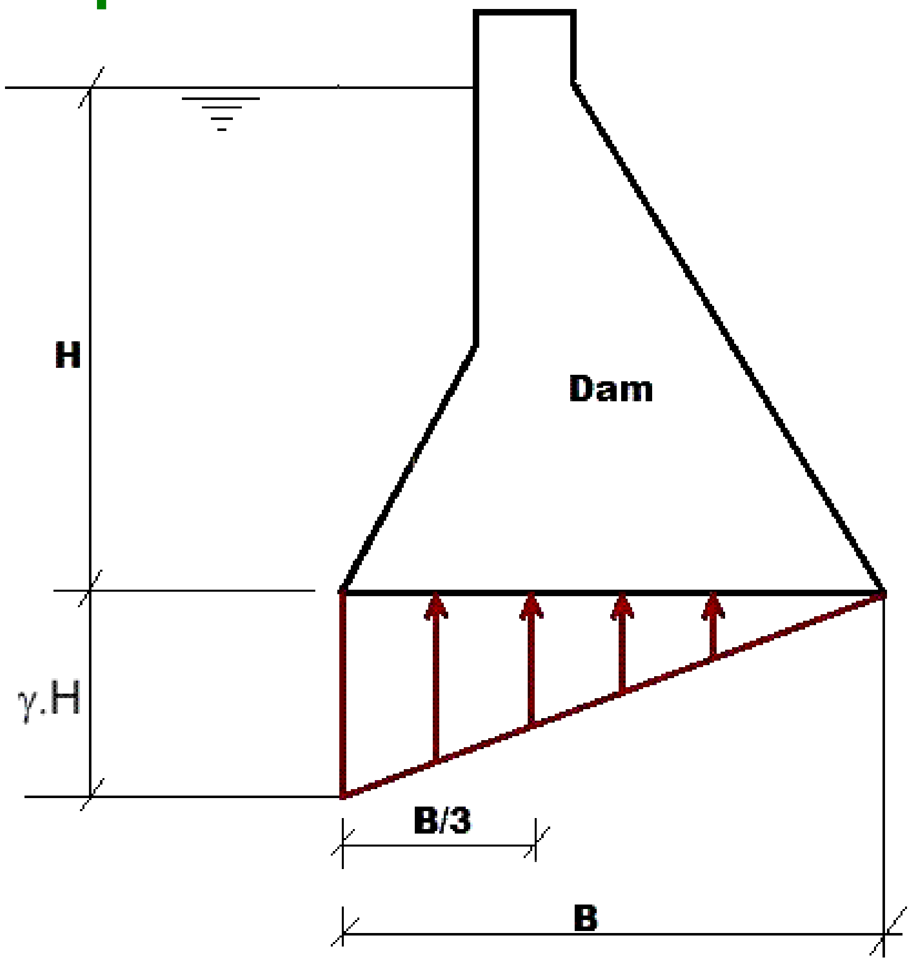
- ➢ enters pores + fissures of foundation material under pressure;
- ➢ enters joints between dam & foundation at base, and pores of dam itself.
- ➢ then seeps through, and tries to emerge out on downstream end.

Forces acting on a Dam Structure.....contd.

2. Water pressure below dam base or Uplift pressure

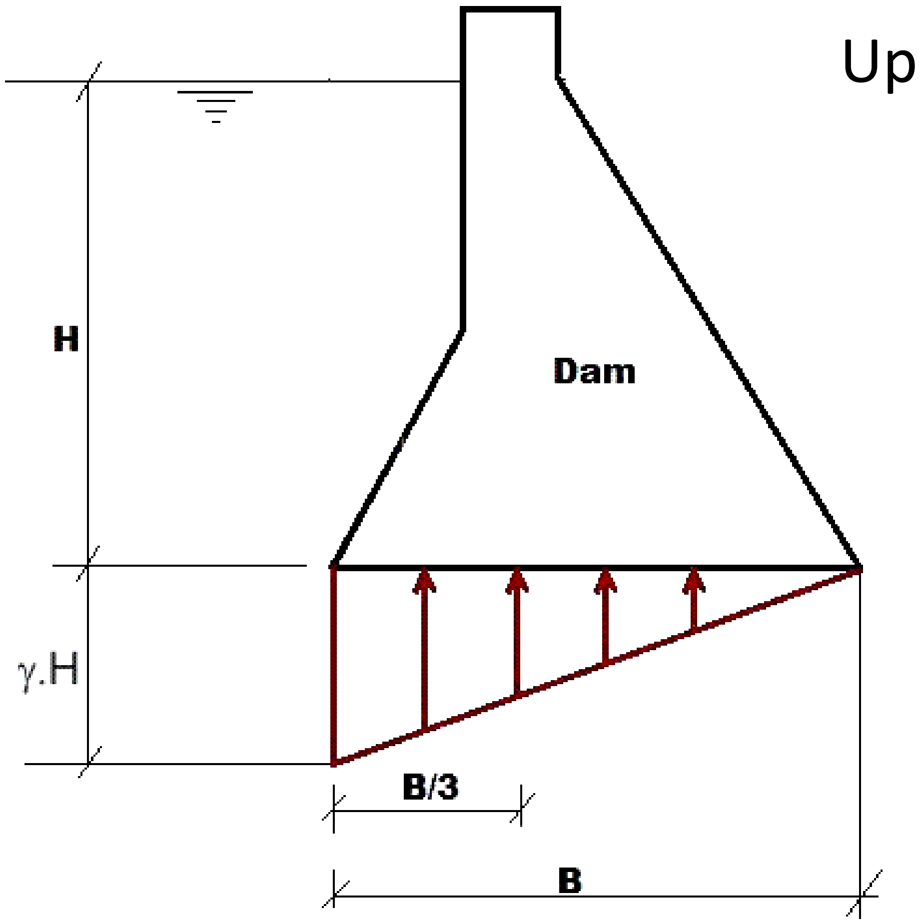
Seeping water:

- creates hydraulic gradient between up- & down-stream sides of dam, causing UPLIFT, which
  - reduces effective weight of structure, and consequently
    - Reducing uplift restoring force



Forces acting on a Dam Structure.....contd.

2. Water pressure below dam base or Uplift pressure



Uplift pressure **(P_u)** is given by :

$$P_u = \frac{\gamma . H * B}{2}$$

where:

$P_u \equiv$ uplift pressure; $B \equiv$ base width of dam; and $H \equiv$ height up to which water is stored.

This total uplift acts at **B/3** from heel or upstream end of dam

Forces acting on a Dam Structure.....contd.

2. Water pressure below dam base or Uplift pressure

- Uplift is generally reduced by providing drainage pipes or holes in dam section.
- Self weight of dam:
  - ✓ the only largest force that stabilizes dam structure.
  - ✓ usually acts vertically downward through centre of gravity
  - ✓ Is high, when specific weight of material of construction is high, implying, **restoring force will be more.**

Effects of Geologic Structures

For **stability of dam:**

- occurrence of favorable **geologic structures is very important as it** imparts to rock certain properties.

Geologic structures can modify rock either:

- Advantageously, or
- disadvantageously

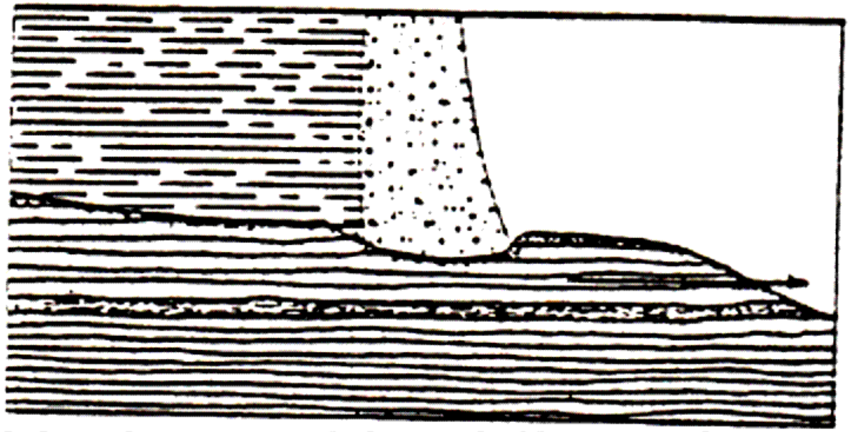
during and after dam construction.

Effects of Geologic Structures.....contd.

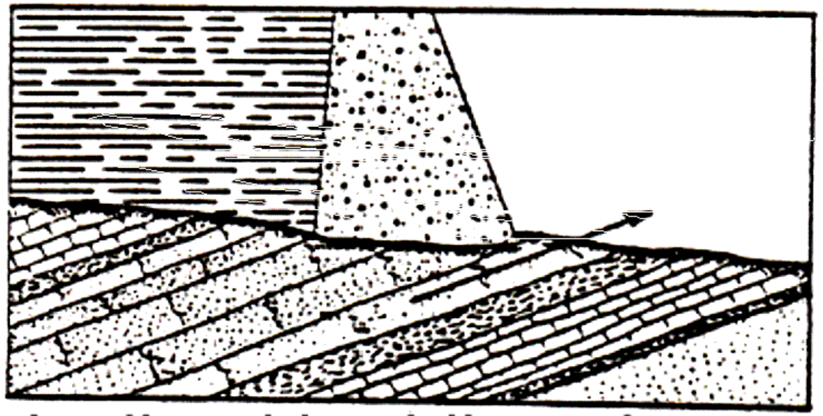
For instance:

a) **Horizontal or beds with 10º to 30º** inclination in upstream direction are ideal because:

- resultant force acts more or less perpendicular to bedding, which is dipping in upstream side - **ADVANTAGE**



Horizontal bedding plane



Inclined bedding plane

Effects of Geologic Structures…..contd.

In areas with horizontal beds:

- Dam-loads act perpendicular to bedding planes, **which means, beds are in an advantageous position to bear loads with full competence.**
- **Seepage of reservoir water beneath dam is effectively** prevented by dam-weight, which acts vertically downwards.
  - **Thus, possible uplift pressure, which is dangerous to stability of dam, is effectively reduced.**

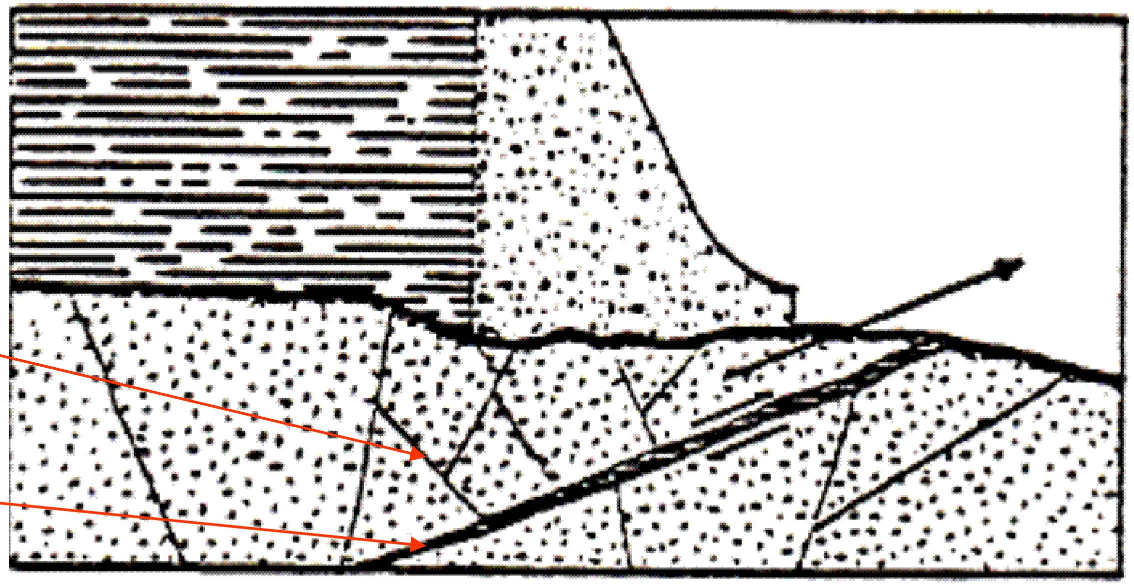
Effects of Geologic Structures.....contd.

On the other hand, in areas with horizontal

forces, dam foundation might slide –

DISADVANTAGEOUSLY – along:

- Shear zones
- Faults



Effects of Geologic Structures…..contd.

b) In Faulted and/or Sheared Beds

- **Occurrence of faulting** (irrespective of its Strike & Dip), right at dam site is most undesirable.
- If faults are active, **under no circumstances, can dam construction be undertaken there**.
    - This is not only because of fear of possible relative displacement of site itself, but also due to possible occurrence of earthquakes.
- if fault zone is crushed or intensely fractured, it becomes physically incompetent to withstand forces of dam.

Effects of Geologic Structures.....contd.

Faulted lithologies

Effects of Geologic Structures.....contd.

c) Beds with **Steep Upstream Dip** are not bad for stability, but not as advantageous as those of previous situation because:

- although there will be **no uplift** on dam site, and **no leakage** of water from reservoir;
  - bedding planes are not perpendicular to resultant force due to steep dip.
    - this means, rock will not be as compatible as in horizontal case.

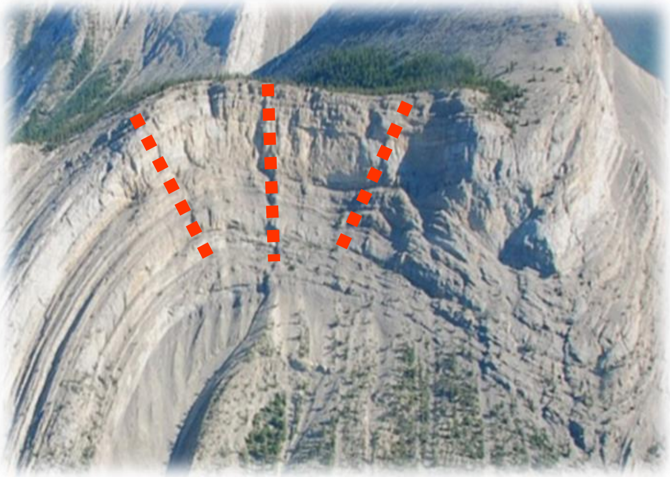
Effects of Geologic Structures.....contd.

d) Folded Beds

Folding of beds is generally less dangerous than faulting, unless folds are of complex nature.

However:

- unlike simply tilted strata, folded rocks are not only under strain but also physically fractured along crests.
  - Hence, grouting & other precautions might have to be considered, depending on context
    - to improve stability & competence of rocks @ dam site.



Foundation Investigations for Dams

Involve:

a) **Field Investigations**, which include preliminary **selection of site** & type of dam using:

- geologic and topographic maps
- photographs of site area, and
- data from field examinations of natural outcrops, road cuts, and other surface conditions.

Foundation Investigations for Dams…..contd.

b) **Feasibility investigations** – stage at which location of dam is usually finalised. Geologic mapping and sections are reviewed, and supplemented by additional data, such as new surveys and additional drill holes.

c) **Final design data** – when/where detailed foundation investigations are conducted to obtain final design data. This investigation involves as many drill holes as are necessary.

Foundation Investigations for Dams…..contd.

d) Drilling of as many holes as are necessary in **Final design** phase is for purposes of accurately defining:

- **Strike, dip, thickness, continuity,** and **composition** of **all faults** and **shears** in foundation.
- Orientation and continuity of Joint
- Depth of overburden.
- Depth of weathering throughout the foundation.
- Lithologic variability.
- Physical properties of foundation rock, including material in the faults and shears.

Foundation Investigations for Dams.....contd.

Detailed Geological investigations must also be done @ dam site to:

- Determine suitability of dam foundation.
- Ensure reservoir basin is water-tight
- Locate quarry sites for construction materials

Foundation Treatment for Dam Foundations

a) **Excavation** – Adequate attention must be paid during blasting operation to avoid unnecessary shattering of rocks, loosening of bed of foundation.

b) **Grouting** – shallow as well as deep holes are drilled and cement grout is filled to establish an effective barrier to seepage under dam and to consolidate foundation.

Foundation Treatment for Dam Foundations…..contd.

Types of grouting:

- Consolidation grouting – Low-pressure grouting to fill voids, fracture zones, and cracks at and below the surface of the excavated foundation is accomplished by drilling and grouting relatively shallow holes.
- Curtain grouting – Construction of a deep grout curtain near the heel of the dam to control seepage is accomplished by drilling deep holes and grouting them using higher pressure.

Environmental Impacts of Dams.

- Loss of land
- Habitat Destruction – area that is covered by reservoir is destroyed, killing whatever habitat existed there beforehand
- Loss of archeological and histrorical places
- Loss of mineral deposits
- Loss of special geological formations
- Aesthetic view reduction
- Sedimentation
- Change in river flow regime and flood effects
- Reservoir induced seismicity

Conclusion

From a **Geological point of view:**

- **A dam can be said to be successful if it is watertight – if it;**
  - **does not suffer from any serious leakage, and**
  - **Has a long life due to very slow rate of silting in reservoir.** When filled, reservoir might reactivate movement along underlying inactive faults.
    - in turn**,** this might **give rise to occurrence of seismicity and landslides in that region.**