STEADY OPEN-CHANNEL FLOW 4

~~RIVER MECHANICS~~ (OPEN-CHANNEL HYDRAULICS) (CE5312 AY15/16)

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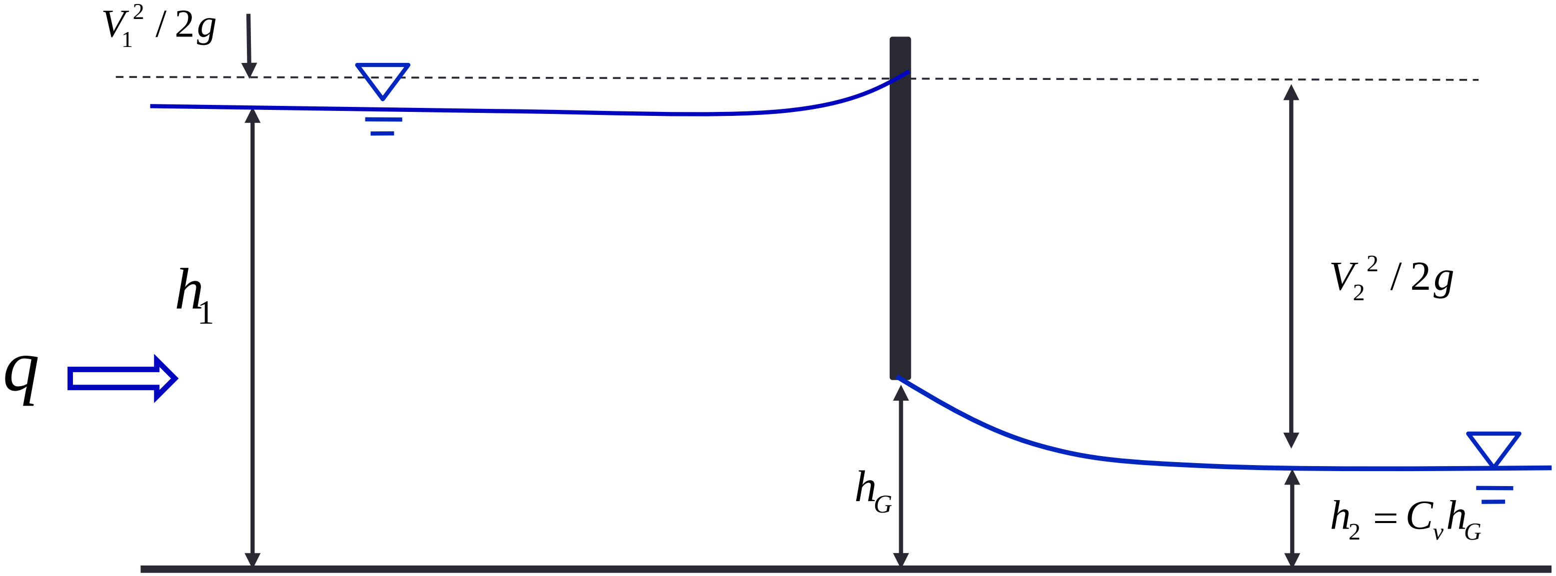
Sluice gate

Questions:

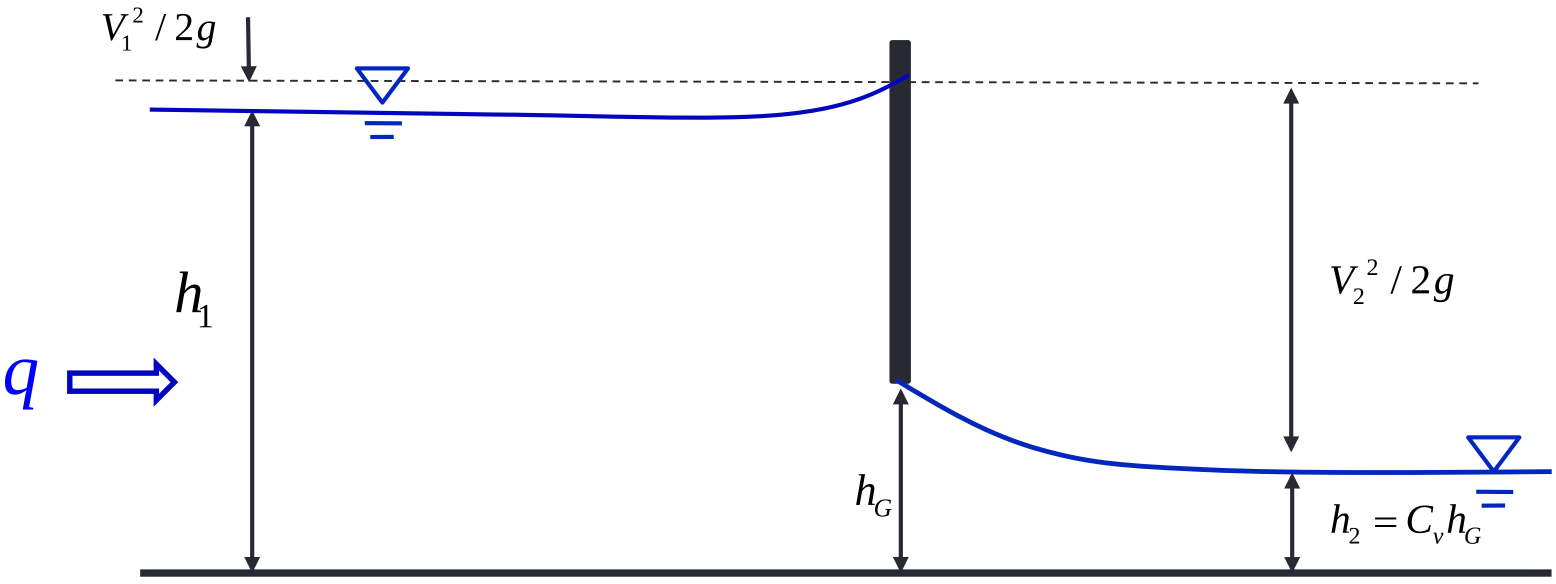
- How does it control the flow?
- What are the upstream and downstream surface profiles?

Flow under a sluice gate



- Always subcritical upstream and supercritical downstream!
- The flow converges after passing the gate until the a vena contracta is reached.
- Water depth at the vena contracta is fixed: $h_2 = C_v h_G$
- The flow is well behaved at the vena contracta.

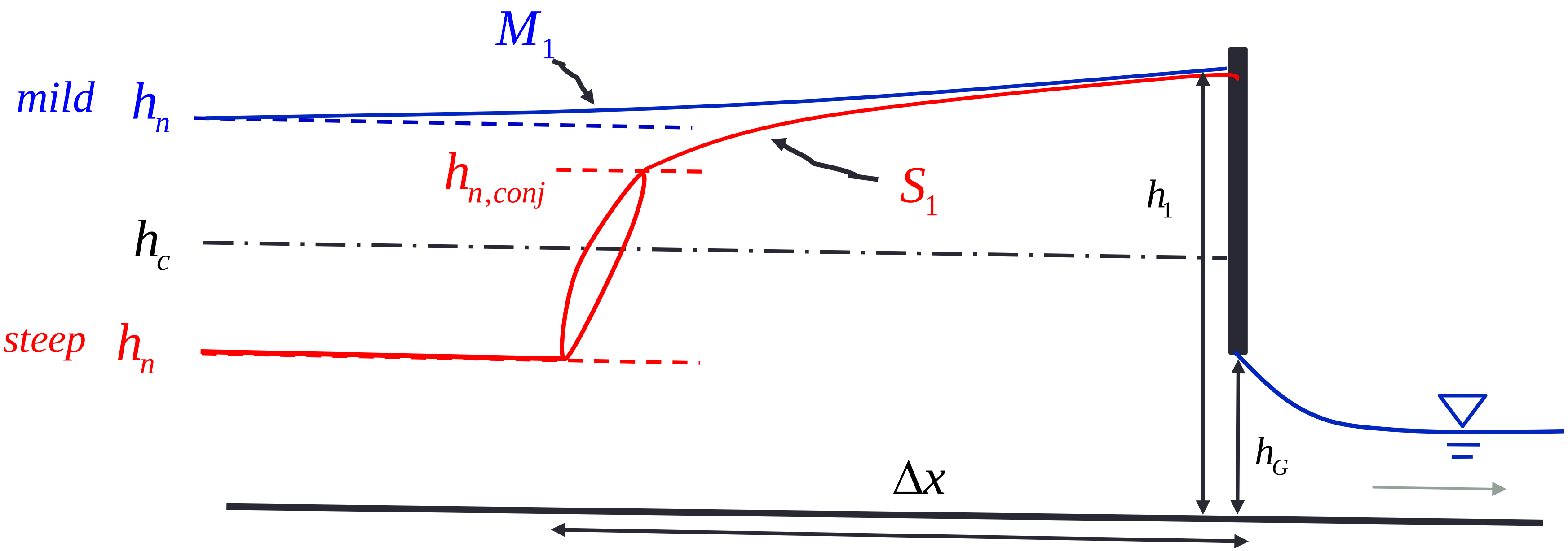
Discharge per unit width



$$q = C_v \sqrt{\frac{2g}{h_1 + C_v h_G} h_1 h_G}$$

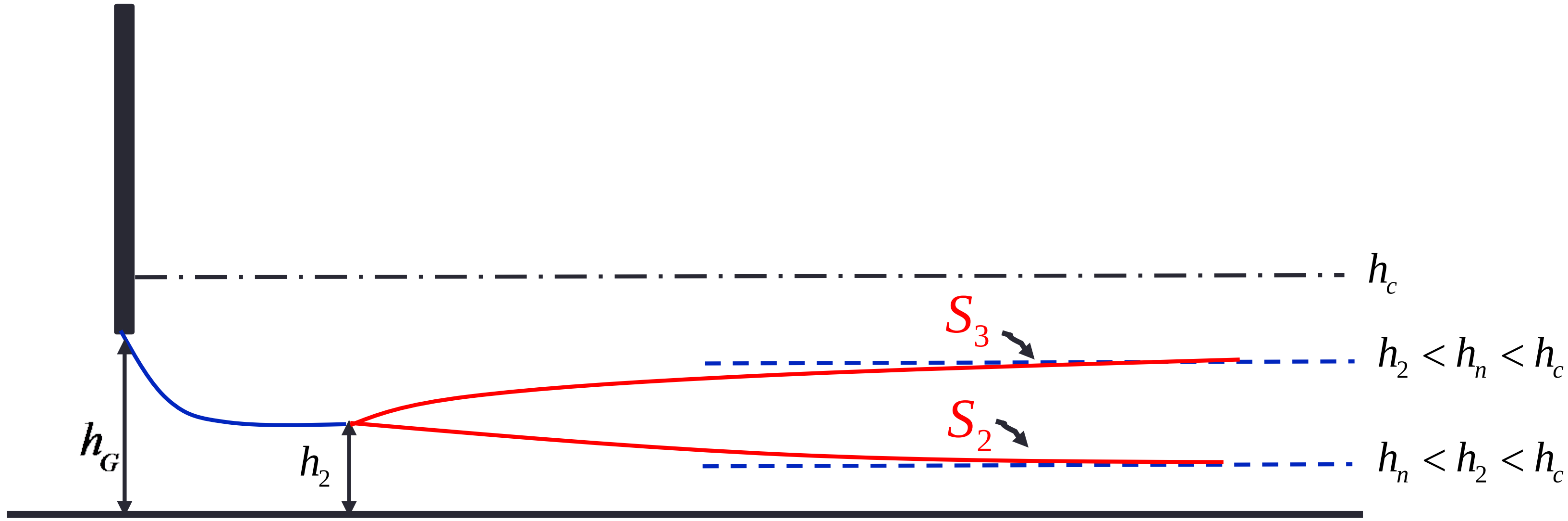
With fixed h_1 (e.g. a big reservoir), we can control discharge by changing h_G.

Upstream surface profiles



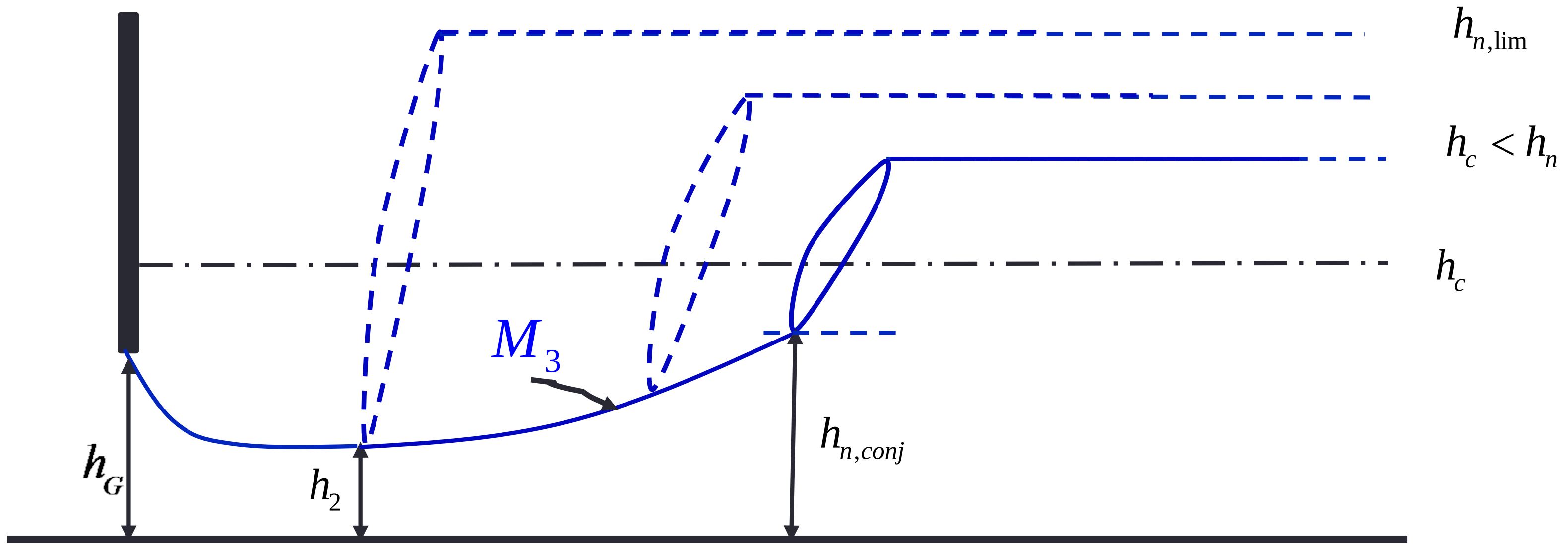
Location of the jump: $\Delta x = ?$

Downstream surface profiles: steep slope



After the vena contracta:
Water depth increases/decreases to normal depth follows a S3/S2 profile if the normal depths is larger/smaller than h2.

Downstream surface profiles: mild slope

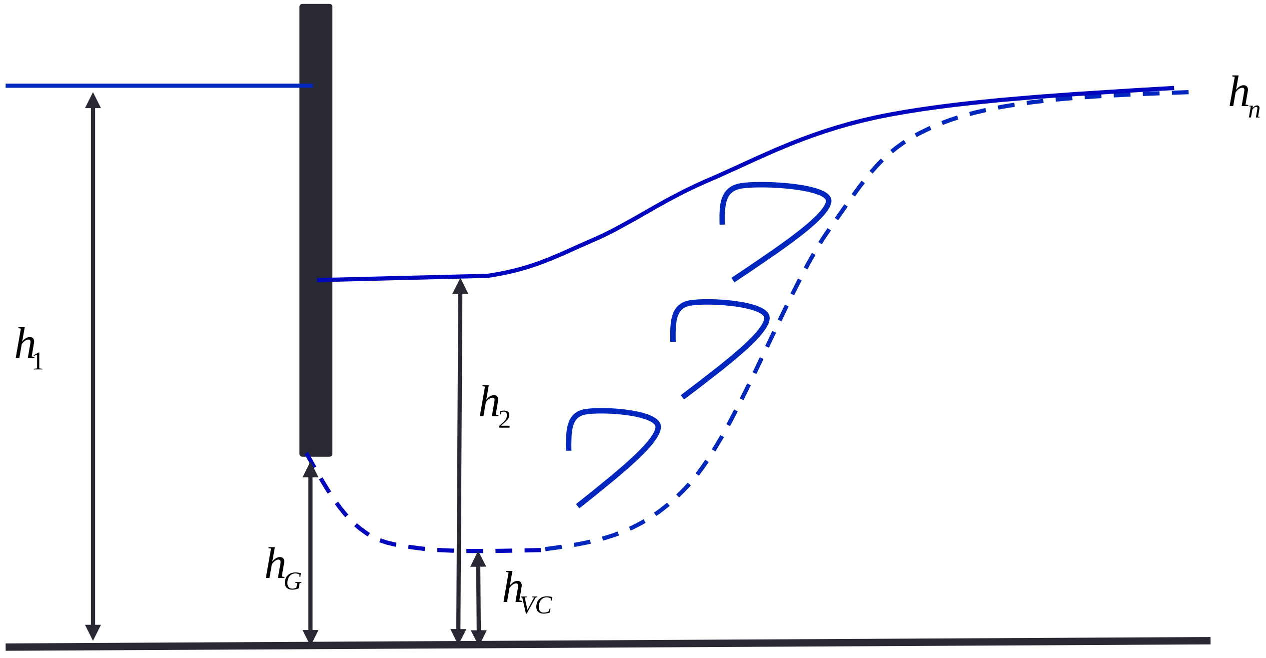


After the vena contracta:

- Water depth first increases via a M3 profile to $h_{n,conj}$ and then a hydraulic jump is created to reach the normal depth (subcritical flow).

- The gate becomes submerged if the jump starts at the vena contracta.

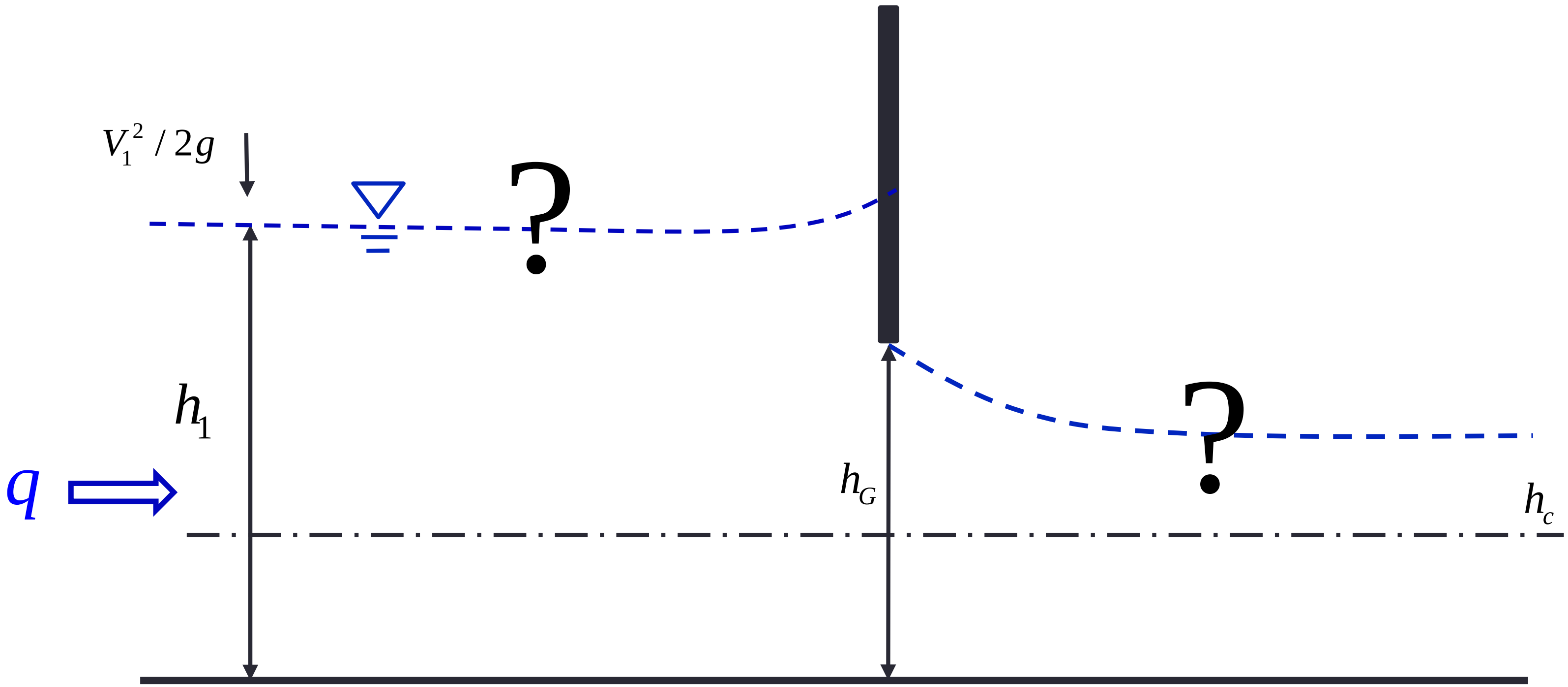
Downstream: submerged vena contracta



Assume the flow still goes through the vena contracta, but with stagnant water above it.

For given Q, apply continuity, momentum and energy principle to find h2 and h1.

What if $C_v h_G > h_c$?



No effect on the flow.

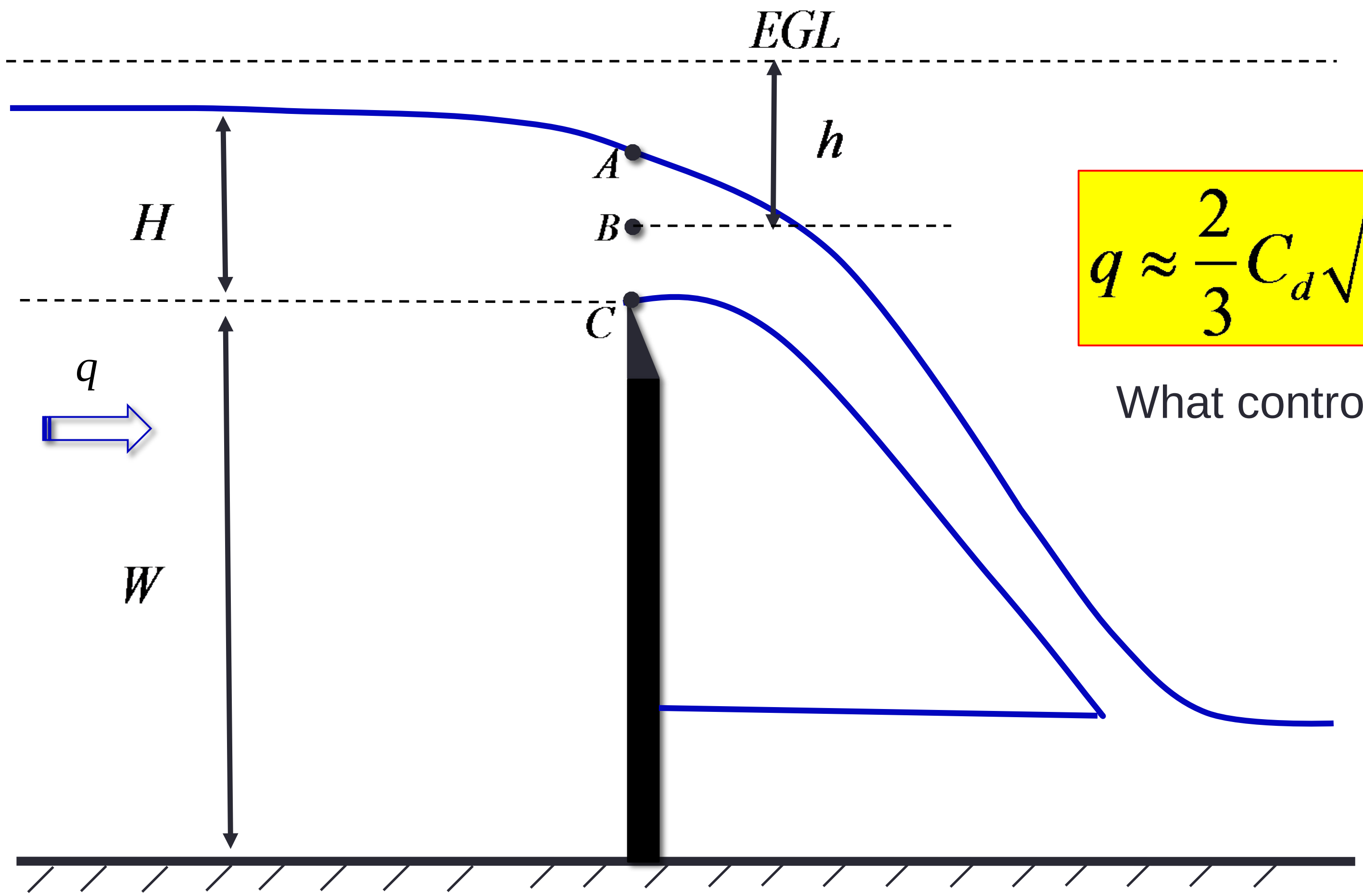
Weir

In most cases, weirs take the form of obstructions smaller than most conventional dams, pooling water behind them while also allowing it to flow steadily over their tops.

Weirs are commonly used to alter the flow of rivers to prevent flooding, measure discharge, and help render rivers navigable. (Wikipedia)

Many kinds of weirs.

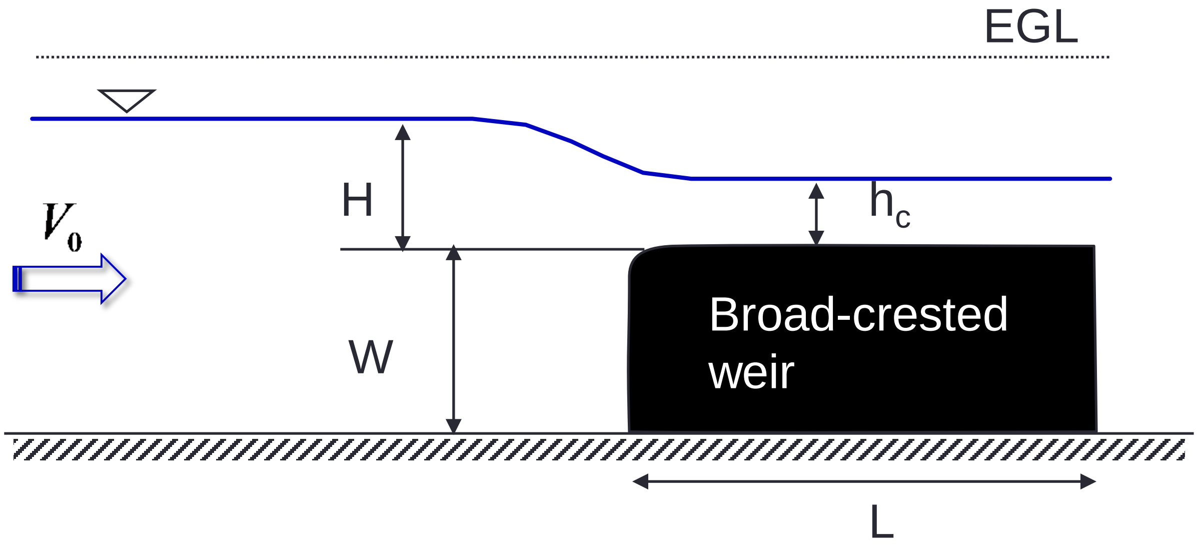
Sharp-crested weir



$$q \approx \frac{2}{3} C_d \sqrt{2g} H^{3/2}$$

What controls C_d?

Broad-crested weir



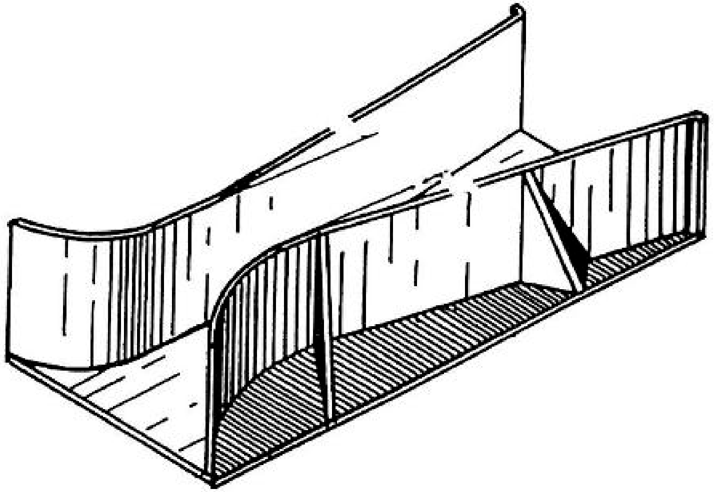
$$\boxed{q = C_d \sqrt{\frac{8}{27} g} \cdot H^{3/2}}$$

$$0.1 < \frac{H}{L} < 0.35$$

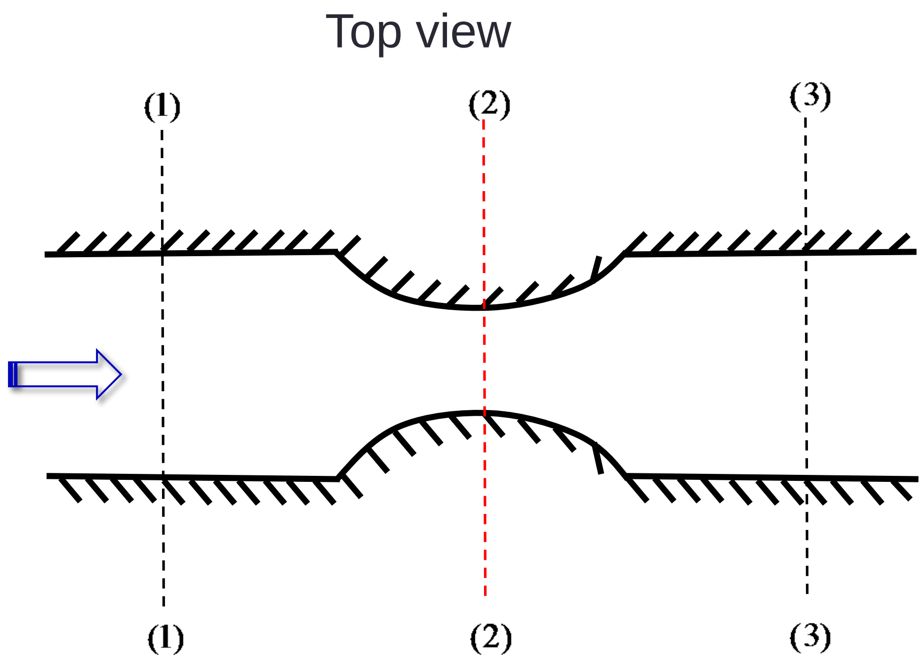
What controls C_d?

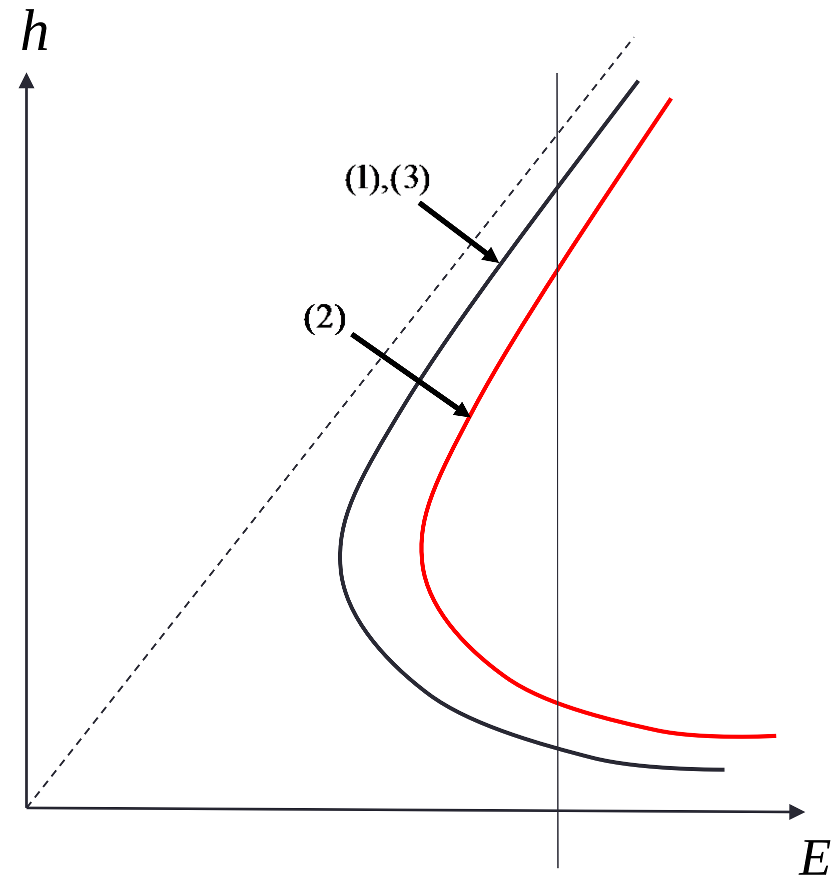
Critical flow control using a channel constrain

A **Venturi flume** is a critical-flow open **flume**, which has a critical flow at the narrowest point of the constrain. It is used in flow measurement of very large flow rates, usually given in millions of cubic units.



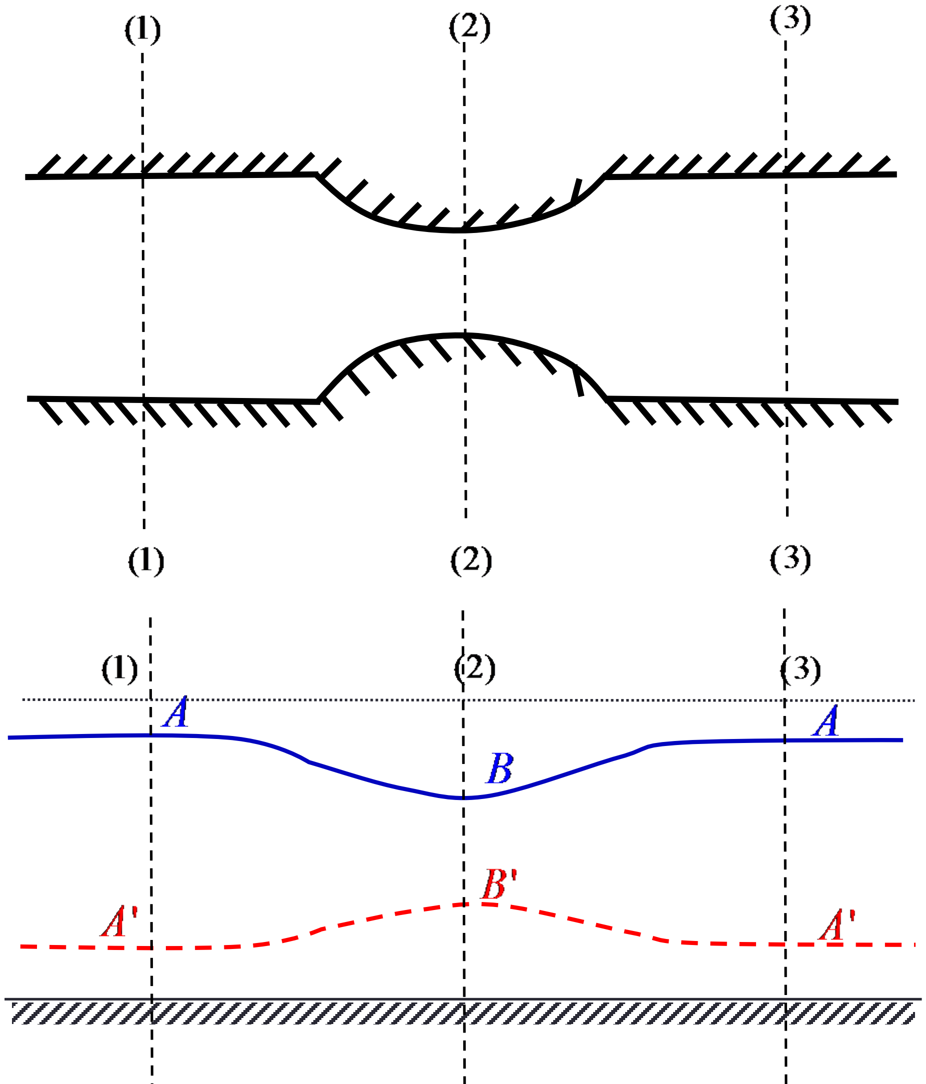
Flow through a channel constrain



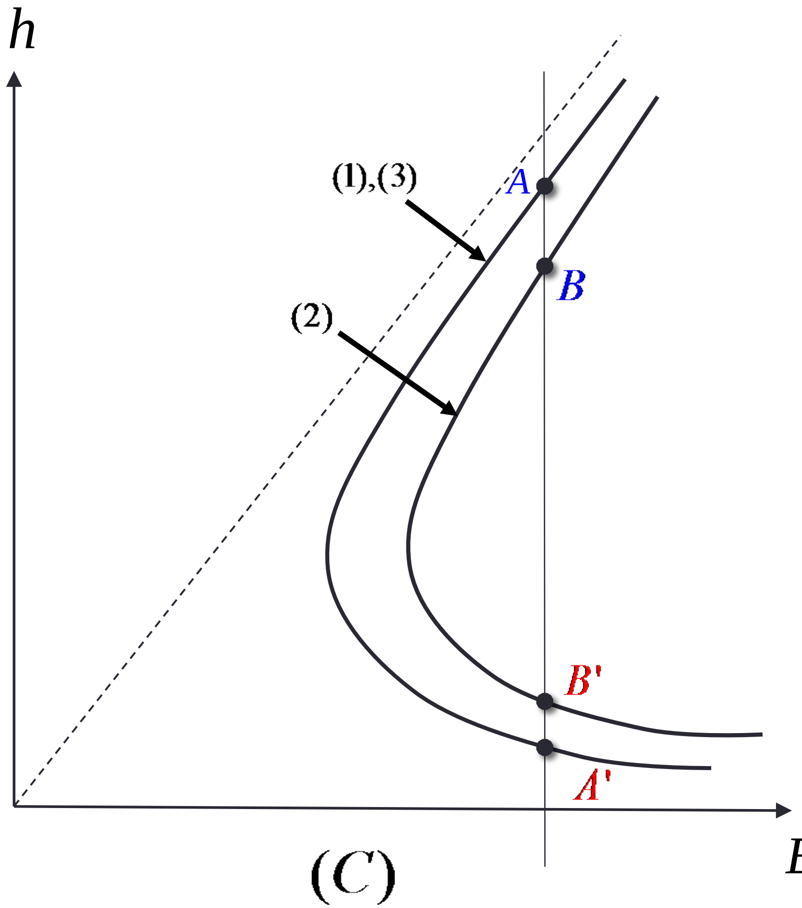


Basic principle: conservation of energy
Draw a vertical line on h-E diagram, the flow "point" must move along this line

Flow has enough energy to pass

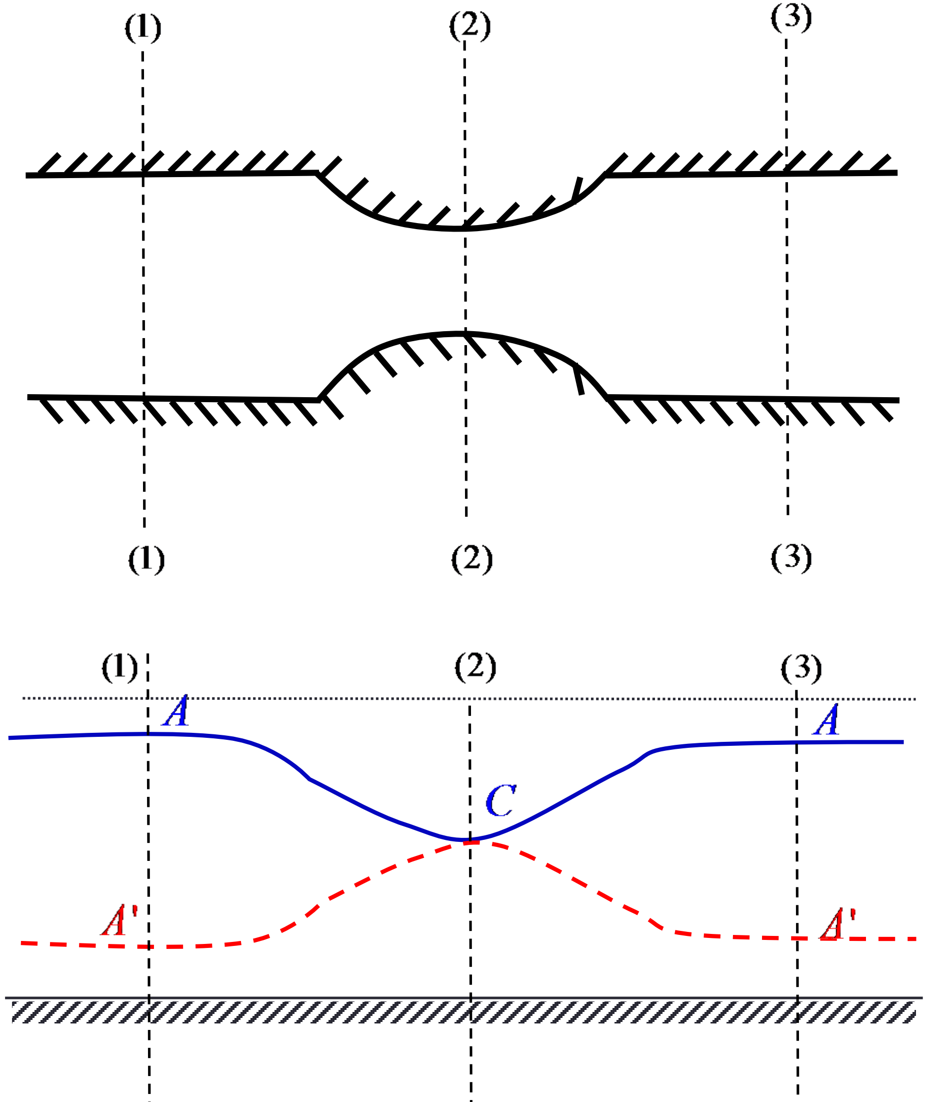


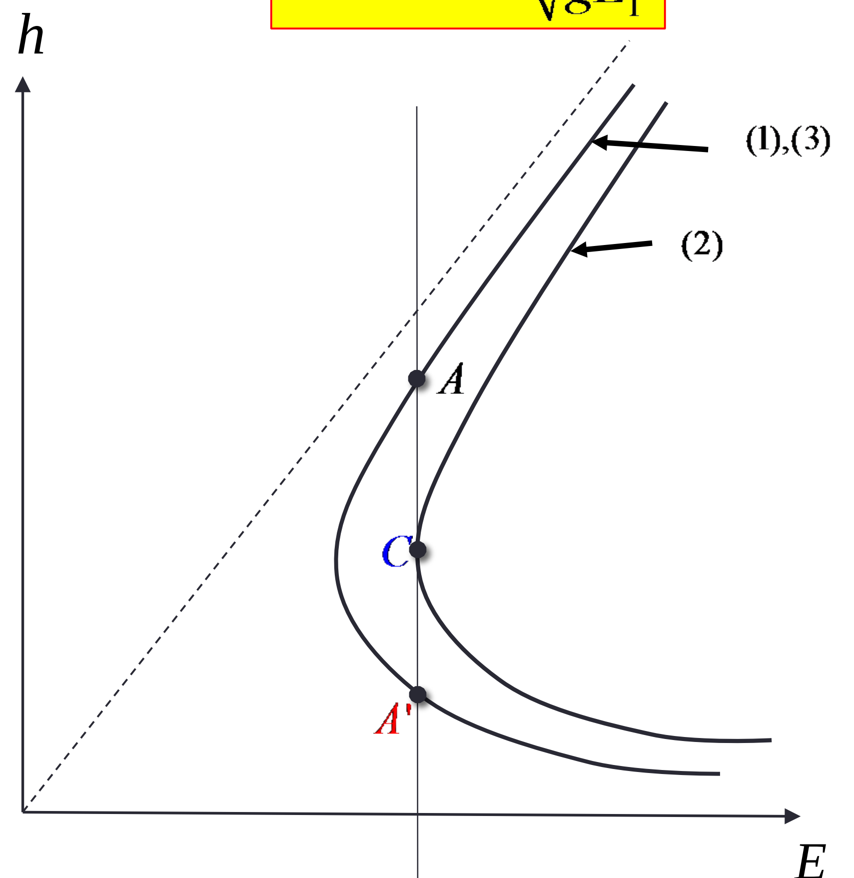
Is it possible to move from A to B’ or A’ to B?



Flow is just able to pass

$$b_c = \left(\frac{3}{2}\right)^{3/2} \frac{Q}{\sqrt{gE_1^3}}$$



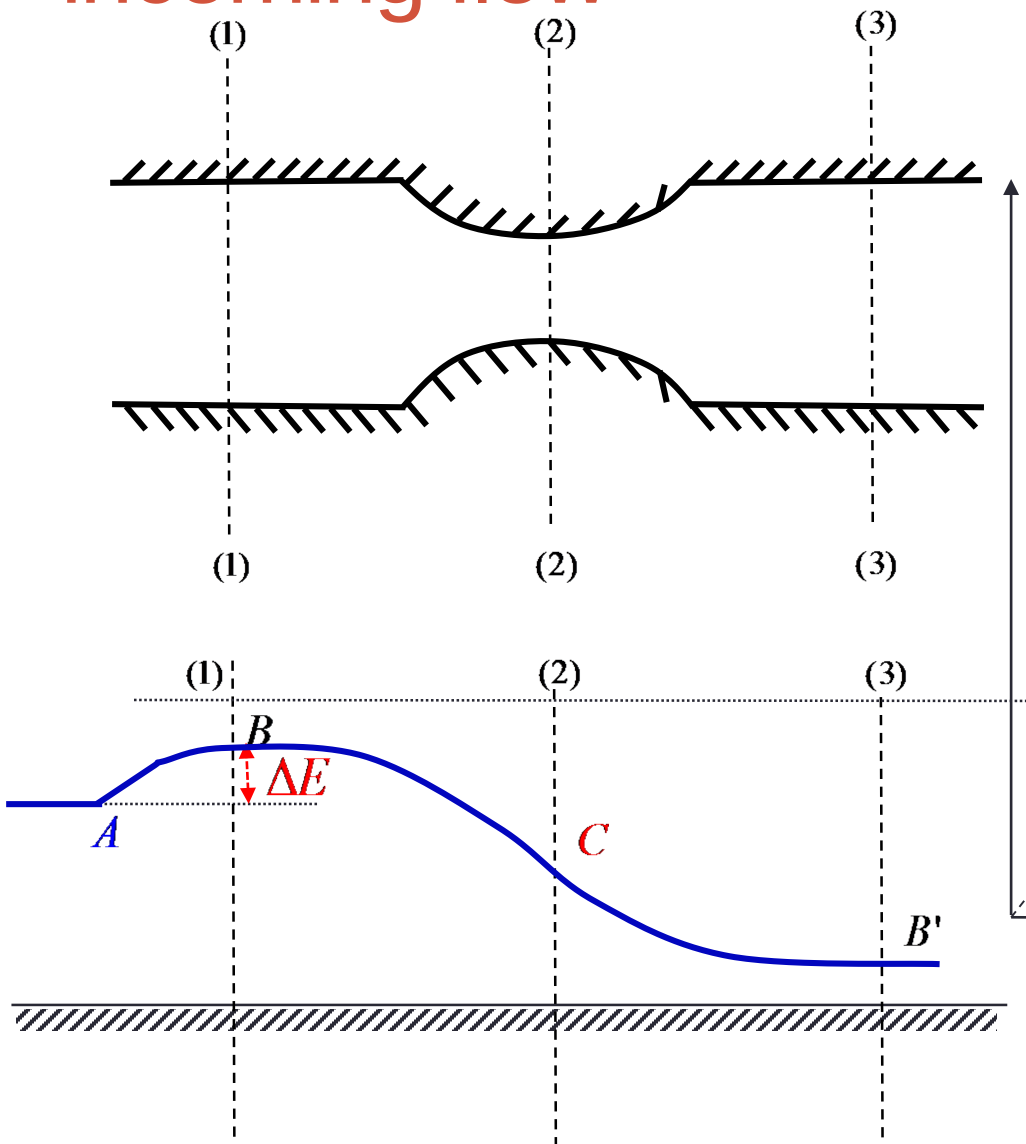


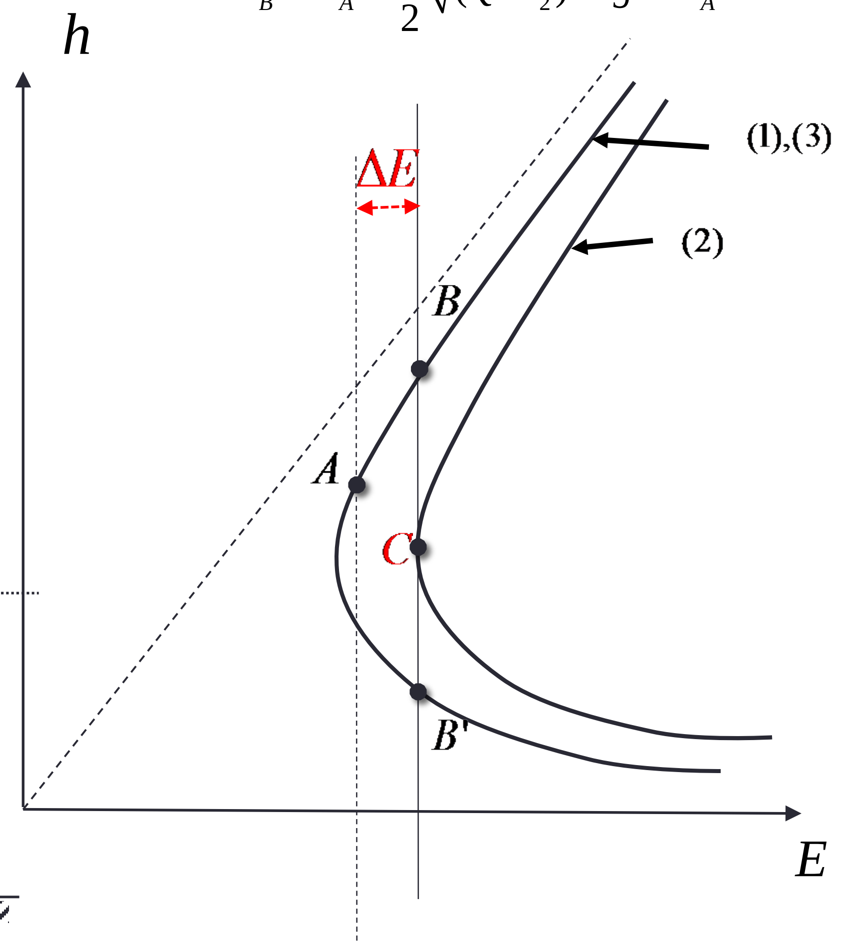
A’ or A in the downstream?

Flow cannot pass freely: subcritical incoming flow

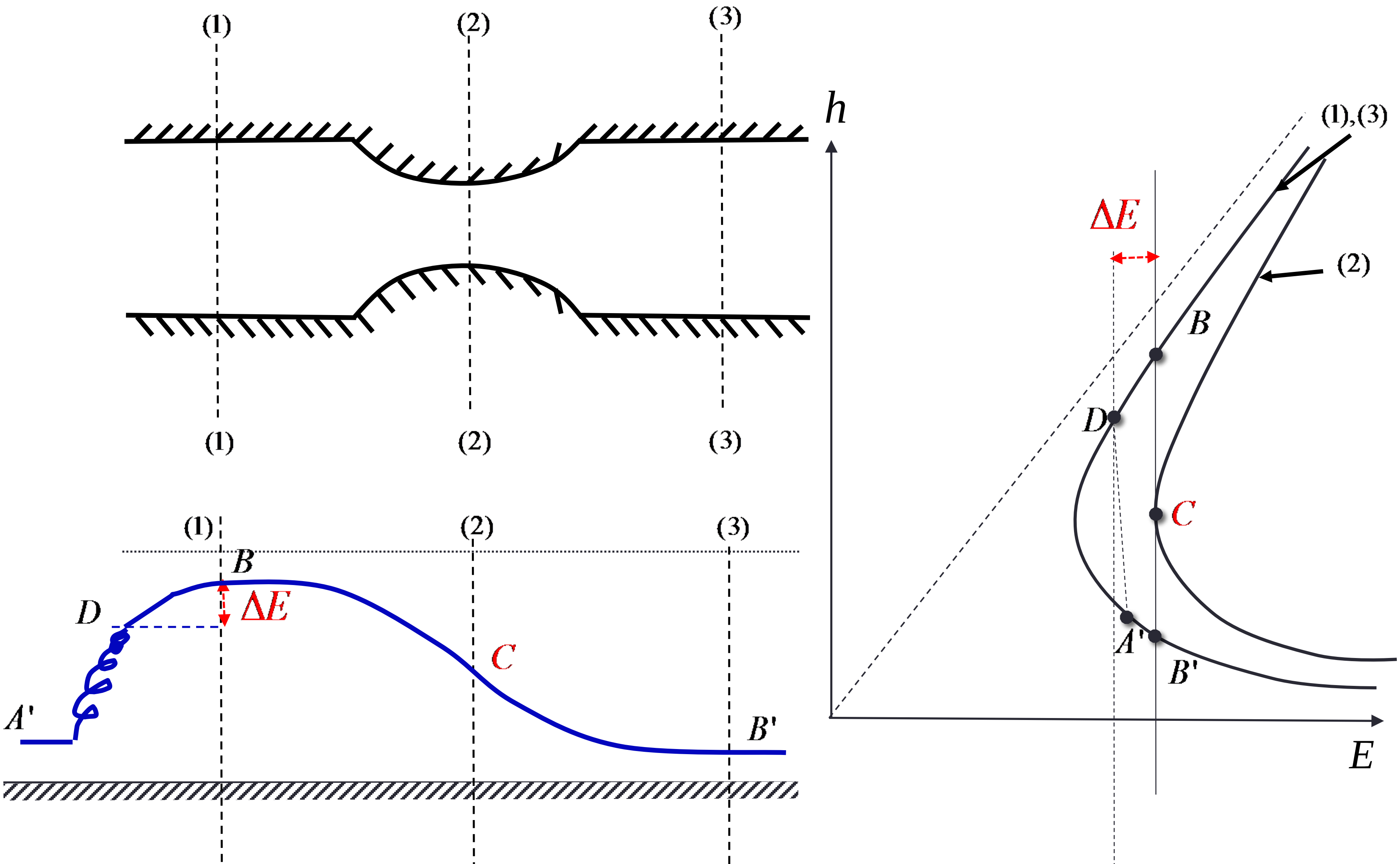
$$E_B = E_C = \frac{3}{2}\sqrt[3]{(Q/b_2)^2/g}$$

$$\Delta E = E_B - E_A = \frac{3}{2}\sqrt[3]{(Q/b_2)^2/g} - E_A$$

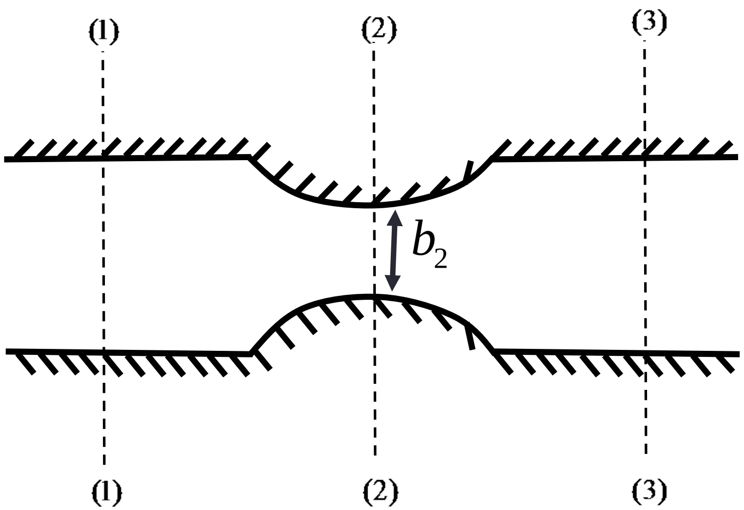




Flow cannot pass freely: supercritical incoming flow

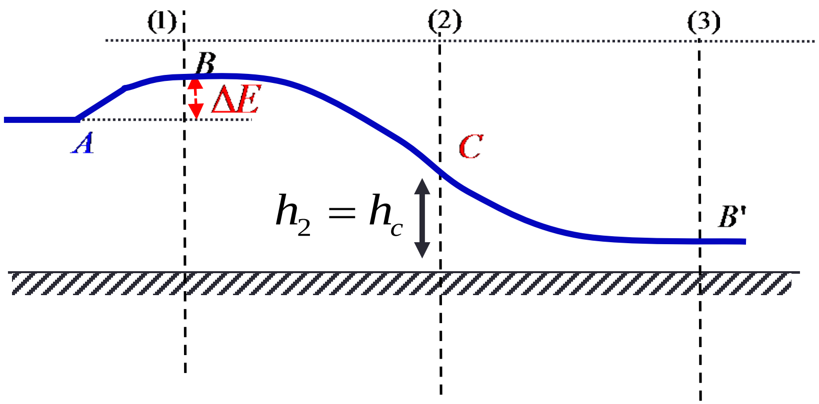


Critical flow control

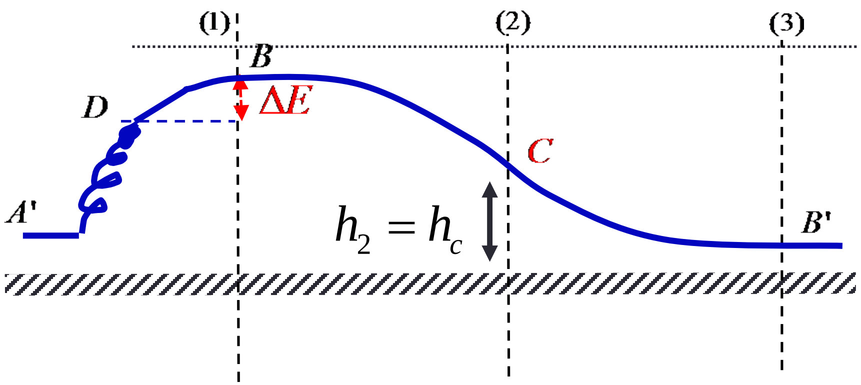


- If the constrain is narrow enough, critical flow will occur at the narrowest point of the constrain:

$$Q = b_2 \sqrt{g} h_2^{3/2}$$



Subcritical incoming flow



Supercritical incoming flow

Parshall flume

A modified version of the Venturi flume is the Parshall flume. Named after it creator, Dr. Ralph L. Parshall of the U.S. Soil Conservation Service