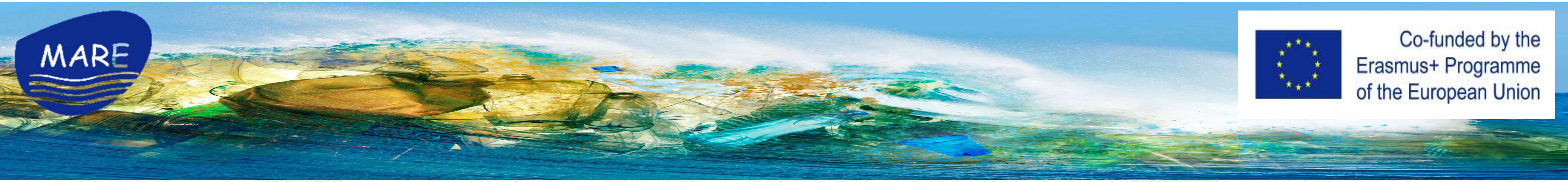

LECTURE 4:
CURRENTS DYNAMICS

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GENERAL CONCEPT AND CURRENTS CLASSIFICATION

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General concept

- *Current is the* horizontal movement of water in a well- defined pattern. Currents are generally measured in meters per second or in knots (1 knot = 1.85 kilometers per hour or 1.15 miles per hour). Currents are driven by three main factors: The rise and fall of the tides, Wind, Thermohaline circulation.

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The role of currents

❖ Currents play a huge role in marine ecosystem:

- Increases water exchange.
- Redistribution of temperature, salt level.
- Transforming the shore.
- Moving sea ice.
- At the same time, it strongly affects the atmospheric circulation and climate of parts of the Earth.

Currents classification

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❖Currents can be classified according to the following basic characteristics:

- According to the factors or forces that driven the currents
- According to stability.
- According to the distribution depth.
- According to the nature of movement.
- According to the physiological nature of the water mass.

❖ In currents theories, classifying currents by factors or forces that cause currents is considered the main classification.

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Currents classification

❖ According to the forces that cause the currents, the currents can be divided into three main groups

- **Tidal currents**: Tides create a current in the oceans, which are strongest near the shore, and in bays and estuaries along the coast. Tidal currents change in a very regular pattern and can be predicted for future dates. In some locations, strong tidal currents can travel at speeds of eight knots or more.
- **Wind currents**: Winds drive currents that are at or near the ocean's surface. Near coastal areas winds tend to drive currents on a localized scale and can result in phenomena like coastal upwelling. On a more global scale, in the open ocean, winds drive currents that circulate water for thousands of miles throughout the ocean basins.
- **Gradient current** is the current caused by the horizontal gradient of hydrostatic pressure that occurs when the sea surface is on its side.

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Currents classification

❖ According to the depth of distribution can be divided into:

- Surface currents are also driven by global wind systems fueled by energy from the sun. Factors like wind direction and the Coriolis effect play a role.
- Deep currents, also known as thermohaline circulation, result **from differences in water density**. These currents occur when cold, dense water at the poles sinks
- The current close to the bottom is the flow observed in the water layer close to the bottom. Bottom friction strongly affects this type of flow.

Currents classification

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❖ According to the nature of movement one divides the flow into:

- Meandering currents
- Straight currents
- Curved currents

❖ According to the physiological nature of the water mass in the flow people divided into:

- Hot current
- Cold currents
- Salty currents
- Light currents

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HYDRODYNAMICS

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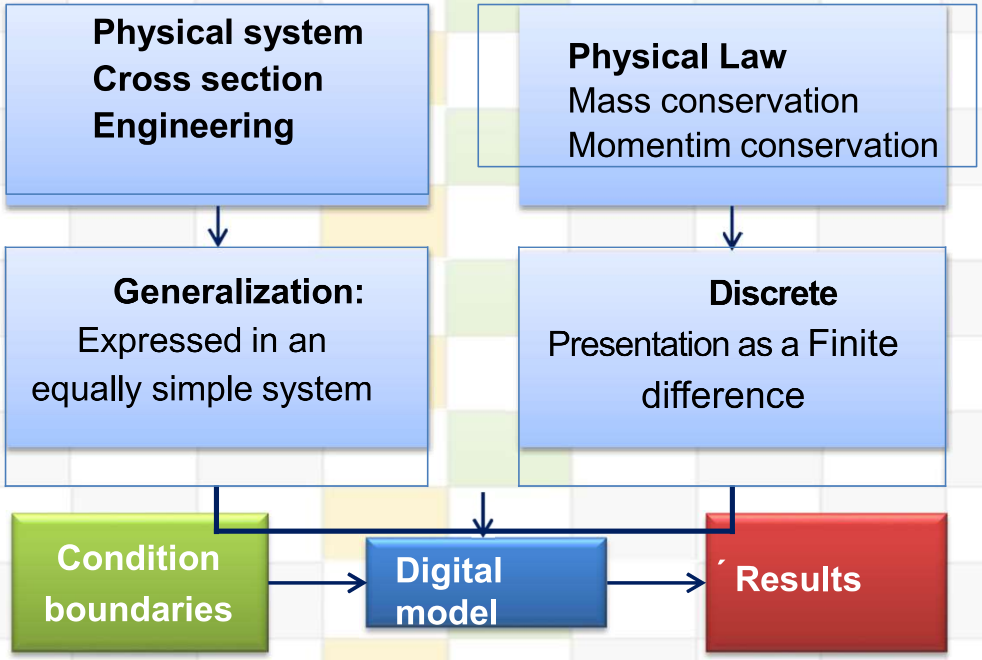
HYDRODYNAMICS

- **Study the movement of the fluid and the forces acting on it.**
- **Flow modeling relies on three basic factors:**
  - Partial differential equations representing the laws of physics
  - Finite difference diagram for generating systems of algebraic equations
  - Algorithms to solve these equations



HYDRODYNAMICS (Cont)

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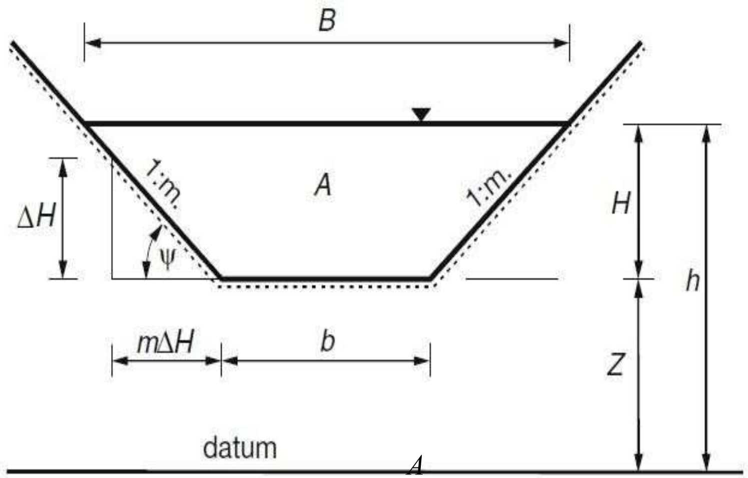
Geometric features of the channel cross section



Bottom width : b
- Surface width : B
- Cross section area : A
- Perimeter : P
- Hydraulic radius : R = A/P
- Slope roof coefficient : m=cotgΨ

Flow: $$Q = \iint^{A} u \times dA$$

Mean velocity $$U = \frac{Q}{A} = \frac{1}{A} \iint^{A} u \times dA$$

Flux $$q = \int_{Z}^{h} u \times dz = U \times H$$

HYDRODYNAMICS (cont)

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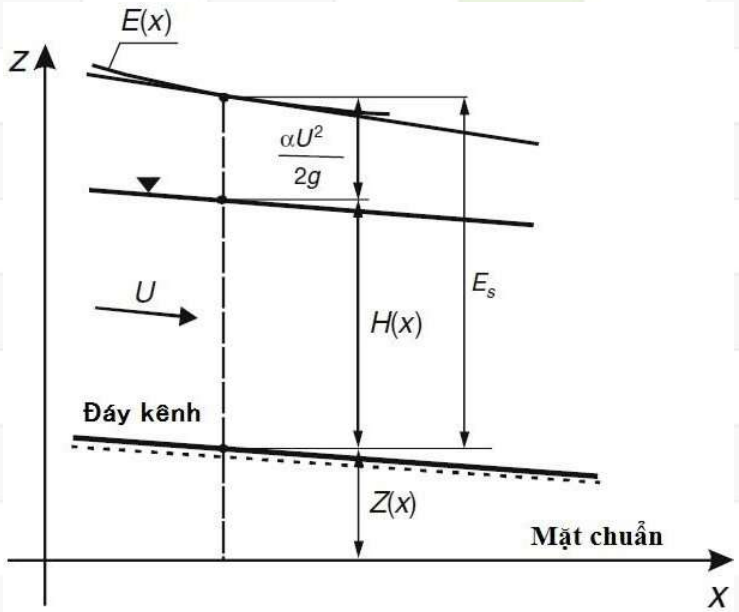
Meaning in terms of energy.

Bernoulli equation (Mechanical energy equation)

$$E_{sl} = z_{sl} + \frac{p_{sl}}{\gamma} + \frac{u_{sl}^2}{2g}$$

Elavation Presure Kinetic



Energy equation for open channel

$$E = a + h + \frac{\alpha U^2}{2g} = H + \frac{\alpha U^2}{2g}$$

α - kinetic energy correction coefficient

$$\alpha = \frac{1}{U^3 A} \iint_A u^3 \times dA$$

HYDRODYNAMICS (Cont)

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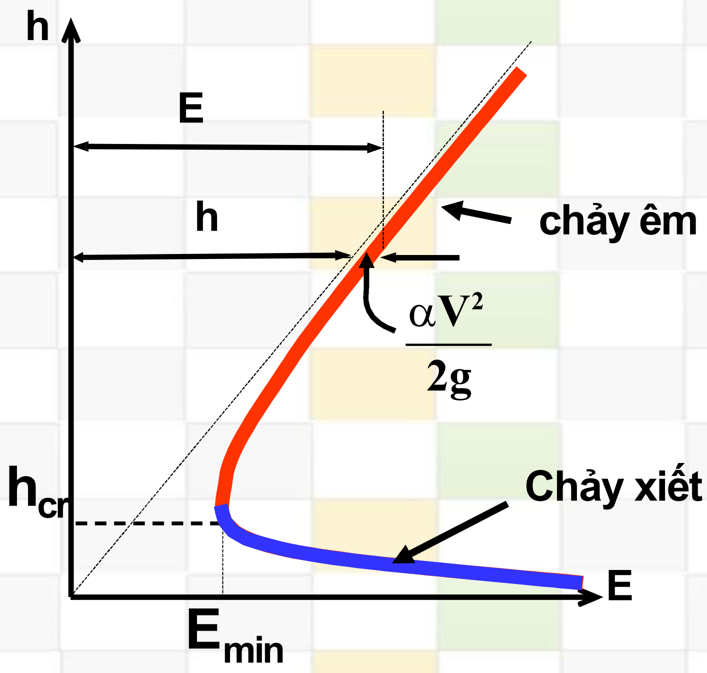
Determine the critical position :

$$\left(\frac{dE}{dh}\right)_{h=h_{cr}} = 0 \Rightarrow \frac{\alpha Q^2}{g} = \frac{A_{cr}^3}{B_{cr}}$$

$$\frac{dE}{dh} = \frac{d}{dh}\left(h + \frac{\alpha U^2}{2g}\right) = 1 - \frac{\alpha U^2}{2gH}$$

$$= 1 - Fr^2$$

Froude: $Fr = \dfrac{U}{\sqrt{gH}}$ $\dfrac{\text{force of inertia}}{\text{gravitation}}$



- Smooth flow : Fr < 1
- Fast flow: Fr > 1
- Demarcation flow: Fr = 1

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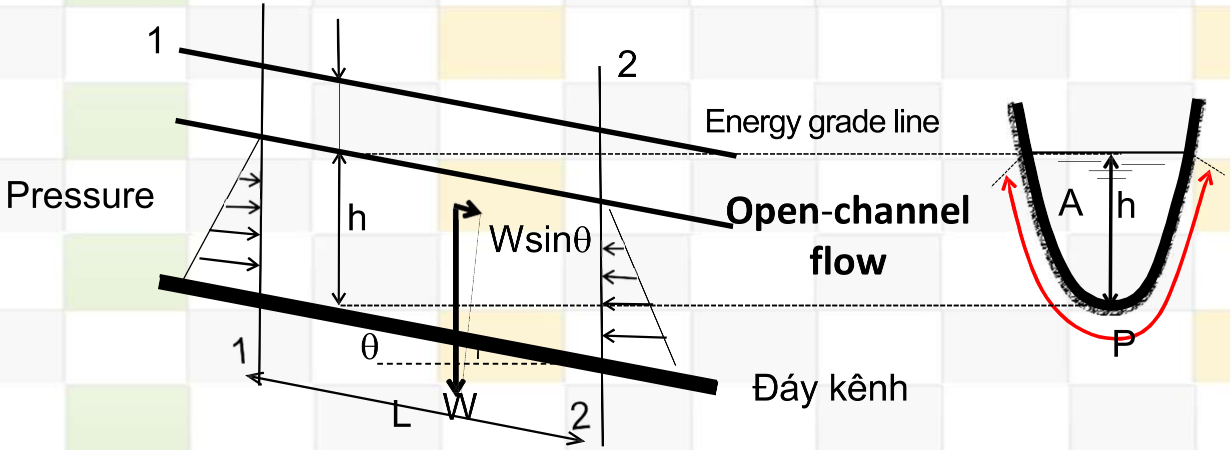
HYDRODYNAMICS (Cont)

Chezy and Manning equations

Chezy equation $$U = C_C (R \times s)^{1/2}$$

C_c – Chezy discharge coefficient



Applied force:

- Gravity
- Friction force
- Pressure = 0

Gravity: $$W_x = W\sin\theta = \gamma AL\sin\theta = \gamma ALs$$

Friction force: $$F_x = LPkU^2$$

Force balance:

$$\Rightarrow U = \left(\frac{\gamma}{k}\right)^{1/2} \sqrt{Rs}$$

$$C_C = \sqrt{\frac{\gamma}{k}}$$

- Manning Equation: $U = \frac{1}{n} R^{2/3} s^{1/2}$ với $C_C = \frac{1}{n} R^{1/6}$

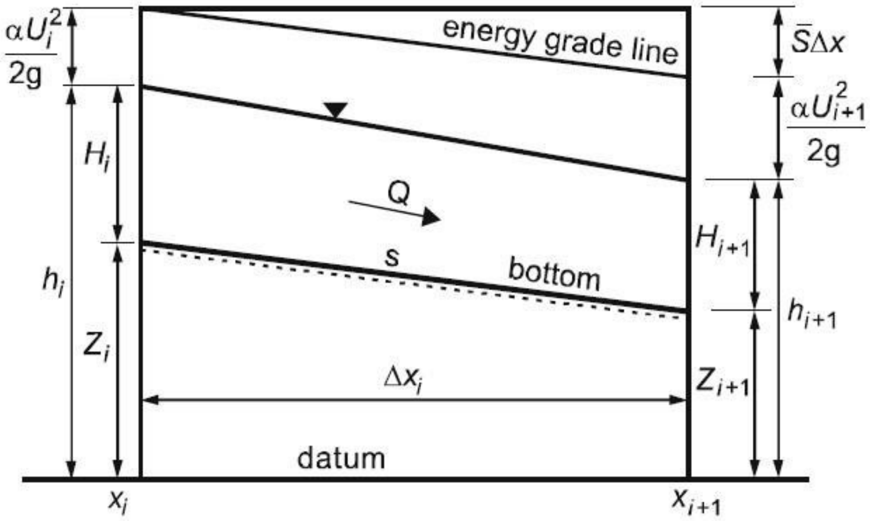
HYDRODYNAMICS (Cont)

Energy equation for fluid

$$h_i + \frac{\alpha U_i^2}{2g} = h_{i+1} + \frac{\alpha U_{i+1}^2}{2g} + \overline{S}\Delta x_i$$

where:

h_i, h_{i+1}	Mực nước tại vị trí i và i+1
U_i, U_{i+1}	Velocity at i and i+1 positions
$\overline{S}$	Energy slope
Δx_i	The distance between the two locations.



Energy slope (friction slope)):

$$S = \frac{n^2 U^2}{R^{4/3}} = \frac{n^2 Q^2}{R^{4/3} A^2}$$

HYDRODYNAMICS (Cont)

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Saint-Venant equation

Approach

Simplifying actual flow processes in a 1-dimensional problem

➢ **Assumption**

- Flow is one-dimensional
- Hydrostatic pressure prevails and vertical accelerations are negligible
- Streamline curvature is small.
- Bottom slope of the channel is small.
- Manning's equation is used to describe resistance effects
- The fluid is incompressible

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HYDRODYNAMICS (Cont)

➢ **The basic law of physics**

Saint-Venant equations

Continuity equation.

Momentum Equation:

HYDRODYNAMICS (Cont.)

- **Saint-Venant equations**
- **Continuity equation**

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q$$

Momentum equation

$$\frac{\partial Q}{\partial t} + \frac{\partial(\alpha \frac{Q^2}{A})}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2 AR} = 0$$

Trong đó:

q - input flow per unit of channel length.

$q > 0$ – inflow to the control volume

$q < 0$ - outflow to the control volume

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--- THE END ---