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Geometry description of local scouring process in various laboratory water structure models

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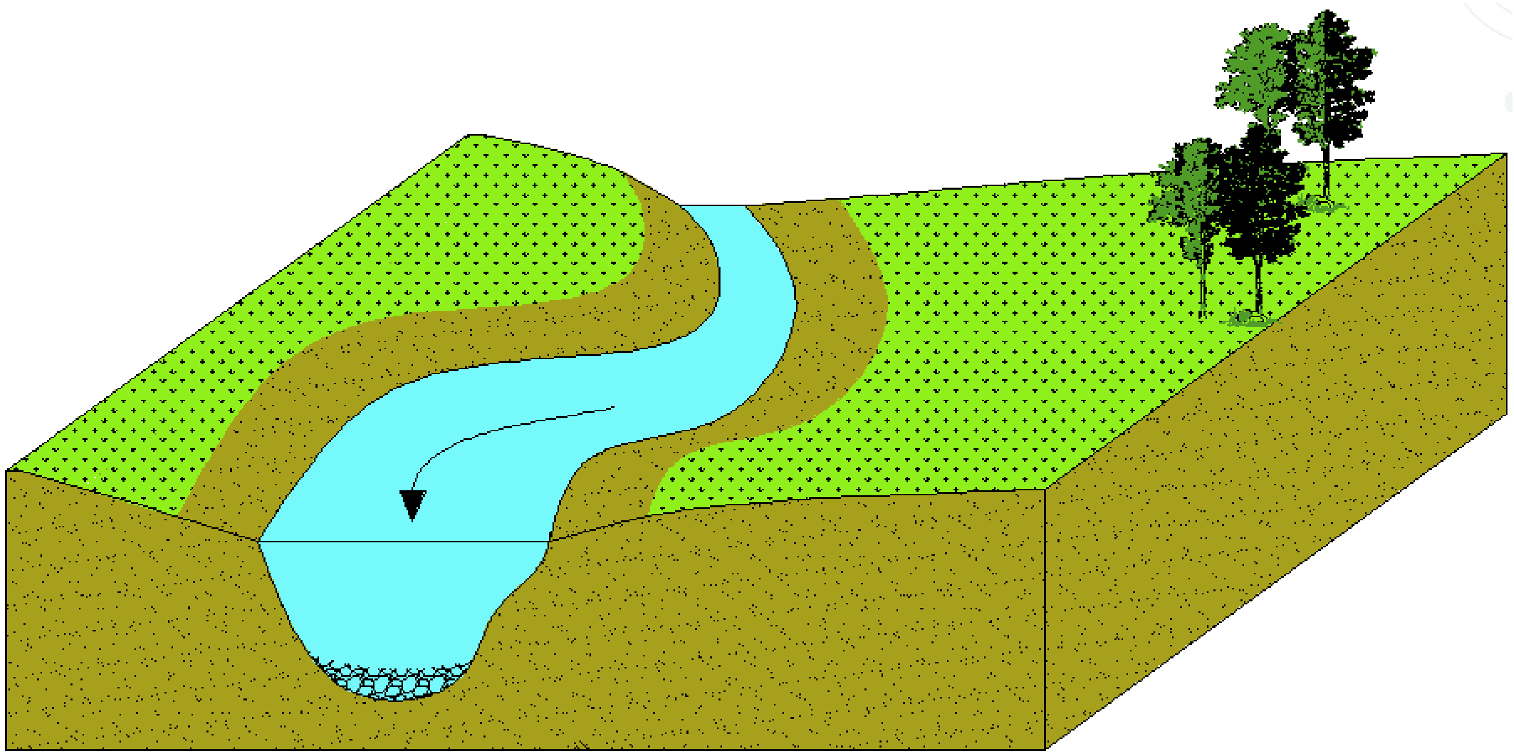
1. Introduction

local scouring process

The river channel and valley forming process is a result of mutual water and sediment flow influence at each other. A river aims at obtaining dynamic equilibrium, described by Lane’s relation in 1955.



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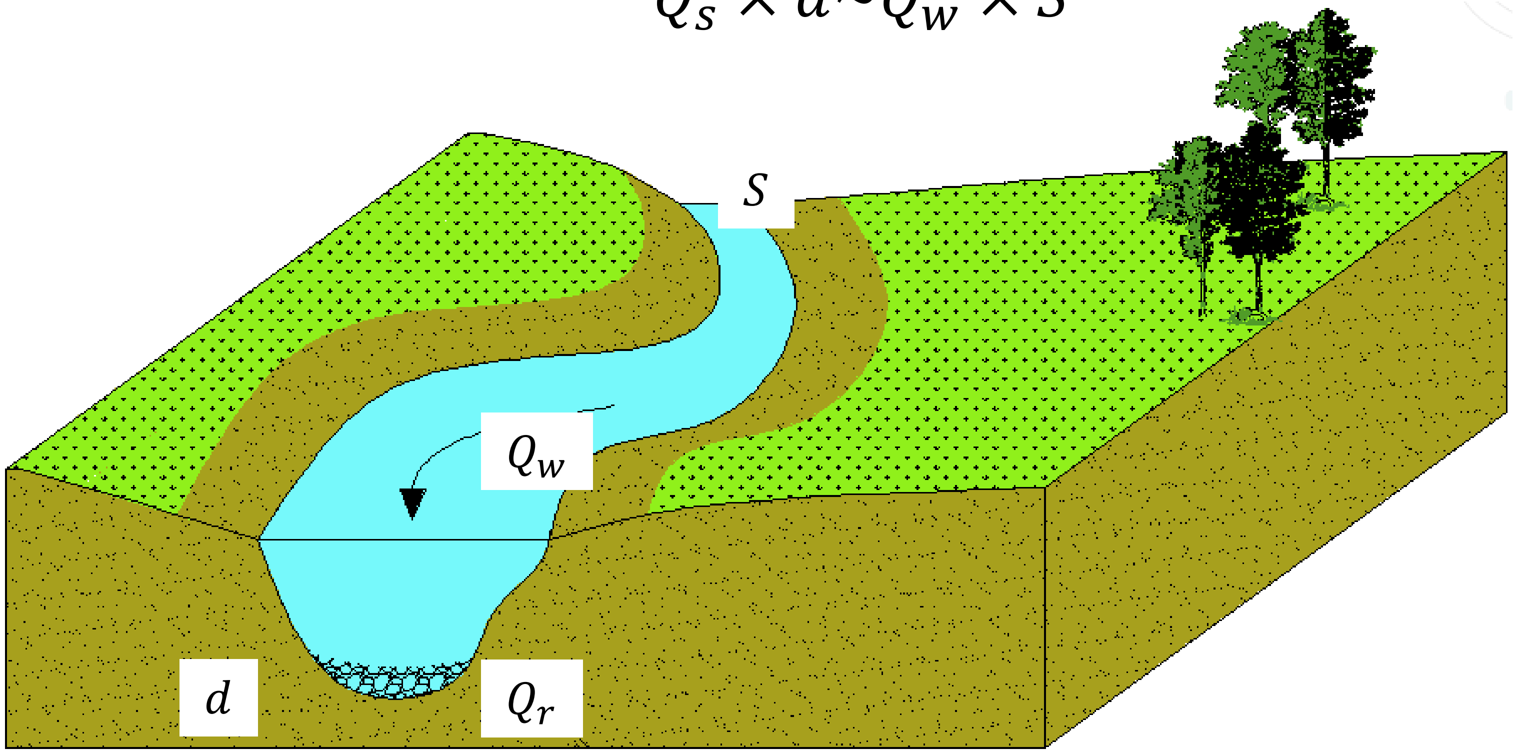
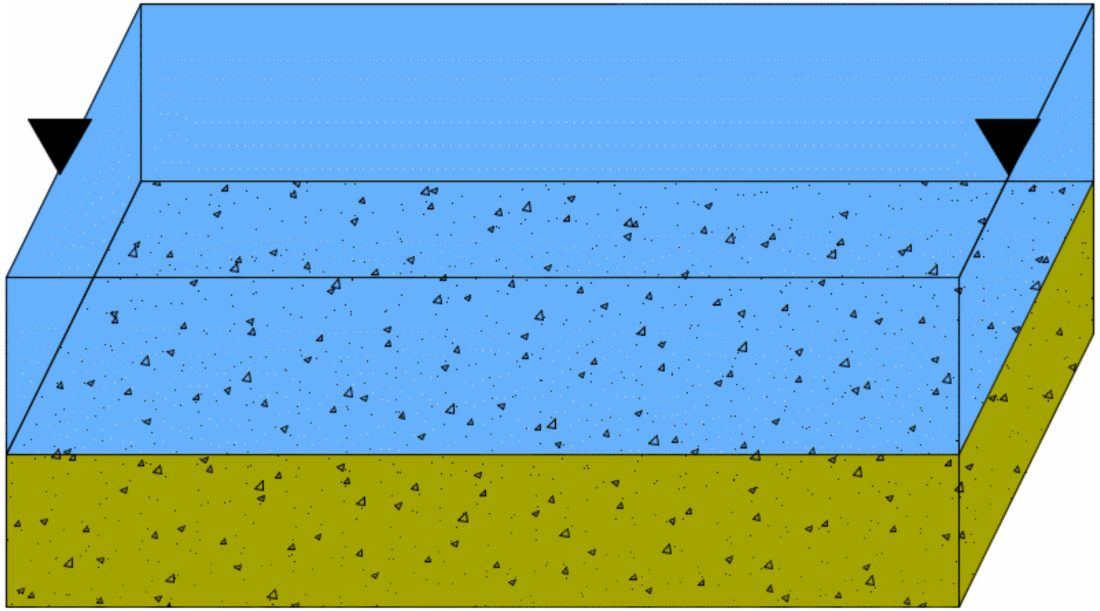
$$Q_s \times d \sim Q_w \times S$$



where:
Q_s—bedload's transport discharge,
d—particle diameter,
Q_w—water discharge,
S—energy grade line slope.

1. Introduction

local scouring process



One of the anthropogenic factors, that influence on the river valley and channel forming process is **damming up the river**. Changes pertrain to upper and lower stand.

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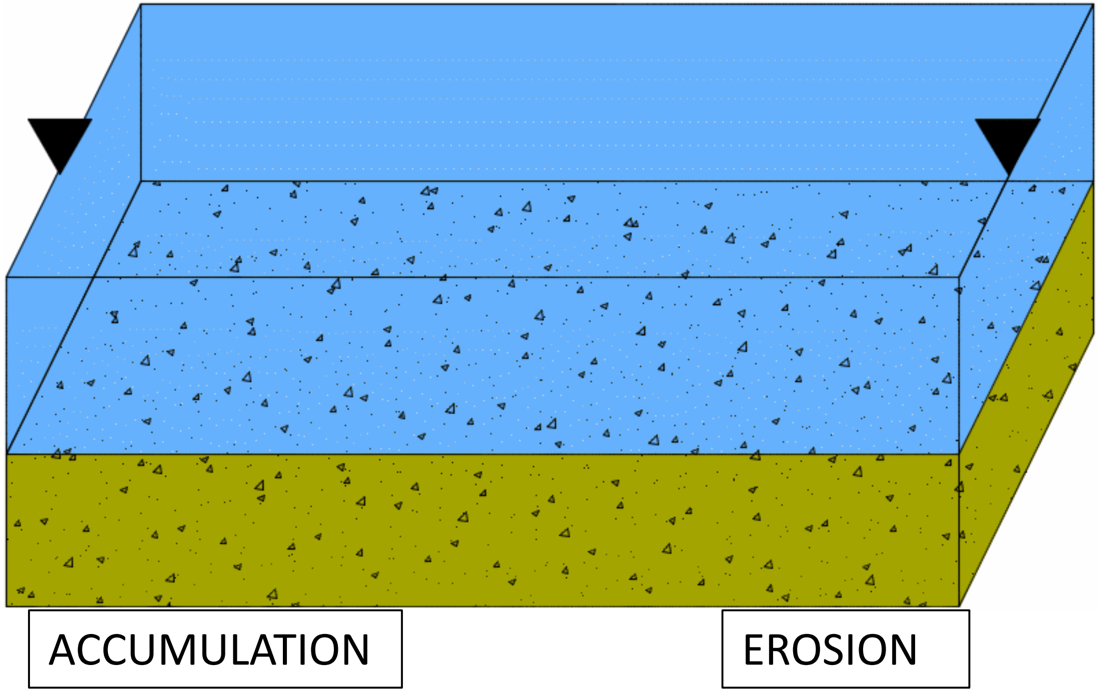

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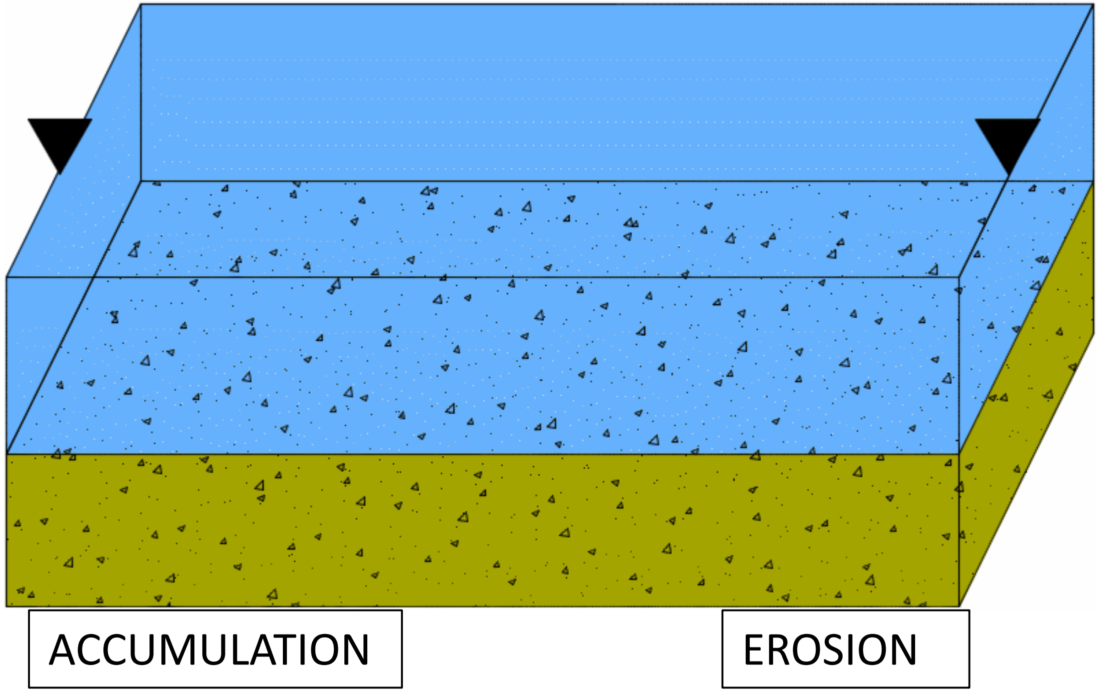

- Erosive process in the lower stand of the structure causes channel morphology changes and could be also dangerous for structure's stability, because of foundation scouring risk.
- That's why GEOMETRICAL PARAMETERS description of local scour is **precious** tool for engineers.

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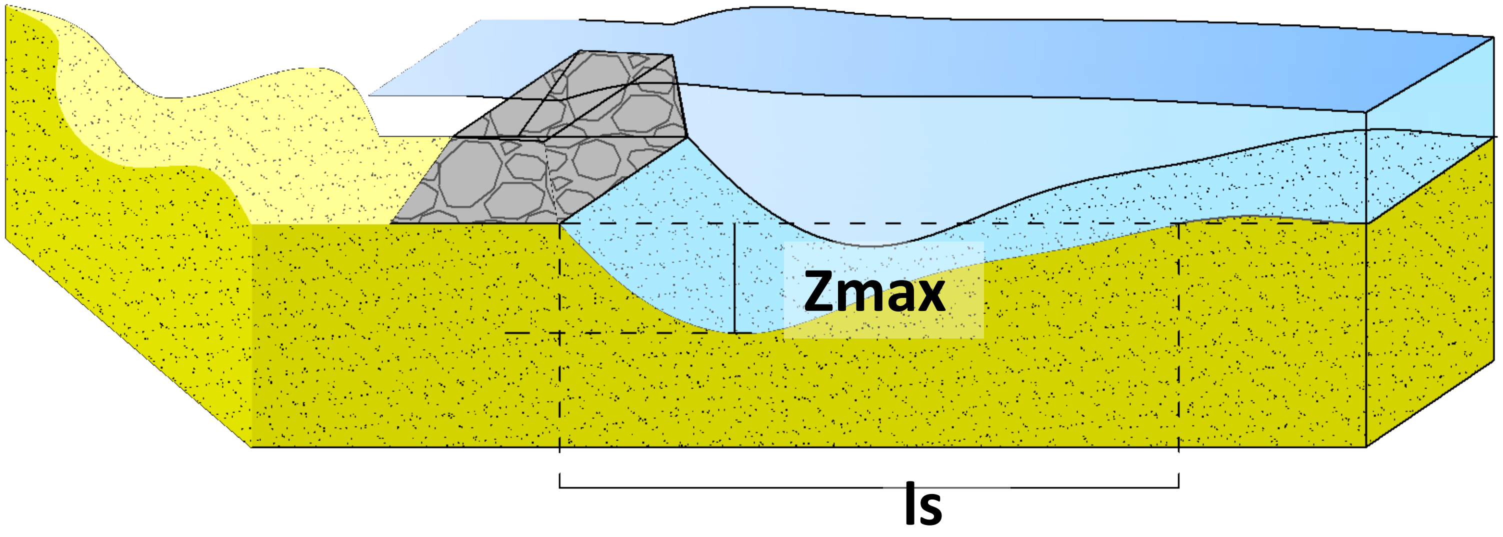
Geometry description

Many studies have been devoted to the problem of local scouring near different hydraulic structures.



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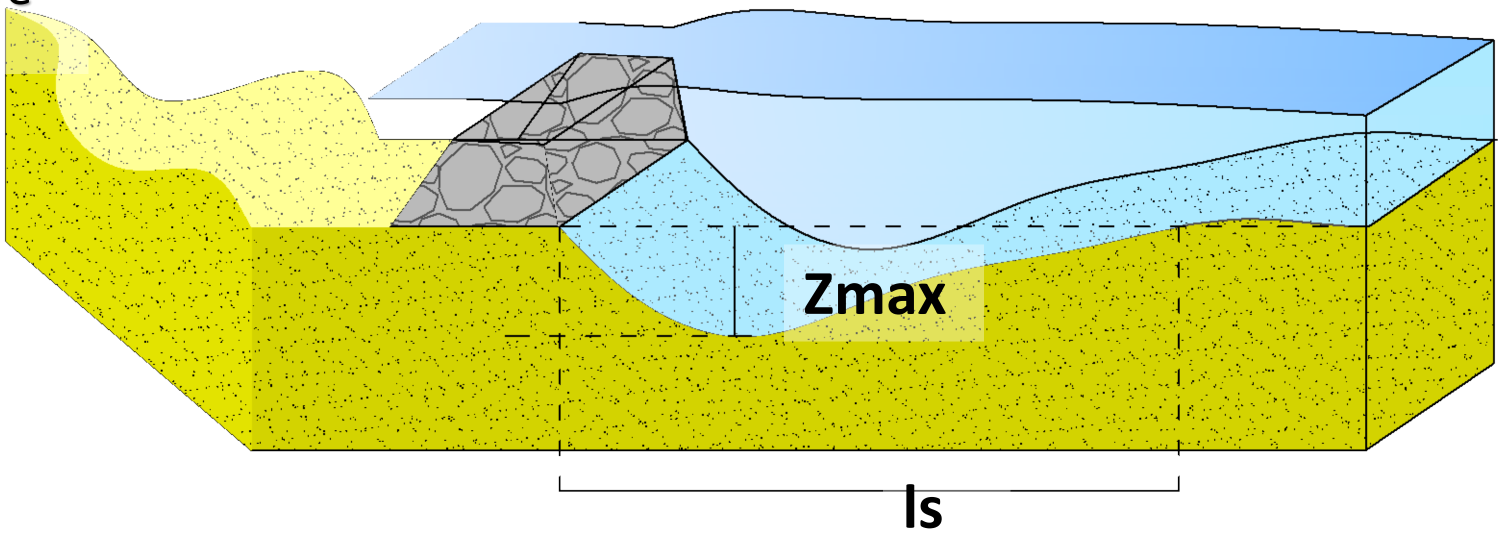
River curvature
(4)



1 - Gaudio et al. 2000, 2 - Lenzi et al. 2002, 3 – Gaudio and Marion 2003, 4 – Pagliara et l. 2015, 5 – Kiraga and Popek 2016, 6 – Ben Meftah and Mossa 2006)

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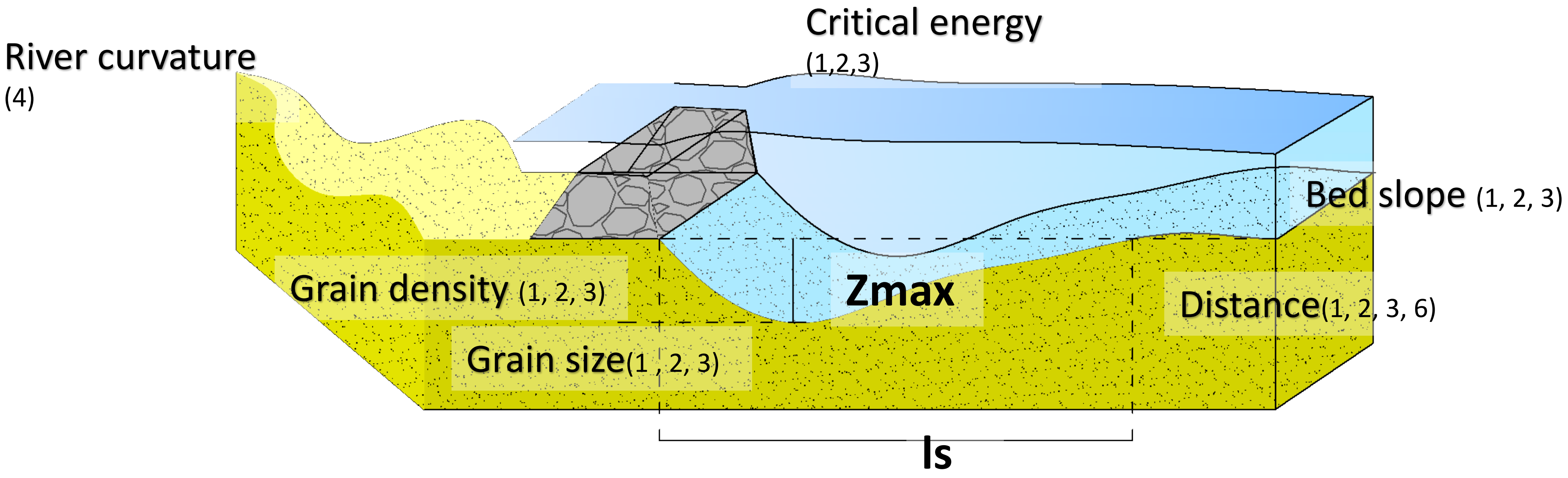

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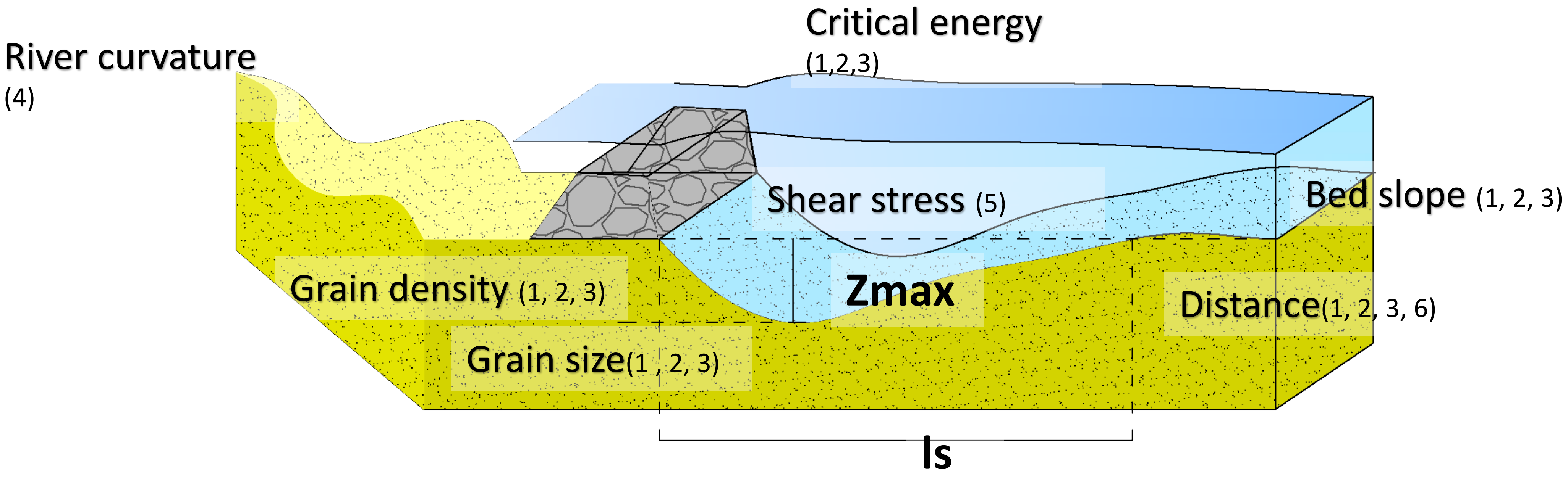

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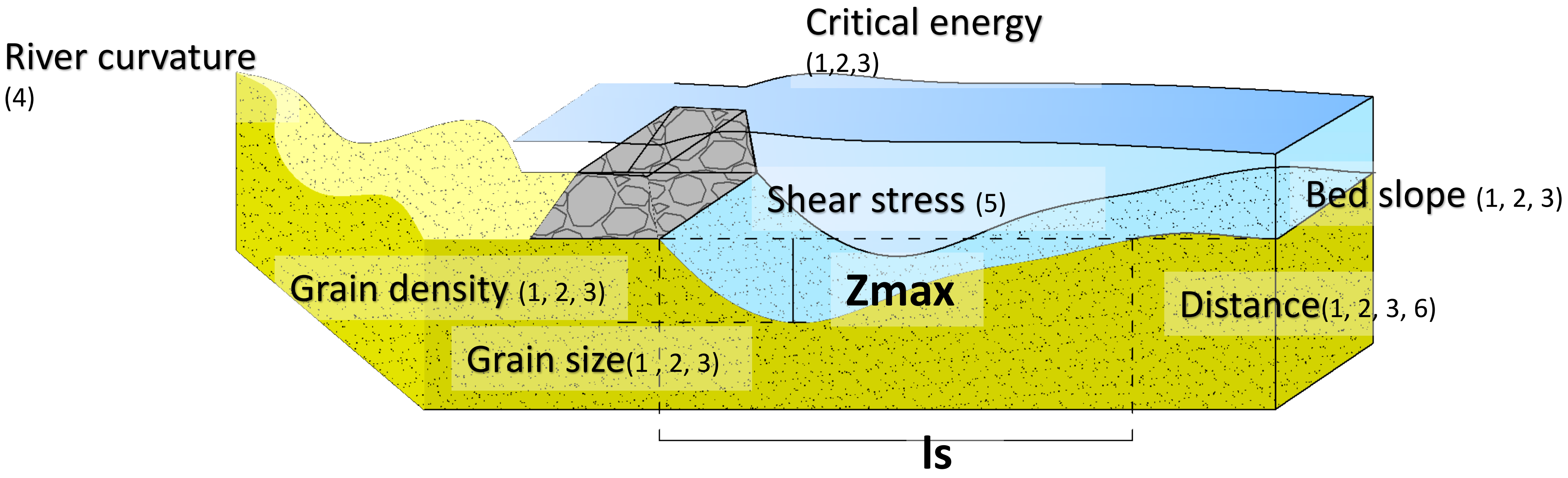
Geometry description

- Attempts to correlate basic geometric properties of local scour with **hydraulic** and **geometric** properties of the flume and **granulometric** characteristic of the bedload.



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1. Introduction

Geometry description - state of the art

- Attempts to correlate basic geometric properties of local scour with **hydraulic** and **geometric** properties of the flume and **granulometric** characteristic of the bedload.
- All methods used in practical applications are **still very inaccurate**, because of the complexity of the transport processes
- **No general equations** so far
- The problem: **unknown initial conditions** (shape of a river bed before scour forming during *in-situ* research)

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- All mentioned experiments were conducted with **no sediment feeding system** adopted
- Live-bed conditions case is still **undeveloped branch** of experimental research, which present paper attempts to fulfil.

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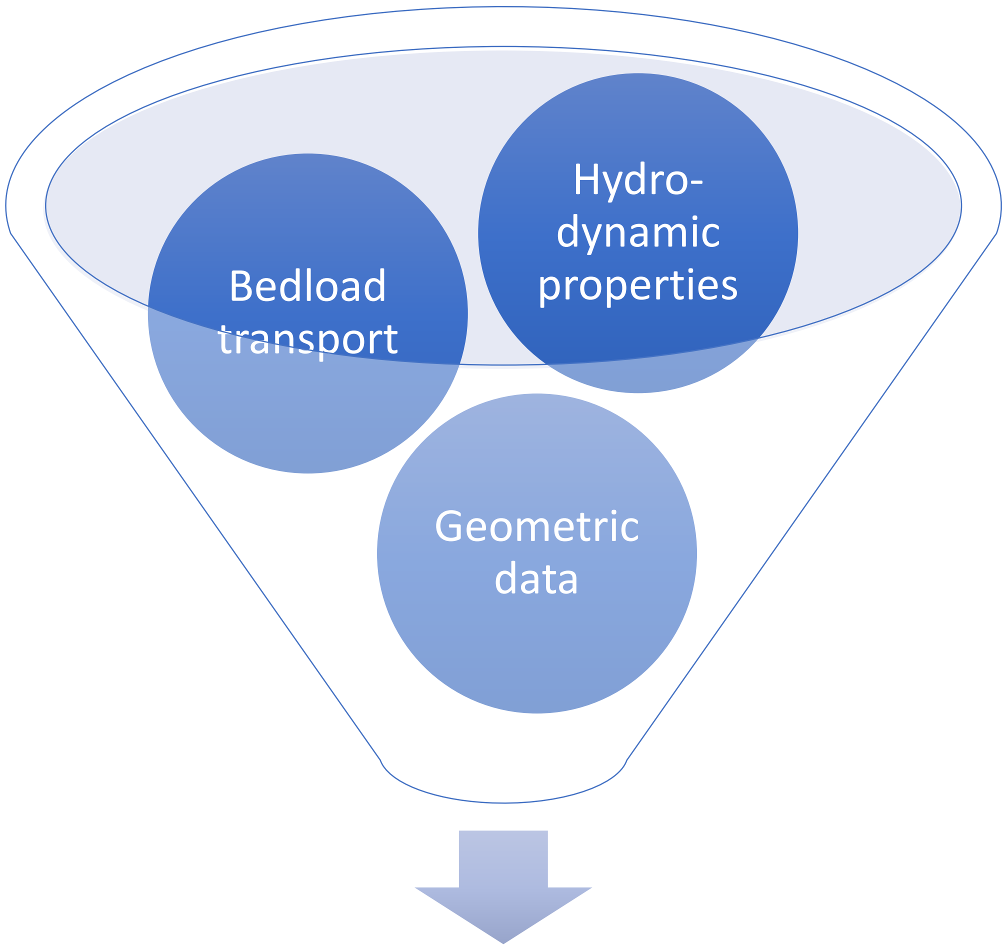
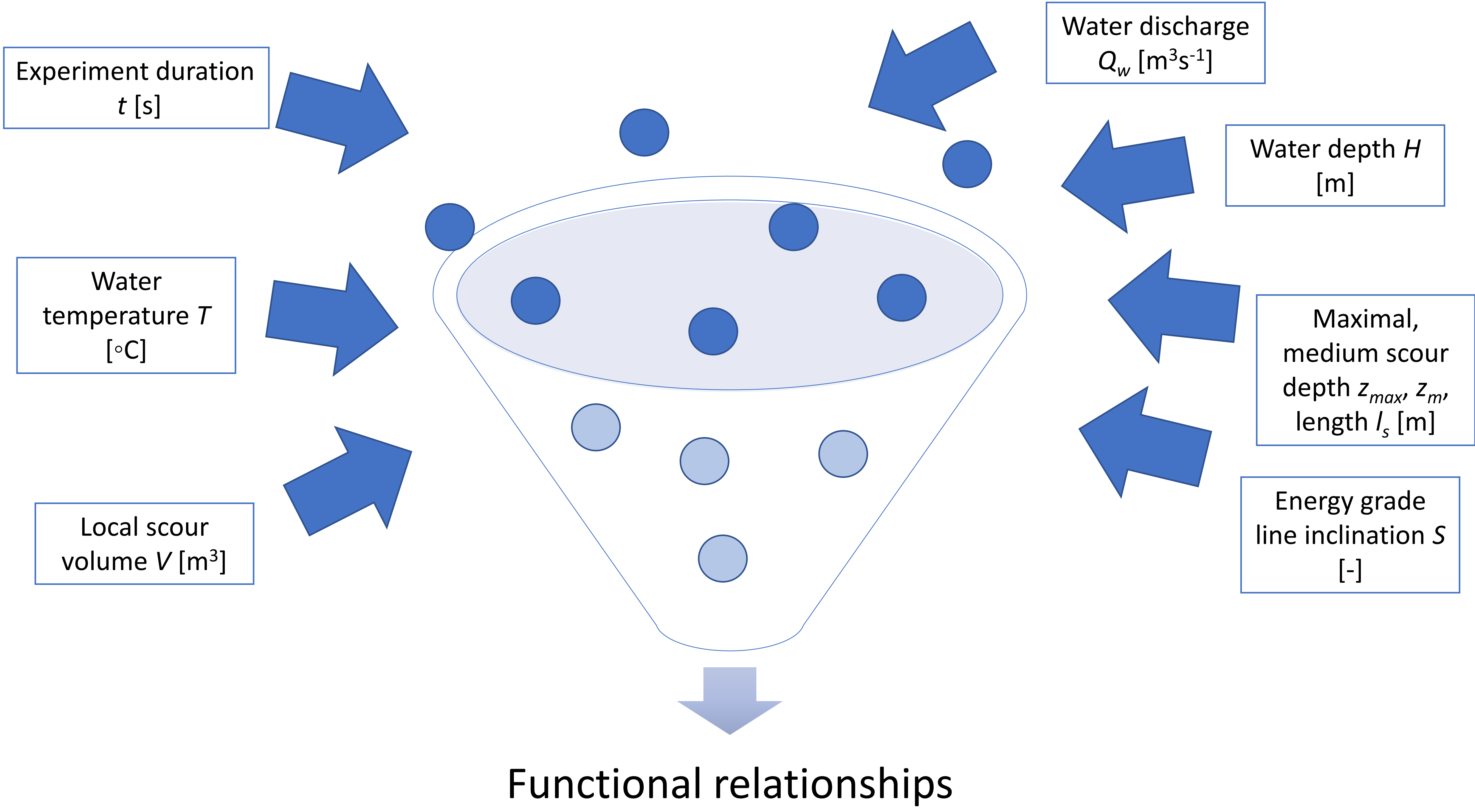
2. Aim of the research

- Attempts of other scientists, on the grounds of lowland river conditions research

- Lane's relation



Functional relationships



Experiment duration t [s]
Water temperature T [◦C]
Local scour volume V [m^3]
Water discharge Q_w [m^{3}s^{-1}]
Water depth H [m]
Maximal, medium scour depth z_{max}, z_m, length l_s [m]
Energy grade line inclination S [-]
Functional relationships

3. Methodology

Geometry description of local scouring process in various laboratory water structure models

3. Methodology

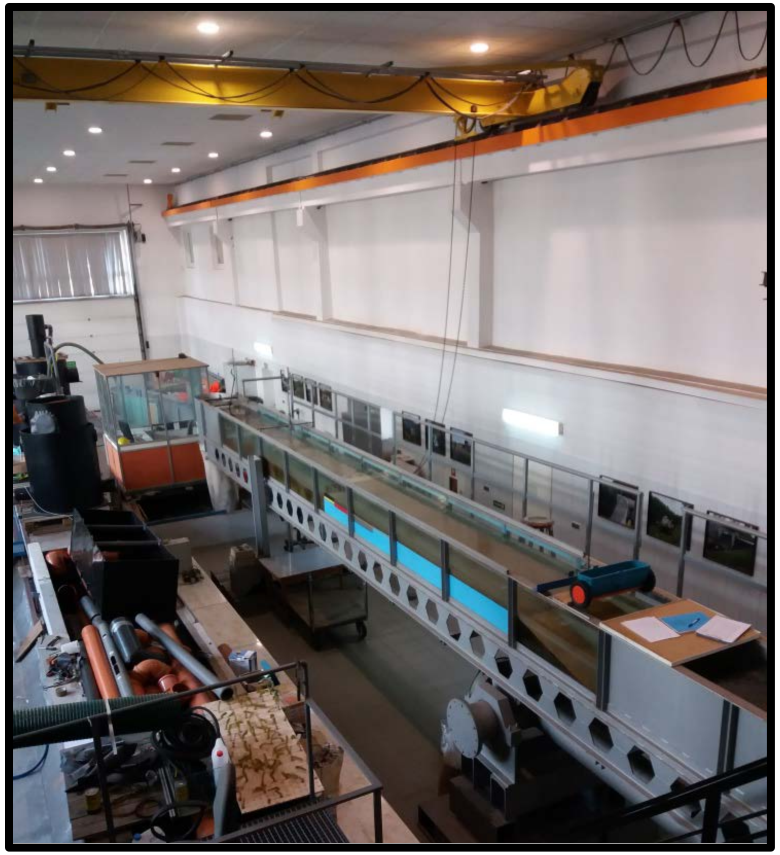
water structure models

Experiment

3 laboratory models x 13 experimental runs

Test stand properties:

- Height: 1.0 m
- Length 8.0 m
- Width 0.58 m



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water structure models

Experiment

3 laboratory models x 13 experimental runs

Test stand properties:

- Height: 1.0 m
- Length 8.0 m
- Width 0.58 m

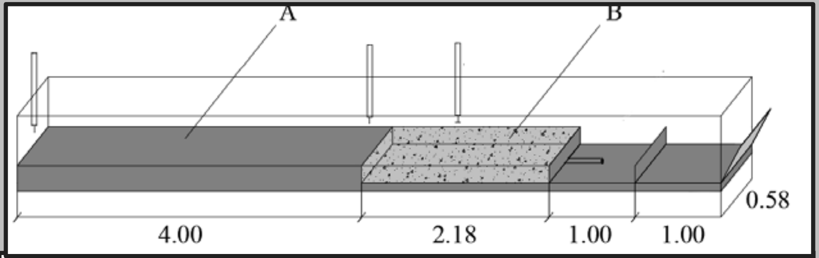
- Water flow 0.020 – 0.045 $m^3 \cdot s^{-1}$
- Water depth 0.10 – 0.20 m
- Duration 8h

3. Methodology

water structure models

3 laboratory models

I



A – non-erodible part
B – erodible part

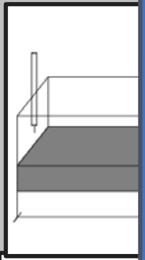
3. Methodology

water structure models

3 laboratory

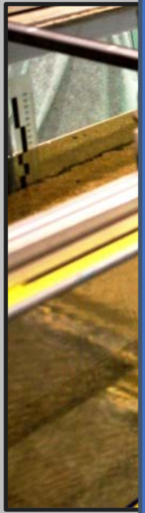
els

I

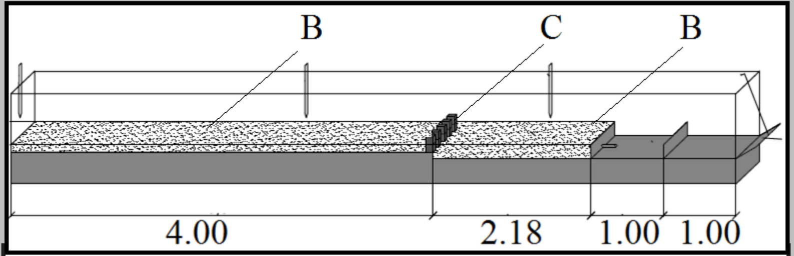


A – non-e

B – erod



II



B – erodible part

D – stone weir

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3 laboratory

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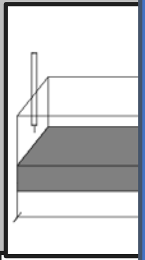

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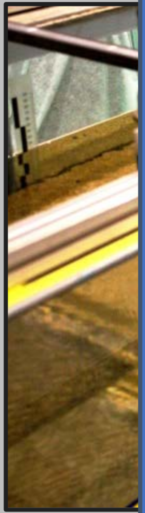

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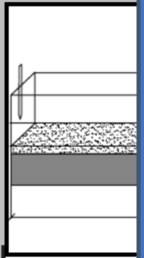

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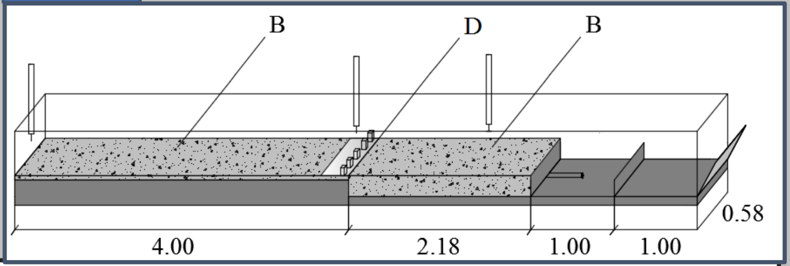
D – ston

III



B – erodible part
D – stone weir with reinforcement

4. Results

Others' attempts

$$\left(\frac{z_{max}}{H_s}\right) = f\left(\frac{a_1}{s \cdot d_{50}}\right) \quad (1)$$

$$\left(\frac{l_s}{H_s}\right) = f\left(\frac{a_1}{s \cdot d_{50}}\right) \quad (1)$$

$$Q_s \times d \sim Q_w \times S \quad (2)$$

$$z_{max} = f(\theta) \quad (3)$$

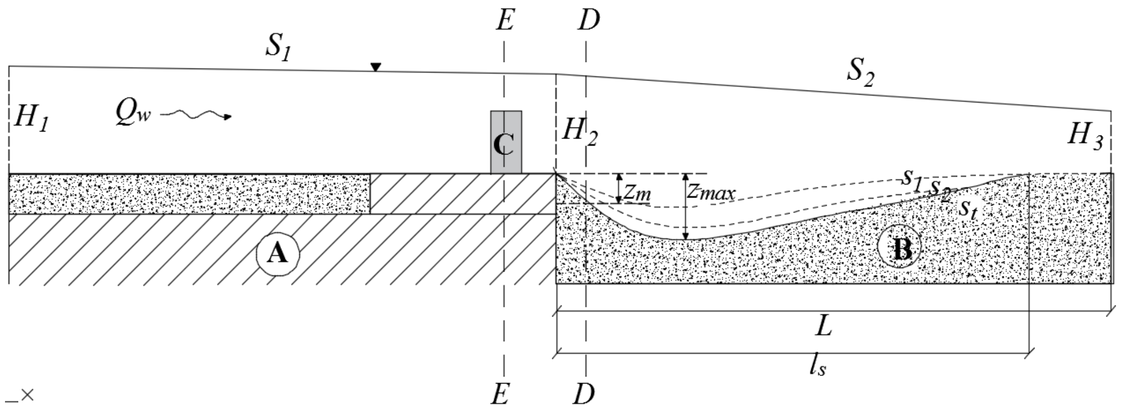
New formulas

$$\left(\frac{z_{max}}{H_s}\right) = c \times \frac{a_1}{s \cdot d_{50}} + d$$

$$\left(\frac{l_s}{H_s}\right) = f \times \frac{a_1}{s \cdot d_{50}} + g$$

$$Q_s \times D_* \times \left(\frac{W}{H}\right)^{-1} \times \left(\frac{z_m}{l_s}\right) = a \cdot Q_w \times (S - S_0) + b$$

$$\left(\frac{z_m}{l_s}\right) = k \times e^{m \cdot \theta}$$



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H_s – critical specific energy [m]

a_1 – morphological jump (Gaudio 2000) [m]

s – relative particle density [-]

d_{50} – median grain size [m]

Q_s – bedload transport discharge [$m^3 \cdot s^{-1}$],

D_* – grain parameter [-]

$$a_1 = (S - S_0)L$$

$$D_* = d_{50} \cdot [(s-1)g/\nu^2]^{1/3}$$

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θ – shear stress in bed region [-]

a - g – linear function parameters

k, m – Exponential function parameters

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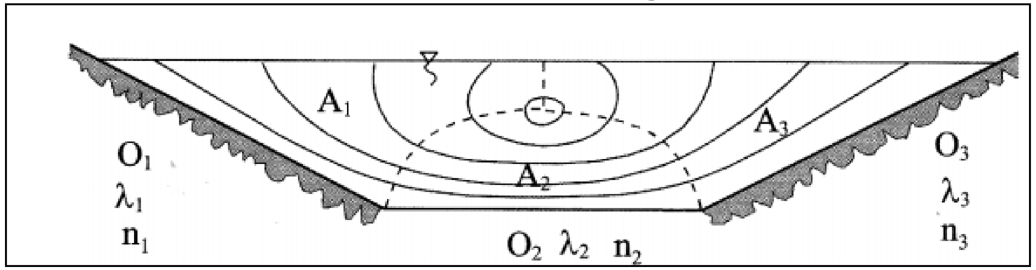
EINSTEIN HYPOTHESIS

$$V = V_b = V_g$$



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$$\theta = \frac{\tau_b}{(\rho_s - \rho_w) \cdot g \cdot d_{50}}$$

$$\tau_b = \rho_w \cdot g \cdot R_b \cdot S$$

4. Results

Formula	**Correlation coefficient *r***
$\left(\frac{z_{max}}{H_s}\right) = c \times \frac{a_1}{s \cdot d_{50}} + d$	***r* = 0.74 – 0.83**
$\left(\frac{l_s}{H_s}\right) = f \times \frac{a_1}{s \cdot d_{50}} + g$	*r* = 0.58 – 0.63
$Q_s \times D_* \times \left(\frac{W}{H}\right)^{-1} \times \left(\frac{z_m}{l_s}\right) = a \cdot Q_w \times (S - S_0) + b$	***r* = 0.71 – 0.82**
$\left(\frac{z_m}{l_s}\right) = k \times e^{m \cdot \theta}$	***r* =0.67 – 0.82**

5. Summary

- The experiment included fifty two test runs in total, on three test stands to investigate the local scours properties, aiming at relating scour geometry with hydrodynamic parameters of water and sediment discharge.

- Test stands included totally and partially sandy bed with and without the water structure (stone weir).

- Measurements were taken when the scour hole obtains its stable shape in clear-water and live-bed conditions.

5. Summary and Conclusions

- ✓ Four empirical formulas were **confirmed** to predict the medium scour depth, maximal scour depth and the length of the scour hole, as far as correlation coefficient *r*> 0.60 signalizes satisfying match and *r*> 0.80 good match of data
- ✓ **Lane's relation could be transformed into equation** and used in local scour dimensions forecasting.
- ✓ Obtained functional relationships could be used in engineering practice, however up to now there is only one real object verified.

What’s next?

- ✓ higher energy grade slopes
- ✓ different stone weir configurations
- ✓ water structure with diminished slots area to intensify scour forming process in proposed test run conditions


Thank you for Your attention!