École polytechnique fédérale de Lausanne
School of Architecture, Civil and Environmental Engineering
Civil Engineering & Environmental Science and Engineering Sections
CIVIL-312: Hydraulic Engineering and Infrastructures

Homework 2

Instructor: Prof. Mirko Musa
Due date: December 5, 2025

General Instructions

- This is an individual and mandatory assignment. Copying will result in a null grade (NA: *non acquis*) and a formal reprimand according to EPFL regulations.
- The assignment must be **typed on a computer** and submitted as a **PDF file** through the corresponding Moodle submission form. This helps ensure clarity and readability. For **Problem 1**, you may submit **neatly handmade** drawings, provided they are in good resolution. Problem 2 must be completed on a computer **without exception**. Submissions that do not follow these instructions will receive a **maximum grade of 5.0**.
- Figures and graphs may be included either in-line with your solution or attached as appendix. These must be neat and, if applicable, created using tools such as Excel, Matlab, or Python.
- Your work must be supported by a clear, logically structured solution process. You are expected to organize your responses effectively. A classic problem-solving approach is recommended:
  - **Conceptualize:** Identify all relevant data and draw a clear sketch showing applied forces, boundary conditions, and interactions.
  - **Categorize:** Define the unknowns, make justified assumptions to simplify the problem, and determine the path to a solution.
  - **Analyze:** Apply the appropriate physical laws, set up equations, and carry out calculations to find the unknowns.
  - **Finalize:** Evaluate your results. Check units, physical consistency, and whether the solution is reasonable by comparing it to similar cases or known benchmarks.
- For any questions related to this assignment, please use the dedicated **Moodle forum** so that everyone can benefit from the discussion and clarifications.
- Late submissions will incur a 0.5 deduction from the final grade for every day of delay.

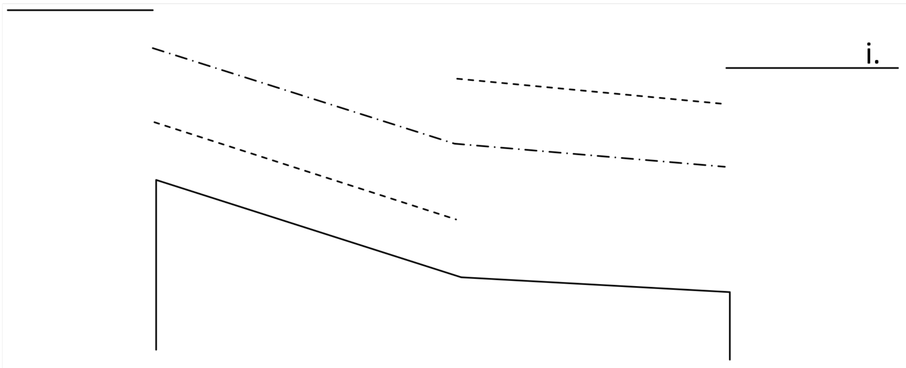
Problem 1

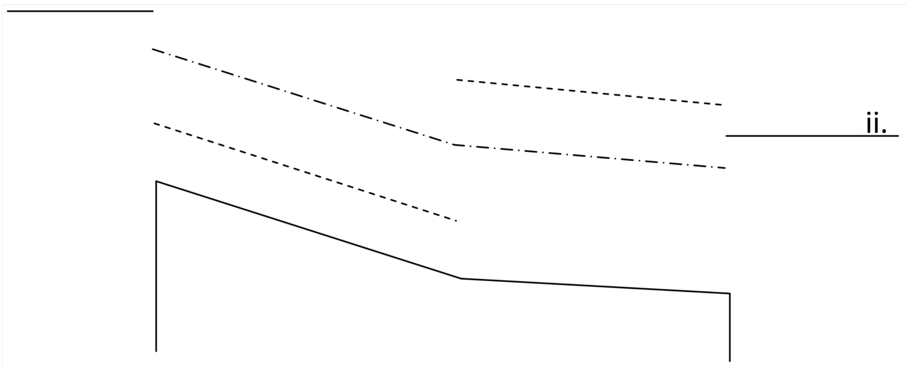
(a) Two large reservoirs are connected by a channel consisting of two **very long reaches**: one with a steep slope and the other with a mild slope, as illustrated in the figure. Draw and classify **all the possible hydraulic grade lines** that may develop in the channel when the water level in the left reservoir is higher than that in the right reservoir, considering the following possible conditions for the right reservoir:

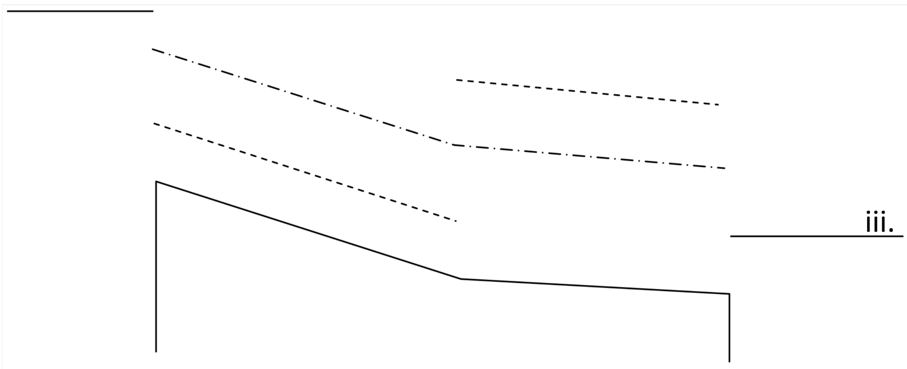
i. Above the normal depth of the second reach (1 pt)

ii. Between the normal and critical depths of the second reach (1 pt)

iii. Below the critical depth of the second reach (1 pt)







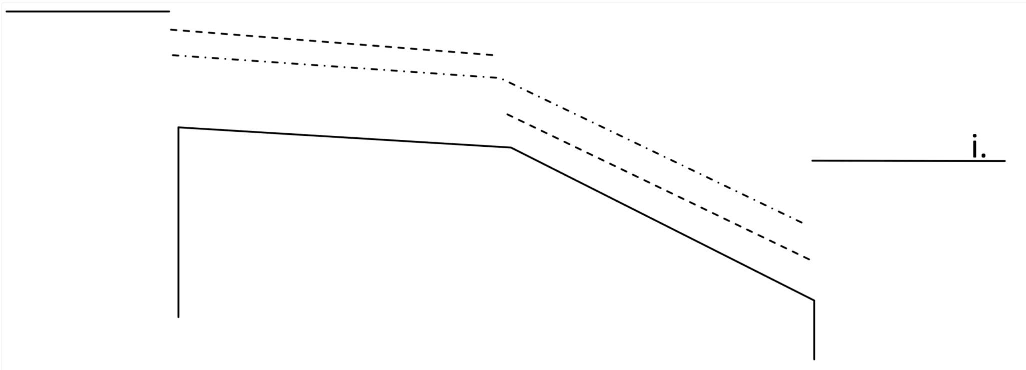
Ensure that each drawing clearly identifies the normal depth (h_n), critical depth (h_c), flow regime (e.g., M_i, S_i), designated control points (CP), and the direction of information propagation.

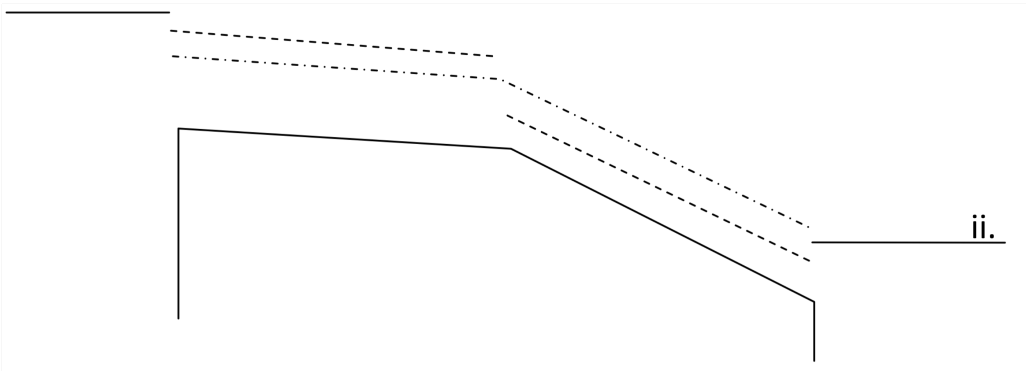
(b) Now suppose the order of the reaches is reversed, with the mild slope on the left and the steep slope on the right. Draw and classify again all the possible hydraulic grade lines that may develop when the water level in the left reservoir is higher than that in the right reservoir, which may be at the following possible levels:

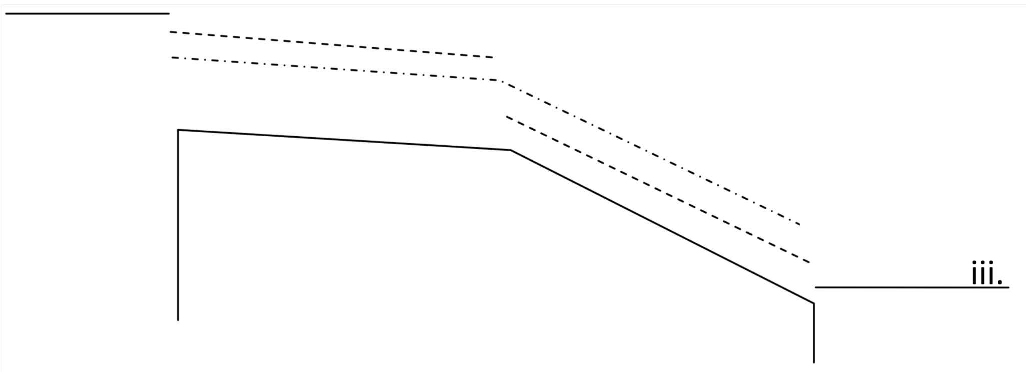
i. Above the critical depth of the second reach (1 pt)

ii. Between the normal and critical depths of the second reach (1 pt)

iii. Below the normal depth of the second reach (1 pt)







Ensure that each drawing clearly identifies the normal depth (h_n), critical depth (h_c), flow regime (e.g., M_i, S_i), designated control points (CP), and the direction of information propagation.

Problem 2

A trapezoidal earthen channel ($n = 0.025$), with a base width of $1\,\mathrm{m}$ and side slopes of $2:1$ (H/V), conveys a discharge of $6\,\mathrm{m}^3/\mathrm{s}$. The system consists of two reaches of slope $S_0 = 0.0005$ separated by a sudden vertical drop of $2\,\mathrm{m}$. Both reaches share identical cross-sectional geometry and slope, and the geometry and Manning's n remain uniform throughout. Reach AB can be considered *very long*, while reach BC is 100 meters long. At point C, the flow undergoes another free fall.

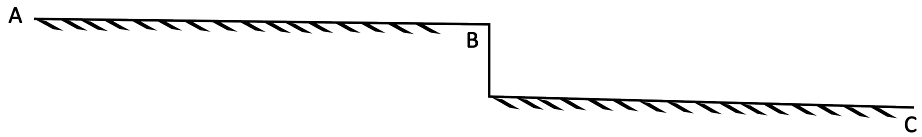


Figure 1: Schematic of the trapezoidal channel with two reaches of same slope with vertical drop.

1. **Critical and Normal Depths (2 pts)** Determine the critical depth and the normal depth for each reach, assuming a discharge of $Q = 6\,\mathrm{m}^3/\mathrm{s}$. Show all calculation steps clearly.
2. **Qualitative Longitudinal Profile (2 pts)** Sketch a qualitative longitudinal profile of the entire channel showing the channel bed, critical depths, and normal depths for both reaches. Identify the control sections and classify each reach according to its profile type (Uniform, M_i or S_i).
3. **Direct Step Method (10 pts)** Using the *Direct Step Method (DSM)*, compute the complete water surface profile with a reasonable water-depth increment. Prepare a table summarizing, for each computational step, the following hydraulic parameters:
   - Flow depth (y) and depth increment (Δy)
   - Flow area (A)
   - Wetted perimeter (P)
   - Hydraulic radius (R)
   - Flow velocity (V)
   - Specific energy (E)
   - Energy slope (S_f)
   - Froude number (Fr)
   - Step size (Δx)
   - Longitudinal position (x)

   Continue the computation until the specified **upstream** or **downstream boundary condition** is reached, ensuring that all results remain within an acceptable error margin of **5%**. Include a discussion on:

   (a) The direction of computation, as determined by the prevailing flow regime.

   (b) Determine whether energy losses at the vertical drop need to be considered, and, if so, specify how they should be incorporated into the analysis.

   (c) The influence of the selected step size (Δy) on numerical accuracy and stability.

4. **HEC-RAS 1D Simulation (15 pts)** Using *HEC-RAS 1D (steady flow)*, simulate the same channel configuration. Clearly justify your choices regarding:

   - The **flow regime** (supercritical, subcritical, or mixed),
   - The **representation of the vertical drop**, and
   - The **boundary conditions**.

   Plot the resulting water surface profile and compare it with your results from part (c). Discuss the reasons for any agreement or discrepancy between the two results. Your discussion must address, at a minimum, the following points:

   - How each model **represents and handles** the vertical drop,
   - The influence of the selected **step size (Downstream Reach Lengths and XS's interpolation)** on numerical accuracy,
   - Potential **differences in the governing equations** or in their numerical implementation that could explain the observed discrepancies,
   - The **limitations** of both models when representing the flow conditions near point B, and
   - Possible **alternative modeling approaches (software)** that may more accurately capture the hydraulic behavior around the drop.

5. **Model Performance in Complex Conditions (2 pts)** Reflect on the performance of both models (DSM and HEC-RAS) when applied to a natural mountain river with irregular topography and complex flow conditions. Discuss:

   - The main limitations of these 1D models in such environments,
   - Other modeling approaches you would consider (e.g., 2D or 3D models) and why,
   - The additional data or information required to implement those models, and
   - How factors such as model dimensionality, flow complexity, time constraints, and project objectives influence the choice of the most appropriate modeling approach? Comment.