Water Resources Engineering and Management

Exercises Lecture 5: Hydropower and flood control

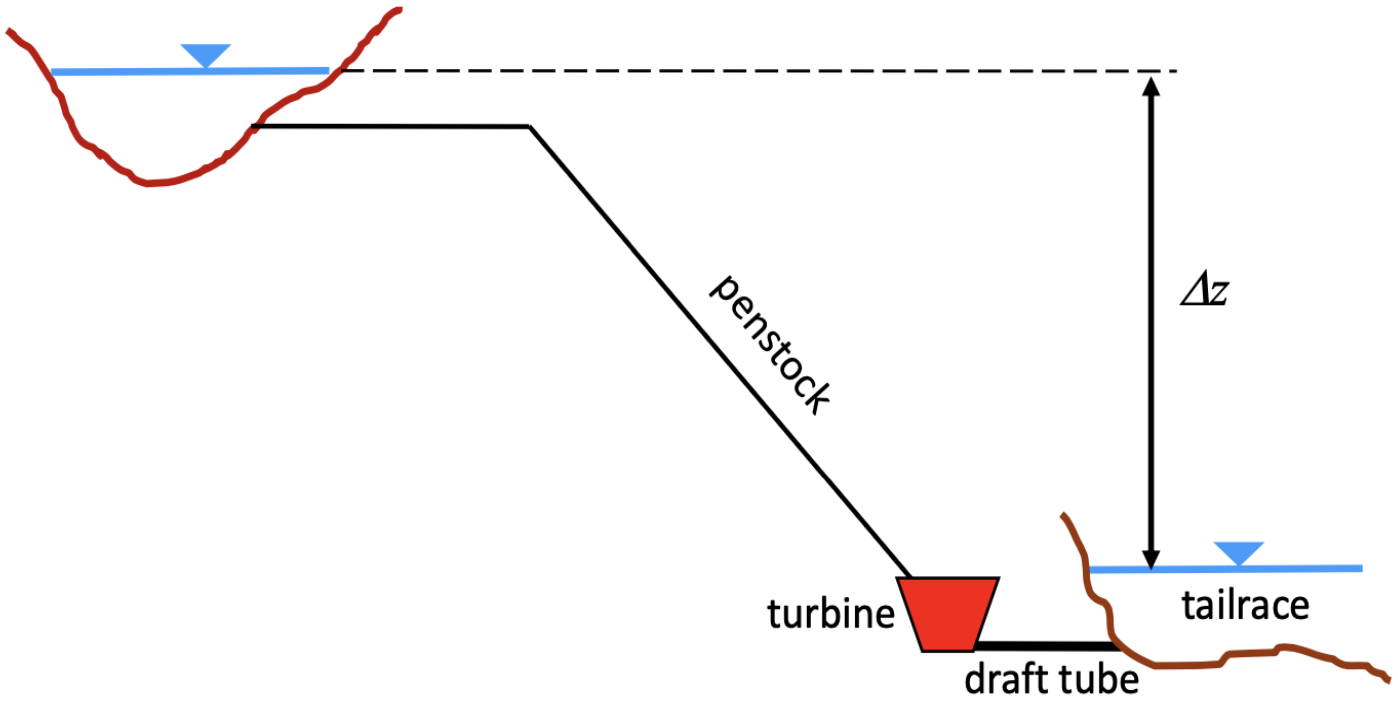
17/03/2025

Exercise 1: Hydropower with storage

A turbine with known operational properties is installed between the two reservoirs sketched in figure, with constant elevation difference between water level. The geometrical and hydraulic characteristic of the penstock are given. The power plant does not work continuously throughout the day.

DATA and ASSUMPTIONS

- Penstock length → L_P = 250 m
- Penstock diameter → D_P = 1 m
- Draft tube length → L_D = 30 m
- Draft tube diameter → L_D = 2.5 m
- Penstock and draft tube roughness → k_s = 0.1 mm
- Inlet loss coefficient of the penstock → ξ_{IN} = 0.5
- Outlet loss coefficient of the draft tube → ξ_{OUT} = 1
- Elevation difference → Δz = 100 m
- Flow rate → Q = 8 m^3/s
- Turbine efficiency → η = 0.8
- Working duration → K_t = 6 hours/day



QUESTIONS

- Determine the power P_T generated by the turbine
- Determine the yearly energy production E_T

Exercise 2: Run-of-river hydropower plant

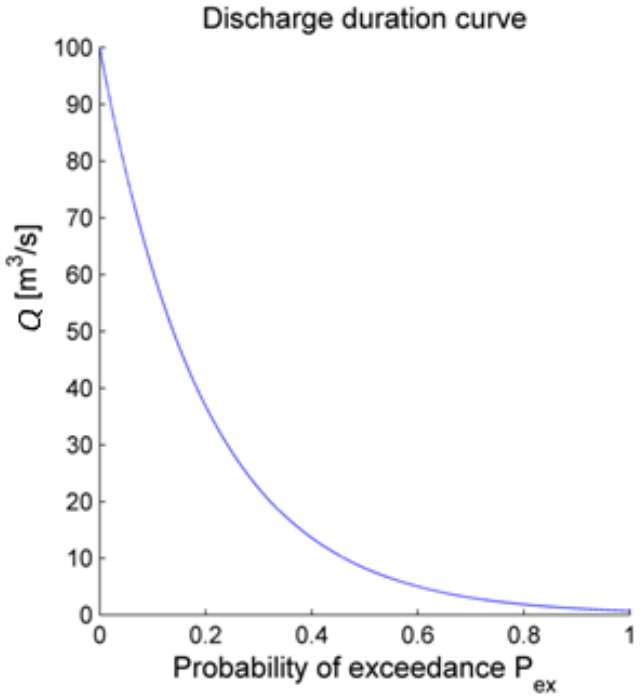
A run-of-river hydropower plant is installed in a river site characterized by a known discharge duration curve in terms of the P_{ex} the exceedance probability (i.e. the fraction of time a certain discharge is equalled or exceeded).
The tailwater rating curve can be approximated as $y[\mathrm{m}] = 0.05\,Q$, where y is the water depth in the tailwater channel.
The water depth in the forebay can be maintained constant for the whole range of discharges considered (0-100 m^3/s).
The hydraulic capacity Q_R of the plant is equal to the discharge that is exceeded 30% of the time ($P_{ex,R}$=0.3).
A horizontal-shaft Kaplan turbine is installed with rated discharge equal to the hydraulic capacity.
The minimum discharge allowable in the turbine is 35% of the rated discharge.
The ratio between the minimum and maximum allowable heads is equal to 0.33.

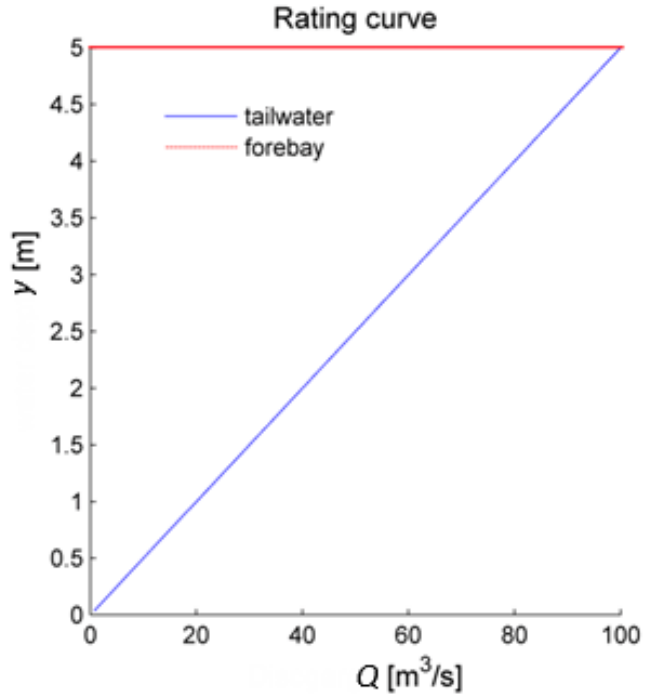
DATA and ASSUMPTIONS

- Flow duration curve → $Q[\mathrm{m}^3/s] = 100\,e^{-5\,P_{\mathrm{ex}}}$
- Flow rating curve → $y = 0.05\,Q$
- Forebay water depth → y_F = 5 m
- Hydraulic capacity → $Q_{\mathrm{R}} = Q(P_{\mathrm{ex},R})$
- Minimum flow rate → $Q_{\mathrm{MIN}} = 0.35\,Q_{\mathrm{R}}$
- Turbine efficiency → η = 0.8
- Min-to-max head ratio → K_H = 0.33 m
- Negligible head losses in the power plant

QUESTIONS

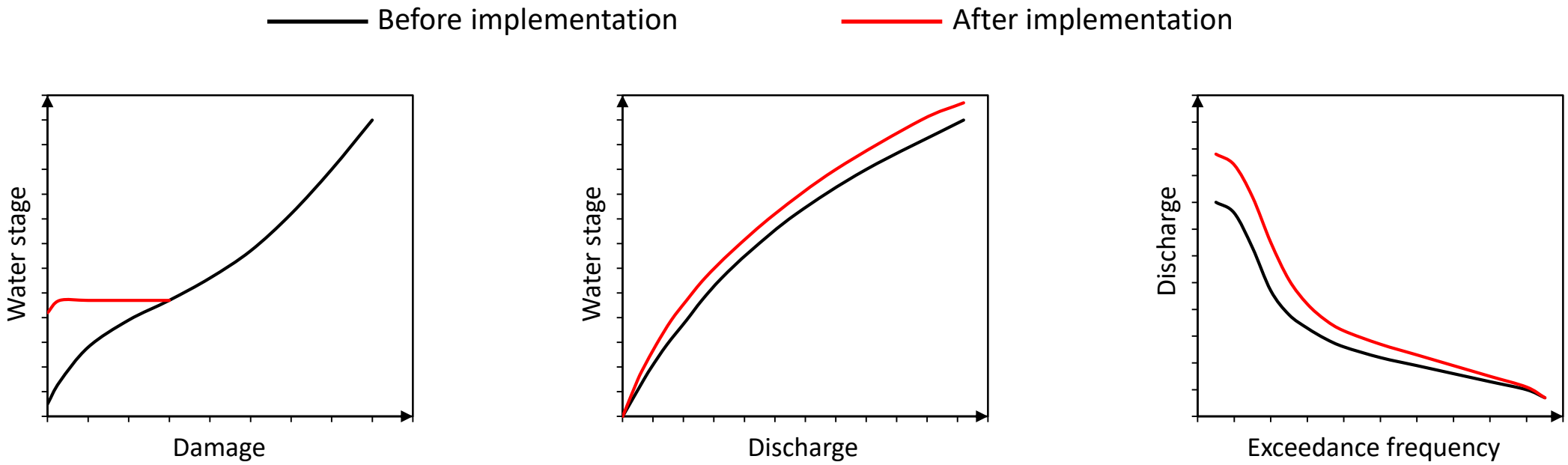
- Determine the expected annual energy production E_T





Exercise 3: Flood control

As a consequence of the implementation of a flood control measure, the flood assessment functional relationships are modified as illustrated below.



QUESTIONS

- Describe what type of flood control measure can produce such modifications
- Qualitatively derive the damage-exceedance frequency relationship and the annual expected damage before and after the implementation of the flood control measure