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Hydraulic structures. Dams and reservoirs

Dam outlet works and Energy dissipation - 1

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HYDROENGINEERING STRUCTURES-4

Dam Outlet Works and Energy Dissipation

1. Introduction
2. Design flood
3. Spilways
4. Bottom outlets
5. Energy dissipation

Introduction

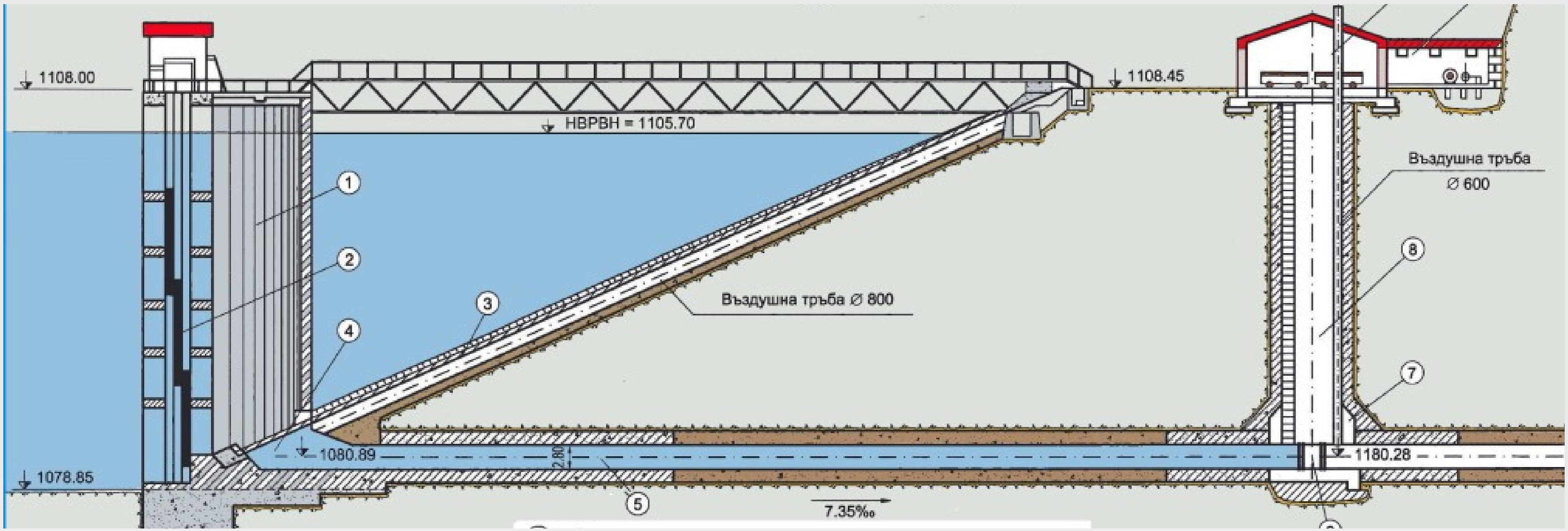
Dams outlet works

in general

Spillways

Bottom outlet

Other outlet works

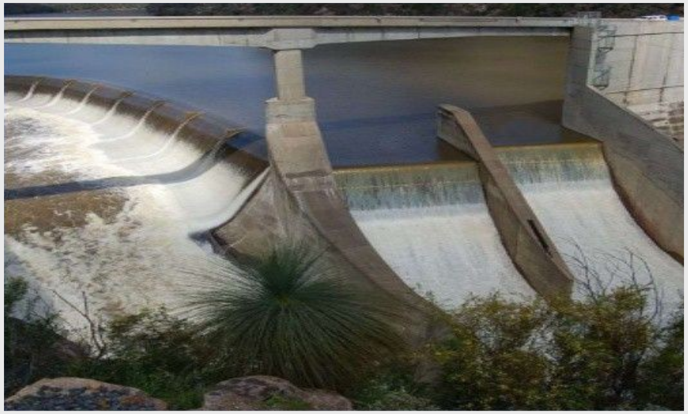


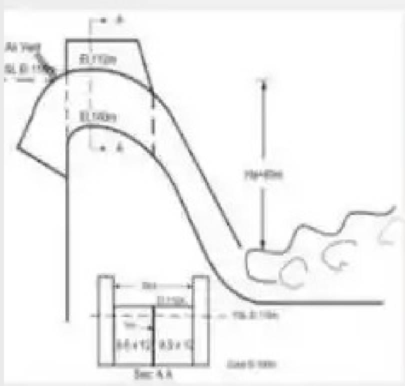
for different needs:

- *electricity production*
- *water suplly*
- *irrigation*
- *other*

Basically, Spillways ensure a safe passage of floods from the reservoir into the downstream river reach.

Different designs of spillways





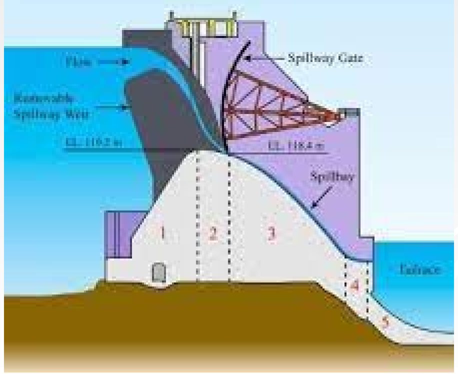
depend on:

- the design flood,
- dam type and location
- reservoir size and operation

Classification of spillways

1.according to the function spillways are: **main** service, **emergency** and **auxiliary** ;

2.according to mode of control: **free (uncontrolled)** or **gated (controlled)** spillways

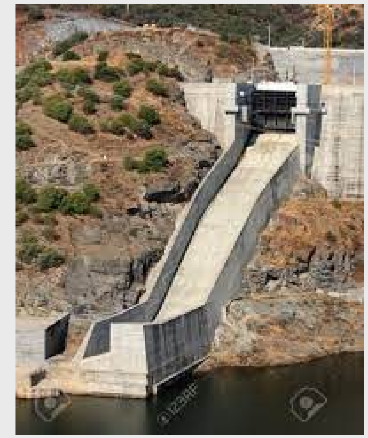


3. according to hydraulic criteria, i.e. type:

Overfall

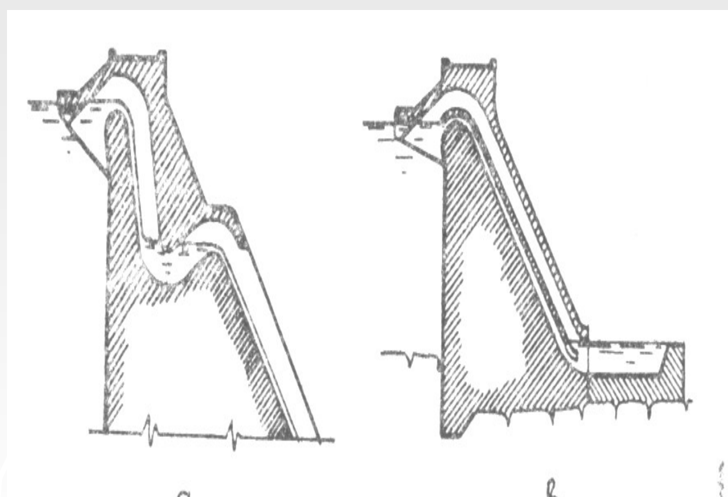
Side channel

Chute



Shaft

Siphon



Tunnel

Selection of a spillway

Main factors governing the choice of spillway are:

1) the reliability and accuracy of flood prediction,

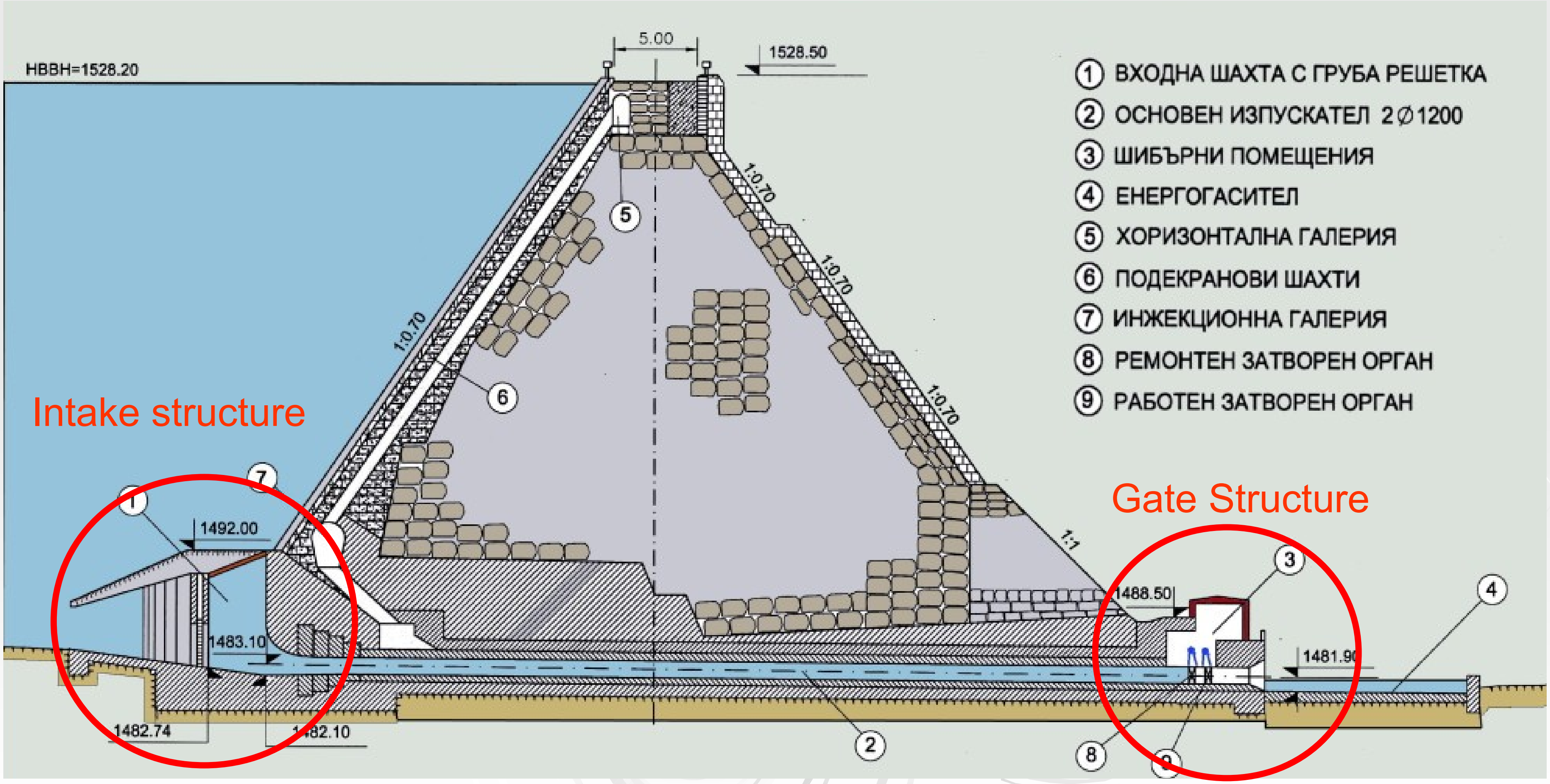
2) the duration and amount of spillage,

3) seismicity of project site, topography and geology,

4) the dam type.

The design of bottom outlet depends on:

- the topography;
- the sediment inflow and deposition in the reservoir.



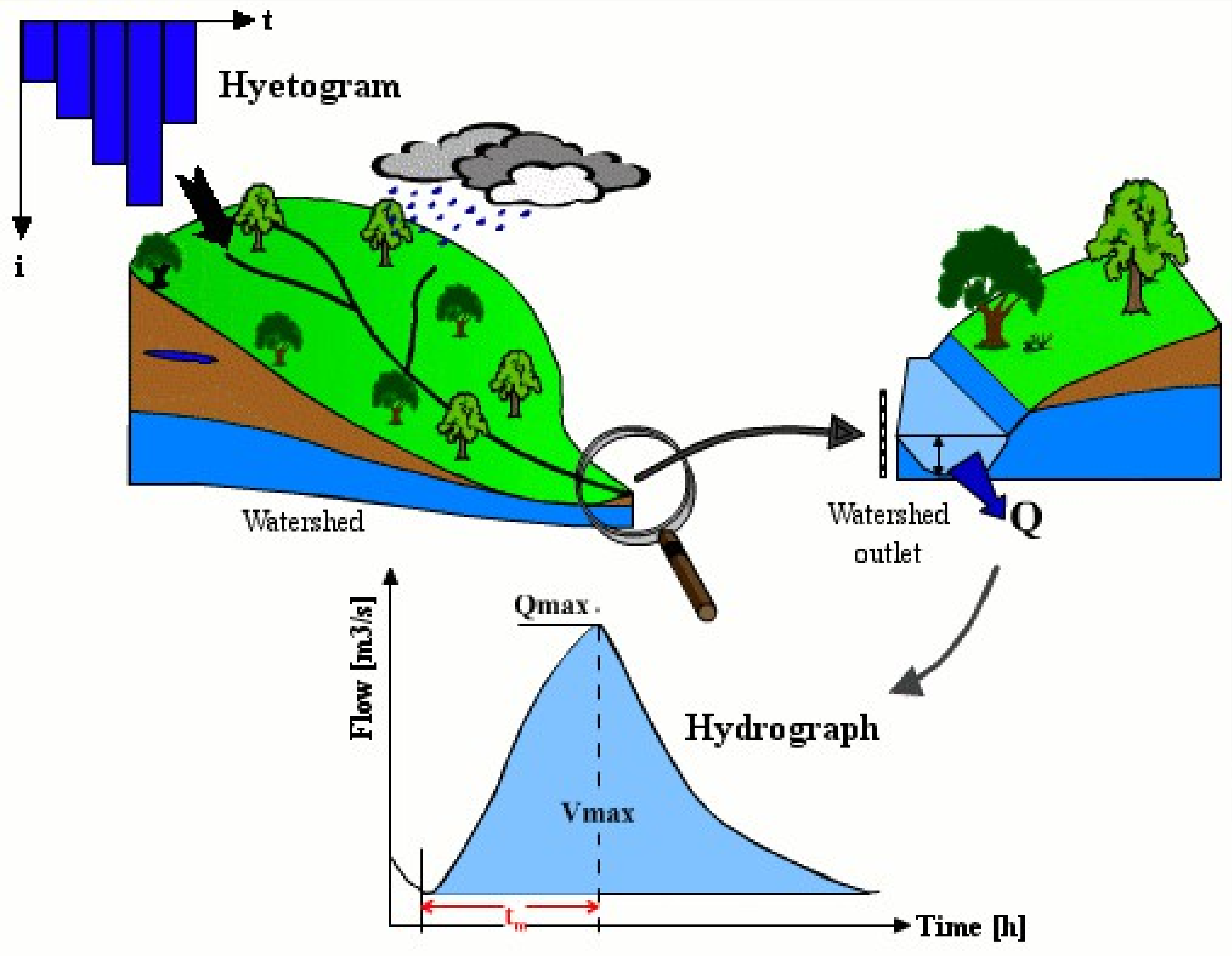
Day 09: #1

Watching video!

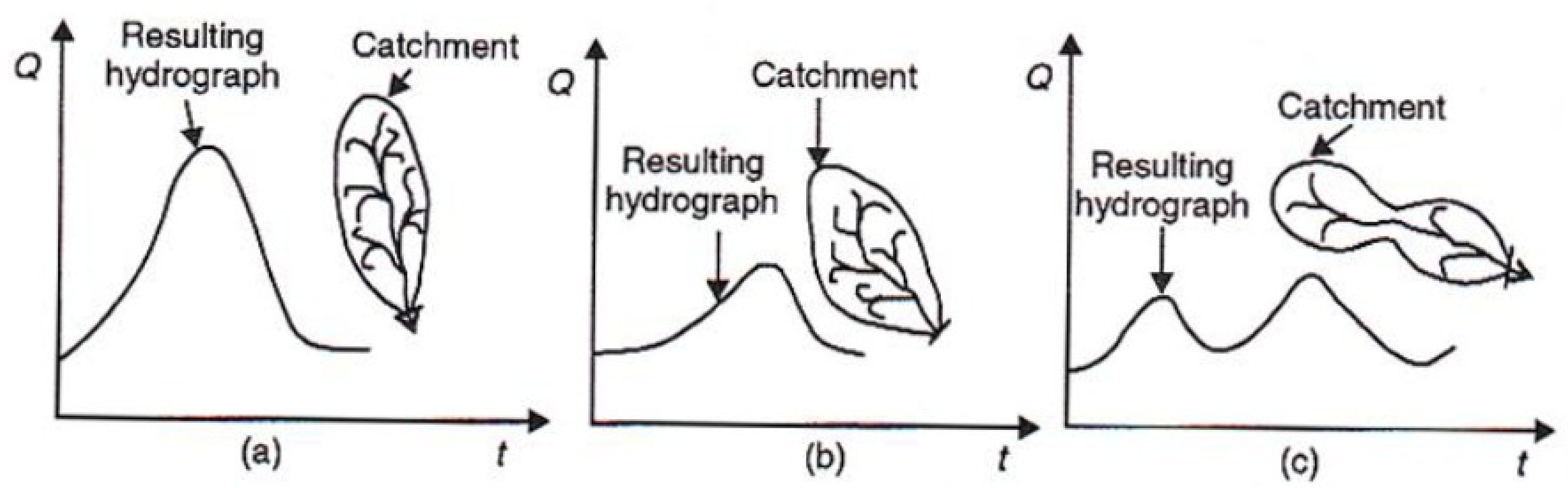
What is a spillway and how does it work?

https://www.youtube.com/watch?v=gLjabuiMqXE

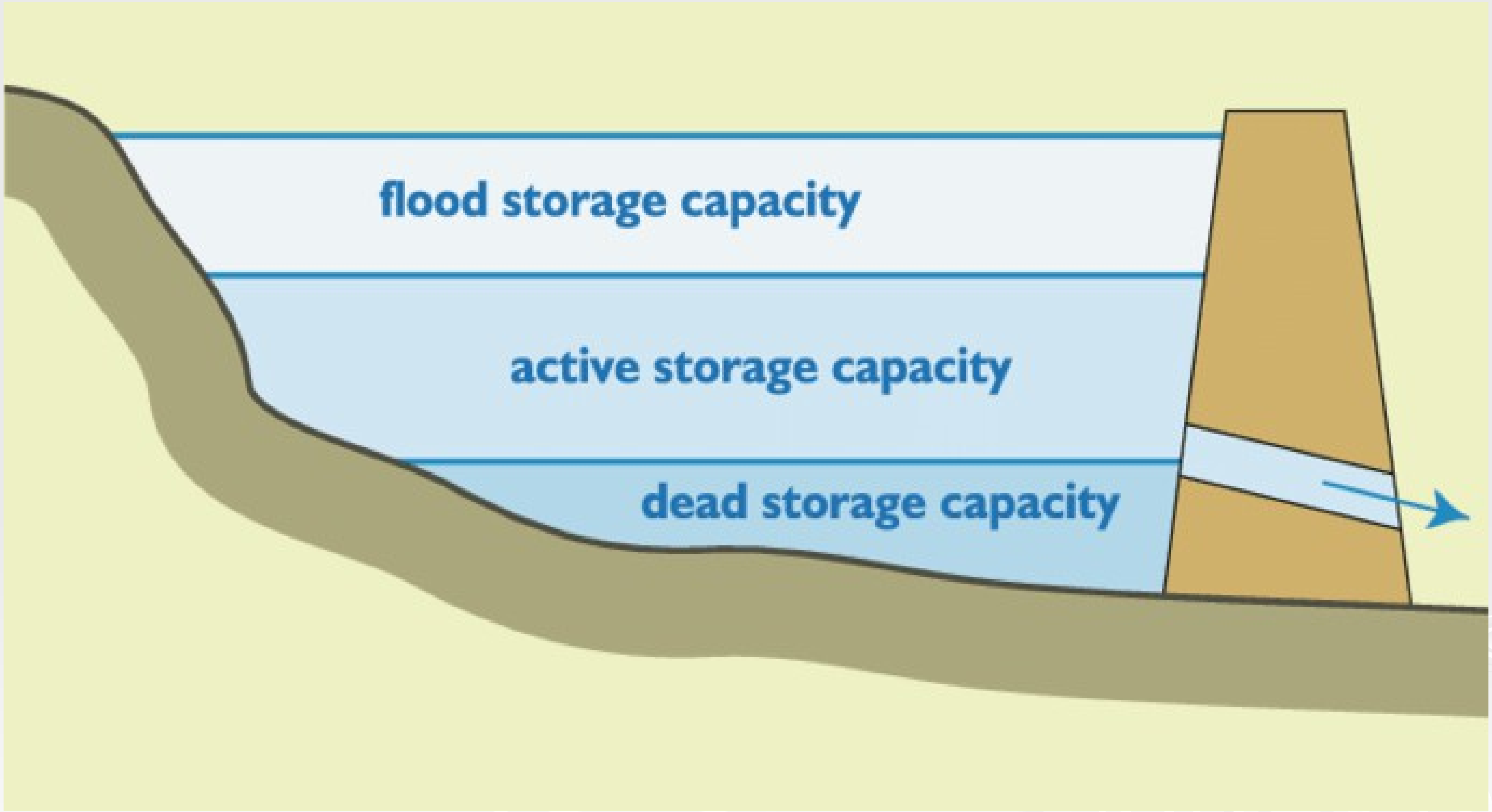
Design flood



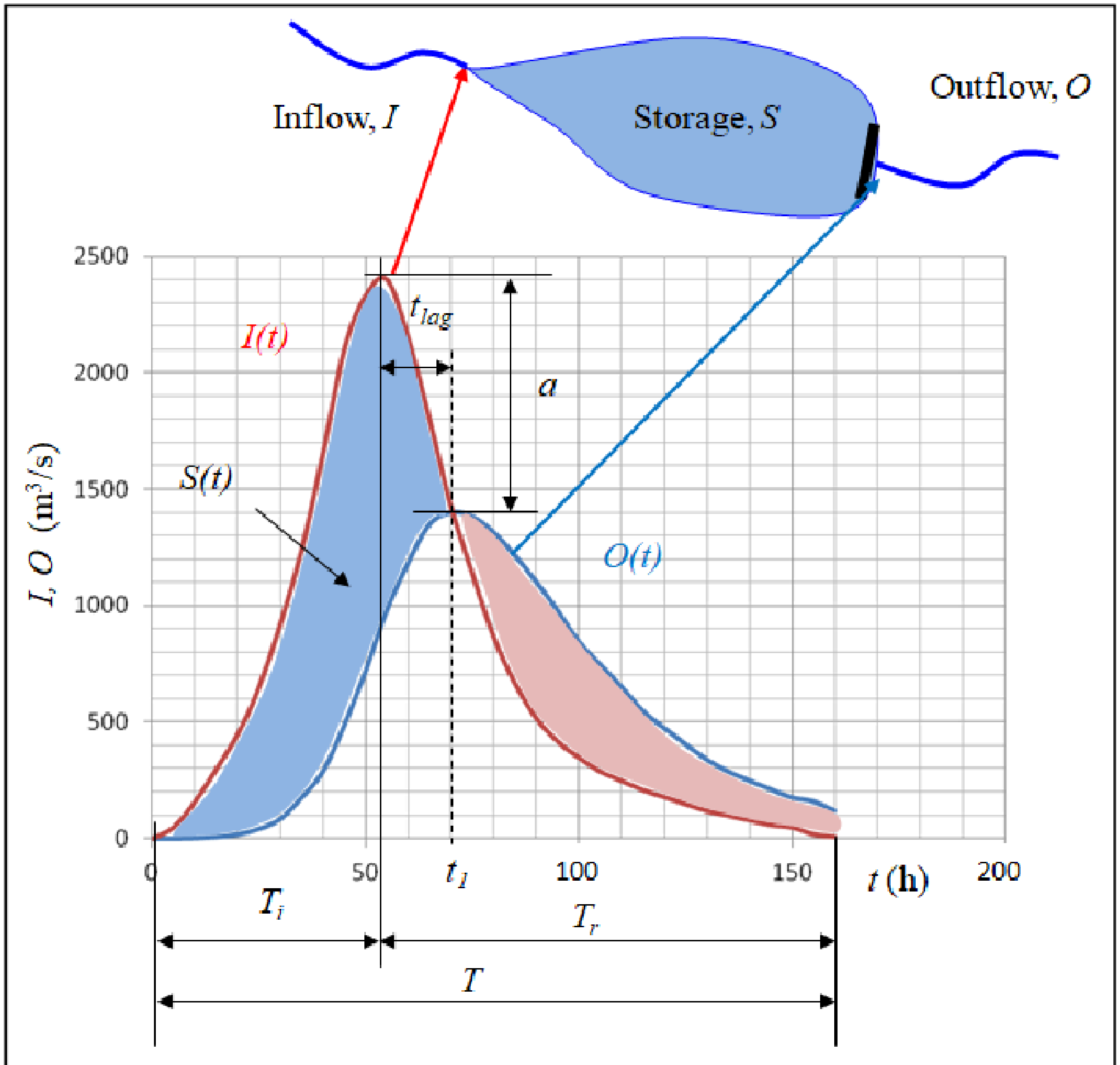
Class of the Dam	Design Flood Probability
1st class	P=0,01 % (1 in 10 000 years)
2nd class	P=0,1 % (1 in 1000 years)
3th class	P=0,5 % (1 in 200 years)
4th class	P=1 % (1 in 100 years)



Flood routing by the storage capacity of a reservoir



Schematic of a reservoir routing process



Balance equation

Vin = ∆V – Vspill – Vво + Vp – Vf – Ve,

where:

Vin – volume of the inflow hydrograph ;

∆V – change in the volume of the reservoir ;

Vspill – outflow volume trough the spillway ;

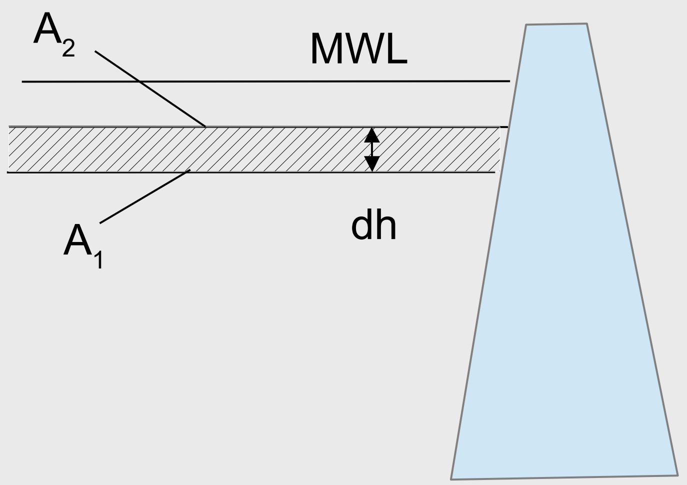
Vbo – outflow volume trough the other outlet works; (=0)

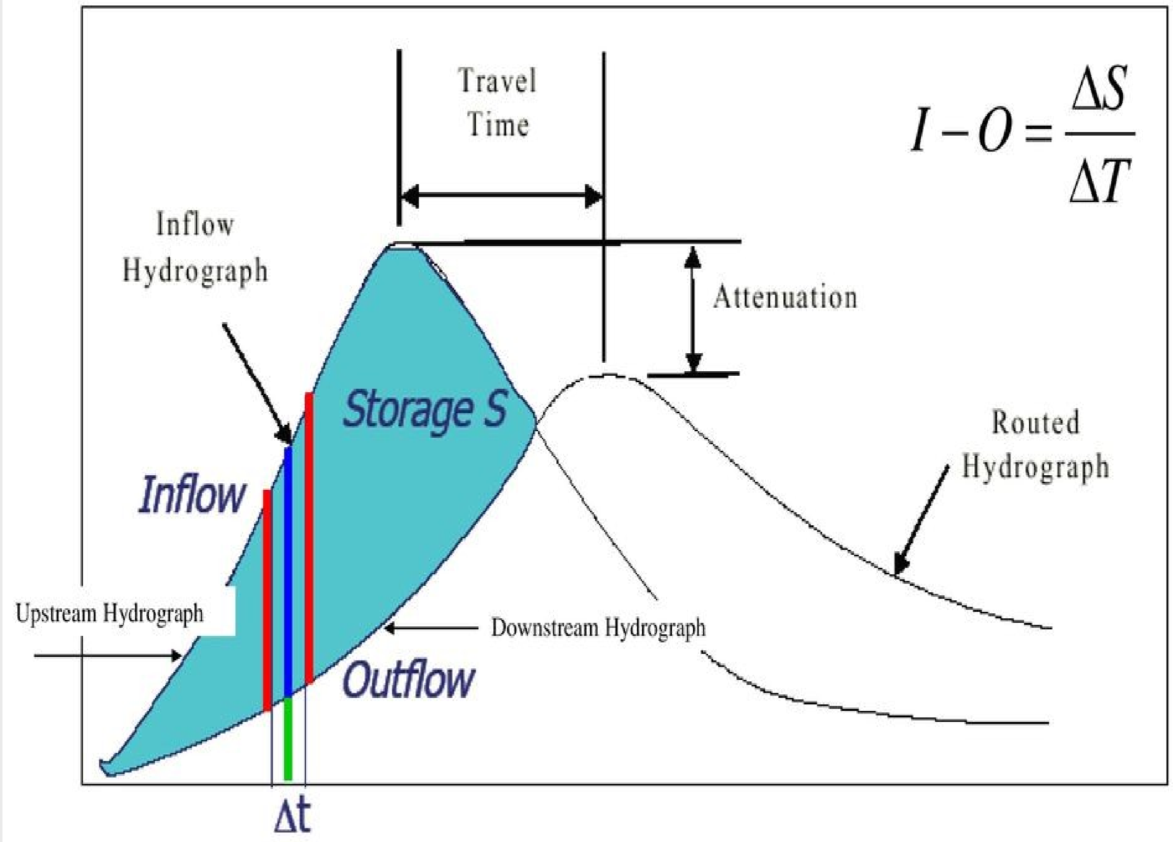
Vp – volume of dirrect rainfall on the storage area ; (=0)

Vf – outflow volume by infiltration; (=0)

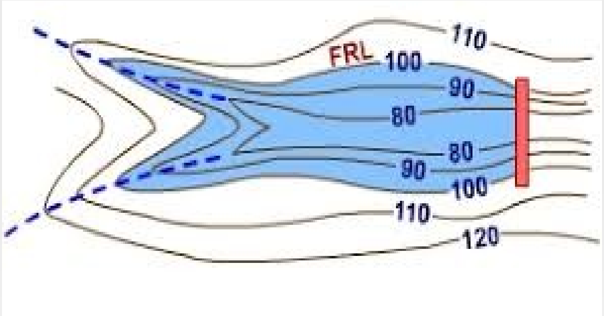
Ve – outflow volume by evapotranspiration (=0)

Vin = ∆V – Vspill





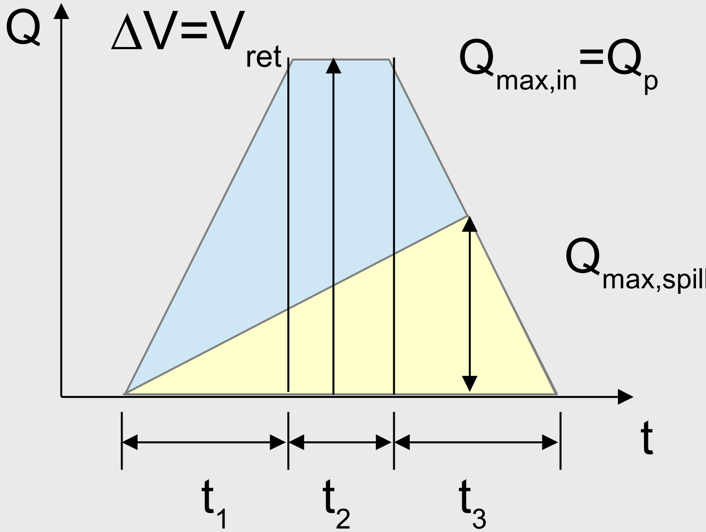
$$I - O = \frac{\Delta S}{\Delta T}$$

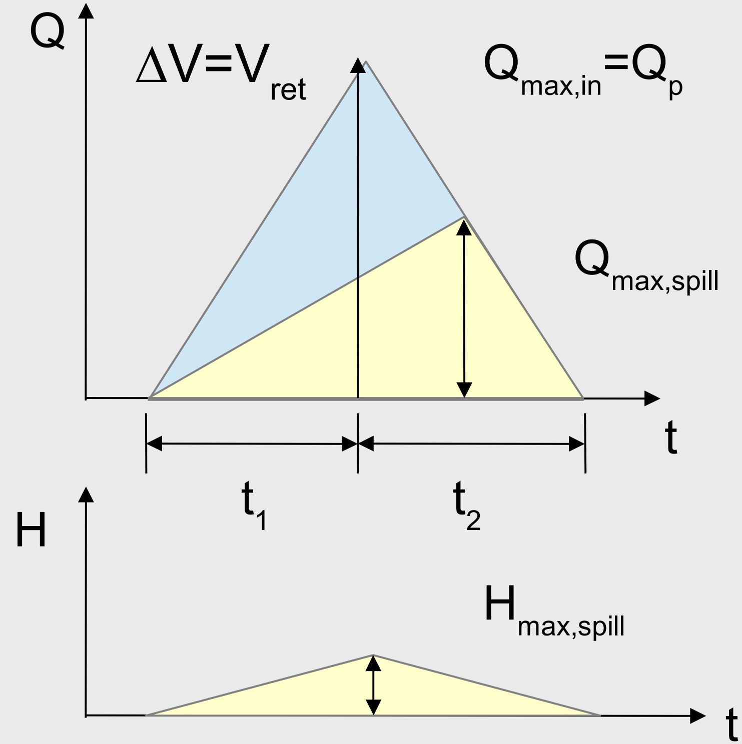


Contures of storage areas - A

$$dQ_{inflow}\, dt = Adh + dQ_{outfow} dt$$

$$A = (A_1 + A_2)/2$$





$\Delta V = V_{ret} = V_{in} - V_{spill}$ - area of blue trapezoid or triangle

$V_{in} = 0{,}5 Q_p (t_1 + t_2)$

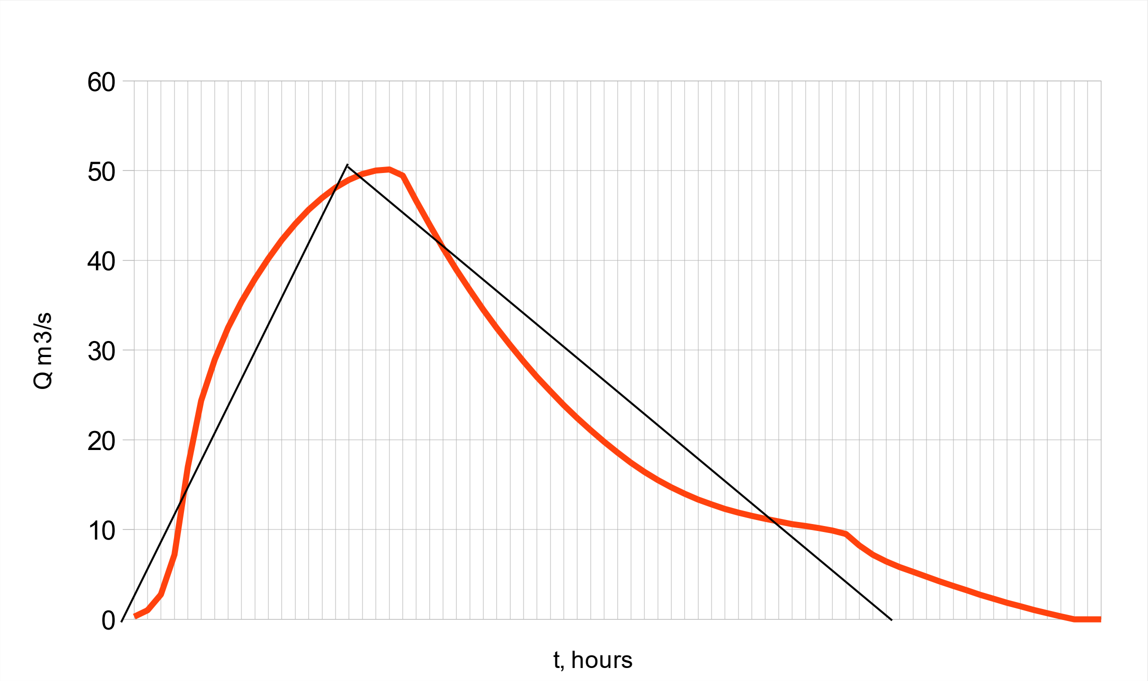
$V_{spill} = 0{,}5 Q_{max,\ spill} (t_1 + t_2)$ - area of yellow triangle

$V_{ret} = V_{in} - Q_{max,\ spill} (V_{in} / Q_p)$

$V_{ret} = A.H_{max}$

Q_p=50,12 m^3/s

V_{in}=5279906 m^3

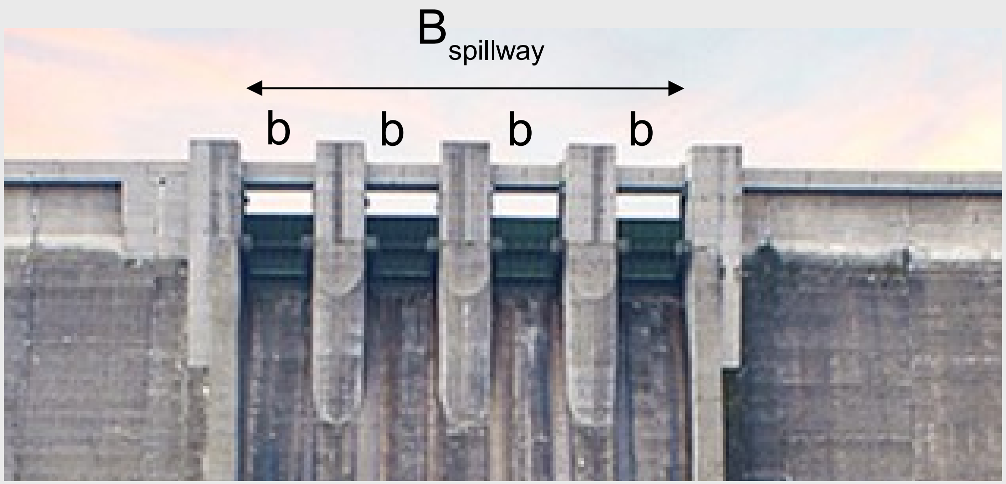


V_{spill}= $0,5Q_{max, spill}(t_1+t_2)$

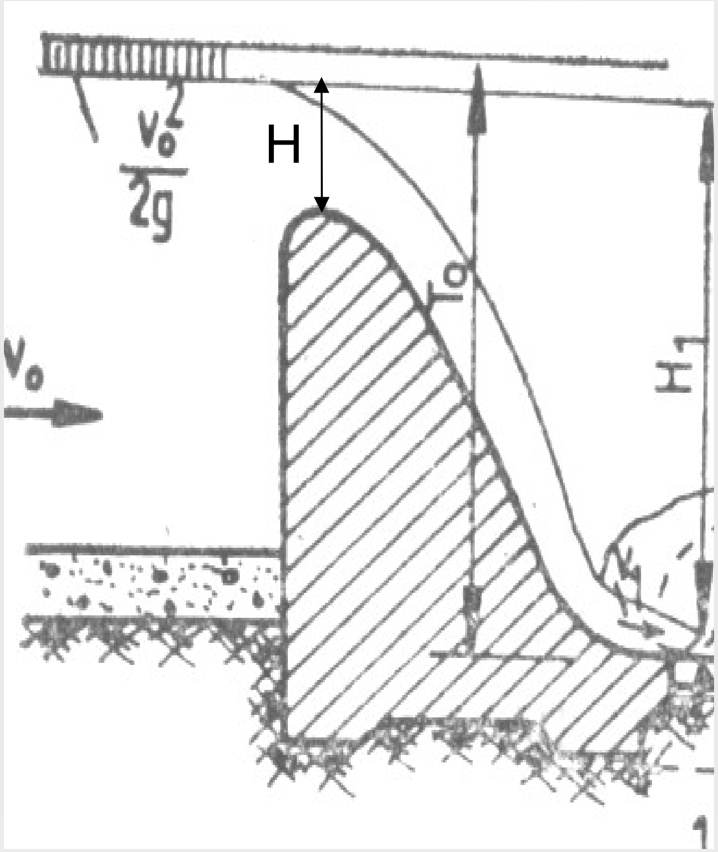
$Q_{max, spill}$ = ?

Calculation with Iterations

Spillway Design

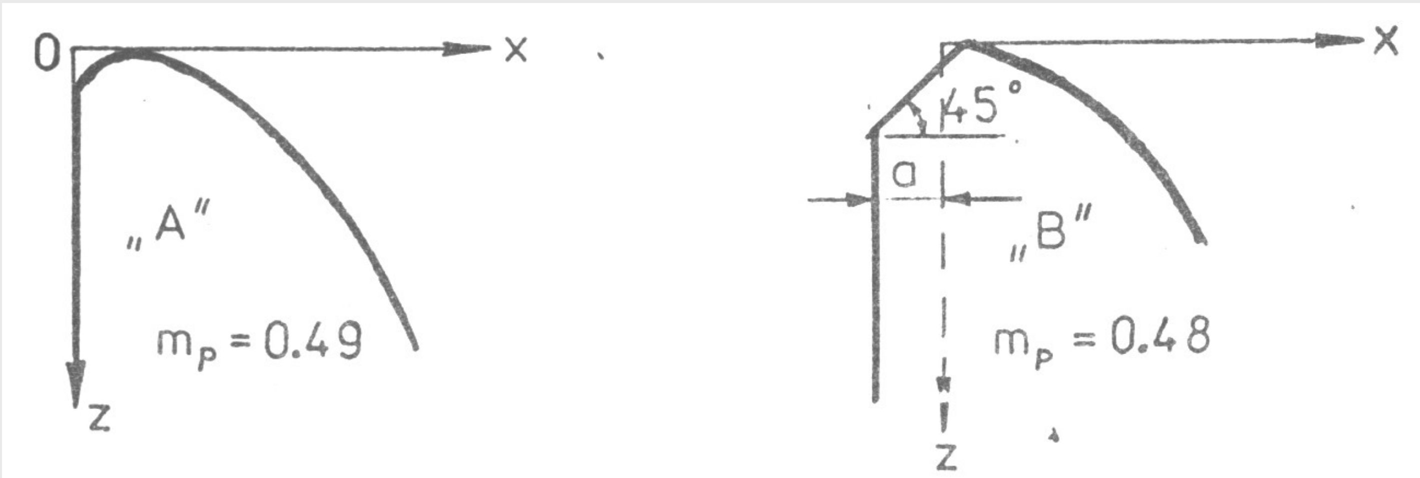


Overfall spillway (Ogee spillway)



$$Q = m\sum b\sqrt{2g}H^{\frac{3}{2}}, where: H = H + \frac{\alpha v^2}{2g}$$

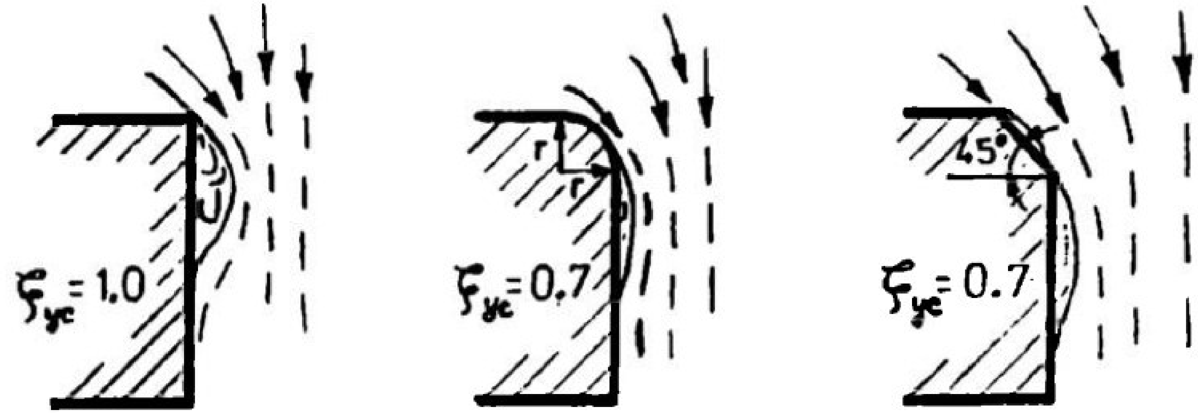
Standard spillway crest by Kriger-Officerov case A and B:



$m_p = m$ is coeficient of discharge

the spillway coordinates /x,z/ have to multiply by H;

x	z		x	z		x	z	
	тип A	тип B		тип A	тип B		тип A	тип B
1	2	3	4	5	6	7	8	9
0.0	0.126	0.043	0.8	0.146	0.189	2.5	1.960	2.14
0.1	0.036	0.010	1.0	0.256	0.321	3.0	2.824	3.06
0.2	0.007	0.000	1.2	0.394	0.480	3.5	3.818	4.08
0.3	0.000	0.005	1.4	0.564	0.665	4.0	4.938	5.24
0.4	0.006	0.023	1.7	0.873	0.992	4.5	6.220	6.58
0.6	0.060	0.090	2.0	1.235	1.377			



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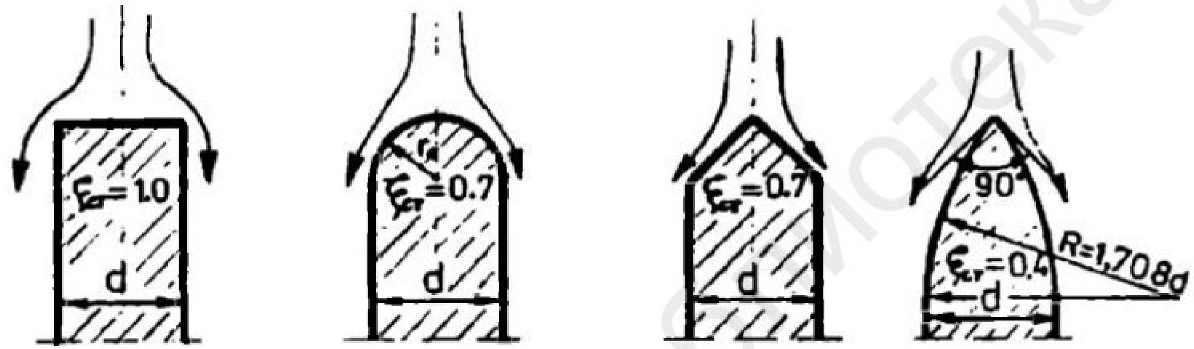
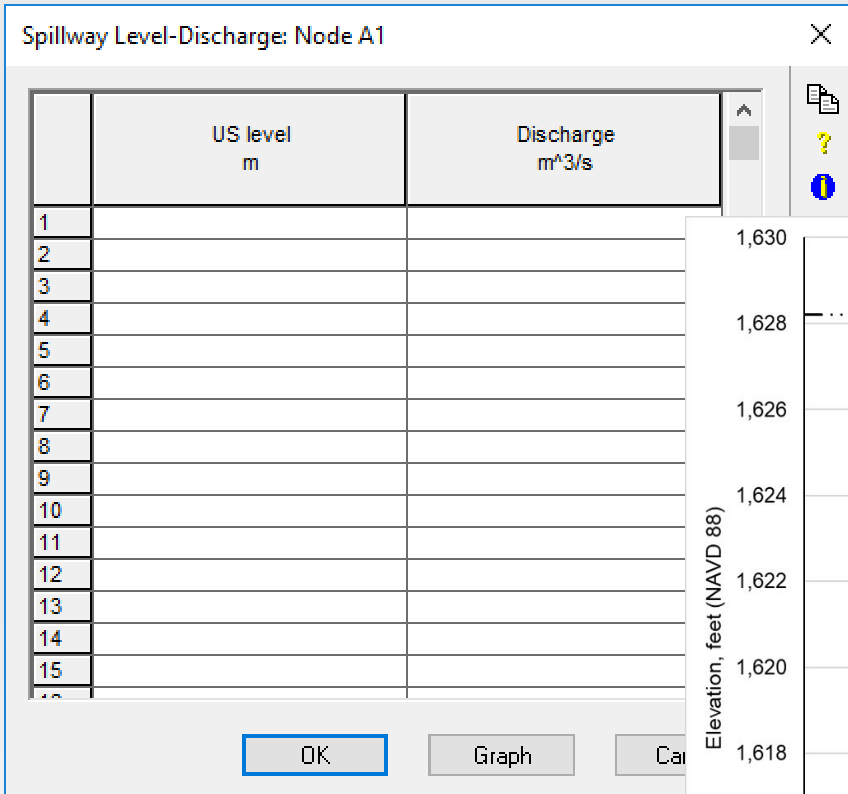


$$Q = m\varepsilon b\sqrt{2g}H_0^{3/2}$$

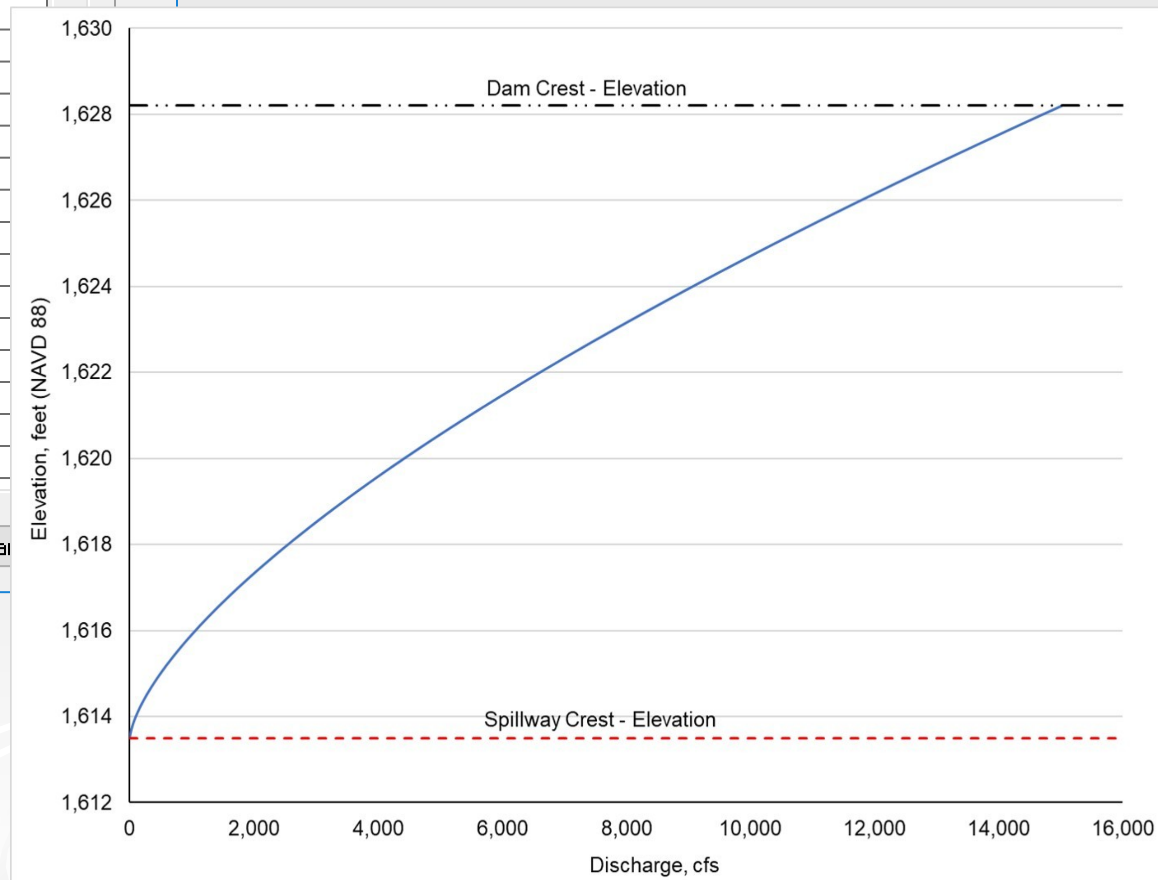
$$\varepsilon = 1 - 0.2\frac{\xi_{ус} + (n-1)\xi_{ст}}{nb}H_0$$

n – nunber of opens

Drawing rating curve of a spillway



$$Q = m\sum b\sqrt{2g}H^{\frac{3}{2}}$$



Day 09: #2

Exercise

How to elaborate a rating curve of a spillway?

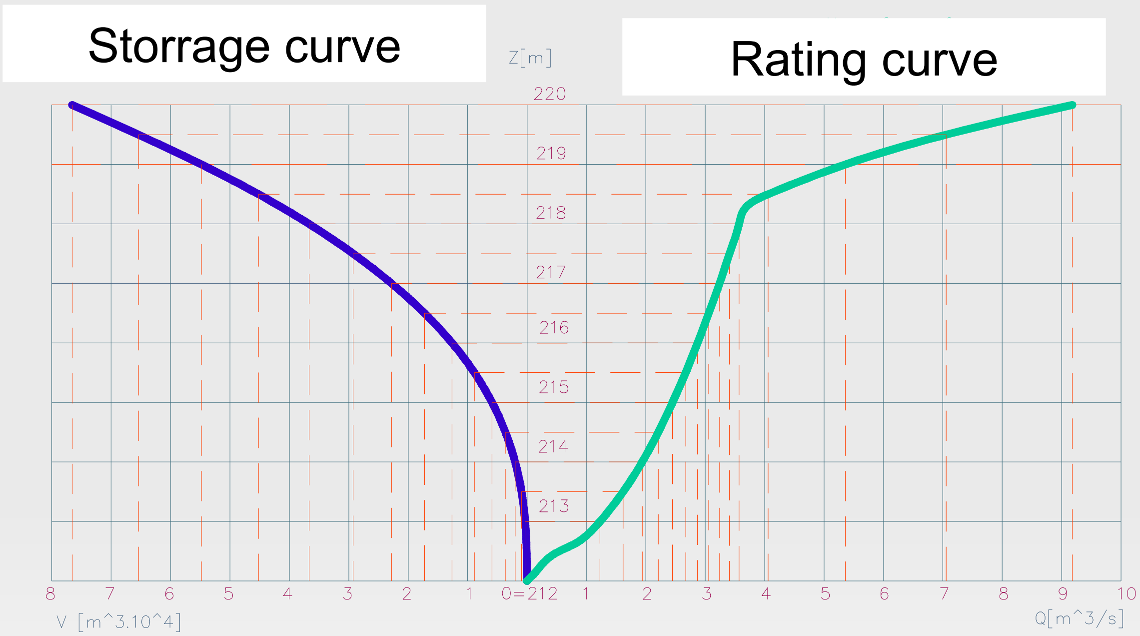
Input data:
b=.... m – spillway wide
n=.... – nomber of opening
H=.... m – spillway water level

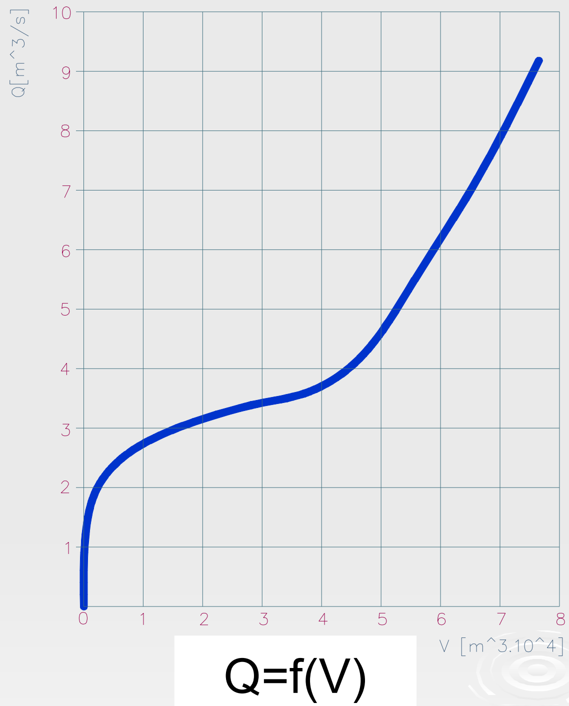
Please solve the spillway equation in a table as you start with H=0 to H=Hmax! After that draw a rating curve!

$$Q = m\sum b\sqrt{2g}H^{\frac{3}{2}}, where: H = H + \frac{\alpha v^2}{2g} \qquad 0$$

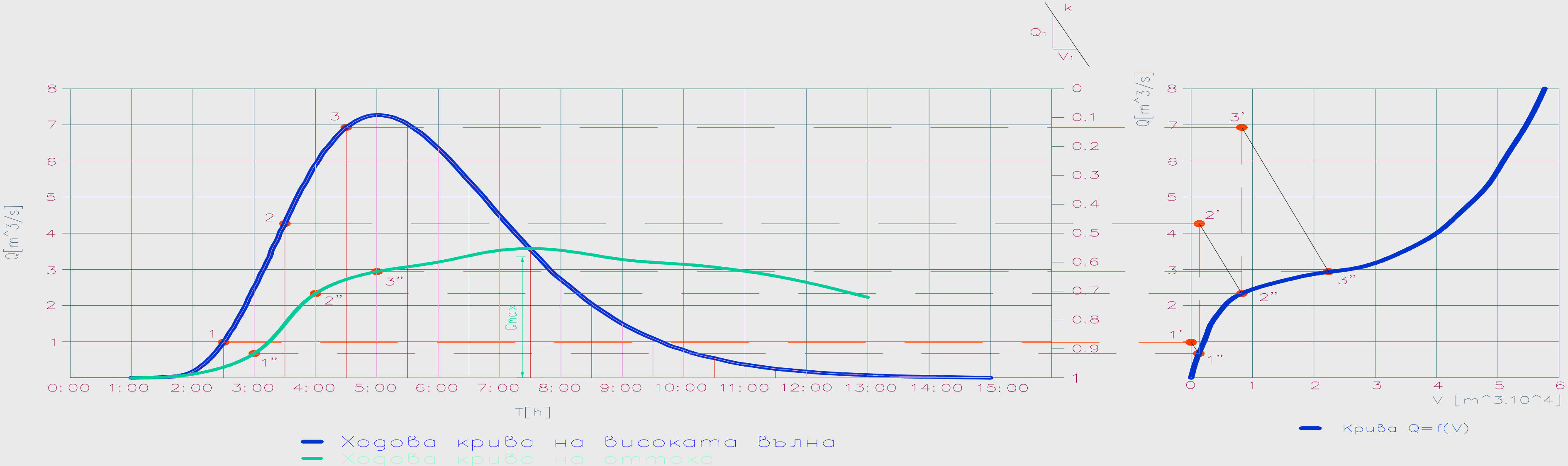
Please solve the balance equation and define the V_{ret}!

Graphical method for flood routing





Graphical method for flood routing

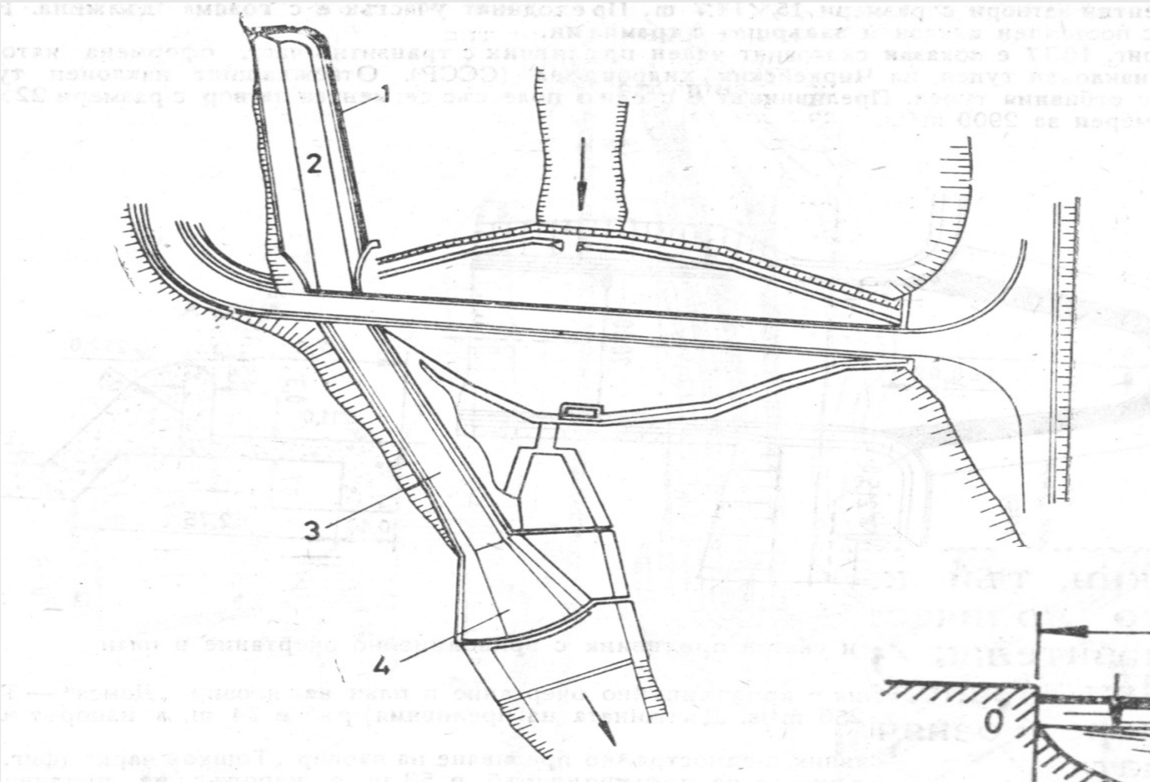


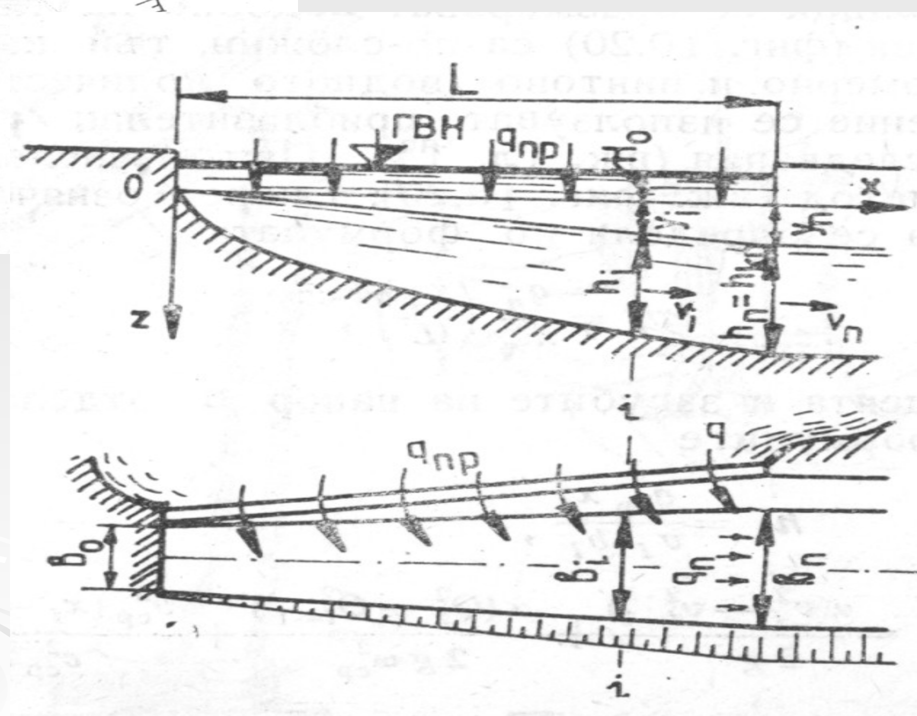
Day 09: #3

Exercise:

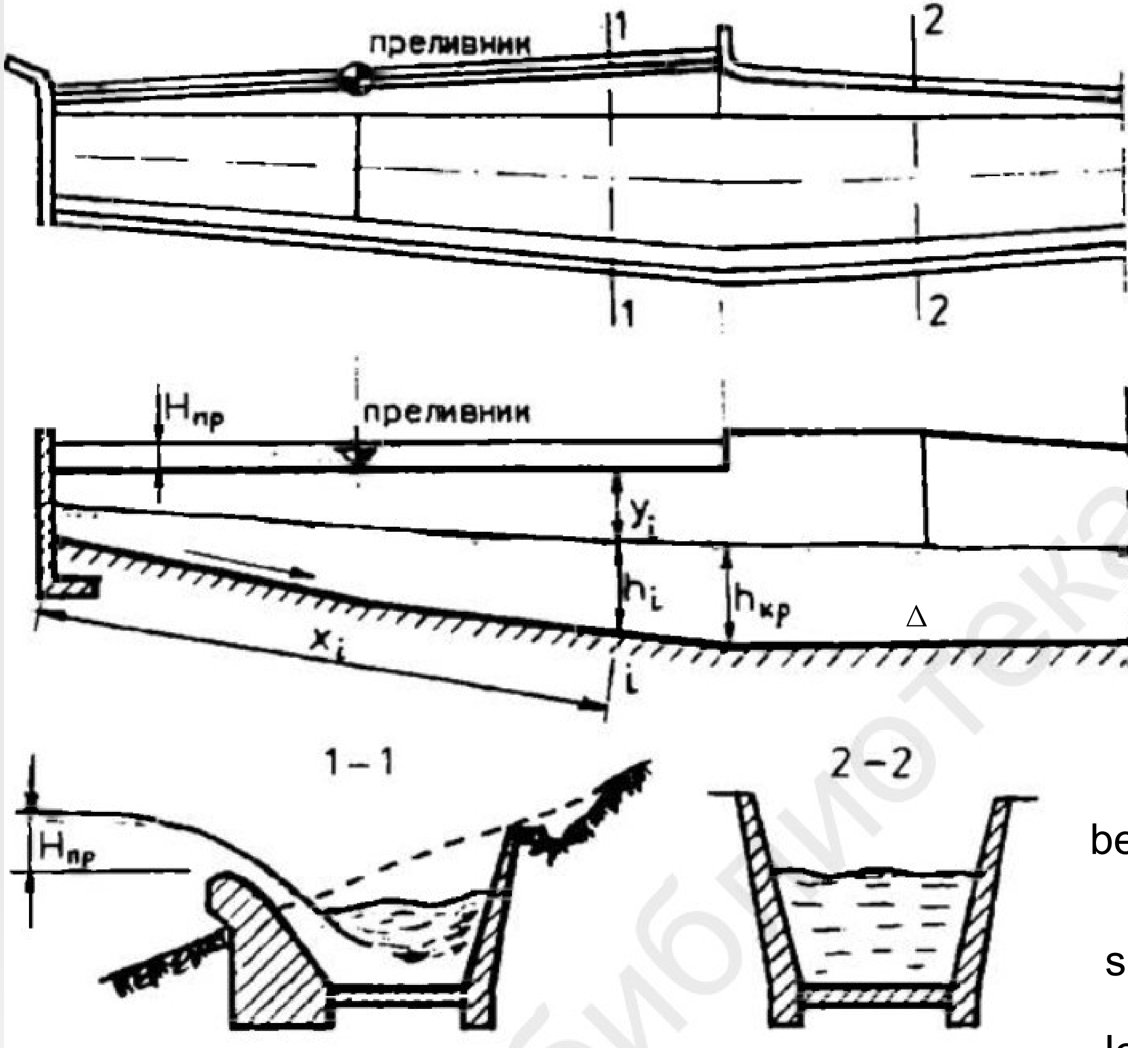
Drowing routed hydrograph

Side spillway





1 – spillway crest
2 – trench
3 – chute
4 – stilling basin



$$v_i = a x_i^n; \qquad a = \frac{v_{кр}}{L_{пр}^n};$$

$$y_i = \frac{n+1}{n}\,\frac{v_i^2}{2g};$$

$$\Delta y_i = \frac{Q_{i-1}}{g}\,\frac{v_{i-1}+v_i}{Q_{i-1}+Q_i}\left(\Delta v_i + \frac{q_* v_i \Delta x}{Q_{i-1}}\right)$$

Vi – velocity in i-section;
Vкр – critical velocity at the end of the trench

∆Vi – change in velocity between each two sations

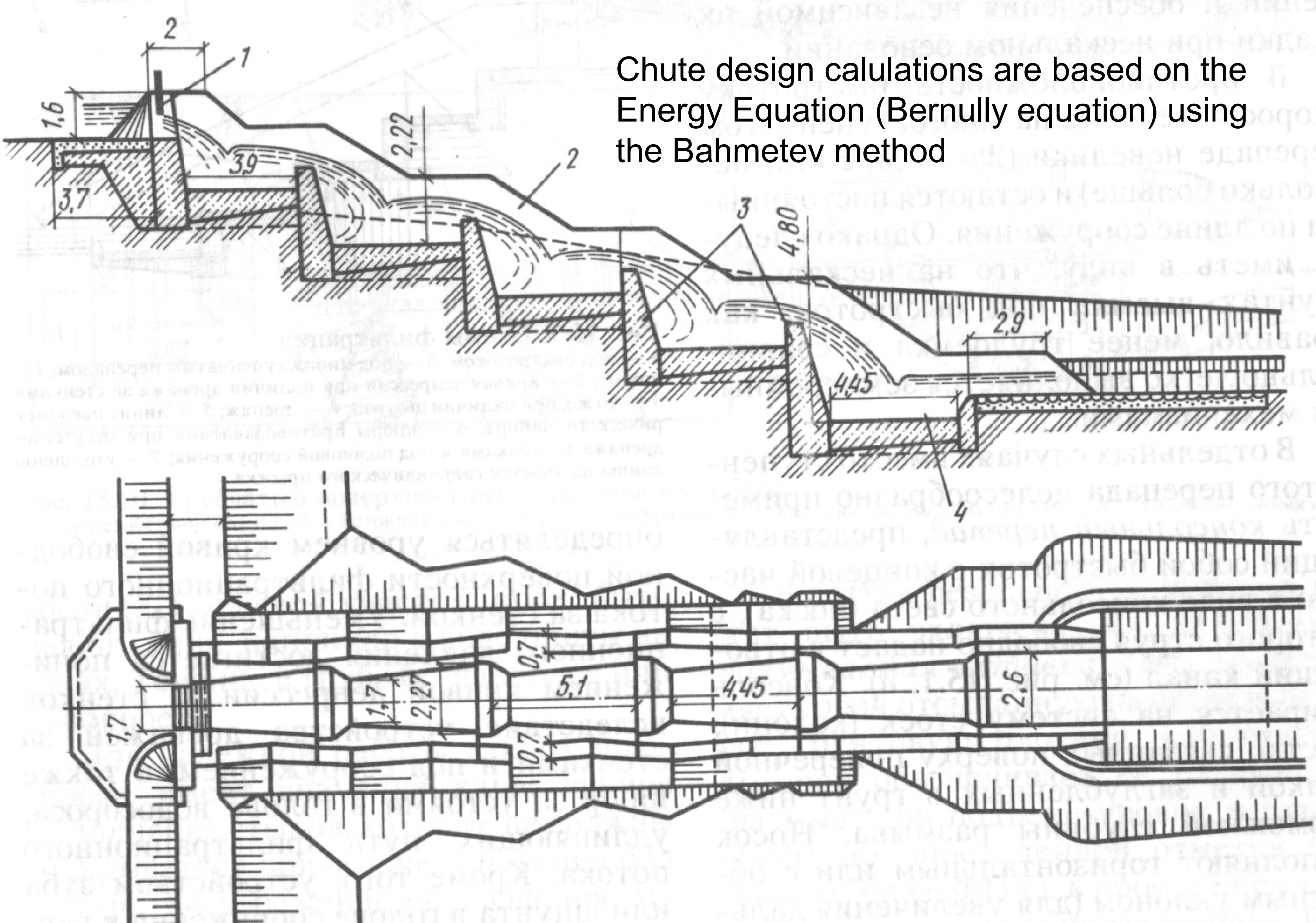
∆x – distance between two sations

∆yi – reguction of the water level between two sations

The trench is separated in 5-10 sections and the parameters bellow are calculated between each two sections.

$$Q_i = q_* x_i; \qquad \omega_i = \frac{Q}{v_i}; \qquad h_i = \frac{\omega_i}{b_i}; \quad y_i \quad и \quad H_i = h_i + y_i$$

Chute design calulations are based on the Energy Equation (Bernully equation) using the Bahmetev method



Frictionless Flow: The Bernoulli Equation

- Closely to the steady flow energy equation is a relation between pressure, velocity, and elevation in a frictionless flow, now called the *Bernoulli Equation*.
- For an unsteady frictionless flow

$$\int_1^2 \frac{\partial V}{\partial t}\,ds + \int_1^2 \frac{dp}{\rho} + \frac{1}{2}(V_2^2 - V_1^2) + g(z_2 - z_1) = 0$$

- For steady frictionless flow

$$\frac{p_2 - p_1}{\rho} + \frac{1}{2}(V_2^2 - V_1^2) + g(z_2 - z_1) = 0$$

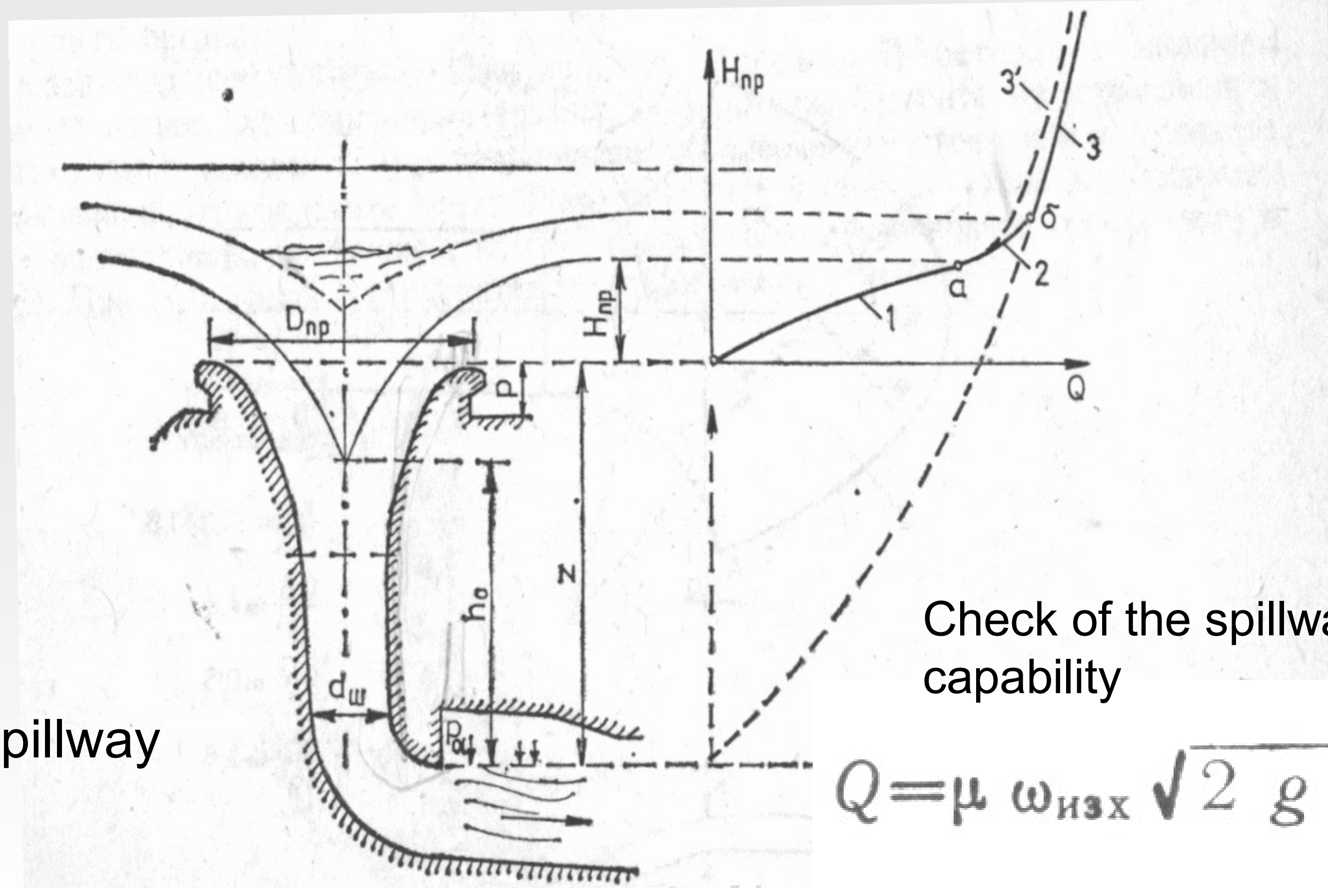
$$\frac{p_1}{\rho} + \frac{1}{2}V_1^2 + gz_1 = \frac{p_2}{\rho} + \frac{1}{2}V_2^2 + gz_2 = \text{const}$$

- in case of k-numbers of pillars with width „d“

1) $$Q = m_{об}\,\varepsilon\,(2\pi R - k\,d)\sqrt{2g}\;H_{пр}^{3/2};$$

- in case of no pillars

2) $$Q = m_{об}\,2\pi R\sqrt{2g}\;H_{пр}^{3/2}.$$



Shaft spillway

Check of the spillway flow capability

$$Q = \mu\,\omega_{изх}\sqrt{2\,g\,(H_{пр} + z)}$$