ALPHABETA

The storage system “Alphabeta” consists of Lake Alpha with a concrete gravity dam and an upper reservoir Pool Beta with an earthen ring dam (see Figure 1). The **maximum discharge capacity of the bottom outlet is 40 m³/s**. The Lake Alpha is an annual storage reservoir for generating electricity in the lower hydro power plant (LHPP) Omega I. It collects the natural inflow from Table 1 of the Alphabeta Creek. **The annual storage volume is full at the end of April**. Starting from that point of time the annual storage is **completely drained to the end of August** by operating a constant discharge over the entire drainage period. The ecological flow in the Tropical Creek is 800 l/s. The upper hydro power plant (UHPP) Omega II is daily turbining and pumping water between Lake Alpha and Pool Beta. The water level and water volume resulting from the daily pump/turbine operation can be seen in Figure 2.

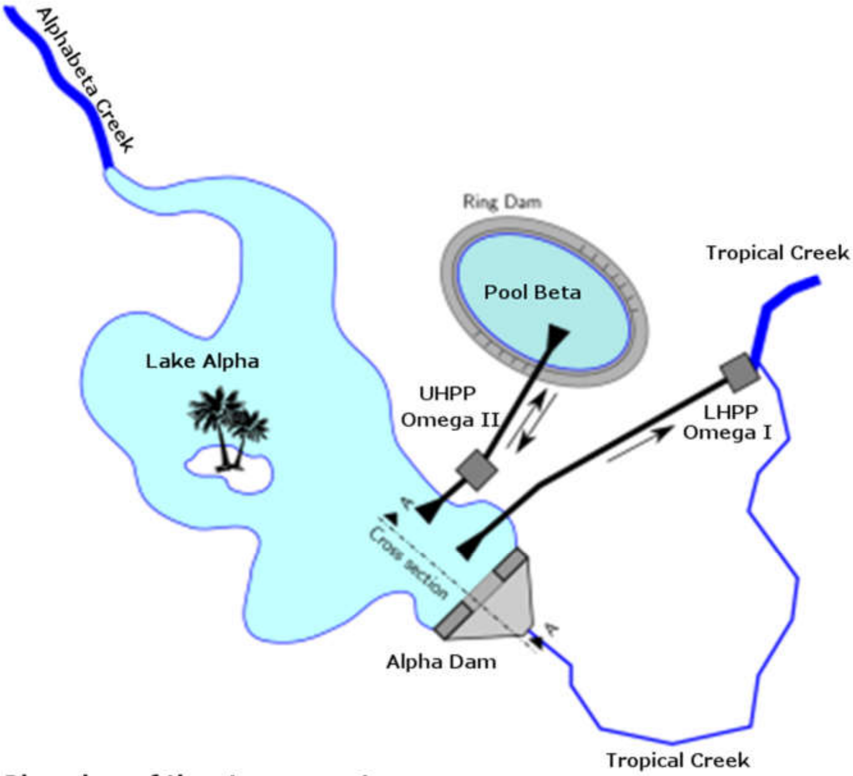


Figure 1 : Plan view of the storage system

Table 1 : Inflow from Alphabeta Creek

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
m3/s	1	4	6	6	4	4	3	3	4	3	2	1,5

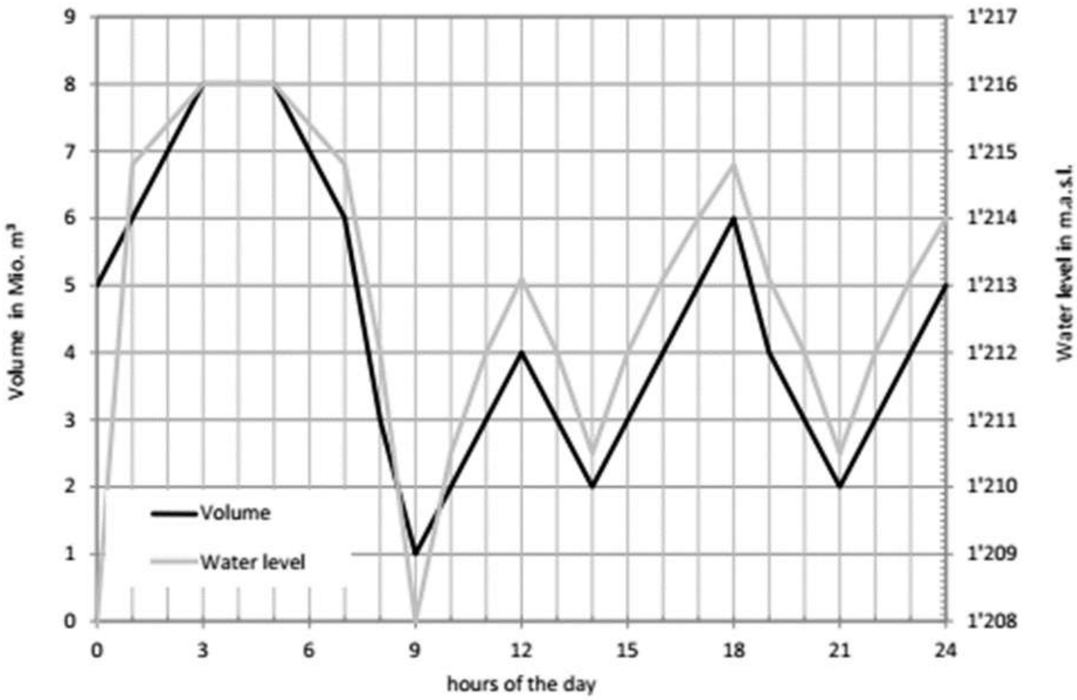


Figure 2 : Volume and Stage hydrograph of Pool Beta

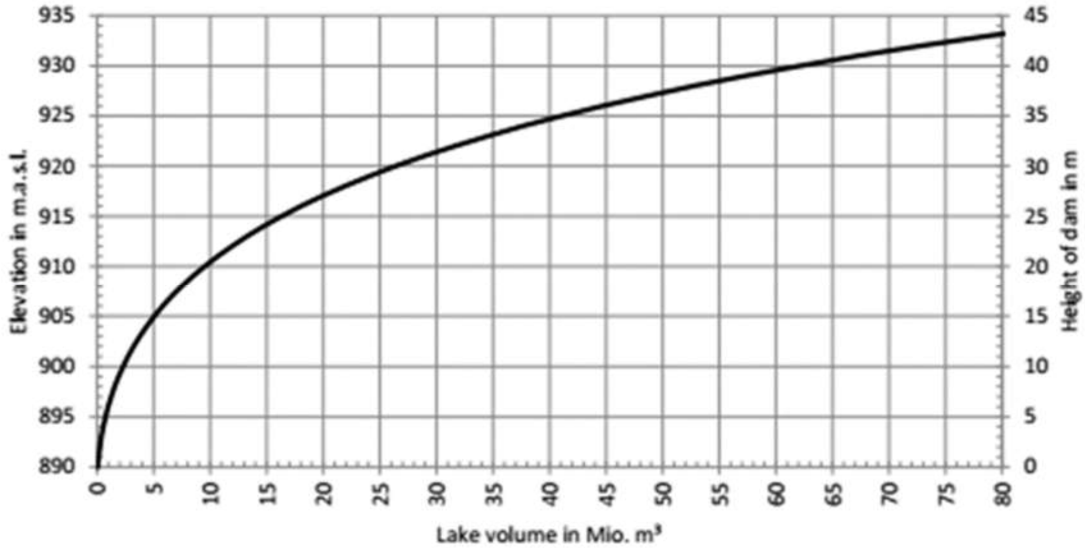


Figure 3 : Stage Storage Curve of Alpha Lake

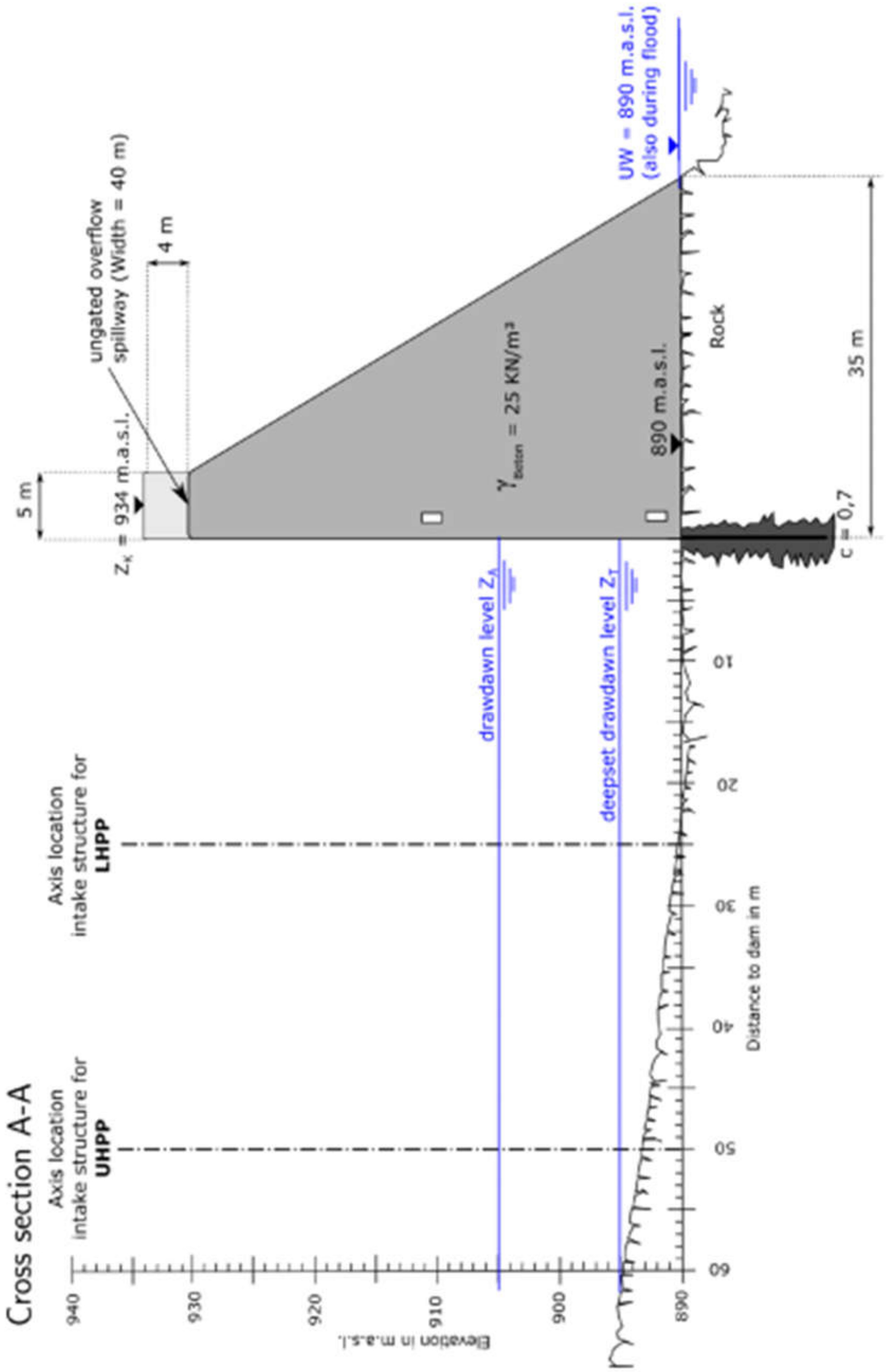


Figure 4 : Cross section A-A of Alpha Dam (see Figure 1)

1. How large is the pump storage volume in the Pool Beta ?

Solution :

Pump storage volume is volume of the reservoir (excluding dead volume) that is used for storing the potential energy. In this case, the potential energy is being stored in the Beta

Pool. So this volume can be seen as a difference between the maximum and minimum volume of water in the Beta Pool (up)

$$V_{pump} = V_{max,up} - V_{min,up} = 8\ Mio.m^3 - 1\ Mio.m^3 = \mathbf{7\ Mio.m^3}$$

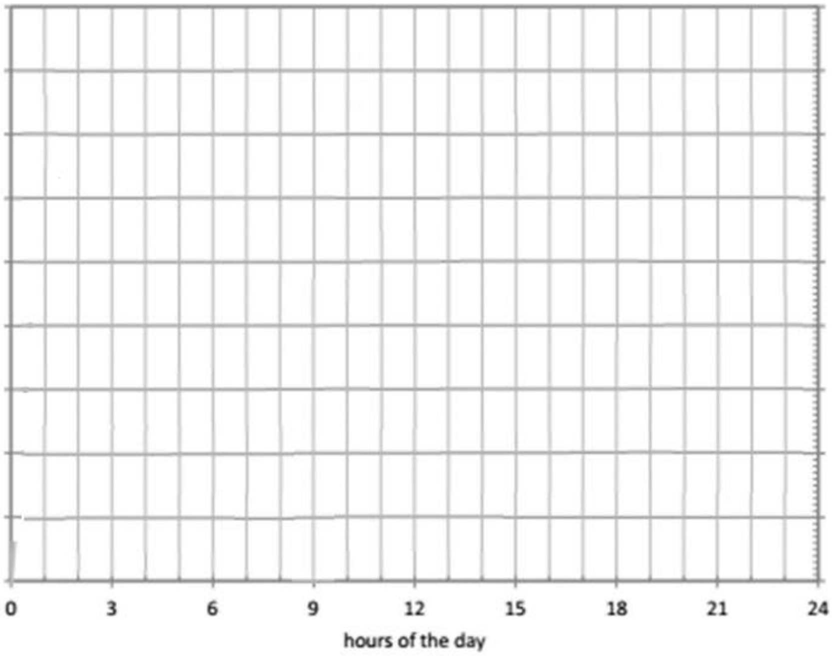
2. What time does the UHPP pumping? And what time does the UHPP turbining?

Solution :

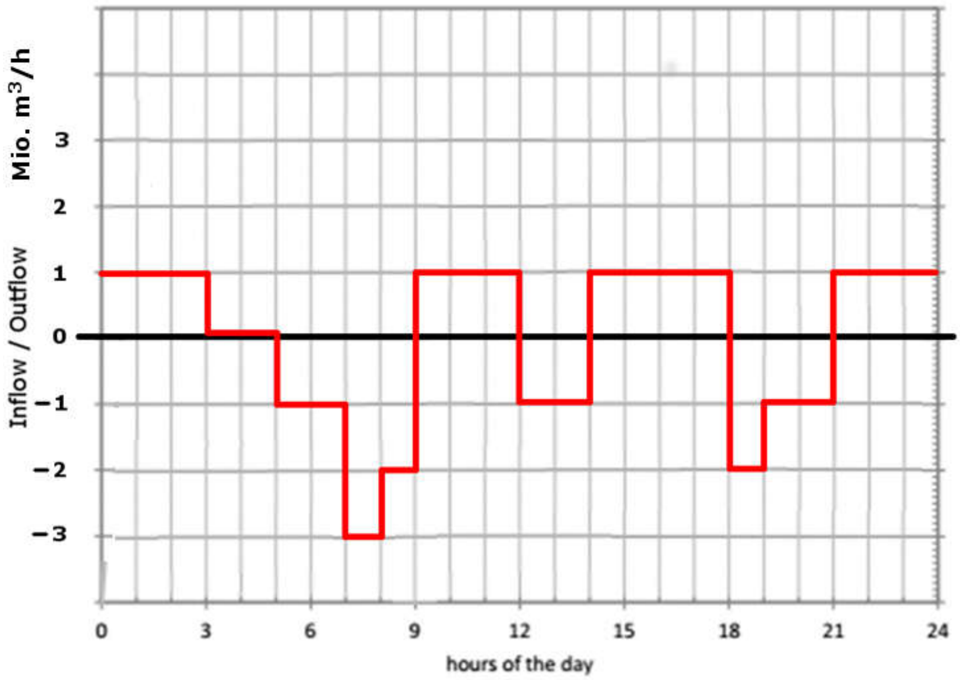
Pumping : 9:00 – 12:00 , 14:00 – 18:00 , 21:00 – 03:00

Turbining : 05:00 – 09:00 , 12:00 – 14:00 , 18:00 – 21:00

3. Draw the inflow/outflow of Pool Beta over the hours of the day !



Solution :



4. How large is the pump storage volume in the Lake Alpha?

Solution:

Same with Pool Beta, **7 $\boldsymbol{Mio. m^3}$**

5. What is the maximum operational water level Zs of the Lake Alpha? Draw it in the cross section in Figure 4 and label it!

Solution:

Maximum operational water level in a reservoir can be seen as the level of its

Overflow gate. In this case, it is **930 masl.**

$$h_{max,pnpl} = \mathbf{930}\ \boldsymbol{masl}$$

6. At which elevation is the location of bottom outlet of the Alpha Dam?

Solution:

Bottom Outlet is located at the deepest drawdown level **(895 masl)**

7. What is the annual storage volume of the Lake Alpha?

Solution:

Annual storage volume of a reservoir is the volume of the reservoir without deadvolume, and pump storage volume. So it can be calculated as:

$$\boldsymbol{V_{annual,alpha}} = V_{max,alpha} - V_{min,alpha} - V_{pump}$$

Maximum Operational Volume happens when the water level is in maximumoperational water level.

$$h_{max,alpha} = 930\ masl \rightarrow V_{max,alpha} = 62\ Mio. m^3$$

Minimum Operational Volume happens when the water level is in minimumoperational/drawdown level.

$$h_{min,alpha} = 905\ masl \rightarrow V_{max,alpha} = 5\ Mio. m^3$$

$$\boldsymbol{V_{annual,alpha}} = V_{max,alpha} - V_{min,alpha} - V_{pump} =$$

$$62\ Mio. m^3 - 5\ Mio. m^3 - 7\ Mio. m^3 = \mathbf{50}\ \boldsymbol{Mio. m^3}$$

8. What is the maximum head and what is the minimum head for the **UHPP** (Omega II). At which time and on which date are they reached, respectively?

Solution:

Maximum head for UHPP happens when Upper Reservoir in its maximum level

IN ADDITION, Lake Alpha in its minimum level. This happens at the **end of August**, **3 o'clock-5 o'clock**.

$\Delta hmax, UHPP = hmax, up - hmin, alpha =$
$1216\ masl - 905masl = \mathbf{311m}$

Minimum head for UHPP happens when Upper Reservoir in its minimum levelAND Lake Alpha in its maximum level. This happens at the **end of April**, **9 o'clock**.

$\Delta h_{min,\ UHPP} = h_{min,\ up} - h_{max,\ alpha} = 1208\ masl - 930masl = \mathbf{278m}$

9. How high is the turbine discharge in the LHPP (Omega I) between end of April and end of August?

Solution:

Between the start of May and the end of August, Lake Alpha Volume goes from Maximum Operational Volume (62 $Mio.\ m^3$) to Minimum Operational Volume (5 $Mio. m^3$).This means the annual storage volume and the inflow volume is being constantly discharged. We can make a formulation such as:

$V_{out,alpha,may-aug} = V_{annual,alpha} + V_{in,alpha,may-aug}$

Where:

$V_{\ in,alpha,may-aug} =$

$(4 + 4 + 3 + 3)\ m^3 / S * 30days * 24hr / day * 3600\ s / hr$

$= \mathbf{36.3Mio.\ m3}$

Then we can calculate the discharge:

$V_{out,alpha,may-aug} = 50Mio. m^3 + 36.3Mio. m^3 = \mathbf{86.3Mio.\ m3}$

$Q_{out,\ alpha,\ may-aug} = 86.3\ Mio. m^3 / 4\ months * 1month / 30days * 1day / 24hr * 1hr / 3600s = \mathbf{8.3\ m3/\ S}$

Moreover, since there are two outflow (to LHPP and to Alphabeta Creek), we can separate the outflow as:

$$Q_{out,\ alpha, may-aug} = Q_{LHPP} + Q_{abc}$$

$$Q_{LHPP} = Q_{out,\ alpha,\ may-aug} - Q_{trp} = 8.3\ m^3/\ s - (800\ l/s * m^3/1000l) = \mathbf{7.5\ m3/\ s}$$