UNIVERSITAT POLITÈCNICA DE VALÈNCIA

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CANALES Y PUERTOS

# FEASIBILITY STUDY FOR A HYDROPOWER PROJECT IN THE TAJO-SEGURA CHANNEL IN THE RAPID OF BELMONTEJO MUNICIPALITY (CUENCA)

Master thesis

Master in Civil Engineering


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# 1. Abstract

This work will treat the feasibility study for a hydropower project in the Tajo-Segura channel which is located in the rapid of Belmontejo Municipality in the province Cuenca. It is a feasibility study that will be used to compare various design options and select the most interesting one. The possibilities to build a hydropower plant in this area are examined regarding the topography of the area, the flow characteristics of the river, the types of turbines and the costs-benefits ratio. With reference to these fields, the most optimal solution in this case is found.

# 2. Acknowledgements

I would like to thank and express my deepest appreciation to my supervisor Prof. Solera Solera, Abel for his guidance and assistance. With every question and on every moment, I could enter his office and he was ready to help me. Besides I would also like to thank my co-supervisor Prof. Navarro Torrijos, José for his support and explanation about the electromechanical parts.
Both professors organized an excursion to Cortes-La Muela, the biggest pumped-storage hydroelectric power station of Europe, which I found very interesting and for which I am very grateful.

# 3. Introduction

In this work the feasibility study will be done for a hydropower project in the Tajo-Segura channel in the rapid of Belmontejo municipality in the province Cuenca of Spain. In chapter 4 the location of the project will be explained more in detail. The project will not be implemented as this is just a study case to determine whether it is beneficial to build a hydro plant in this place or not. Because there is already built a channel with available data, this is a good place to do this research.

The Tajo-Segura channel conducts a maximum volume of 600 $hm^3$ a year and has an average between 300 and 400 $hm^3$ a year. This volume passes through the Júcar river and leads into the Alarcón reservoir where the water goes further downstream. When descending, the channel decreases with a height of approximate 50 meters due to two rapids.

The goal of this work is to make a feasibility study of three possible solutions to build hydropower plants in these two rapids above the Alarcón reservoir. In these three situations the amount of energy produced and the possibility to sell it at the energy market are compared.
The first solution is a case where at both rapids a hydropower plant is built that works 24h a day. Both plants are different whereas the head of the rapids are different.
As second solution a powerplant is built only at the second rapid and it is working 24h a day.
Last the possibility will be examined for a regulated plant only at the second rapid.

In this introduction first, the importance of hydropower plants in Spain and in the world will be discussed. Next the basics of hydropower plants are explained in a brief way. The fourth chapter will make clear how Spain divides his country in terms of water supplies and where the project exactly is situated.
After, a study is done about the flow characteristics based on some historical data of monthly and daily flows in the Tajo-Segura channel that have been made available by professor Solera Solera Abel. The results of this study will be used in the following parts of the work to determine the operational flow that passes the turbine. With this knowledge, the turbine type, the generator and transformer can be chosen.
Last the economical side of the project will be investigated regarding the electricity prices on the market and an estimation of the construction costs of the central.

This all is resumed in the conclusion where the three solutions are compared and where is discussed if this project is beneficial to build on this place or not.

## 3.1 Importance of hydro energy in Spain and around the world

Nowadays the way how energy is produced is more important than ever before. The Paris climate conference aims that the global average temperature may not pass the maximum 2°C above pre-industrial levels. [1] An important part to achieve this goal is to reduce the $CO_2$ production in the world. A considerably large part of this $CO_2$ production is caused by the energy production with fossil fuels. [2] Therefore it is essential to switch this source of fossil fuels to sources of natural green energy. One of these types of energy is the use of river flows in hydroelectric powerplants.

Comparing Spain with Belgium, Europe and the rest of the world regarding the figures below, some comparisons can be made about the use of water power. [3]
Spain produces a little bit more hydropower than the average country in Europe and a little bit less than the world average. This can be explained because in Europe there are not many countries with a big height differences and a large amount of water supply. In Africa or South-America there are a lot of countries which do have this and where hydro energy often provides more than 50% of the country's electricity. [4]
Compared to Belgium, Spain is using way more hydro-energy because Belgium does not have that many height difference where it is able to build hydropower plants. [5]

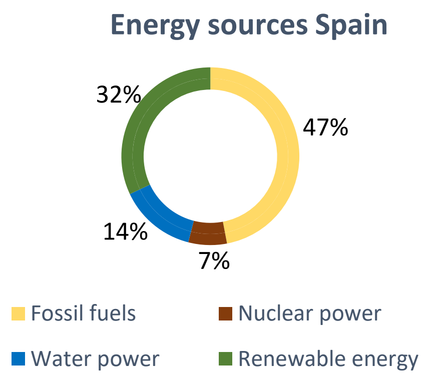



*Figure 1: Total yearly net electricity production in Spain by source*

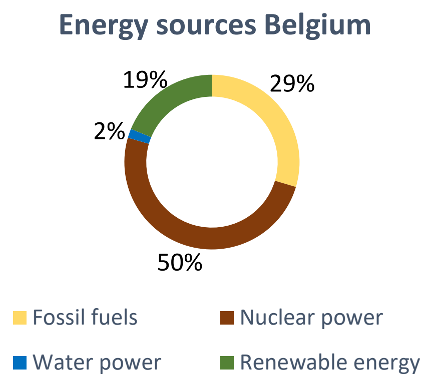



*Figure 2: Total yearly net electricity production in Belgium by source*

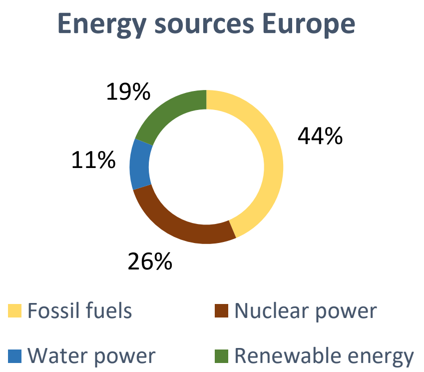



*Figure 3: Total yearly net electricity production in Europe by source*

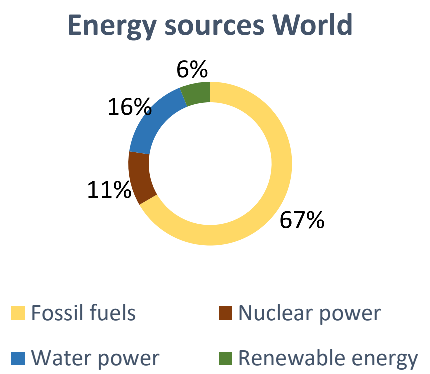



*Figure 4: Total yearly net electricity production in the World by source*

In Europe, Spain is one of the most vulnerable country regarding water supply. And with irrigation as the primary economic contribution, this vulnerability can lead to serious economical as social problems. [6] In Andalucía, the South of Spain, this issue can be bigger by reason of the longer periods of droughts. As a solution of these times without enough water, they consider desalination of seawater in this region.

Since irrigation contributes to more than 50% of the food production in Spain, the irrigation infrastructure is very critical for the Spanish citizens. As well other countries in the world do have some concerns about this subject whereas Spain has a big export market regarding food products. Besides, one hectare of irrigated land has an income four times bigger than a rain-fed hectare of land and additionally this produces six times more crops. [7] Because there is such a big network of channels, there is also a vast amount of possibilities to build hydroelectric powerplants.

Due to climate change, a lot of challenges are heading to Spain respecting the continuously ability of water supply. Some scientific models predict larger evapotranspiration, lower rainfall, and lower river flows. Where this last one is also disastrous for the energy production of hydro plants.
The population boom, the rising demand of agricultural export, the big amount of building projects and the growth of tourism in Spain will also lead to an increase of water use including a more stressful environment. [8]

With 1200 reservoirs and with a storage of 56000 $hm^3$, this artificial system of water management is unique in Europe. [9] For the reasons mentioned above, it is very important to maintain and develop the water infrastructure in Spain.

## 3.2 Basics of hydropower plants

### *3.2.1 Functioning*

In this section the basic parts and working of a hydropower station are explained, this just to understand the next chapters.

The basic idea of a hydropower plant is that it uses the gravitational force of falling flowing water to generate electricity. It uses the transformation of the water from potential energy to kinetic energy. In the figure below the most significant parts of a hydropower plant are mentioned.

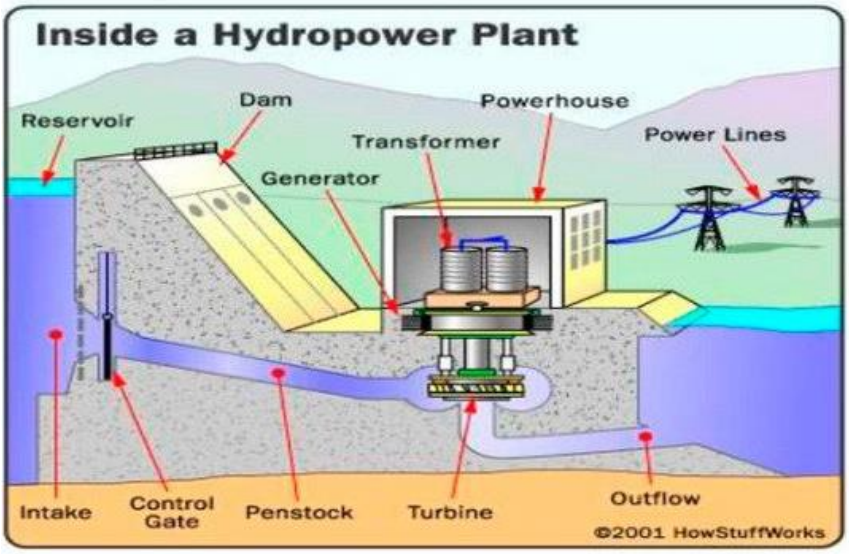



*Figure 5: Schematic presentation of the parts of a hydropower plant* [10]

The **dam** assures that the **reservoir** can be filled with water and that a certain head can be created. This head decides which type of turbine must be used and what is the amount of energy that can be produced. Through the **intake** the water passes a **filter** to stop the waste that is in the water. Next a **control gate** is used as a safety equipment in emergency shut-off situations and deliver absolute reliability in case of a penstock rupture, this gate is always open. Later, a **butterfly valve** or a spherical valve opens before starting the turbine and always closes once it is finished. They are situated between the penstock and the turbine and deliver seal tightness, even in critical situations. The valves are welded constructions using high quality steel, or in some cases made of forged steel. They only can be completely closed or completely open, nothing in between (called on-off valves). [11]

The water flows through the penstock to the **turbine** where the kinetic energy will be transformed to mechanical energy. The **penstock** is a pipe that delivers the right amount of water from the forebay to the turbine. The water enters the turbine through a **scroll case**, formed like a snail shell, which let the water enter the turbine from all sides with a consistent pressure. Inside the scroll case a set of vanes are located, which are called the **wicket gates** (see figure below). These vanes control how the water flows into the turbine. After, it flows through the outflow to go back into a natural river.

Figure 6: Wicket gates in turbine fieldtrip Cortes-La Muela

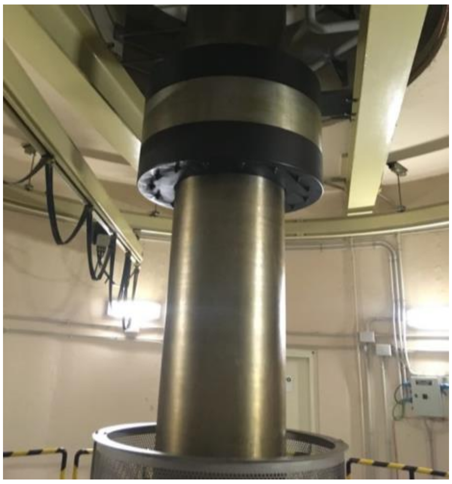


Figure 7: Turbine shaft/runner fieldtrip Cortes-La Muela

The turbine that is driven by the power of the water, passes the mechanical energy to the generator by use of a **runner** (see figure above of the fieldtrip to the central of Cortes-La Muela). This **generator** converts the mechanical energy into electrical energy and is further explained in chapter 6.5 'electromechanical parts'.

Next, the current goes to the **transformer** where the voltage increases and the current reduces. This makes the transfer of electricity more efficient as less energy is lost as heat.
After, the electricity is transported to the grid where it is divided over smaller distributors. The way the Spanish electric market works is explained in chapter 7.1 'Electric market in Spain'.

One of the most important reasons for a perfect design to avoid **cavitation**. Cavitation is the formation of water vapor bubbles in areas of the turbine water passage where localized pressure levels fall below the vapor pressor. When these bubbles travel into higher pressure areas they collapse back into liquid. If this occurs adjacent to a turbine blade, the removal of metal can be a result. To avoid cavitation, the absolute pressure within the turbine must be such that vapor pressure will not be encountered or created. This is done by keeping the unit elevation sufficiently low relative to tailwater to ensure proper absolute pressures.

Another part that can be added to the construction of the powerplant is an equilibrium chimney. This component makes sure the pressures in the tube does not change too much. Because the swapping of low and high pressures can damage the pipe material, the pressure must be kept constant. When this phenomenon occurs, they are taking about the '**water hammer effect'** and it can be easily detected by the noise it makes.
Mostly the chimney is only built when the pipe length is very long and it must be constructed in the penstock, before the powerhouse.

### *3.2.2 Consequences*

As the amount of energy produced by hydropower is bigger than all the renewable energy sources combined, it is important to consider all the positive and negative consequences of the implementation of a hydropower plant.
The biggest positive effect of producing energy with a hydropower plant is that it avoids green-house gas emissions and that it is a renewable source of energy. Besides, it is a free form of trash removal as the majority of anthropogenic waste floats on the water and got stopped by the dam. The dam also can resist big floods caused by long periods of rainfall. Though this can also be a huge negative point considering that if the dam breaks it can destroy a whole city. For example in this year 2019 there was a big disaster in the state of Minas Gerais, Brazil where died more than 100 people due to the collapsing of a dam. [11]
Some other negative consequences are that often a whole community needs to move for the construction of the dam. Most of the time the government provides another place to live, but this is not always the case. The construction of a dam means that the surrounding environment changes a lot. The esthetical view of the environment is different, a lot of animals will die or need to move or fishes will not be able to pass the dam. Because of this environmental and ecological changes, a lot of preliminary studies need to be done. Apart it also causes a large amount of noise emissions due to the operation of the hydroelectric unit, the speed increasers and the trash rack cleaner. [12]

# 4. Site description

Spain divides its land in 25 river basin districts, including those of the islands. Six of them are international sharing water courses with Portugal and France. In the figure below the river basin districts of Spain are shown, with in grey the autonomous Communities or intra-communities.

El Sistema Español de Información sobre el Agua, HISPAGUA, defines a river basin as: 'River basin is defined as land and marine area consisting of one or more neighboring river basins and transitional waters, coastal and groundwater associated with these basins, in accordance with Article 16 of the Revised bis.1 Water Act approved by Royal Legislative Decree 1 / 2001 of 20 July.' [13]

The name of the Tajo-Segura channel is derived from the fact that this channel flows from the district Tajo, in the north of Júcar, to the Segura basin in the south of Júcar. The part of the channel with which is worked passes the Alarcón reservoir and is located in the eastern district Júcar. As seen in figure 8, the river basin district Júcar is divided over 4 autonomous communities; Valencia, Castilla La-Mancha, Cataluña and Aragón, with half of its percentage in Valencia.


*Figure 8: River basin districts Spain* [14]

| Autonomous Community | Area (Km²) | Basin Fraction (%) |
|---|---|---|
| Comunidad Valenciana | 24.447,344 | 49,6 |
| Castilla La-Mancha | 18.039,774 | 36,6 |
| Cataluña | 295,734 | 0,6 |
| Aragón | 6.703,304 | 13,6 |

*Figure 9: Area of Júcar in autonomous communities of Spain* [13]

## 4.1 Location

As said in the previous part, the project is located in the river basin district Júcar in the east of Spain. More specifically the channel is located in the south of the province Cuenca and in the north of the reservoir Alarcón, marked in red on figure 10. On figure 11 and 12 the rapid of Belmontejo of the Tajo-Segura channel is marked in red, the study of this work will be done in this part.

The water supply of this channel is coming from some reservoirs in the north. The biggest supplies are those of the reservoirs of 'Entrepeñas' and 'Buendia', which lead their water to the reservoir of 'Bolarque'. Next the water flows to the reservoir of 'Bujeda', where it can flow into the channel of Belmontejo to the reservoir of Alarcón.

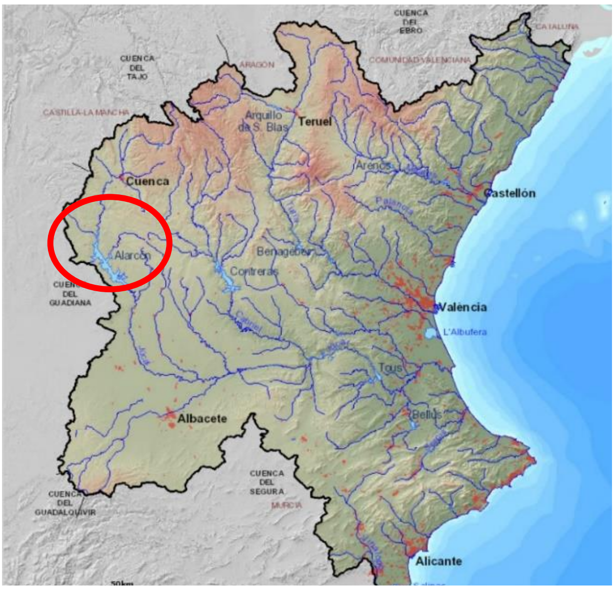



*Figure 10: Rapid of Belmontejo in the northern part of reservoir Alarcón* [15]

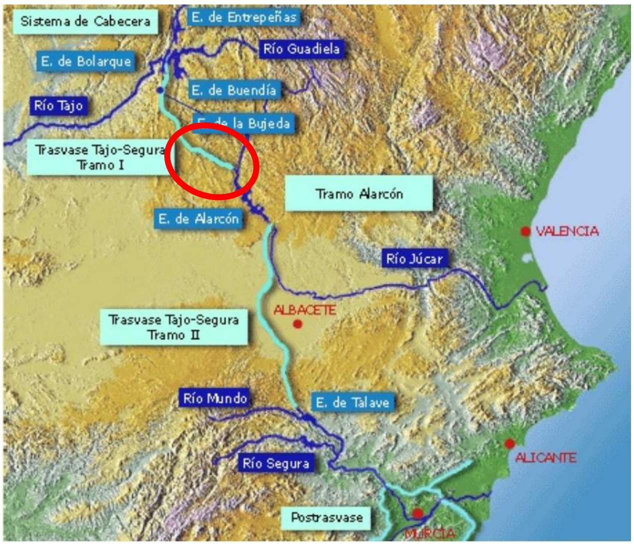



*Figure 11: Tajo-Segura channel with its connecting rivers and reservoirs* [35]


*Figure 12: River basin district Júcar and Cuenca in the Belmontejo Rapid [15]*

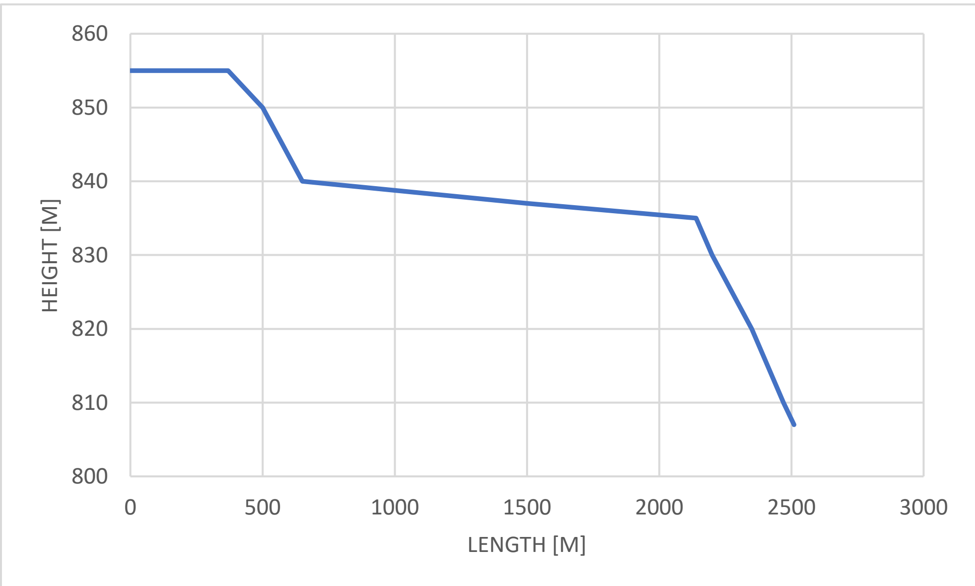
*Figure 13: Belmontejo rapid* [15]

## 4.2 Topography

To decide where the location of the hydropower plant will be, the topographic map need to be examined. The part of the channel that is treated in this case, is pointed on the map with two red dots. In this section there are two rapids with a possibility to build a hydropower plant.


*Figure 14: topography of Belmontejo rapid* [16]

With a **total height difference** of approximately **50 meters** between begin- and endpoint, the availability of head is rather little. In the graph below, it is clear that there are two locations with a possibility to build a hydropower plant. The first powerhouse can be built at 650 meters from the beginning point, whereas the second one at 2500m from the beginning point. Respectively they have a **gross head of 15 and 30 meters**, so the second one has a bigger amount of potential energy and can therefore produce more energy. Because there are a lot of losses between begin and start point, this is a rough estimation of the real net head. This net head is calculated in the next section and will be used to dimension the turbine.




*Graph 1: relation height-length of the channel*

## 4.3 Geology

To know whether it would be easy to build a hydropower plant in a certain area, it is recommended to analyse the quality of the soil. After all, there will be built a large and heavy construction that the soil must be able to resist. As well the big amount of water will have a not underestimated influence on the underlying and adjacent land.
If the ground is not able to resist this kind of loads, soil improvements need to be done. A stronger foundation in the reservoir and under the dam can be built, some geofilters can be placed or another kind of soil can be applied in this zone. [17]

The grey colour (number 102) in figure 15 indicates the presence of gravels, sands, clays and silts. The orangish colour (number 90), around the river, indicates the presence of reef limestones, calcarenites, conglomerates and clays with olistoliths.[18] Sandy types of soil are used for the filter to maintain the core soils and to avoid their migration. Clayey types of soil are applied to ensure the stability of this core. [17] Because of the current presence of sand and clay in this area, this location is at first sight a good location to build a hydropower plant without the necessity of big soil improvement works.

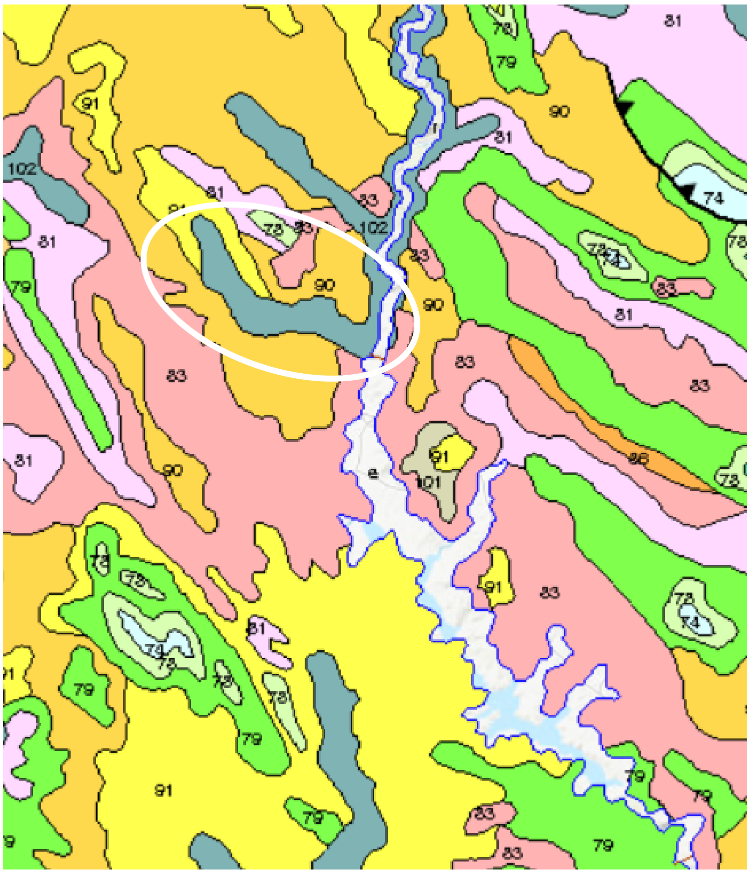



*Figure 15: Geological map of the area around the Belmontejo rapid* [18]

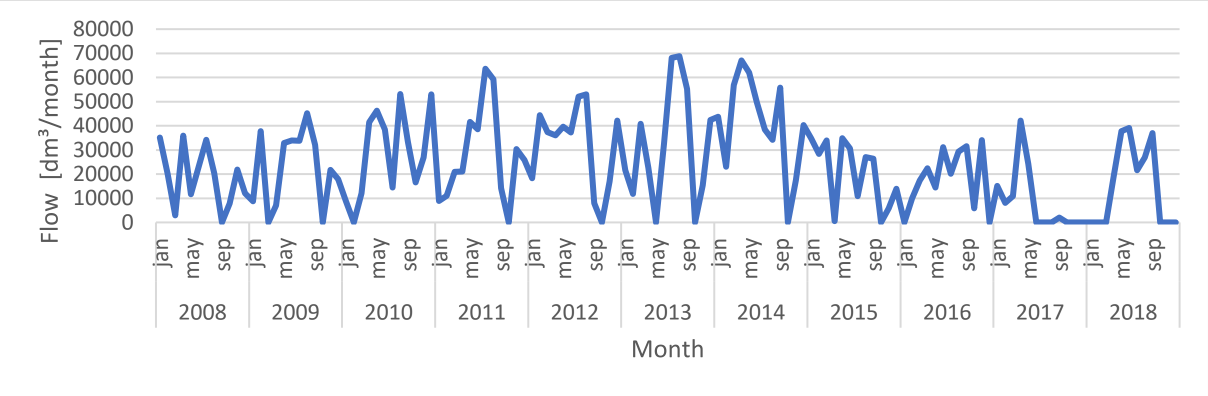
# 5. Flow characteristics

In this chapter the flow characteristics of the channel are examined. The data is used to get an overview of the flow that passes the channel and will then be used to determine the type of turbine in the powerhouse.
All the data used in this chapter has been made available by 'La Confederación Hidrográfica del Segura'.

## 5.1 Data processing

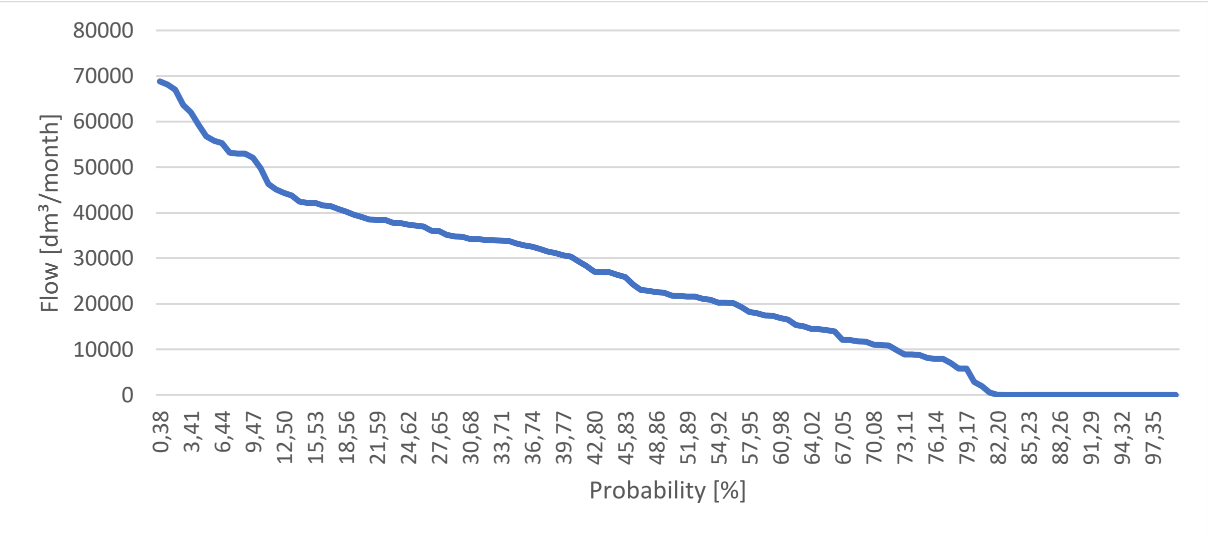
### *5.1.1 Monthly flow*

Appendix A shows the data used for this section. The flow is examined from the year 2008 till the year 2018 to make sure there is enough data to be able to work with the averages.
The data is placed in a graph with on the X-axis the year with its months and on the Y-axis the flow in dm³ that passes this channel. In the summer of 2011-2014 the flow was significantly higher than the last 4 years. During winter all the months have a low flow.




*Graph 2: Monthly flow curve*

In the graph below, the data of the previous graph is ordered. This way the probability a certain flow will pass the channel can be calculated.



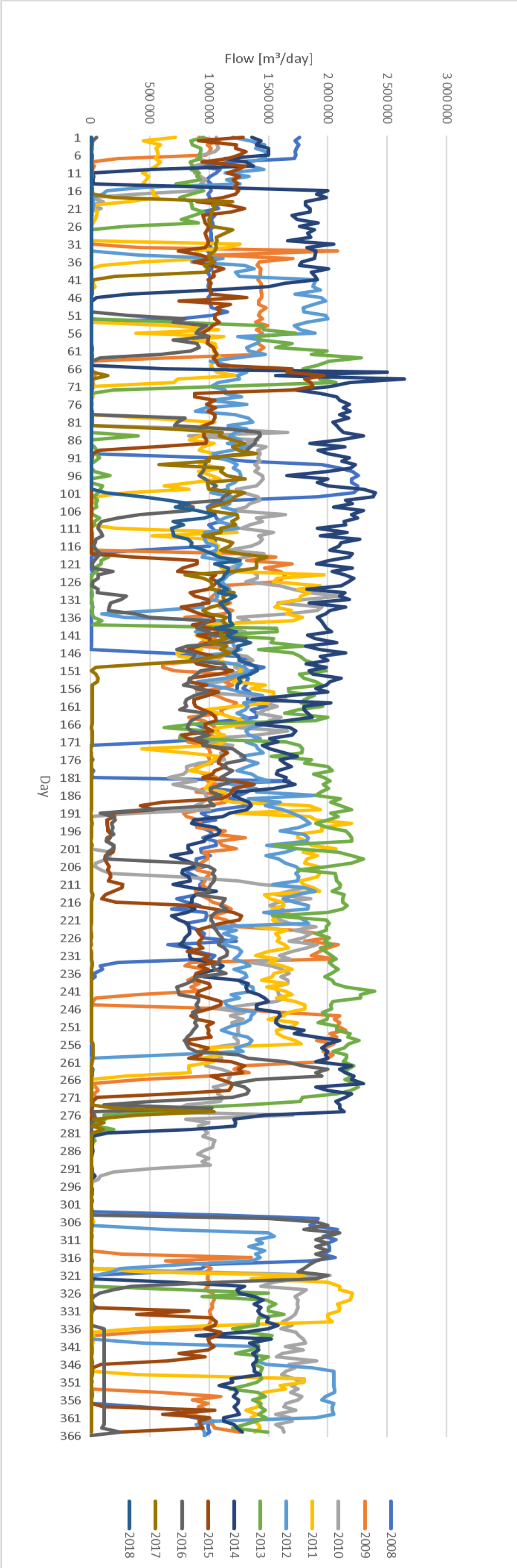

*Graph 3: Ordered monthly flow curve*

### 5.1.2 Daily flow

The data used for this section are made available by the supervisor. Equal as in 5.1.1, there is worked with data from 2008-2018.

What can be derived from the graph is that there are two notable trends. The first one can be found at a daily flow of approximately 1000000m³ during the whole year. The second trend has a value of roughly 2000000m³ and can be seen as a maximum flow.

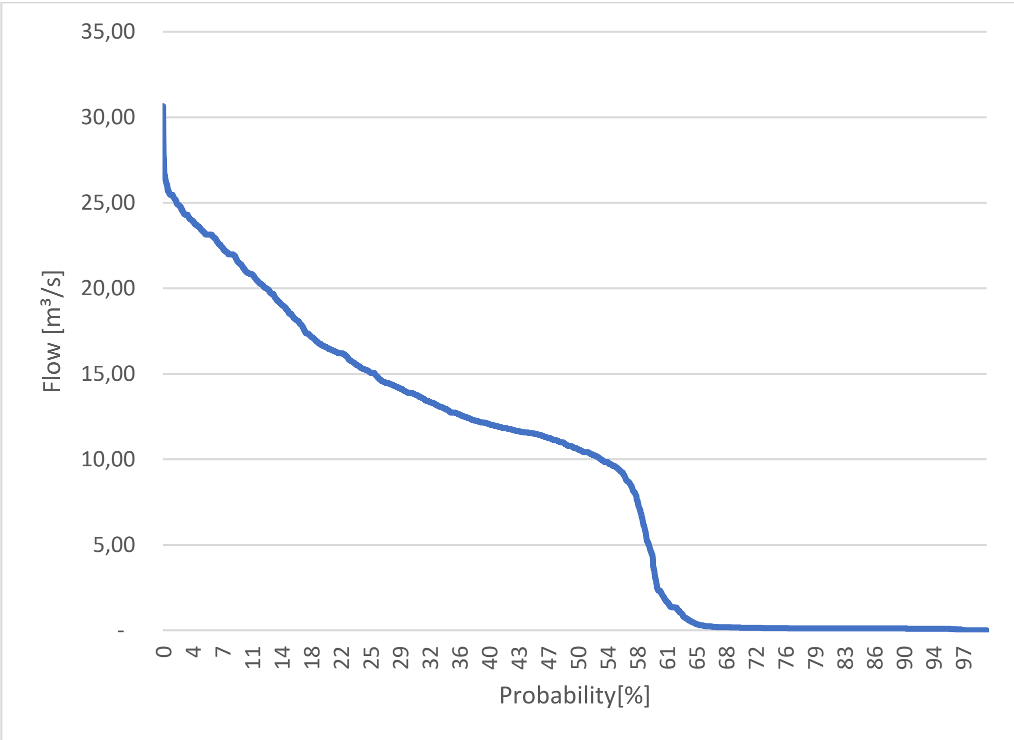
In the month of November, the flow is every year very little, whereas in the years 2011-2014 a bigger flow can be noticed during summer. This observation is the same as what was concluded from the dates of the monthly flow.




*Graph 4: Daily flow curve*

The unity of the data above is then changed from m³/day to m³/s by use of some simple math. Next, this data has formed the graph underneath after the data has been ordered from high to low in an Excel file.
Willing that the powerplant produces its maximum, a sufficient high flow combined with a probability as high as possible must be chosen. Regarding these two requirements the most optimal flow to work with lies between the 10 and 20m³/s combined with a probability of 15-55%.
The exact flow that will be worked with in this project will be determined in the next section.

Giving an example how to read the following curve:
If there would be worked with a flow of 15m³/s, this amount of flow will only pass the channel 25% of the year. This means that the central will function only 91 days on its maximum capacity. The other days of the year a lower amount of flow will pass the channel and the central will therefore work on less capacity.




*Graph 5: Ordered flow curve*

### 5.1.3 Used flow

Before determining the used flow for this project, the volume according to each flow need to be calculated. This is done the following way:

- Of every day of the ordered list of 5.1.2 the minimum is taken of the value of the flow from this day and another assumed flow (ranked from 1 till 30). This is done for each of these assumed flows.
- The average of all the days is taken and is then converted into the unity of $hm^3$/year.

As said in the previous section, the flow that will be worked with will lay between 10 and 15$m^3$/s. Graph 6 is presenting the profit of volume compared to previous flow passing the channel in a year in function of the flow. This marginal profit is calculated by subtracting the volume of one assumed flow from the previous flow.

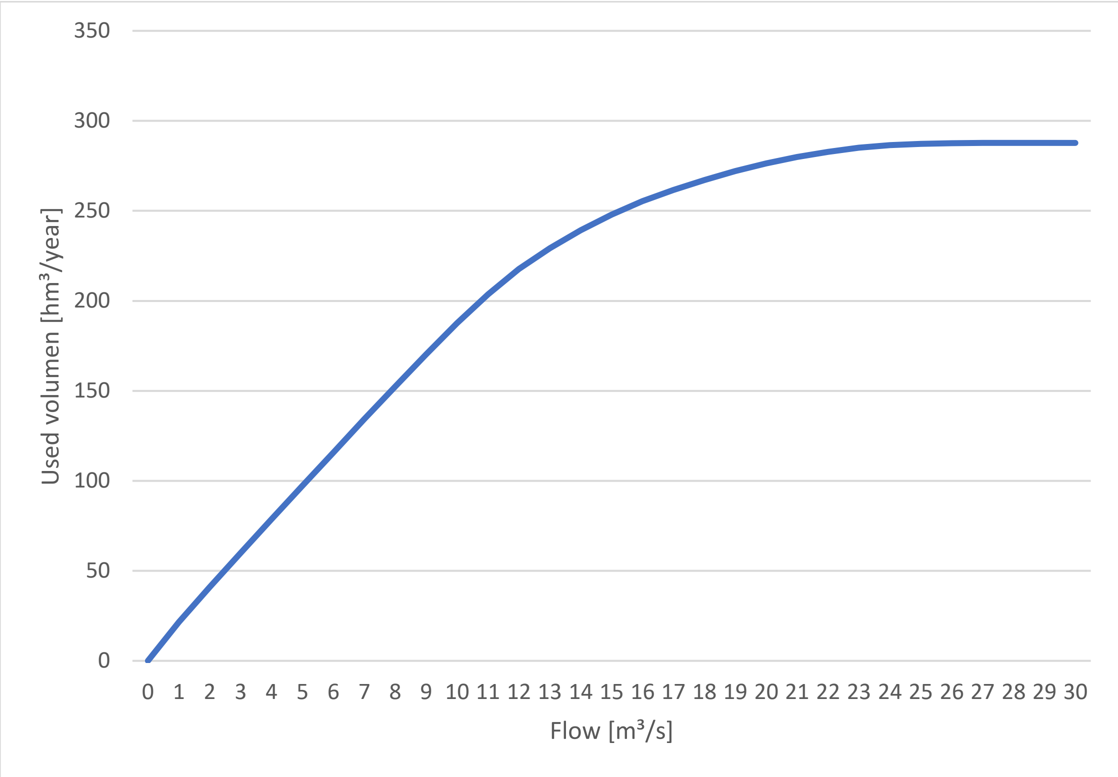
| **Allowed Flow Q [m³/s]** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|
| **Volume [hm³/year]** | 21,48 | 40,92 | 59,88 | 78,68 | 97,38 | 115,89 | 134,24 | 152,41 | 170,29 |
| *Marginal Profit [hm³/year]* | - | *19,44* | *18,96* | *18,80* | *18,70* | *18,50* | *18,35* | *18,17* | *17,88* |

| 10 | 11 | 12 | 13 | 14 | **15** | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|
| 187,61 | 203,65 | 217,68 | 229,25 | 239,27 | **247,86** | 255,34 | 261,70 | 267,18 | 272,07 |
| *17,31* | *16,04* | *14,04* | *11,57* | *10,02* | *8,59* | *7,48* | *6,36* | *5,47* | *4,89* |

| 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
|---|---|---|---|---|---|---|---|---|---|
| 276,34 | 279,92 | 282,83 | 285,05 | 286,49 | 287,28 | 287,59 | 287,68 | 287,71 | 287,73 |
| *4,27* | *3,58* | *2,92* | *2,21* | *1,45* | *0,78* | *0,31* | *0,08* | *0,03* | *0,02* |

*Table 1: volume and profit ordered by flow*

As seen in the graph below, the marginal profit decreases as the flow increases. Until a flow of 12m³ the profit increases with the same acceleration. After, it is decreasing until the profit stagnates. From a flow of more or less 15m³ the increasing of the profit is lowering clearly and makes it not worth it to invest in a bigger infrastructure.
As a conclusion there will be worked with a **flow of 15m³/s** in this project.




*Graph 6: Marginal profit of volume compared to previous amount of flow*

# 6. Study of alternative solutions

In this chapter the different possible solutions for a hydro powerplant in this location are given and investigated. First, the alternative solutions are listed and explained. After, the power, net head and produced energy in each solution is calculated. These data can be used in the economic study later on. Last, the electromechanical parts with its estimated costs are discussed.

## 6.1 Alternative solutions

In this case three solutions are investigated. Each solution has a different amount of powerplants or a different period of time the plant is working. The situations are represented with a curve of the two rapids.

### *6.1.1 Solution 1*

The first solution is a case where at both rapids a hydropower plant is built that works 24h a day. Both plants are different whereas the head of the rapids are different. The first plant has a head of 15m, the second plant has a head of 30m. A flow of 15m³/s in both plants is used to calculate the gross energy. Even because the water is flowing 24h a day, there is need to build a reservoir with a minimum capacity.
The blue cubes represent the two powerplants, the open rectangles represent the reservoirs.

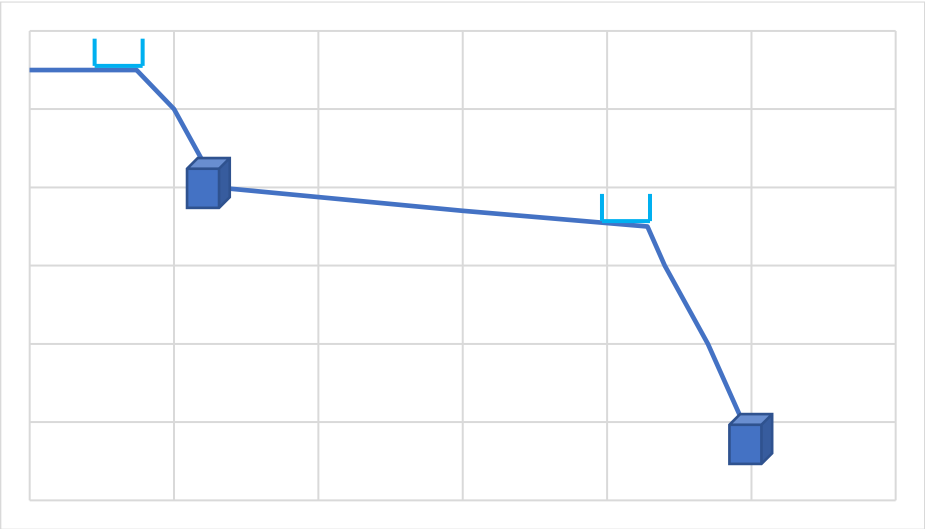


*Figure 16: simplified representation situation 1*

### *6.1.2 Solution 2*

As second solution a powerplant is built only at the second rapid and is working as well for 24h a day. In this case the head is bigger than in situation 1, therefore the amount of energy that can be produced, is also higher. Since the water is flowing 24h a day, there is need to build a reservoir with a minimum capacity. Because the pipe has a length of 2100m, it is necessary to put a chimney before the power station. This is needed to avoid the water hammer effect, as explained in 3.2.1.

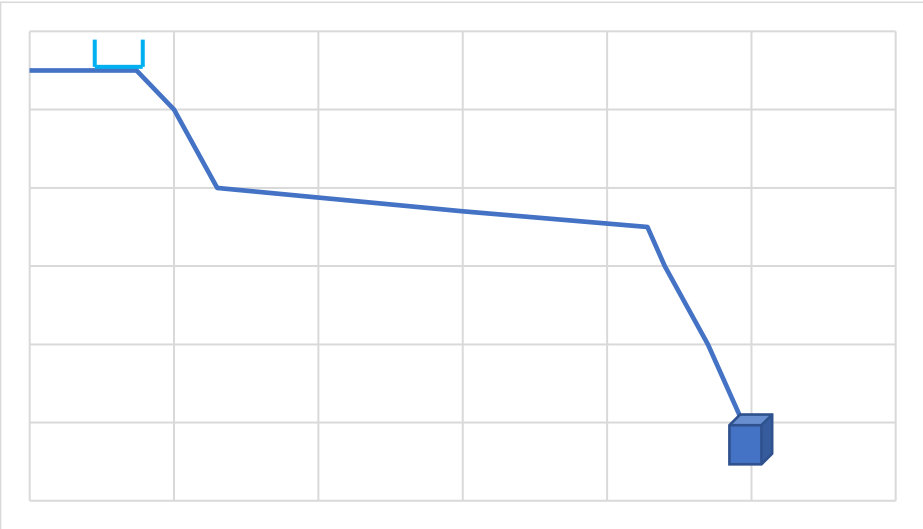


*Figure 17: simplified representation situation 2*

### 6.1.3 Solution 3

In the third situation the possibility will be examined for a regulated plant at the second rapid.
A regulated plant is a plant that only works when the price of the electricity is high (or the demand of it is high), therefore it only works some hours a day. Because the water can only pass some hours a day, the amount of flow that passes the turbine will be higher and the powerhouse requires **a turbine with a larger capacity**. Let's propose a powerplant that works 6h a day and a powerplant that works 8 hours a day.
The capacity of the forebay depends on how many hours a day the water can flow through the penstock. This extra parameter will influence the costs of the project.
Because the supply of water is variable, it is even more important than in the second solution to put a chimney before the power station. The opening and closing of the valves cause even a bigger risk of pressure differences and thus the hammer effect.

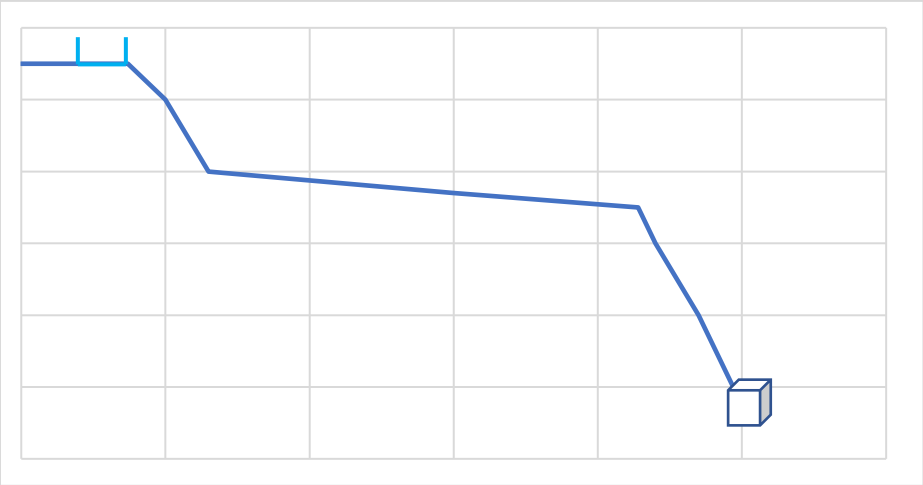


*Figure 18: simplified representation situation 3*

## 6.2 Power capacity

Knowing the flow (Q) of 15m³/s that has been found in chapter 5, the head (H) of both rapids and the efficiency (η=80%) , the power each plant can generate can be calculated with the next formula :
$P = 9,8*Q*H*\eta$.
In the first solution, the first powerplant has a power of 1756 kW, whereas the second has a power of 3531 kW. With this power, these powerplants can be categorized as 'small hydropower plants'.
The plant of the second solution has a power of 5886 kW, and belongs as well to the small hydropower plants. The two powerplants with 17658 and 23544 kW are categorized as medium Hydropower plants.

| | | **Power** |
|---|---|---|
| Solution 1 | Plant 1 | 1765 kW |
| | Plant 2 | 3531 kW |
| Solution 2 | | 5886 kW |
| Solution 3 | 8h | 17658 kW |
| | 6h | 23544 kW |

## 6.3 Net head

Because there are a lot of losses between the forebay and turbine, the gross head is not the most appropriate head to use for the dimensioning of the electromechanical equipment.

The biggest losses are the losses by friction of the water against the walls of the forced pipe and the losses through valves. Besides there are the losses caused by turbulence, when the flow changes direction, when passing through a grid, etc. These pressure losses are calculated using formulas derived from fluid dynamics.

- Losses caused by friction

$$h_f = f * \frac{L}{D} * \frac{v^2}{2*g}$$

With:
$h_f$ = losses caused by friction
f = Darcy friction factor (In function of the roughness, diameter and number of Reynolds)
L = length of the pipe
D = diameter of the pipe
v = velocity of the water
g = acceleration due to gravity (=9,81 m/s²)

Depending of the choice of the diameter of the pipe, the velocity, the Darcy friction factor and the caused friction are different.
Because the Reynolds number in all cases is high (> 4000), the flow can be seen as turbulent. Therefore, the friction factor only depends from the roughness of the tube and the pipe diameter.
For iron e=0,000045m.

$\mathbb{R}e = \frac{v*D}{V}$ > 4000, with V (=1*10^-6) viscosity of the water

$$\frac{1}{\sqrt{f}} = 2 * \log(3{,}7 * \frac{D}{e})$$

With the formulas above the losses caused by friction are calculated for some pipe diameters. Because there are 5 different length-flow combinations, the friction loses in these situations will be different as well.

| Pipe length 280m; Flow 15 m³/s; Gross head 15m | |
|---|---|
| **Pipe diameter [m]** | **Friction losses [m]** |
| 1 | 53,926 |
| 2 | 1,685 |
| 3 | 0,222 |
| 4 | 0,053 |
| 5 | 0,017 |

| Pipe length 350m; Flow 15 m³/s; Gross head 30m | |
|---|---|
| **Pipe diameter [m]** | **Friction losses [m]** |
| 1 | 67,408 |
| 2 | 2,106 |
| 3 | 0,277 |
| 4 | 0,066 |
| 5 | 0,022 |

| Pipe length 2100m; Flow 15 m³/s; Gross head 50m | |
|---|---|
| **Pipe diameter [m]** | **Friction losses [m]** |
| 1 | 404,447 |
| 2 | 12,639 |
| 3 | 1,664 |
| 4 | 0,395 |
| 5 | 0,129 |

| Pipe length 2100m; Flow 45 m³/s; Gross head 50m | |
|---|---|
| **Pipe diameter [m]** | **Friction losses [m]** |
| 1 | 3640.02 |
| 2 | 113,751 |
| 3 | 14,980 |
| 4 | 3,555 |
| 5 | 1,165 |
| 6 | 0,468 |

| Pipe length 2100m; Flow 60 m³/s; Gross head 50m | |
|---|---|
| **Pipe diameter [m]** | **Friction losses [m]** |
| 1 | 6471,15 |
| 2 | 202,223 |
| 3 | 26,63 |
| 4 | 6,319 |
| 5 | 2,071 |
| 6 | 0,832 |

- Losses caused by valves

Analogue, the losses caused by valves are calculated with the next formula.

$$h_v = k * \frac{v^2}{2*g}$$

With:
$h_v$= losses caused by valves
k = coefficient of the valve, in this project k = 0,6 as there is worked with a butterfly valve

v = velocity of the water
g = acceleration due to gravity

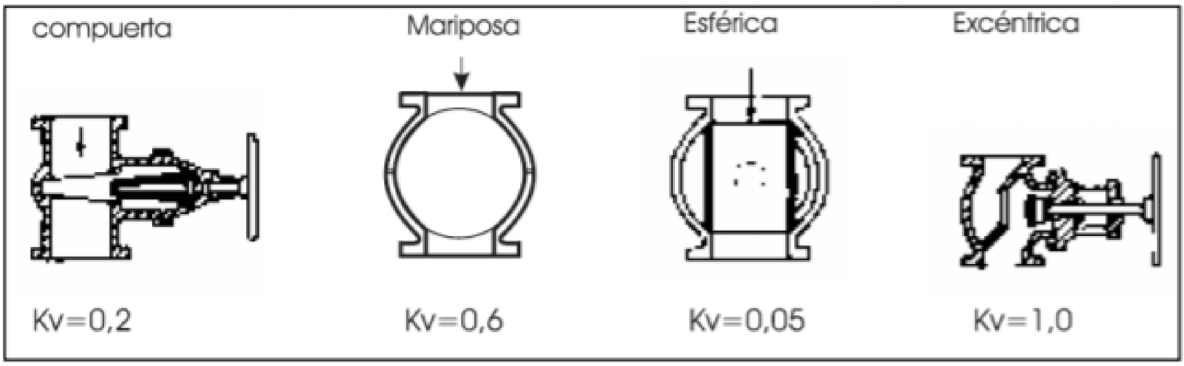



*Figure 19: loss coefficient of valves* [19]

| Pipe length 280, 350 and 2100m; Flow 15 $m^3/s$; Gross head 15m | |
|---|---|
| **Pipe diameter [m]** | **Valve losses [m]** |
| 1 | 11,15 |
| 2 | 0,69 |
| 3 | 0,13 |
| 4 | 0,04 |
| 5 | 0,02 |

| Pipe length 2100m; Flow 45 $m^3/s$; Gross head 50m | |
|---|---|
| **Pipe diameter [m]** | **Valve losses [m]** |
| 1 | 100,39 |
| 2 | 6,27 |
| 3 | 1,24 |
| 4 | 0,39 |
| 5 | 0,16 |
| 6 | 0,08 |

| Pipe length 2100m; Flow 60 $m^3/s$; Gross head 50m | |
|---|---|
| **Pipe diameter [m]** | **Valve losses [m]** |
| 1 | 178,47 |
| 2 | 11,15 |
| 3 | 2,20 |
| 4 | 0,69 |
| 5 | 0,29 |
| 6 | 0,14 |

- Total head loses

The sum of the losses caused by friction and the losses caused by the valves needs to be smaller than 5% of the gross head. For the gross head of 15m the total head loss needs to stay under 0,75m, for the gross head of 30m the total head loss needs to stay under 1,5m and for the gross head of 50m the total head loss must not exceed 2,5m. Besides this maximum head loses, also the cost of the tubes by increasing diameter need to be considered.
The most optimal combination of these two parameters is given in the table below.

| Situation | Used pipe diameter | Total head loses |
|---|---|---|
| Pipe length 280m ; Flow 15 $m^3/s$ ; Gross head 15m | 3m | 0,352m < 0,75m |
| Pipe length 350m ; Flow 15 $m^3/s$ ; Gross head 30m | 3m | 0,407m < 1,5m |
| Pipe length 2100m ; Flow 15 $m^3/s$ ; Gross head 50m | 3m | 1,794m < 2,5m |
| Pipe length 2100m ; Flow 45 $m^3/s$ ; Gross head 50m | 5m | 1,325m < 2,5m |
| Pipe length 2100m ; Flow 60 $m^3/s$ ; Gross head 50m | 5m | 2,361m < 2,5m |

| Situation | Net head |
|---|---|
| Pipe length 280m ; Flow 15 $m^3/s$ ; Gross head 15m | 14,648m |
| Pipe length 350m ; Flow 15 $m^3/s$ ; Gross head 30m | 29,539m |
| Pipe length 2100m ; Flow 15 $m^3/s$ ; Gross head 50m | 48,206m |
| Pipe length 2100m ; Flow 45 $m^3/s$ ; Gross head 50m | 48,675m |
| Pipe length 2100m ; Flow 60 $m^3/s$ ; Gross head 50m | 47,639m |

*Table 2: Net head of all situations*

This net head will be used in the program TURBNPRO to design the turbine.

## 6.4 Energy Production

As said in 6.1, there will be discussed three possible solutions to build hydropower plant(s) in this channel. In every situation the amount of energy that can be produced, is calculated and compared. The formula that is used to calculate the gross energy is E=2,722*η*V*H, at which η is the efficiency which takes into account all the loses from the penstock to the transformer. [20]
Small hydropower plants have an efficiency between 60-80%, whereas modern turbines tend to have an efficiency up to 90%. In this case we assume an efficiency of 80%. [21]

### 6.4.1 *Solution 1*

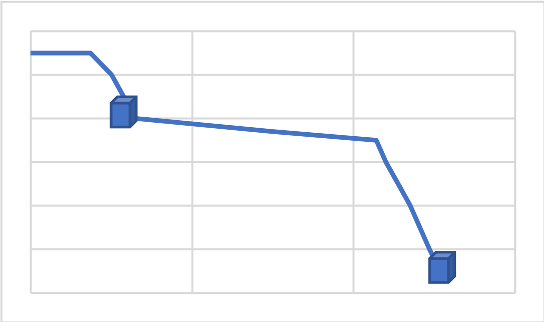
The amount of energy produced by two powerplants that work 24h a day, is calculated in this section.

- Plant 1

| | |
|---|---|
| Head [m] | 15 |
| Volume [hm³/year] | 247,86 |
| **$E_b$ [MWh/year]** | **8096,1** |

- Plant 2

| | |
|---|---|
| Head [m] | 30 |
| Volume [hm³/year] | 247,86 |
| **$E_b$ [MWh/year]** | **16192,29** |

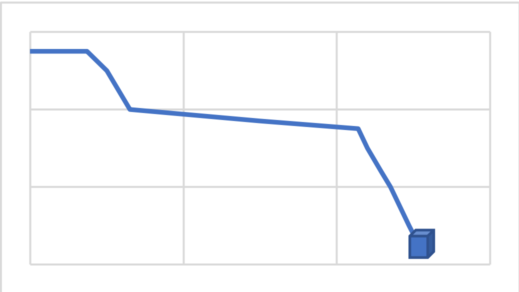


The total amount of energy that can be produced by this solution is the sum of the produced energy of both powerplants and is equal to **24288 MWh/year**.

### 6.4.2 *Solution 2*

The amount of energy produced by one powerplant that works 24h a day, is calculated in this section.

| | |
|---|---|
| Head [m] | 50 |
| Volume [hm³/year] | 247,86 |
| **$E_b$ [MWh/year]** | **26987,15** |



The total amount of energy that can be produced by this solution is **26987 MWh/year**.

### 6.4.3 *Solution 3*

The amount of energy produced by one powerplant that works 6 or 8 hours a day, is calculated in this section.
Because the head and the total volume that passes the plant stays the same, the amount of energy that can be produced stays the same as in the second situation, **26987 MWh/year**.
The flow and forebay capacity differs from the amount of time the powerplant is working.

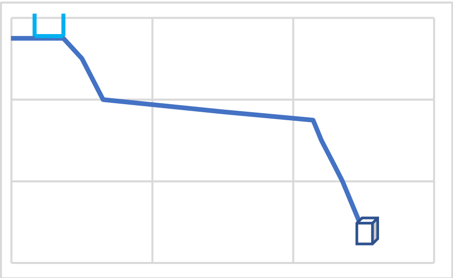
- 6h working

| Time [h/day] | Entering flow $Q_e$ [m³/s] | Leaving flow $Q_l$ [m³/s] | Forebay capacity [m³] |
|---|---|---|---|
| 18 | 15 | 0 | **972000** |
| **6** | 15 | **60** | |

- 8h working

| Time [h] | Entering flow $Q_e$ [m³/s] | Leaving flow $Q_l$ [m³/s] | Forebay capacity [m³] |
|---|---|---|---|
| 16 | 15 | 0 | **864000** |
| **8** | 15 | **45** | |

The 6h working solution requires a forebay capacity of 972000m³ and in both powerhouses a turbine that can handle a flow of 60m³/s. The 8h working solution requires a volume of the forebay of 864000m³ and turbines that can handle a flow of 45m³/s.
The needed capacity of the forebays are used later to compare the costs of the different solutions.



## 6.5 Electromechanical parts

In this section the major electromechanical parts needed in a hydropower plant are explained. More, the specific type of turbine for each situation is given. The prices of these turbines are given by the co-supervisor and give an idea of the electromechanical costs of each situation.

### *6.5.1 Turbine*

The choice of the turbine is very important whereas this part is essential for the conversion of the kinetic energy of the water into mechanical energy. In general, there are three main-types of turbines: the Pelton, Kaplan and Francis turbine. The type of the turbine depends on the head and the flow of the water of each project. This three most used turbines are shown in the figures below. [22]

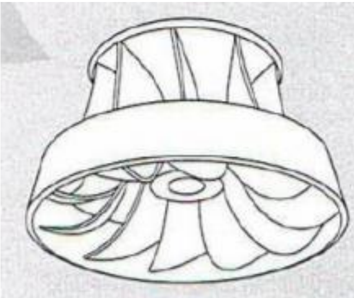


*Figure 20: Francis turbine*

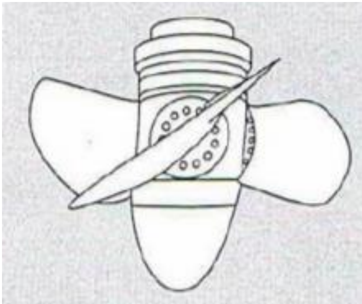


*Figure 21: Kaplan turbine*

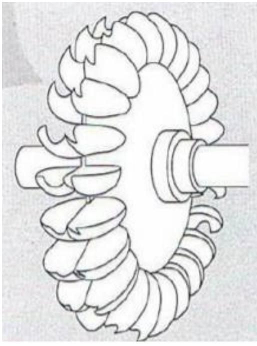


*Figure 22: Pelton turbine*

Regarding the location of the reservoirs and centrals the head can be calculated. The head of the first plant is more or less 15m, whereas the head of the second plant is around 30m. As said in chapter 5, the flow that will be used is $15m^3/s$.

Considering this head and this flow and noticing figure 23, the most recommended turbine for both plants would be **the Kaplan Turbine** or **the Francis Turbine**.

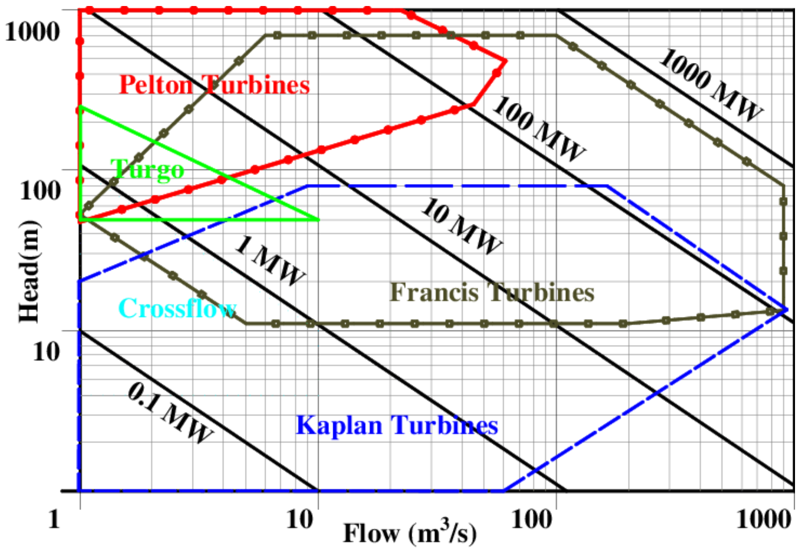


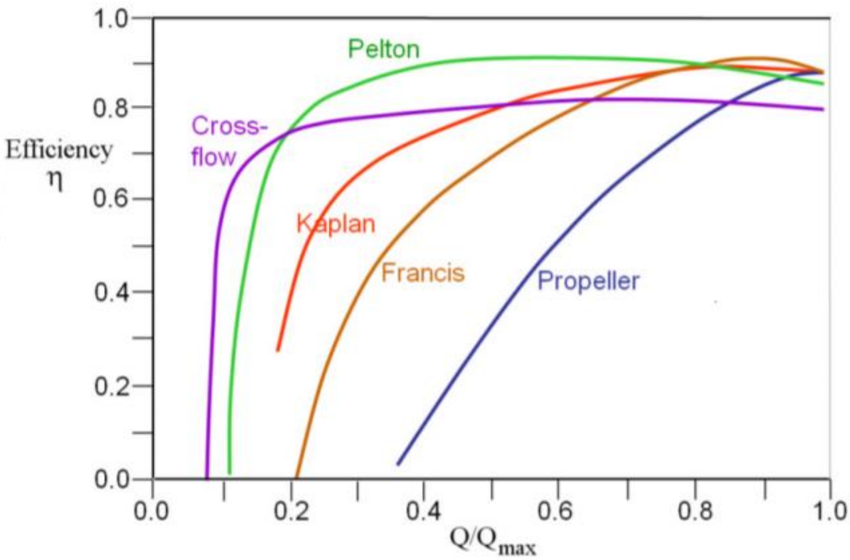

*Figure 23: Head-flow ranges of hydro turbines* [23]

The Kaplan turbine is an axial-flow reaction propeller turbine and is generally used for large flows and small heads between 2 and 40 meters. The flow enters in an axial way and also leaves the runner in an axial direction. There are double and single regulated Kaplan turbines. The double regulated turbine has adjustable runner blades and adjustable guide vanes while the single regulated turbine has only adjustable runner blades.

The Francis turbine is a reaction turbine with adjustable guide vanes and fixed runner blades used for medium heads and medium flows. The flow enters in a radial way in the runner and then turns a right angle so it leaves the turbine in an axial way. The axis can be placed in a vertical or a horizontal way. [24]

The efficiency of a Francis turbine is higher than the efficiency of a Kaplan turbine when there is worked with a discharge close to the maximum possible discharge. This can be seen on the graph below. Therefor a Francis turbine is more interesting to work with.

**The turbine used for this project is a Francis Turbine**.




*Graph 7: Efficiencies versus discharges for Kaplan, Pelton and Francis turbine* [25]

### *6.5.1.1 Turbine dimensioning*

To get to know the size of the turbine that need to be used in every situation, the software tool TURBNPRO is used. This programme is used by hydroelectric project developers, consulting engineers performing feasibility studies and preliminary project designs water power systems educators. It develops information on hydraulic turbines, their selection and application under specific site conditions.

Three different situations with 5 different turbines are treated. Given some characteristics of the powerplant, TURBNPRO calculates the most suitable turbine for each situation.
Because this software is a made in the USA , the unities are given in feet, cfs and Fahrenheit.
The net head that is used, is calculated in 6.3. The used characteristics of each turbine are always given in the yellow frame. Only at the first turbine all the steps in the program are shown, the other four turbines just give the characteristics and the results

- ***<u>Turbine 1 (Pipe length 280m ; Flow 15 m³/s ; Gross head 15m)</u>***

The data in the yellow frame are the characteristics of the powerplant of the first situation in the first rapid. The frame next to it indicates the possible solutions for these characteristics. In this case the first option is chosen whereas here the centreline is the least. As higher the centreline setting, as deeper the turbine needs to be placed, as more costs can occur for excavation works.

| Characteristic | Entry |
|---|---|
| Rated Discharge in cfs | 530 |
| Net Head in feet | 48 |
| Gross Head in feet | 49 |
| Site Elevation in feet | 2625 |
| Water Temp in degrees F | 59 |
| Unit Setting to TW in feet | 0.000 |
| Efficiency Priority (0 to 10) | 0 |
| System Freq (50 or 60Hz) | 50 |
| Minimum Net Head in feet | 43 |
| Maximum Net Head in feet | 49 |

*Figure 24: characteristics of hydropower plant 1*

| Solution Number | Runner Diameter Inches | Runner Diameter Millimeters | Unit Speed rpm | Specific Speed NS | Centerline Setting feet |
|---|---|---|---|---|---|
| 1 | 66.7 | 1695 | 214.3 | 86 | 15.9 |
| 2 | 68.3 | 1735 | 200.0 | 80 | 16.9 |
| 3 | 69.8 | 1774 | 187.5 | 75 | 17.9 |
| 4 | 71.4 | 1814 | 176.5 | 71 | 18.7 |
| 5 | 73.0 | 1853 | 166.7 | 67 | 19.5 |
| 6 | 74.5 | 1893 | 157.9 | 63 | 20.3 |
| 7 | 75.9 | 1928 | 150.0 | 60 | 21.0 |
| 8 | 77.3 | 1962 | 142.9 | 57 | 21.7 |
| 9 | 78.6 | 1996 | 136.4 | 55 | 22.4 |
| 10 | 79.9 | 2030 | 130.4 | 52 | 23.0 |

Preliminary Output: 1917 KW

*Figure 25: turbine solution possibilities*

Next, the turbine configuration needs to be determined. In all the five cases the default solution is chosen.

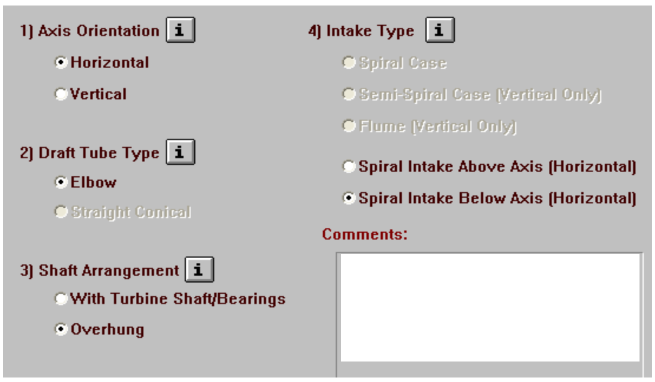
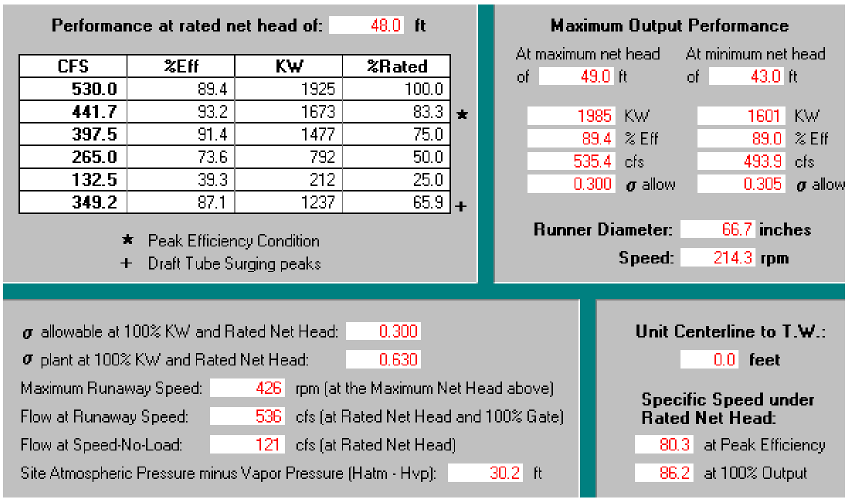



*Figure 26: turbine configuration*

After the input of this data is finished, the solution information can be consulted, as seen in the frames below. All the performance data and dimensions of the calculated turbine are displayed.



Performance at rated net head of: 48.0 ft

| CFS | %Eff | KW | %Rated | |
|---|---|---|---|---|
| 530.0 | 89.4 | 1925 | 100.0 | |
| 441.7 | 93.2 | 1673 | 83.3 | ★ |
| 397.5 | 91.4 | 1477 | 75.0 | |
| 265.0 | 73.6 | 792 | 50.0 | |
| 132.5 | 39.3 | 212 | 25.0 | |
| 349.2 | 87.1 | 1237 | 65.9 | + |

★ Peak Efficiency Condition
+ Draft Tube Surging peaks

Maximum Output Performance

| | At maximum net head of 49.0 ft | At minimum net head of 43.0 ft |
|---|---|---|
| KW | 1985 | 1601 |
| % Eff | 89.4 | 89.0 |
| cfs | 535.4 | 493.9 |
| σ allow | 0.300 | 0.305 |

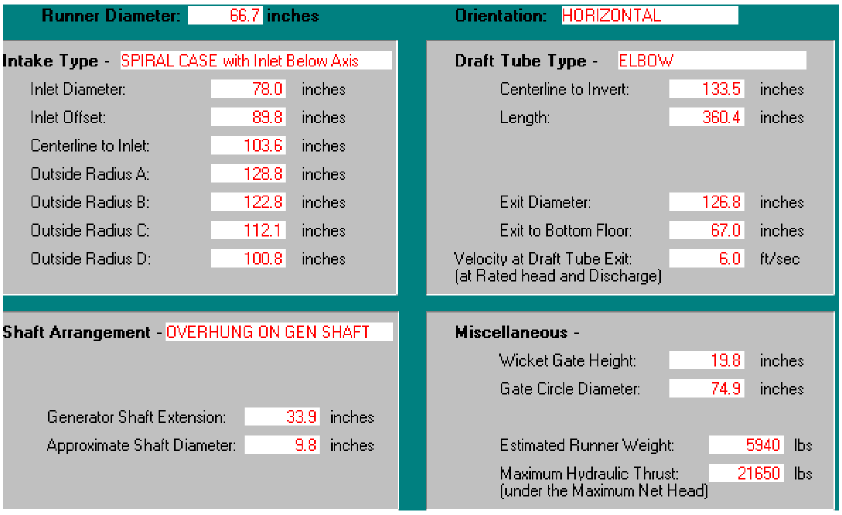
Runner Diameter: 66.7 inches
Speed: 214.3 rpm

σ allowable at 100% KW and Rated Net Head: 0.300
σ plant at 100% KW and Rated Net Head: 0.630
Maximum Runaway Speed: 426 rpm (at the Maximum Net Head above)
Flow at Runaway Speed: 536 cfs (at Rated Net Head and 100% Gate)
Flow at Speed-No-Load: 121 cfs (at Rated Net Head)
Site Atmospheric Pressure minus Vapor Pressure (Hatm - Hvp): 30.2 ft

Unit Centerline to T.W.: 0.0 feet

Specific Speed under Rated Net Head:
80.3 at Peak Efficiency
86.2 at 100% Output

*Figure 27: Turbine 1 performance data*



Runner Diameter: 66.7 inches
Orientation: HORIZONTAL

Intake Type - SPIRAL CASE with Inlet Below Axis

| | | |
|---|---|---|
| Inlet Diameter: | 78.0 | inches |
| Inlet Offset: | 89.8 | inches |
| Centerline to Inlet: | 103.6 | inches |
| Outside Radius A: | 128.8 | inches |
| Outside Radius B: | 122.8 | inches |
| Outside Radius C: | 112.1 | inches |
| Outside Radius D: | 100.8 | inches |

Draft Tube Type - ELBOW

| | | |
|---|---|---|
| Centerline to Invert: | 133.5 | inches |
| Length: | 360.4 | inches |
| Exit Diameter: | 126.8 | inches |
| Exit to Bottom Floor: | 67.0 | inches |
| Velocity at Draft Tube Exit: (at Rated head and Discharge) | 6.0 | ft/sec |

Shaft Arrangement - OVERHUNG ON GEN SHAFT

| | | |
|---|---|---|
| Generator Shaft Extension: | 33.9 | inches |
| Approximate Shaft Diameter: | 9.8 | inches |

Miscellaneous -

| | | |
|---|---|---|
| Wicket Gate Height: | 19.8 | inches |
| Gate Circle Diameter: | 74.9 | inches |
| Estimated Runner Weight: | 5940 | lbs |
| Maximum Hydraulic Thrust: (under the Maximum Net Head) | 21650 | lbs |

*Figure 28: Turbine 1 dimensional data*

Besides the related figures of the turbine are given. The measurement of the different parts can be found in the frames above. One of the most important parameters to determine the price of the turbine, is the runner diameter. This turbine needs a **runner diameter of 1,95m** and has **a speed of 214,3 rpm**. This speed can be used to determine the right generator.
Regarding these parameters, an estimation of the price of this turbine is done; **245.000€**.

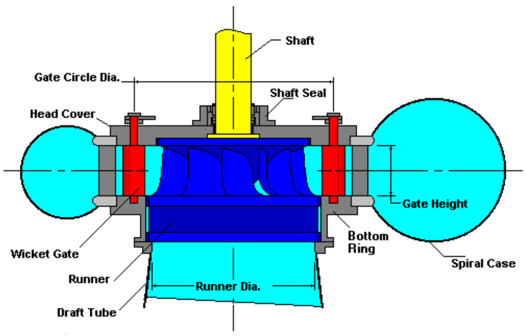



*Figure 29: distributor section*

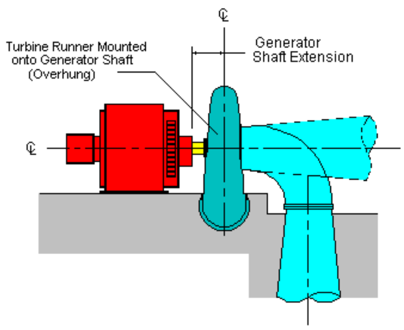



*Figure 30: Arrangement*

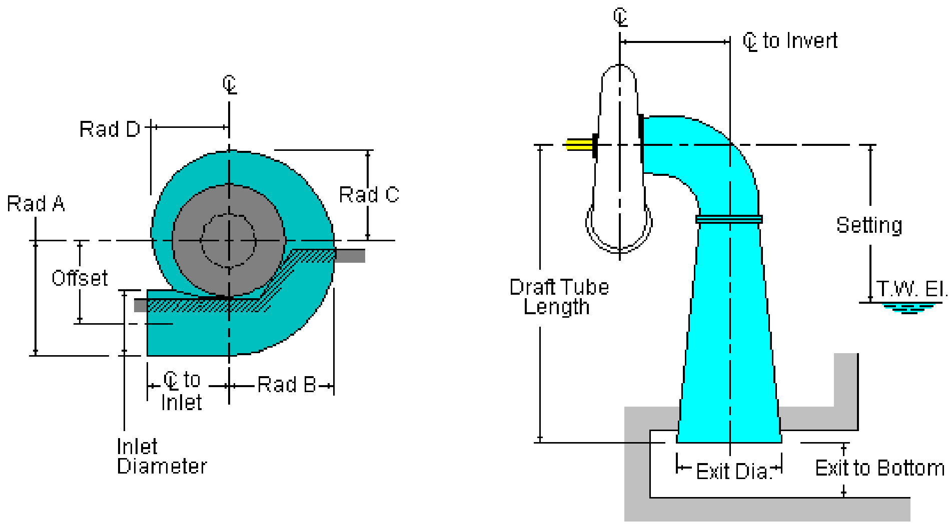



*Figure 31: Intake/Draft tube*

Another option of the software is to display the hill curve of the turbine. A hill curve shows the efficiency as a function of head and flow with its operating limits imposed by cavitation.

The hill curve below shows that the maximum efficiency is at a flow of 12,5 m³/s and a head of 14,6m. The red line indicates the edge that may not be exceeded because of the presence of cavitation.

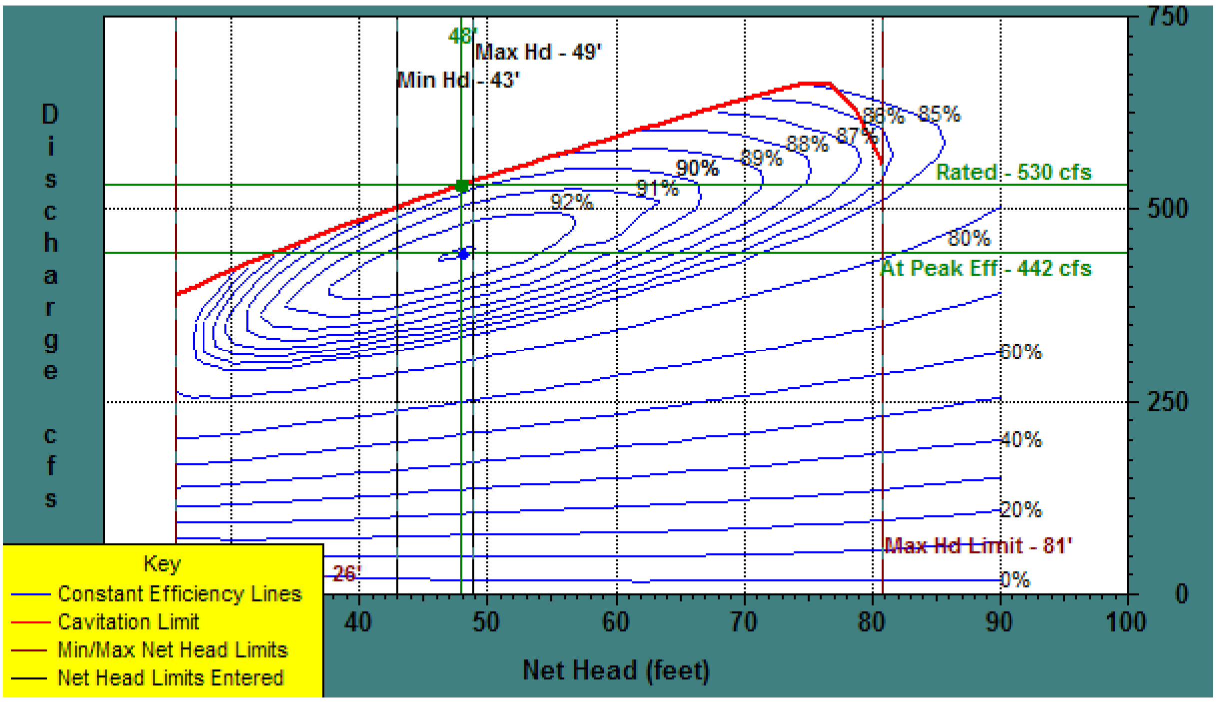



*Figure 32: Hill curve*

- ***Turbine 2 (Pipe length 350m ; Flow 15 m³/s ; Gross head 30m)***

The data in the yellow frame are the characteristics of the powerplant of the first situation in the second rapid.

| Characteristic | Entry |
|---|---|
| Rated Discharge in cfs | 530 |
| Net Head in feet | 97 |
| Gross Head in feet | 98 |
| Site Elevation in feet | 2625 |
| Water Temp in degrees F | 59 |
| Unit Setting to TW in feet | 0.000 |
| Efficiency Priority (0 to 10) | 0 |
| System Freq (50 or 60Hz) | 50 |
| Minimum Net Head in feet | 85 |
| Maximum Net Head in feet | 98 |

*Figure 33: characteristics of hydropower plant 2*

**Performance at rated net head of:** 97.0 **ft**

| CFS | %Eff | KW | %Rated | |
|---|---|---|---|---|
| 530.0 | 89.6 | 3901 | 100.0 | |
| 441.7 | 93.0 | 3375 | 83.3 | ★ |
| 397.5 | 91.5 | 2988 | 75.0 | |
| 265.0 | 75.6 | 1645 | 50.0 | |
| 132.5 | 43.0 | 468 | 25.0 | |
| 335.3 | 86.2 | 2375 | 63.3 | + |

★ Peak Efficiency Condition
+ Draft Tube Surging peaks

**Maximum Output Performance**

| At maximum net head of 98.0 ft | | At minimum net head of 85.0 ft | |
|---|---|---|---|
| 3942 | KW | 3183 | KW |
| 89.6 | % Eff | 89.2 | % Eff |
| 530.0 | cfs | 495.4 | cfs |
| 0.273 | σ allow | 0.279 | σ allow |

**Runner Diameter:** 57.6 **inches**
**Speed:** 333.3 **rpm**

σ allowable at 100% KW and Rated Net Head: 0.273
σ plant at 100% KW and Rated Net Head: 0.312
Maximum Runaway Speed: 646 rpm (at the Maximum Net Head above)
Flow at Runaway Speed: 483 cfs (at Rated Net Head and 100% Gate)
Flow at Speed-No-Load: 105 cfs (at Rated Net Head)
Site Atmospheric Pressure minus Vapor Pressure (Hatm - Hvp): 30.2 ft

**Unit Centerline to T.W.:** 0.0 **feet**

**Specific Speed under Rated Net Head:**
73.7 at Peak Efficiency
79.2 at 100% Output

*Figure 34: Turbine 2 performance data*

**Runner Diameter:** 57.6 **inches**
**Orientation:** HORIZONTAL

**Intake Type -** SPIRAL CASE with Inlet Below Axis

| | | |
|---|---|---|
| Inlet Diameter: | 72.0 | inches |
| Inlet Offset: | 75.3 | inches |
| Centerline to Inlet: | 108.0 | inches |
| Outside Radius A: | 111.3 | inches |
| Outside Radius B: | 106.0 | inches |
| Outside Radius C: | 96.8 | inches |
| Outside Radius D: | 87.0 | inches |

**Draft Tube Type -** ELBOW

| | | |
|---|---|---|
| Centerline to Invert: | 115.2 | inches |
| Length: | 311.1 | inches |
| Exit Diameter: | 109.5 | inches |
| Exit to Bottom Floor: | 58.0 | inches |
| Velocity at Draft Tube Exit: (at Rated head and Discharge) | 8.1 | ft/sec |

**Shaft Arrangement -** OVERHUNG ON GEN SHAFT

| | | |
|---|---|---|
| Generator Shaft Extension: | 30.9 | inches |
| Approximate Shaft Diameter: | 10.7 | inches |

**Miscellaneous -**

| | | |
|---|---|---|
| Wicket Gate Height: | 16.9 | inches |
| Gate Circle Diameter: | 65.1 | inches |
| Estimated Runner Weight: | 4853 | lbs |
| Maximum Hydraulic Thrust: (under the Maximum Net Head) | 30714 | lbs |

*Figure 35: Turbine 2 dimensional data*

The calculated diameter of the runner is 1,5m and the used speed is 333,3 rpm.
An estimation of the price of this turbine is **295.000€**.

- ***Turbine 3 (Pipe length 2100m ; Flow 15 m³/s ; Gross head 50m)***

The data in the yellow frame are the characteristics of the powerplant of the second situation.

| Characteristic | Entry |
|---|---|
| Rated Discharge in cfs | 530 |
| Net Head in feet | 158 |
| Gross Head in feet | 164 |
| Site Elevation in feet | 2625 |
| Water Temp in degrees F | 59 |
| Unit Setting to TW in feet | 0.000 |
| Efficiency Priority (0 to 10) | 0 |
| System Freq (50 or 60Hz) | 50 |
| Minimum Net Head in feet | 154 |
| Maximum Net Head in feet | 164 |

*Figure 36: characteristics of hydropower plant 3*

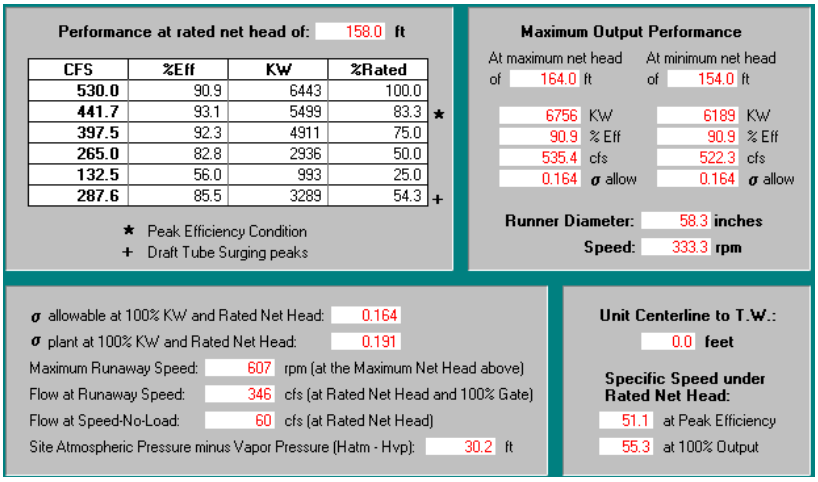



*Figure 37: Turbine 3 performance data*

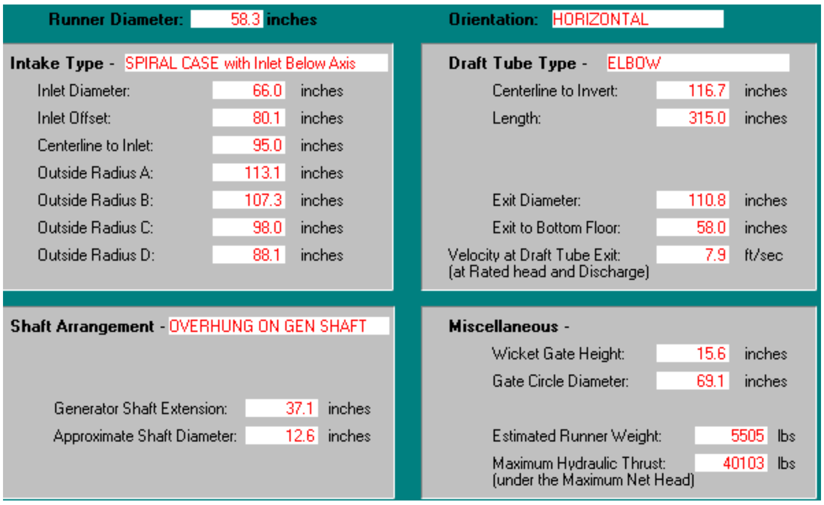



*Figure 38: Turbine 3 dimensional data*

The calculated diameter of the runner is 1,50m and the used speed is 333,3 rpm.
An estimation of the price of this turbine is **325.000€**.

- ***Turbine 4 (Pipe length 2100m ; Flow 45 m³/s ; Gross head 50m)***

The data in the yellow frame are the characteristics of the 8 hour working powerplant of the third situation.

| Characteristic | Entry |
|---|---|
| Rated Discharge in cfs | 1589 |
| Net Head in feet | 156 |
| Gross Head in feet | 164 |
| Site Elevation in feet | 2625 |
| Water Temp in degrees F | 59 |
| Unit Setting to TW in feet | 0.000 |
| Efficiency Priority (0 to 10) | 0 |
| System Freq (50 or 60Hz) | 50 |
| Minimum Net Head in feet | 154 |
| Maximum Net Head in feet | 164 |

*Figure 39: characteristics of hydropower plant 4*

**Performance at rated net head of:** 156.0 ft

| CFS | %Eff | KW | %Rated | |
|---|---|---|---|---|
| 1589.0 | 91.1 | 19131 | 100.0 | |
| 1324.2 | 93.5 | 16351 | 83.3 | * |
| 1191.8 | 92.7 | 14589 | 75.0 | |
| 794.5 | 82.4 | 8646 | 50.0 | |
| 397.3 | 54.8 | 2878 | 25.0 | |
| 878.0 | 85.7 | 9944 | 55.3 | + |

* Peak Efficiency Condition
\+ Draft Tube Surging peaks

**Maximum Output Performance**

| At maximum net head of 164.0 ft | | At minimum net head of 154.0 ft | |
|---|---|---|---|
| 20522 | KW | 18607 | KW |
| 91.1 | % Eff | 91.1 | % Eff |
| 1621.4 | cfs | 1565.6 | cfs |
| 0.179 | σ allow | 0.178 | σ allow |

**Runner Diameter:** 99.6 **inches**
**Speed:** 200.0 **rpm**

σ allowable at 100% KW and Rated Net Head: 0.178
σ plant at 100% KW and Rated Net Head: 0.194
Maximum Runaway Speed: 369 rpm (at the Maximum Net Head above)
Flow at Runaway Speed: 1074 cfs (at Rated Net Head and 100% Gate)
Flow at Speed-No-Load: 191 cfs (at Rated Net Head)
Site Atmospheric Pressure minus Vapor Pressure (Hatm - Hvp): 30.2 ft

**Unit Centerline to T.W.:** 0.0 **feet**

**Specific Speed under Rated Net Head:**
53.7 at Peak Efficiency
58.1 at 100% Output

*Figure 40: Turbine 4 performance data*

**Runner Diameter:** 99.6 **inches** **Orientation:** VERTICAL

**Intake Type -** SPIRAL CASE

| | | |
|---|---|---|
| Inlet Diameter: | 114.0 | inches |
| Inlet Offset: | 136.0 | inches |
| Centerline to Inlet: | 164.2 | inches |
| Outside Radius A: | 193.0 | inches |
| Outside Radius B: | 183.2 | inches |
| Outside Radius C: | 167.3 | inches |
| Outside Radius D: | 150.4 | inches |

**Draft Tube Type -** ELBOW

| | | |
|---|---|---|
| Centerline to Invert: | 299.5 | inches |
| Length: | 477.9 | inches |
| Exit Width: | 298.7 | inches |
| Exit Height: | 179.2 | inches |
| Velocity at Draft Tube Exit: (at Rated head and Discharge) | 4.3 | ft/sec |

**Shaft Arrangement -** WITH SHAFT AND BEARINGS

| | | |
|---|---|---|
| Centerline to Shaft Coupling: | 116.7 | inches |
| Turbine Shaft Diameter: | 22.0 | inches |

**Miscellaneous -**

| | | |
|---|---|---|
| Wicket Gate Height: | 27.2 | inches |
| Gate Circle Diameter: | 116.7 | inches |
| Runner and Shaft Weight: | 38186 | lbs |
| Estimated Runner Weight: | 24579 | lbs |
| Maximum Hydraulic Thrust: (under the Maximum Net Head) | 114524 | lbs |

*Figure 41: Turbine 4 dimensional data*

The calculated diameter of the runner is 2,5m and the used speed is 200 rpm.
An estimation of the price of this turbine is **385.000€**.

- ***Turbine 5 (Pipe length 2100m ; Flow 60 m³/s ; Gross head 50m)***

The data in the yellow frame are the characteristics of the 6 hour working powerplant of the third situation.

| Characteristic | Entry |
|---|---|
| Rated Discharge in cfs | 2119 |
| Net Head in feet | 160 |
| Gross Head in feet | 164 |
| Site Elevation in feet | 2625 |
| Water Temp in degrees F | 59 |
| Unit Setting to TW in feet | 0.000 |
| Efficiency Priority (0 to 10) | 0 |
| System Freq (50 or 60Hz) | 50 |
| Minimum Net Head in feet | 154 |
| Maximum Net Head in feet | 164 |

*Figure 42: characteristics of hydropower plant 5*

**Performance at rated net head of:** 160.0 ft

| CFS | %Eff | KW | %Rated | |
|---|---|---|---|---|
| 2119.0 | 91.2 | 26194 | 100.0 | |
| 1765.8 | 93.6 | 22388 | 83.3 | ★ |
| 1589.3 | 92.8 | 19975 | 75.0 | |
| 1059.5 | 82.5 | 11838 | 50.0 | |
| 529.8 | 54.9 | 3941 | 25.0 | |
| 1170.7 | 85.8 | 13615 | 55.2 | + |

★ Peak Efficiency Condition
+ Draft Tube Surging peaks

**Maximum Output Performance**

| | At maximum net head of 164.0 ft | At minimum net head of 154.0 ft |
|---|---|---|
| KW | 27120 | 24454 |
| % Eff | 91.2 | 91.1 |
| cfs | 2140.4 | 2057.4 |
| σ allow | 0.178 | 0.179 |

**Runner Diameter:** 114.3 **inches**
**Speed:** 176.5 **rpm**

σ allowable at 100% KW and Rated Net Head: 0.178
σ plant at 100% KW and Rated Net Head: 0.189
Maximum Runaway Speed: 322 rpm (at the Maximum Net Head above)
Flow at Runaway Speed: 1432 cfs (at Rated Net Head and 100% Gate)
Flow at Speed-No-Load: 255 cfs (at Rated Net Head)
Site Atmospheric Pressure minus Vapor Pressure (Hatm - Hvp): 30.2 ft

**Unit Centerline to T.W.:** 0.0 **feet**

**Specific Speed under Rated Net Head:**
53.7 at Peak Efficiency
58.1 at 100% Output

*Figure 43: Turbine 5 performance data*

**Runner Diameter:** 114.3 **inches** **Orientation:** VERTICAL

**Intake Type -** SPIRAL CASE

| | | |
|---|---|---|
| Inlet Diameter: | 132.0 | inches |
| Inlet Offset: | 155.5 | inches |
| Centerline to Inlet: | 192.6 | inches |
| Outside Radius A: | 221.5 | inches |
| Outside Radius B: | 210.3 | inches |
| Outside Radius C: | 192.0 | inches |
| Outside Radius D: | 172.5 | inches |

**Draft Tube Type -** ELBOW

| | | |
|---|---|---|
| Centerline to Invert: | 343.7 | inches |
| Length: | 548.5 | inches |
| Exit Width: | 342.8 | inches |
| Exit Height: | 205.7 | inches |
| Velocity at Draft Tube Exit: (at Rated head and Discharge) | 4.3 | ft/sec |

**Shaft Arrangement -** WITH SHAFT AND BEARINGS

| | | |
|---|---|---|
| Centerline to Shaft Coupling: | 134.0 | inches |
| Turbine Shaft Diameter: | 25.5 | inches |

**Miscellaneous -**

| | | |
|---|---|---|
| Wicket Gate Height: | 31.2 | inches |
| Gate Circle Diameter: | 134.0 | inches |
| Runner and Shaft Weight: | 56500 | lbs |
| Estimated Runner Weight: | 35611 | lbs |
| Maximum Hydraulic Thrust: (under the Maximum Net Head) | 150752 | lbs |

*Figure 44: Turbine 5 dimensional data*

The calculated diameter of the runner is 2,9m and the used speed is 176,5 rpm.
An estimation of the price of this turbine is **430.000€**.

### *6.5.2 Generator*

The generator transforms the mechanical energy of the turbine rotations into electrical energy using electromagnetic induction.

A runner leads the movements of the turbine to a generator. Using a rotor, this generator converts the mechanical energy into electric energy.
At the top of the generator the **exciter** is located. This equipment gets a small DC power supply from the **AVR** (automatic voltage regulator). The AVR gives the first pulses of electric current to the electromagnets on the **rotor** in order to give the rotor the same pulse frequency as the pulses of the grid. The **stator** is located at the outside part and is made of windings, which are three coils of copper wire. The magnetic poles on top of the rotor create a magnetic field for each magnet. These magnets are placed alternating by poles so that each magnet has a neighbour with a different pole.
Because the rotor is located inside the stator, the magnetic fields creates a reaction on the windings of the stator. These reactions generate pulses of AC power and next it gets transmitted to the grid by conductors attached to the stator. The stator has three different types of conductors, so the generator can produce a three-phase alternating current.

A generator can be synchronous or asynchronous. The synchronous generator the conversion of energy occurs at a constant speed. The asynchronous generator works at speeds above its synchronous speed and is used in most small hydropower plants.

### *6.5.3 Transformer*

After the (possible) speed increaser, the electricity passes a transformer. This transformer increases the voltage and reduces the current. This makes the transfer of electricity more efficient as less energy is lost as heat. Because this transformation releases a lot of heat, the transformer must be provided by a cooling system. Depending the constructive characteristics, another type of cooling system is used.

### 6.5.4 Control, protection and regulation

To be able to control, regulate and protect the good functioning of the powerplant, the installation of several extra elements is needed. These components as well act and correct when any failure occurs in the machinery.

All parts of the powerhouse are linked through a **control and protection system**. This system makes sure that all elements keep functioning the most optimal way and that they are not being overloaded. The load on the generator, the velocity of the rotor, the velocity of the turbine, the position of the wicket gates, the flow etc. can be changed when needed.

The most important control elements for the **control of the turbine** are the speed regulator in installations with synchronous groups, the level regulators for plants with asynchronous groups connected to the network, the power regulator generated for power plants in isolated network and the turbine flow regulator. For the **control of the generator**, the most important elements are the voltage regulator for synchronous groups, the synchronization equipment and the capacitor banks. Furthermore there are mechanical protections, electric protections and protection of the voltage lines. [26]

Another important protection equipment are the **bearings**. The main functions of this equipment are to keep the shaft on the right place and minimalize frictions that can be harmful for the electromechanical equipment. One of the most important runners is the guide bearing, which resists the water forces and mechanical imbalance and keeps the turbine in its centred position.
Most of the bearings are either water or oil lubricated.

To regulate the speed of the turbine shaft, a **speed increaser** can be used. Most generators work with velocity of 750-1000 rpm, whereas the turbine used in this case only has a 333,3 rpm. Therefore, a speed increaser is needed to reach the speed of the generator. There are three kinds of speed increasers; parallel-shaft, bevel gears and belt speed increasers.

# 7. Economic Study

In this chapter the economical part of the project is examined. In the first section the Spanish electric market with its participants is explained. Next the prices of the electricity in this market are resumed and the costs a project can have are explained. These prices are used in the fourth section to calculate the benefits one single powerplant in every situation can get.

## 7.1 Electric market in Spain

Before we can use the electricity in our house, it needs to pass a lot of actors. In this section all these actors, that are involved bringing the electricity to the consumer, are mentioned and explained. [27]

- **Operators**
  The operators can be divided in two organisations: the market operators and the system operators. The operator of the market must supervise the economic management of the system, such as agreement operations and offer matching of prices. This responsibility is done by the company OMIE (Operador del Mercado Ibérico de Energía).
  The function of system operator is carried out by the company REE (Red Eléctrica de España) and has a responsibility to manage the technical part. Its function is to manage the activities related to the management of energy flows and the determination and allocation of transport losses.

- **Producers**
  The first thing that needs to be done is the production of the electricity. This can be done in a lot of different ways with many different resources as explained in the introduction.
  The producers are responsible for the generation of the electricity. At the same time they are responsible for the construction, maintenance and operation of the plants.

- **Transporters**
  The organ that is responsible for the transport is REE, they need to be sure that the high-voltage transport networks are able to work and in good conditions. As well it is their function to build these 220-400kV transport lines.

- **Distributors**
  The distributers have as task to distribute and bring the electricity to the end consumers. They also build, maintain and operate these voltage lines of less than 220kV. Besides they take care of the measuring of consumption, the informing of the agents and customers involved, the annually presenting of their investment plans to the Autonomous Communities.

  In Spain there are 5 companies that provide this distribution: Endesa, Iberdrola, union Fenosa, hc energia and Viesgo. The territories where they work are marked in the figure below.


*Figure 45: territories of action of each distribution company* [27]

- **Marketers**
  The marketers buy daily energy on the market and sell it to the consumers or to international exchange operations. The consumers can make their decision in the open market, what means they have a choice from which company they buy their electricity.
  The money that the consumer pays to his marketing company consists as well of the contribution for the use of the electricity networks of the distribution company and of the price of the consumed energy.

  Small consumers can make use of ‘PVPC - Precio Voluntario para el Pequeño Consumidor’ (voluntary prices for the small consumer). This price is calculated from the average of the hourly electricity prices and changes every month according to the behaviour of the market. [28]

These actors are not only present in Spain, but in most countries of Europe. Therefore it is possible to have a cooperation of energy systems. The strengthening of international electricity connections is essential for an optimal use of the energy system. This collaboration of neighbouring countries makes sure that Spain has a more secure energy supply, a better integration of renewable energy and an increase of efficiency. [29]

Figure 46 show the commercial exchange capacity of Spain in MW from 04/27/2019 to 05/10/2019. Besides France and Morocco, it has the largest cooperation with Portugal.

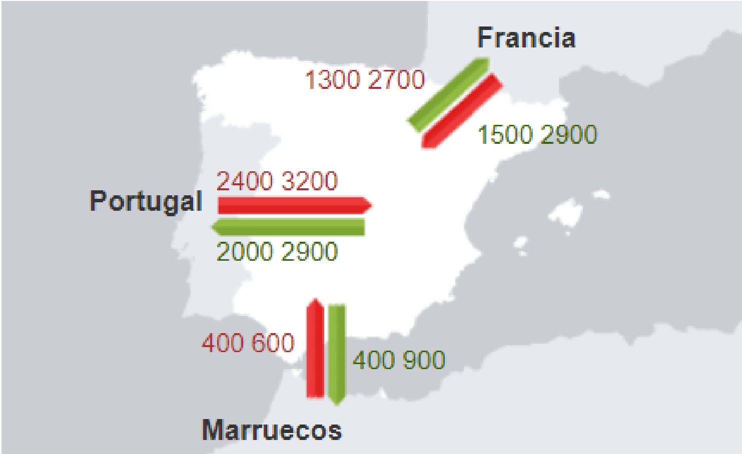



*Figure 46: commercial exchange capacity* [29]

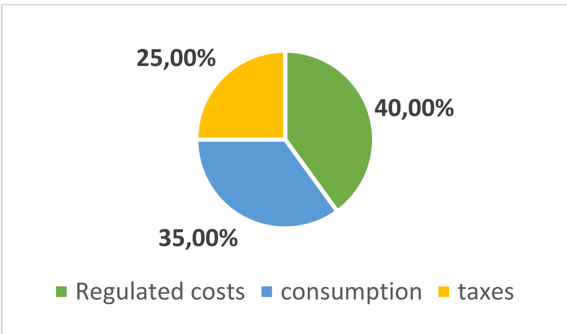
The prices of the electricity rest on the trading between operators and are determined in the daily market or the intraday market.

- **Daily market**
  Every day at noon the electricity prices are set for the 24 hours of the next day. The amount and price of the energy at a specific hour are calculated in advance using the marginal pricing model adopted by the European Union. This price is determined at the point where the demand and supply curves cross. The way companies interact in the free trade between buying and selling energy is the most efficient solution.

- **Intraday market**
  When the prices of the daily market are set, companies still have other opportunities to sell and buy electricity on the intraday market. It is possible to negotiate up to one hour before the delivering of the energy.
  [30]

Only 35% of the price consumers pay for their electricity in Spain is the actual consumption of the energy at home. The other 65% of the price is divided in regulated costs and taxes.

With 40% of the total price, regulated costs have the biggest impact. They exist of the contribution for the development of renewable energy, for the access of the electricity, for the transport and distribution of the electricity. The other 25% are taxes. [31]




*Graph 8: composition of electricity bill*

## 7.2 Energy prices

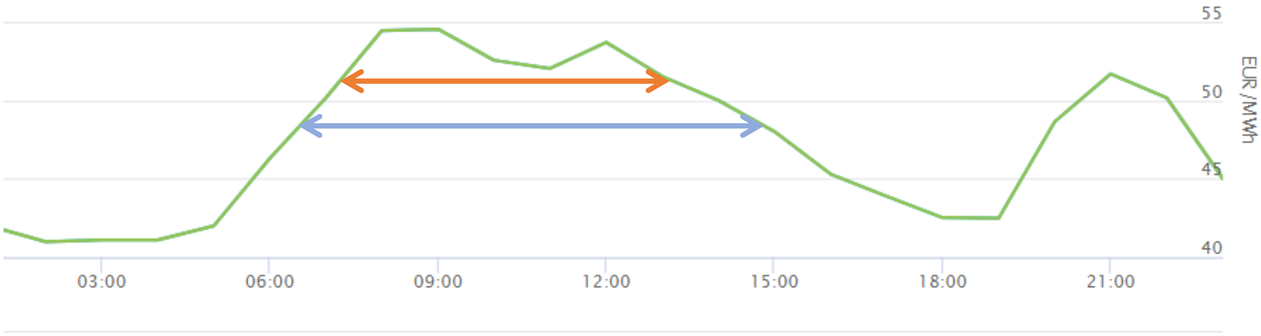
The way the electric market works and how energy prices are determined, is explained in the previous section. In this section the average monthly energy price of the daily market is shown . Further, this price is used to calculate the benefits one single powerplant has.

After every year OMIE provides a form with energy-price related information of the past year.
In this project the daily market prices are chosen, whereas these are more stable and reliable. In the table below, the average monthly price in €/MWh is shown of the year 2017 and 2018. From these years a trend is deduced and this results in a value of more or less **55 €/MWh**. Choosing this value, a rising trend is taken into account. In the next section, this value is used to determine the benefits of the first and second situation where the powerplant works for 24h.

| **Electricity Price** | | |
|---|---|---|
| **average monthly price [€/MWh]** | 2018 | 2017 |
| jan | 49,98 | 71,49 |
| feb | 54,88 | 51,74 |
| mar | 40,18 | 43,19 |
| apr | 42,67 | 43,69 |
| may | 54,92 | 47,11 |
| jun | 58,46 | 50,22 |
| jul | 61,88 | 48,63 |
| aug | 64,33 | 47,46 |
| sep | 71,27 | 49,15 |
| oct | 65,08 | 56,77 |
| nov | 61,97 | 59,19 |
| dec | 61,81 | 57,94 |

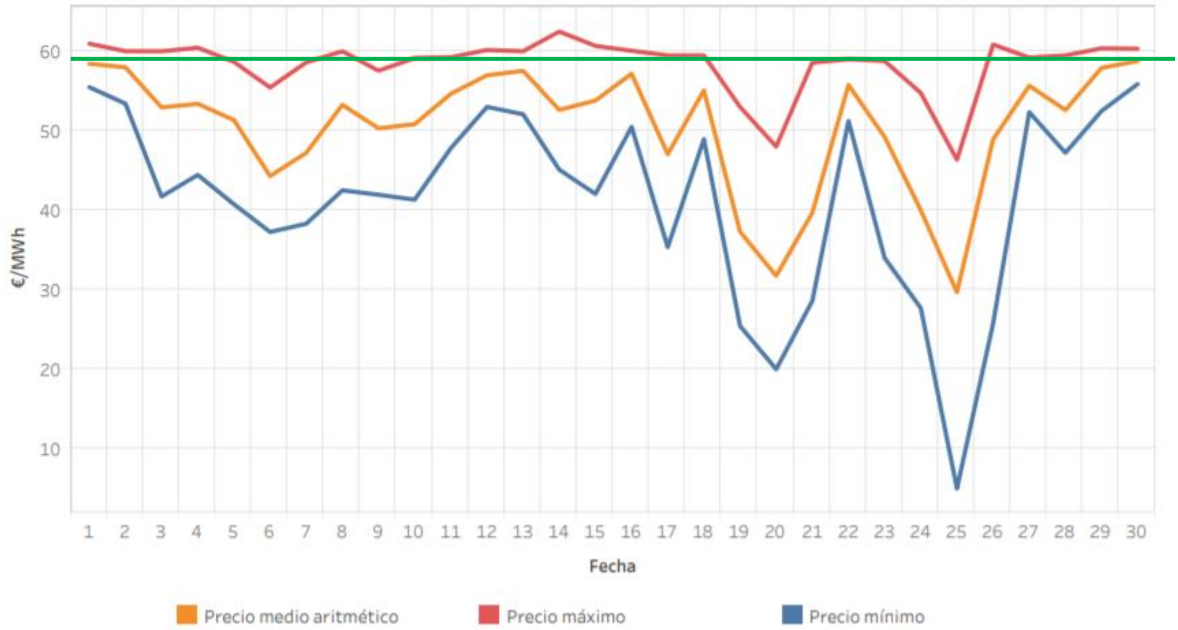
*Table 3: Monthly energy and average price of the daily market*

For the third solution with the regulated powerplant, the maximum electricity prices in a day are chosen. In this case, the turbine is working for 6 or 8 hours, therefore the 6 or 8 hours with the highest energy prices are chosen. As an example to explain the working of a regulated plant, the next graph is shown.
Since the energy operators strive for a maximum profit, the working hours of the regulated turbines need to be chosen wisely. The most profitable hours to produce energy in this day are between 8 and 12 am, in these hours the average electricity price is around 53€/MWh. As well the most optimal price for a 6 and 8 hour working turbine lies during these hours.
Whereas the energy prices between 7:30am and 1:30pm are the highest, the optimal hours of working are between these hours. This period of time is indicated in orange on the graph.
For the 8 hour working powerplant the most optimal working hours lies between 6:30am and 2:30pm. This period of time is indicated in blue on the graph. During these hours, the most profit is obtained.




*Graph 9: Hourly electricity price of in Spain on 27th of May* [30]

As the graph above is just an example of one day and these values can't be seen as sufficiently reliable, a monthly trend is shown next. In this graph the minimum, medium and maximum prices are displayed. To look for the energy price used in the third solution, an average value of the maximum prices is chosen.
The average price is a little less than 60€/MWh, so the value of **59€/MWh** is chosen as energy price in the third solution. This value is indicated by the green horizontal line.




*Graph 10: Maximum, minimum and medium arithmetic prices in the daily Spanish market, Monthly [32]*

## 7.3 Cost analysis

When taken into account the initial costs and the annual costs, a roughly total project cost analysis can be made. The initial costs contain the construction- and equipment costs whereas the annual costs come from the maintenance, staff, insurances etc.

In the figure below a roughly estimation is made from the distribution of the investments of a hydropower plant. Almost every cost-estimation model shows that the biggest cost is this one of the civil works, in this case it is 40%. The second largest part of the costs are the electromechanical equipment such as the turbine and generator, these take a percentage of more or less 30%. Next comes the electric, regulation and control equipment with more or less 20%. And last the engineering and management part takes his place.
This example is just a roughly estimation to give the reader an idea of the distribution of the costs. Most of the distribution of the hydropower projects cost are in line with this model, but it depends a lot on the circumstances of the activity.

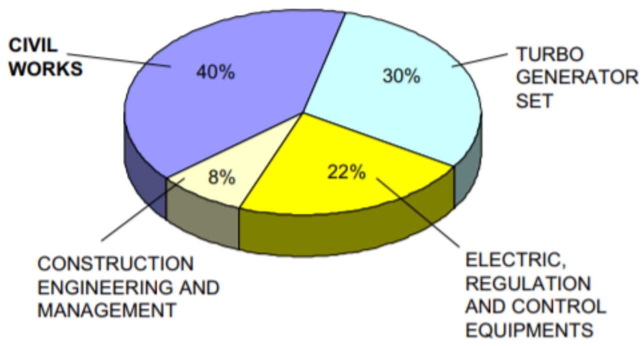



*Figure 47: Estimation of the distribution of investments on a hydropower plant* [33]

Because the construction of a hydropower plant includes many fixed costs, it is recommendable not to build one with a power output less than 50kW, as can be seen on the graph below. As bigger the power output, as fewer the cost per kw installed. Once at the point of a power output of 250kw, the costs per kW do not decrease that much anymore.
This graph is useful for very small hydro plants, but the general idea is also valid for bigger plants.

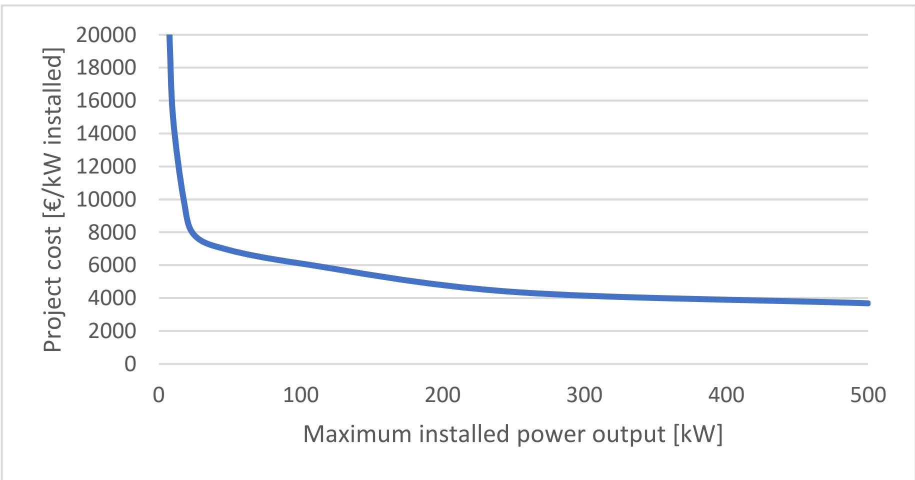



*Figure 48: Cost to build a small hydropower systems* [34]

## 7.4 Benefits vs costs

In this section the benefits one situation can have, are calculated. This is done by multiplying the produced energy by the electricity price. The produced gross energy of every situation is calculated in 6.4 and the electricity price is found in 7.2.
Besides, the roughly estimated costs of the equipment and of the construction are put next to the benefits. These costs and benefits are compared in the conclusion to decide what is the most suitable solution in this location.

### *7.4.1 Solution 1*

- **Benefits**

The benefits are calculated by multiplying the produced energy by the electricity price. In this situation it is 8093,1 [MWh/year] x 55 [€/MWh] = 443267 €/year of benefits for the first powerplant. Analogous the second powerplant get a benefit of 886534,77 €/year. In total this first situation with two powerplants has a benefit of 1 329 801 €/year.

Plant 1

| | |
|---|---|
| Flow [m³/s] | 15 |
| $E_b$ [MWh/year] | 8096,1 |
| **Benefits [€/year]** | **443267,39** |

Plant 2

| | |
|---|---|
| Flow [m³/s] | 15 |
| $E_b$ [MWh/year] | 16192,29 |
| **Benefits [€/year]** | **886534,77** |

Total benefits: 1 329 801 €/year

- **Costs**

Because there are two powerplants in this situation, the total costs will depend more on the costs of the construction of the dam and the equipment in the powerhouse than on the pipes that transport the water from the reservoir to the powerhouse. In the two other situations, the costs will depend more on the pipes than on the electromechanical equipment and the construction. The costs of turbine 1 and turbine 2, that are given in 6.5.1.1 must be summed in this situation. This makes a total **turbine cost** of **540.000€** and together with the **tube length of 630m** and the **tube diameter of 3m**, it can be compared to the other situations in the conclusion

Apart of these costs, an idea of the costs of the reservoir construction can be made. In the first two situations the costs of the reservoir can be minimalized because there is no need to build a big one.

Another cost that needs to be considered is the cost of the excavation of the earth to be able to build the powerhouse with its electromechanical equipment. The estimation of the volume of earth that needs to be excavated is done with TURBNPRO. This programme gives the dimensions of the turbine and tubes in the powerhouse, as can be seen in 6.5.1.1. An estimation can be made using these dimensions. Regarding the runner diameter, the centreline to invert, the draft tube length, the draft tube exit diameter and the exit to bottom floor, a width of more or less 13,5m is estimated in the powerhouse of the first turbine in this situation. The estimated height is 11m and the length 8m. These measurements include some meters (+-3m) next to the turbine to give enough space to workers. With these measurements, an excavation volume of 1188m³ is calculated for this powerhouse. This value is rounded to 1200m³.

The second powerhouse in this situation has the same dimensions as the first one, except for the turbine dimension which is 1,5m instead of 1,95m. Whereas this is just a rough estimation, the same volume as the first powerhouse can be taken, 1188m³.
This makes a **total excavation volume of 2400m³** for this solution.

| Turbine costs [€] | Tube ø [m] | Tube length [m] | Reservoir capacity [m³] | Excavation volume [m³] |
|---|---|---|---|---|
| 540 000 | 3 | 630 | Min | 2400 |

*Table 4: Solution 1 cost parameters*

### 7.4.2 Solution 2

- **Benefits**

In the second situation with only one powerplant, a benefit of 1477558 € is obtained.

| | |
|---|---|
| Flow [m³/s] | 15 |
| $E_b$ [MWh/year] | 26987,2 |
| **Benefits [€/year]** | **1477557,95** |

Total benefits: 1477558 €/year

- **Costs**

Because there is only one powerplant with a long distance of pipes in this situation, the costs will depend more on the pipes than on the construction of the dam and powerhouse.
The cost of the turbine is **325.000€** , the diameter of the tubes is **3m** with a length of **2100m**.
Equal as in the first situation, the costs of the reservoir can be minimized because there is no need to build a big one.

Whereas the turbine diameter, the runner diameter, the centreline to invert, the draft tube length, the draft tube exit diameter and the exit to bottom floor are the same as the second powerhouse of the first situation, the same excavation volume of 1188m³ can be considered.

| Turbine costs [€] | Tube ø [m] | Tube length [m] | Reservoir capacity [m³] | Excavation volume [m³] |
|---|---|---|---|---|
| 325 000 | 3 | 2100 | Min | 1200 |

### 7.4.3 *Solution 3*

- **Benefits**

In the third situation, where only the second powerplant works for six or eight hours, the amount of energy produced is the same as in the second solution. Because this powerplant only works some hours a day when the electricity prices are high, the produced energy is multiplied by the maximum daily energy price which is found in 7.2. This price is 59 [€/MWh] and thus the total benefits are 26987,2 [MWh/year] x 59 [€/MWh] = 1592242,11€/year

| | |
|---|---|
| Flow [m³/s] | 45 or 60 |
| $E_b$ [MWh/year] | 26987,2 |
| **Benefits [€/year]** | **1592242,11** |

Total benefits: 1592242 €/year

- **Costs**

Whereas the distance between the reservoir and the powerhouse is very high, the costs in this solution depend a lot on the pipes. Even more the pipes in this solution do have a diameter of **5m** and a length of **2100m**. Apart from the two other solutions, the reservoir capacity does have a big part of the cost. Depending on how many hours the turbine works a day, the turbine costs and the reservoir capacity have another value. For the 6 hour working turbine this is respectively **430000€** and **972000m³**. For the 8 hour working turbine this is **385000€** and **864000m³**.

Using the dimensions displayed by TURBNPRO, the excavation volume is calculated. For the 6 hour working turbine a width of 18.5m, a height of 9m and a length of 9m of excavation volume is obtained. This results in a rounded volume of **1500m³.**
For the 8 hour working turbine, this is respectively 16.15m , 8m and 8,5m and results in an excavation volume of **1150m³**.

| Hours turbine working [h] | Turbine costs [€] | Tube ø [m] | Tube length [m] | Reservoir capacity [m³] | Excavation volume [m³] |
|---|---|---|---|---|---|
| 6 | 430 000 | 5 | 2100 | 972000 | 1500 |
| 8 | 385 000 | 5 | 2100 | 864000 | 1150 |

# 8. Conclusions

In this chapter is discussed whether it is advisable or not to build a hydropower plant on this location and which solution is the most suitable regarding its benefits versus its costs.

The topographic location of this channel is very good, whereas there is a quite big altitude difference of 50 meters between begin and end-point with a not that high horizontal distance of 2100 meters. Because of the current presence of sand and clay in this area, this location is at first sight a good location to build a hydropower plant without the necessity of big soil improvement works.
Even more the close surrounding is not cultivated or civilized, what makes it easy to do construction works. This all makes this location a good place for a hydropower plant project.

In the table below, the data mentioned in chapter 7.4 is summarized. With this knowledge the comparison is made of which is the most optimal solution for this case.

| | Benefits a year [€/year] | Turbine cost [€] | Tube ø [m] | Tube length [m] | Reservoir capacity [m³] | Excavation volume [m³] |
|---|---|---|---|---|---|---|
| Solution 1 | 1 329 801 | 540 000 | 3 | 630 | Min | 2400 |
| Solution 2 | 1 477 558 | 325 000 | 3 | 2100 | Min | 1200 |
| Solution 3 | 1 592 242 | 430 000/385 000 | 5 | 2100 | 972000/864000 | 1150/1500 |

*Table 5: comparison of different situations*

Comparing the parameters of the three solutions does not result in only one best solution, but every situation always has its pros and contras. Because the parameters are all roughly estimated values, this comparison is just a way to tell which solution has which advantages.
The cost of the turbine can be extended to the costs of the other electromechanical equipment. This way the costs of the machines can be compared as well.

Comparing the benefits of each solution with its costs, a first idea can be given about the profit of a solution. Looking at the first solution, the benefits a year are lower than the two other solutions and the electromechanical cost and the excavation volume are a lot higher. It is probably that the shorter tube length does not compensate the other bigger construction costs. **Because of its high one-time initial costs, and its little benefits a year, this solution can be seen as the least advantageous solution of the three.**

Solution two and three can be compared regarding their similar benefits and turbine costs. A big extra cost of the third solution is the construction of a bigger reservoir. Additionally, the tube diameter is two meters wider, which can result in a big difference of costs when the pipe length is 2100 meters. Apart from the higher benefits of the regulated turbines, this third solution can also been seen as positive for its fewer hours of noise disturbance. But the additional costs of the reservoir and the tube diameter probably makes this solution way more expensive than the other two. For these reasons**, one can say that the second solution is more interesting than the third one.** Thus **the second solution can be seen as the most advantageous** in this situation.

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# 10. Appendices

## Appendix A: Data Monthly flow

MINISTERIO
DE AGRICULTURA, ALIMENTACIÓN
Y MEDIO AMBIENTE

# VOLÚMENES TRASVASADOS ($dm^3$) TRAMO I

CONFEDERACIÓN
HIDROGRÁFICA
DEL TAJO

| AÑOS 08/10 MES | BUJEDA | TABLAS DE DAIMIEL | | ABASTº GUADIANA | | CESION USO AGUA | PÉRDIDAS TRAMO I | BELMON-TEJO | SALDO ALARCÓN | PICAZO | SUMINISTRO JUCAR | | | OBSERVACIONES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | EN ORIGEN | EN DESTINO | EN ORIGEN | EN DESTINO | | | | | | M. BAJA | TAIBILLA | RGº SEGUR. | |
| ANTERIOR ACUMULADO | **9 973 331** | **216 433** | **216 362** | **0** | **0** | **138 589** | **124 656** | **9 632 242** | **-220** | **9 931 659** | **29 600** | **65 400** | **20 000** | |
| 2008 Oct | 9 335 | | | | | | 1 452 | 7 883 | 3 211 | 5 624 | | | | |
| Nov | 20 665 | | | | | | -1 177 | 21 842 | -2 950 | 26 057 | | | | |
| Dic | 13 204 | | | | | | 1 102 | 12 102 | 3 105 | 10 558 | | | | |
| TOTAL 08 | **227 330** | **0** | **0** | **0** | **0** | **67 989** | **2 201** | **225 129** | **1 735** | **242 681** | **0** | **0** | **0** | |
| 2009 Ene | 8 943 | | | | | | 204 | 8 739 | 2 299 | 7 322 | | | | |
| Feb | 36 853 | | | | | | -938 | 37 791 | -1 750 | 40 976 | | | | |
| Mar | | | | | | | -10 | 10 | -3 800 | 4 768 | | | | |
| Abr | 9 397 | 1 220 | 1 211 | | | | 1 194 | 6 983 | 1 225 | 7 216 | | | | |
| May | 40 894 | 9 156 | 9 091 | | | | -1 064 | 32 802 | -3 134 | 42 863 | | | | |
| Jun | 44 967 | 9 624 | 9 556 | | | | 1 407 | 33 936 | 3 271 | 39 044 | | | | |
| Jul | 34 699 | | | | | | 895 | 33 804 | -755 | 40 624 | | | | |
| Ago | 45 806 | | | | | 23 938 | 662 | 45 144 | 4 266 | 42 327 | | | | |
| Sep | 31 387 | | | | | 7 112 | -662 | 32 049 | -4 752 | 38 087 | | | | |
| TOTAL 08/09 | **296 150** | **20 000** | **19 858** | **0** | **0** | **31 050** | **3 065** | **273 085** | **236** | **305 466** | **0** | **0** | **0** | |
| TOTAL ACUMULADO | **10 269 481** | **236 433** | **236 220** | **0** | **0** | **169 639** | **127 721** | **9 905 327** | **16** | **10 237 125** | **29 600** | **65 400** | **20 000** | |
| 2009 Oct | | | | | | | 0 | | -534 | 1 347 | | | | |
| Nov | 22 789 | | | | | | 1 083 | 21 706 | 1 944 | 21 808 | | | | |
| Dic | 17 949 | | | | | | 2 | 17 947 | 4 321 | 14 834 | | | | |
| TOTAL 09 | **293 684** | **20 000** | **19 858** | **0** | **0** | **31 050** | **2 773** | **270 911** | **2 601** | **301 216** | **0** | **0** | **0** | |
| 2010 Ene | 10 162 | 1 500 | 1 489 | | | | -255 | 8 917 | -5 531 | 15 266 | | | | |
| Feb | | | | | | | 0 | | -640 | 1 622 | | | | |
| Mar | 13 035 | | | | | | 962 | 12 073 | 1 148 | 12 459 | | | | |
| Abr | 41 622 | | | | | | 197 | 41 425 | -260 | 42 738 | | | | |
| May | 46 648 | | | | | | 360 | 46 288 | -424 | 47 768 | | | | |
| Jun | 38 661 | | | | | | 227 | 38 434 | 751 | 43 915 | | | | |
| Jul | 15 154 | | | | | | 732 | 14 422 | -843 | 25 277 | | | | |
| Ago | 53 504 | | | | | | 333 | 53 171 | 852 | 61 242 | | | | |
| Sep | 33 527 | | | | | | 251 | 33 276 | -933 | 38 980 | | | | |
| TOTAL 09/10 | **293 051** | **1 500** | **1 489** | **0** | **0** | **0** | **3 892** | **287 659** | **-149** | **327 256** | **0** | **0** | **0** | |
| TOTAL ACUMULADO | **10 562 532** | **237 933** | **237 709** | **0** | **0** | **169 639** | **131 613** | **10 192 986** | **-133** | **10 564 381** | **29 600** | **65 400** | **20 000** | |
| 2010 Oct | 16 172 | | | | | | -410 | 16 582 | 94 | 17 534 | | | | |
| Nov | 28 233 | | | | | | 1 299 | 26 934 | 245 | 28 368 | | | | |
| Dic | 53 183 | | | | | | 221 | 52 962 | 418 | 54 222 | | | | |
| TOTAL 10 | **349 901** | **1 500** | **1 489** | **0** | **0** | **0** | **3 917** | **344 484** | **-5 123** | **389 391** | **0** | **0** | **0** | |

MINISTERIO
DE MEDIO AMBIENTE

# VOLÚMENES TRASVASADOS ($dm^3$) TRAMO I

CONFEDERACIÓN
HIDROGRÁFICA
DEL TAJO

| AÑOS 10/12 MES | BUJEDA | TABLAS DE DAIMIEL EN ORIGEN | TABLAS DE DAIMIEL EN DESTINO | ABASTº GUADIANA EN ORIGEN | ABASTº GUADIANA EN DESTINO | CESION USO AGUA | PÉRDIDAS TRAMO I | BELMON-TEJO | SALDO ALARCÓN | PICAZO | SUMINISTRO JUCAR M. BAJA | SUMINISTRO JUCAR TAIBILLA | SUMINISTRO JUCAR RGº SEGUR. | OBSERVACIONES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTERIOR ACUMULADO | **10 562 532** | **237 933** | **237 709** | **0** | **0** | **169 639** | **131 613** | **10 192 986** | **-133** | **10 564 381** | **29 600** | **65 400** | **20 000** | |
| 2010 Oct | 16 172 | | | | | | -410 | 16 582 | 94 | 17 534 | | | | |
| Nov | 28 233 | | | | | | 1 299 | 26 934 | 245 | 28 368 | | | | |
| Dic | 53 183 | | | | | | 221 | 52 962 | 418 | 54 222 | | | | |
| TOTAL 10 | **349 901** | **1 500** | **1 489** | **0** | **0** | **0** | **3 917** | **344 484** | **-5 123** | **389 391** | **0** | **0** | **0** | |
| 2011 Ene | 7 949 | | | | | | -958 | 8 907 | -3 150 | 12 536 | | | | |
| Feb | 11 860 | | | | | | 795 | 11 065 | 1 509 | 10 908 | | | | |
| Mar | 21 038 | | | | | | 164 | 20 874 | -659 | 22 953 | | | | |
| Abr | 21 293 | | | | | | 216 | 21 077 | 1 314 | 21 407 | | | | |
| May | 42 031 | | | | | | 404 | 41 627 | -390 | 45 299 | | | | |
| Jun | 39 010 | | | | | | 506 | 38 504 | 3 581 | 43 867 | | | | |
| Jul | 64 549 | | | | | | 936 | 63 613 | 3 440 | 64 645 | | | | |
| Ago | 59 588 | | | | | | 317 | 59 271 | 9 089 | 61 280 | | | | |
| Sep | 13 094 | | | | | | -1 134 | 14 228 | -15 356 | 33 821 | | | | |
| TOTAL 10/11 | **378 000** | **0** | **0** | **0** | **0** | **0** | **2 356** | **375 644** | **135** | **416 840** | **0** | **0** | **0** | |
| TOTAL ACUMULADO | **10 940 532** | **237 933** | **237 709** | **0** | **0** | **169 639** | **133 969** | **10 568 630** | **2** | **10 981 221** | **29 600** | **65 400** | **20 000** | |
| 2011 Oct | | | | | | | 0 | | 0 | 2 041 | | | | |
| Nov | 30 870 | | | | | | 479 | 30 391 | 689 | 31 106 | | | | |
| Dic | 26 871 | | | | | | 992 | 25 879 | 234 | 26 386 | | | | |
| TOTAL 11 | **338 153** | **0** | **0** | **0** | **0** | **0** | **2 717** | **335 436** | **301** | **376 249** | **0** | **0** | **0** | |
| 2012 Ene | 17 445 | | | | | | -803 | 18 248 | 114 | 19 212 | | | | |
| Feb | 45 451 | | | | | | 1 113 | 44 338 | -54 | 46 359 | | | | |
| Mar | 37 721 | | | | | | 360 | 37 361 | -311 | 39 242 | | | | |
| Abr | 36 369 | | | | | | 333 | 36 036 | -594 | 37 585 | | | | |
| May | 39 916 | | | | | | 327 | 39 589 | 4 581 | 39 068 | | | | |
| Jun | 37 585 | | | | | | 383 | 37 202 | -3 168 | 50 624 | | | | |
| Jul | 53 122 | | | | | | 1 097 | 52 025 | -740 | 63 282 | | | | |
| Ago | 53 614 | | | | | | 650 | 52 964 | 8 978 | 52 377 | | | | |
| Sep | 7 222 | | | | | | -724 | 7 946 | -9 440 | 20 867 | | | | |
| TOTAL 11/12 | **386 186** | **0** | **0** | **0** | **0** | **0** | **4 207** | **381 979** | **289** | **428 149** | **0** | **0** | **0** | |
| TOTAL ACUMULADO | **11 326 718** | **237 933** | **237 709** | **0** | **0** | **169 639** | **138 176** | **10 950 609** | **291** | **11 409 370** | **29 600** | **65 400** | **20 000** | |
| 2012 Oct | | | | | | | **0** | | 71 | 813 | | | | |
| Nov | 16 534 | | | | | | **-372** | 16 906 | 2 472 | 15 604 | | | | |
| Dic | 43 220 | | | | | | **1 037** | 42 183 | -2 543 | 46 029 | | | | |
| TOTAL 12 | **388 199** | **0** | **0** | **0** | **0** | **0** | **3 401** | **384 798** | **-634** | **431 062** | **0** | **0** | **0** | |

MINISTERIO AGRICULTURA
ALIMENTACION
Y MEDIO AMBIENTE

# VOLÚMENES TRASVASADOS ($dm^3$)

CONFEDERACIÓN
HIDROGRÁFICA
DEL TAJO

miércoles, 03 de diciembre del 2014 -- 11:31:39 AM

| AÑOS 12/14 | MES | BUJEDA | BELMON-TEJO | DIF. VOL. AFORADOS T-I | PICAZO | SUMINISTROS DE LA C.H. JÚCAR: ABAST° ALBACETE EN ORIGEN | ABAST° ALBACETE EN DESTINO | RIEGOS LLANOS EN ORIGEN | RIEGOS LLANOS EN DESTINO | SALDO ALARCÓN | COMPENSAC. LLANOS ALBACETE | ENTRADA TÚNEL | SALIDA TÚNEL | DIF. VOL. AFORADO EN TUNEL | DIF. VOL. AFORADOS T-II | DIF. VOL. AFORADOS T-1 Y T-II | OBSERVACIONES |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ANTERIOR ACUMULADO | | **11.326.758** | **10.950.609** | **138.216** | **11.409.370** | **146.150** | **144.681** | **198.097** | **196.522** | **291** | **168.252** | **10.744.131** | **10.972.654** | **228.523** | **152.740** | **290.956** | |
| 2012 | Oct | 0 | 0 | 0 | 813 | 881 | 864 | 3 | 3 | 71 | 0 | 0 | 344 | 344 | -71 | -71 | |
| | Nov | 16.534 | 16.906 | -372 | 15.604 | 1.170 | 1.148 | 0 | 0 | 2.472 | 0 | 14.426 | 14.971 | 545 | 8 | -364 | |
| | Dic | 43.220 | 42.183 | 1.037 | 46.029 | 1.270 | 1.246 | 33 | 32 | -2.543 | 0 | 42.798 | 43.280 | 482 | 1.928 | 2.965 | |
| TOTAL 12 | | **388.199** | **384.798** | **3.401** | **431.062** | **13.148** | **12.923** | **32.482** | **31.963** | **-634** | **6.444** | **371.620** | **377.510** | **5.890** | **7.368** | **10.769** | |
| 2013 | Ene | 21.214 | 21.605 | -391 | 23.049 | 1.415 | 1.388 | 129 | 127 | 100 | 0 | 22.231 | 22.970 | 739 | -726 | -1.117 | |
| | Feb | 13.102 | 11.800 | 1.302 | 12.091 | 803 | 788 | 127 | 124 | 639 | 0 | 9.168 | 9.232 | 64 | 1.993 | 3.295 | |
| | Mar | 40.694 | 40.863 | -169 | 20.849 | 582 | 571 | 31 | 31 | 20.627 | 0 | 23.361 | 23.954 | 593 | -3.125 | -3.294 | |
| | Abr | 22.204 | 22.609 | -405 | 396 | 173 | 170 | 148 | 145 | 22.534 | 0 | 960 | 1.336 | 376 | -885 | -1.290 | |
| | May | 0 | 0 | 0 | 26.043 | 973 | 954 | 2.350 | 2.307 | -22.720 | 0 | 20.879 | 21.037 | 158 | 1.841 | 1.841 | |
| | Jun | 34.185 | 32.573 | 1.612 | 58.206 | 1.202 | 1.179 | 7.448 | 7.311 | -16.983 | 0 | 48.994 | 49.525 | 531 | 562 | 2.174 | |
| | Jul | 68.794 | 68.129 | 665 | 73.842 | 977 | 958 | 3.019 | 2.964 | -1.717 | 6.444 | 62.591 | 63.235 | 644 | 811 | 1.476 | |
| | Ago | 69.594 | 68.816 | 778 | 74.100 | 928 | 910 | 9.492 | 9.317 | 5.136 | 0 | 62.840 | 63.335 | 495 | 840 | 1.618 | |
| | Sep | 55.427 | 55.265 | -838 | 69.392 | 2.284 | 2.241 | 4.665 | 4.579 | -7.178 | 0 | 61.960 | 62.677 | 717 | 483 | -355 | |
| TOTAL 12/13 | | **384.968** | **380.749** | **3.219** | **420.414** | **12.658** | **12.417** | **27.444** | **26.940** | **437** | **6.444** | **370.208** | **375.896** | **5.688** | **3.660** | **6.879** | |
| TOTAL ACUMULADO | | **11.711.726** | **11.331.358** | **141.435** | **11.829.784** | **158.808** | **157.098** | **225.541** | **223.462** | **728** | **174.696** | **11.114.339** | **11.348.550** | **234.211** | 156.400 | **297.835** | |
| 2013 | Oct | 0 | 53 | -53 | 1.401 | 917 | 902 | 63 | 62 | -368 | 0 | 2.314 | 2.982 | 668 | -1.893 | -1.946 | |
| | Nov | 16.497 | 15.346 | 1.151 | 15.790 | 1.047 | 1.029 | 0 | 0 | 603 | 0 | 12.993 | 13.176 | 183 | 1.750 | 2.901 | |
| | Dic | 42.673 | 42.447 | 226 | 43.823 | 1.272 | 1.251 | 129 | 127 | 25 | 0 | 42.365 | 43.008 | 643 | 57 | 283 | |
| TOTAL 13 | | **384.384** | **379.506** | **3.878** | **418.982** | **12.573** | **12.341** | **27.600** | **27.093** | **697** | **6.444** | **370.656** | **376.467** | **5.811** | **1.709** | **5.587** | |
| 2014 | Ene | 44.298 | 43.782 | 516 | 45.163 | 1.031 | 1.014 | 198 | 195 | -152 | 0 | 43.272 | 43.490 | 218 | 662 | 1.178 | |
| | Feb | 21.973 | 23.084 | -1.111 | 23.316 | 1.146 | 1.127 | 129 | 127 | 1.043 | 0 | 23.821 | 24.394 | 573 | -1.780 | -2.891 | |
| | Mar | 58.526 | 56.781 | 1.745 | 56.181 | 1.335 | 1.313 | 386 | 380 | 2.321 | 1.637 | 49.637 | 49.875 | 238 | 3.186 | 4.931 | |
| | Abr | 67.583 | 67.002 | 581 | 70.431 | 1.252 | 1.231 | 0 | 0 | -2.177 | 4.653 | 63.195 | 63.677 | 482 | 1.331 | 1.912 | |
| | May | 62.759 | 61.990 | 769 | 70.428 | 1.316 | 1.294 | 6.092 | 5.995 | -1.030 | 155 | 62.000 | 62.266 | 266 | 865 | 1.634 | |
| | Jun | 49.964 | 49.718 | 246 | 59.653 | 1.149 | 1.130 | 6.866 | 6.756 | -1.920 | 0 | 50.932 | 51.232 | 300 | 706 | 952 | |
| | Jul | 39.050 | 38.427 | 623 | 41.381 | 1.474 | 1.450 | 8.904 | 6.866 | 7.424 | 0 | 30.548 | 30.892 | 344 | 455 | 1.078 | |
| | Ago | 34.710 | 34.212 | 498 | 39.415 | 1.092 | 1.074 | 8.559 | 8.423 | 4.448 | 0 | 27.693 | 28.042 | 349 | 2.071 | 2.569 | |
| | Sep | 54.943 | 55.781 | -838 | 62.226 | 1.618 | 1.591 | 2.145 | 2.111 | -2.682 | 0 | 55.461 | 56.132 | 671 | 3.002 | 2.164 | |
| TOTAL 13/14 | | **492.976** | **488.623** | **4.353** | **529.208** | **14.649** | **14.406** | **33.470** | **31.040** | **7.534** | **6.444** | **464.231** | **469.166** | **4.935** | **10.414** | **14.767** | |
| TOTAL ACUMULADO | | **12.204.702** | **11.819.981** | **145.788** | **12.358.992** | **173.457** | **171.504** | **259.011** | **254.502** | **8.262** | **181.140** | **11.578.570** | **11.817.716** | **239.146** | **166.814** | **312.602** | |
| 2014 | Oct | 0 | 10 | -10 | 9.537 | 1.486 | 1.463 | 104 | 103 | **-7.937** | 0 | 10.355 | 11.140 | 785 | -2.408 | -2.418 | |
| | Nov | 18.519 | 17.445 | 1.074 | 17.899 | 988 | 972 | 3 | 3 | **537** | 0 | 15.088 | 15.322 | 234 | 1.820 | 2.894 | |
| | Dic | | | 0 | | | | | | **0** | | | | 0 | 0 | 0 | |
| TOTAL 14 | | **452.325** | **448.232** | **4.093** | **495.630** | **13.887** | **13.659** | **33.386** | **30.958** | **-125** | **6.444** | **432.002** | **436.462** | **4.460** | **9.911** | **14.004** | |

MINISTERIO AGRICULTURA
ALIMENTACION
Y MEDIO AMBIENTE

# VOLÚMENES TRASVASADOS ($dm^3$)

CONFEDERACIÓN
HIDROGRÁFICA
DEL TAJO

| AÑOS 15/16 | | BUJEDA | BELMON-TEJO | DIF. VOL. AFORADOS T-I | PICAZO | SUMINISTROS DE LA C.H. JÚCAR | | | | SALDO ALARCÓN | COMPENSAC. LLANOS ALBACETE | ENTRADA TÚNEL | SALIDA TÚNEL | DIF. VOL. AFORADO EN TUNEL | DIF. VOL. AFORADOS T-II | DIF. VOL. AFORADOS T-1 Y T-II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ABASTº ALBACETE | | RIEGOS LLANOS | | | | | | | | |
| | MES | | | | | EN ORIGEN | EN DESTINO | EN ORIGEN | EN DESTINO | | | | | | | |
| **ANTERIOR ACUMULADO** | | **12.204.662** | **11.819.981** | **145.748** | **12.358.992** | **173.457** | **171.504** | **259.011** | **256.399** | **8.262** | **181.140** | **11.578.570** | **11.817.716** | **239.146** | **166.814** | **312.562** |
| 2014 | Oct | 0 | 10 | -10 | 9.537 | 1.486 | 1.463 | 104 | 103 | -7.937 | 0 | 10.355 | 11.140 | 785 | -2.408 | -2.418 |
| | Nov | 18.519 | 17.445 | 1.074 | 17.899 | 988 | 972 | 3 | 3 | 537 | 0 | 15.088 | 15.322 | 234 | 1.820 | 2.894 |
| | Dic | 40.451 | 40.249 | 202 | 41.098 | 1.439 | 1.416 | 127 | 125 | 717 | 0 | 39.206 | 39.947 | 741 | 326 | 528 |
| TOTAL 14 | | **492.776** | **488.481** | **4.295** | **536.728** | **15.326** | **15.075** | **33.513** | **32.980** | **592** | **6.444** | **471.208** | **476.409** | **5.201** | **10.237** | **14.532** |
| 2015 | Ene | 34.866 | 34.749 | 117 | 36.510 | 937 | 922 | 242 | 239 | -582 | 0 | 34.754 | 35.249 | 495 | 577 | 694 |
| | Feb | 28.775 | 28.329 | 446 | 29.892 | 1.434 | 1.412 | 63 | 62 | -66 | 0 | 27.943 | 28.327 | 384 | 452 | 898 |
| | Mar | 33.389 | 33.883 | -494 | 35.597 | 1.116 | 1.098 | 29 | 29 | -569 | 1.389 | 34.012 | 34.577 | 565 | -949 | -1.443 |
| | Abr | 1.476 | 545 | 931 | 4.334 | 872 | 858 | 190 | 187 | -2.728 | 688 | 1.268 | 1.447 | 179 | 1.317 | 2.248 |
| | May | 35.043 | 34.804 | 239 | 38.803 | 1.601 | 1.576 | 5.882 | 5.791 | 3.484 | 2.100 | 28.676 | 29.262 | 586 | 545 | 784 |
| | Jun | 31.250 | 30.639 | 611 | 39.393 | 1.740 | 1.713 | 8.029 | 7.906 | 1.016 | 0 | 29.327 | 29.821 | 494 | 296 | 907 |
| | Jul | 10.231 | 10.922 | -691 | 22.244 | 1.383 | 1.361 | 8.752 | 8.617 | -1.187 | 0 | 12.699 | 13.245 | 546 | -590 | -1.281 |
| | Ago | 28.198 | 27.060 | 1.138 | 38.063 | 1.525 | 1.501 | 8.697 | 8.563 | -781 | 0 | 26.526 | 26.849 | 323 | 1.315 | 2.453 |
| | Sep | 25.918 | 26.380 | -462 | 30.185 | 1.492 | 1.468 | 2.258 | 2.224 | -55 | 0 | 27.251 | 28.277 | 1.026 | -816 | -1.278 |
| TOTAL 14/15 | | **288.116** | **285.015** | **3.101** | **343.555** | **16.013** | **15.759** | **34.378** | **33.850** | **-8.149** | **4.176** | **287.105** | **293.463** | **6.358** | **1.883** | **4.984** |
| TOTAL ACUMULADO | | **12.492.778** | **12.104.996** | **148.849** | **12.702.547** | **189.468** | **187.263** | **293.389** | **290.249** | **112** | **185.316** | **11.865.675** | **12.111.179** | **245.504** | **168.698** | **317.547** |
| 2015 | Oct | 0 | 0 | 0 | 1 | 947 | 930 | 132 | 130 | 1.079 | 0 | 0 | 180 | 180 | -1.079 | -1.079 |
| | Nov | 6.679 | 5.819 | 860 | 6.998 | 1.908 | 1.872 | 0 | 0 | 729 | 0 | 3.464 | 3.707 | 243 | 1.626 | 2.486 |
| | Dic | 13.321 | 13.946 | -625 | 17.215 | 1.451 | 1.424 | 284 | 279 | -1.533 | 0 | 16.695 | 17.022 | 327 | -1.216 | -1.841 |
| TOTAL 15 | | **249.146** | **247.076** | **2.070** | **299.235** | **16.407** | **16.133** | **34.560** | **34.028** | **-1.192** | **4.176** | **242.615** | **247.963** | **5.348** | **1.477** | **3.547** |
| 2016 | Ene | 0 | 3 | -3 | 958 | 910 | 893 | 355 | 348 | 310 | 0 | 79 | 397 | 318 | -386 | -389 |
| | Feb | 10.000 | 9.878 | 122 | 12.825 | 1.414 | 1.387 | 838 | 822 | -695 | 0 | 9.105 | 9.311 | 206 | 1.468 | 1.590 |
| | Mar | 18.519 | 17.359 | 1.160 | 18.789 | 879 | 862 | 1.984 | 1.948 | 1.433 | 0 | 15.501 | 15.693 | 192 | 425 | 1.585 |
| | Abr | 21.481 | 22.413 | -932 | 20.342 | 781 | 766 | 214 | 210 | 3.065 | 3.963 | 15.429 | 15.937 | 508 | -44 | -976 |
| | May | 15.538 | 14.479 | 1.059 | 22.863 | 925 | 907 | 3.907 | 3.835 | -3.552 | 213 | 16.752 | 17.135 | 383 | 1.066 | 2.125 |
| | Jun | 31.487 | 31.138 | 349 | 39.030 | 1.284 | 1.259 | 8.030 | 7.882 | 1.422 | 0 | 28.657 | 29.224 | 567 | 1.059 | 1.408 |
| | Jul | 20.622 | 20.154 | 468 | 29.520 | 1.580 | 1.550 | 8.198 | 8.047 | 412 | 0 | 19.340 | 19.704 | 364 | 402 | 870 |
| | Ago | 29.644 | 29.287 | 357 | 41.168 | 1.037 | 1.017 | 8.705 | 8.544 | -2.140 | 0 | 30.938 | 31.375 | 437 | 489 | 846 |
| | Sep | 31.098 | 31.495 | -397 | 36.451 | 1.393 | 1.367 | 3.025 | 2.969 | -538 | | 32.563 | 32.986 | 423 | -530 | -927 |
| TOTAL 15/16 | | **198.389** | **195.971** | **2.418** | **246.160** | **14.508** | **14.232** | **35.672** | **35.014** | **-9** | **4.176** | **188.523** | **192.671** | **4.148** | **3.281** | **5.699** |
| TOTAL ACUMULADO | | **12.691.167** | **12.300.967** | **151.267** | **12.948.707** | **203.977** | **201.496** | **329.061** | **325.263** | **103** | **189.492** | **12.054.198** | **12.303.850** | **249.652** | **171.979** | **323.246** |
| 2016 | Oct | | | 0 | | | | | | **0** | | | | 0 | 0 | 0 |
| | Nov | | | 0 | | | | | | **0** | | | | 0 | 0 | 0 |
| | Dic | | | 0 | | | | | | **0** | | | | 0 | 0 | 0 |
| TOTAL 16 | | **178.389** | **176.206** | **2.183** | **221.946** | **10.202** | **10.008** | **35.255** | **34.605** | **-283** | **4.176** | **168.364** | **171.762** | **3.398** | **3.949** | **6.132** |

MINISTERIO PARA LA TRANSICIÓN ECOLÓGICA

# ACUEDUCTO TAJO-SEGURA

## VOLÚMENES AFORADOS (dam$^3$)

Año hidrológico: 2017 - 2018

CONFEDERACIÓN HIDROGRÁFICA DEL TAJO
DIRECCIÓN TÉCNICA
*ÁREA DEL ACUEDUCTO TAJO-SEGURA*

| MES | | BUJEDA | BELMON-TEJO | DIF. VOL. AFORADOS T-I | PICAZO | SUMINISTROS DE LA C.H. JÚCAR | | | | SALDO ALARCÓN ÚLTIMO DIA DEL MES | COMPENSAC. LLANOS ALBACETE | ENTRADA TÚNEL | SALIDA TÚNEL | DIF. VOL. AFORADO EN TUNEL | DIF. VOL. AFORADOS T-II | DIF. VOL. AFORADOS T-1 Y T-II |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | ABASTECIMIENT ALBACETE | | RIEGOS LOS LLANOS | | | | | | | | |
| | | | | | | EN ORIGEN | EN DESTINO | EN ORIGEN | EN DESTINO | | | | | | | |
| T. ACUMULADO | | 12.691.167 | 12.300.967 | | 12.948.707 | 203.979 | 201.496 | 329.058 | 325.263 | | 189.492 | 12.054.198 | 12.303.850 | 249.652 | 171.980 | 171.980 |
| | Oct | 7.149 | 5.795 | 1.354 | 6.186 | 762 | 749 | 7 | 7 | 603 | 0 | 2.952 | 3.123 | 171 | 2.465 | 3.819 |
| | Nov | 32.851 | 34.015 | -1.164 | 35.199 | 1.177 | 1.157 | 133 | 131 | 733 | 0 | 35.972 | 36.444 | 472 | -2.083 | -3.247 |
| | Dic | 0 | 0 | 0 | 815 | 892 | 877 | 27 | 26 | 837 | 0 | 0 | 388 | 388 | -104 | -104 |
| TOTAL 16 | | **218.389** | **216.016** | **2.373** | **264.146** | **13.032** | **12.791** | **35.422** | **34.769** | | **4.176** | **207.288** | **211.717** | **4.429** | **4.228** | **6.601** |
| 2017 | Ene | 16.115 | 15.070 | 1.045 | 16.352 | 1.169 | 1.150 | 36 | 36 | 815 | 0 | 13.551 | 13.747 | 196 | 1.596 | 2.641 |
| | Feb | 7.394 | 8.100 | -706 | 8.673 | 619 | 609 | 131 | 129 | 1.341 | 0 | 8.680 | 9.071 | 391 | -757 | -1.463 |
| | Mar | 12.954 | 10.867 | 2.087 | 12.174 | 1.282 | 1.261 | 1.452 | 1.429 | 2.388 | 0 | 8.258 | 8.555 | 297 | 1.182 | 3.269 |
| | Abr | 42.764 | 42.161 | 603 | 41.299 | 1.615 | 1.589 | 1.558 | 1.533 | 6.056 | 4.176 | 33.579 | 33.968 | 389 | 371 | 974 |
| | May | 23.273 | 24.288 | -1.015 | 38.940 | 1.129 | 1.110 | 6.911 | 6.800 | 23 | 0 | 32.137 | 32.288 | 151 | -1.237 | -2.252 |
| | Jun | 0 | 0 | 0 | 9.264 | 1.080 | 1.062 | 7.537 | 7.416 | -47 | 0 | 148 | 515 | 367 | 499 | 499 |
| | Jul | 0 | 0 | 0 | 8.723 | 1.277 | 1.255 | 7.469 | 7.349 | -613 | 0 | 0 | 308 | 308 | -23 | -23 |
| | Ago | 0 | 0 | 0 | 8.396 | 979 | 962 | 6.878 | 6.768 | -1.043 | 0 | 0 | 296 | 296 | 539 | 539 |
| | Sep | 1.952 | 1.945 | 7 | 4.883 | 1.441 | 1.417 | 2.200 | 2.165 | -657 | 0 | 1.585 | 1.968 | 383 | -343 | -336 |
| TOTAL 16/17 | | **144.452** | **142.241** | **2.211** | **190.904** | **13.421** | **13.198** | **34.340** | **33.788** | | **4.176** | **136.862** | **140.671** | **3.809** | **2.104** | **4.315** |
| T. ACUMULADO | | 12.835.619 | 12.443.208 | | 13.139.611 | 217.400 | 214.694 | 363.398 | 359.051 | | 193.668 | 12.191.060 | 12.444.521 | 253.461 | 174.084 | 176.295 |
| | Oct | 0 | 0 | 0 | 1.892 | 1.413 | 1.391 | 744 | 733 | -302 | 0 | 0 | 244 | 244 | -265 | -265 |
| | Nov | 0 | 0 | 0 | 784 | 1.071 | 1.054 | 94 | 92 | -25 | 0 | 0 | 281 | 281 | -381 | -381 |
| | Dic | 0 | 0 | 0 | 817 | 924 | 909 | 22 | 22 | 104 | 0 | 0 | 315 | 315 | -129 | -129 |
| TOTAL 17 | | **104.452** | **102.431** | **2.021** | **152.197** | **14.000** | **13.769** | **35.033** | **34.471** | | **4.176** | **97.938** | **101.556** | **3.618** | **1.050** | **3.071** |
| 2018 | Ene | 0 | 0 | 0 | 1.049 | 761 | 749 | 3 | 3 | 204 | 0 | 0 | 296 | 296 | 285 | 285 |
| | Feb | 0 | 0 | 0 | 1.220 | 1.380 | 1.357 | 4 | 4 | -17 | 0 | 0 | 262 | 262 | -163 | -163 |
| | Mar | 0 | 0 | 0 | 763 | 835 | 822 | 153 | 150 | 207 | 0 | 0 | 295 | 295 | -225 | -225 |
| | Abr | 19.707 | 19.278 | 429 | 21.960 | 881 | 867 | 3.554 | 3.499 | 2.258 | 0 | 15.839 | 16.082 | 243 | 1.686 | 2.115 |
| | May | 37.798 | 37.770 | 28 | 44.482 | 1.017 | 1.000 | 3.665 | 3.608 | 154 | 2.711 | 36.734 | 37.001 | 267 | 356 | 384 |
| | Jun | 38.495 | 39.072 | -577 | 42.026 | 996 | 980 | 4.262 | 4.196 | 3.838 | 1.465 | 34.784 | 35.047 | 263 | 519 | -58 |
| | Jul | 23.245 | 21.626 | 1.619 | 27.010 | 1.271 | 1.251 | 8.050 | 7.925 | 6.084 | 0 | 17.150 | 17.760 | 610 | 538 | 2.157 |
| | Ago | 27.154 | 26.918 | 236 | 37.744 | 1.063 | 1.046 | 7.061 | 6.952 | 3.928 | 0 | 28.949 | 29.790 | 841 | 671 | 907 |
| | Sep | 36.501 | 36.945 | -444 | 43.313 | 1.425 | 1.489 | 2.251 | 2.217 | 1.091 | 0 | 40.633 | 40.996 | 363 | -997 | -1.441 |
| TOTAL 17/18 | | **182.900** | **181.609** | **1.291** | **223.060** | **13.038** | **12.915** | **29.864** | **29.400** | | **4.176** | **174.089** | **178.369** | **4.280** | **1.894** | **3.185** |
| T. ACUMULADO | | 13.018.519 | 12.624.817 | | 13.362.671 | 230.438 | 227.609 | 393.262 | 388.452 | | 197.844 | 12.365.149 | 12.622.890 | 257.741 | 175.978 | 175.978 |
| | Oct | | | 0 | | | | | | | | | | 0 | 0 | 0 |
| | Nov | | | 0 | | | | | | | | | | 0 | 0 | 0 |
| | Dic | | | 0 | | | | | | | | | | 0 | 0 | 0 |
| TOTAL 18 | | **182.900** | **181.609** | **1.291** | **219.567** | **9.629** | **9.561** | **29.004** | **28.554** | | **4.176** | **174.089** | **177.529** | **3.440** | **2.669** | **3.960** |

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