Downstream Spillway Erosion in EDP Dams

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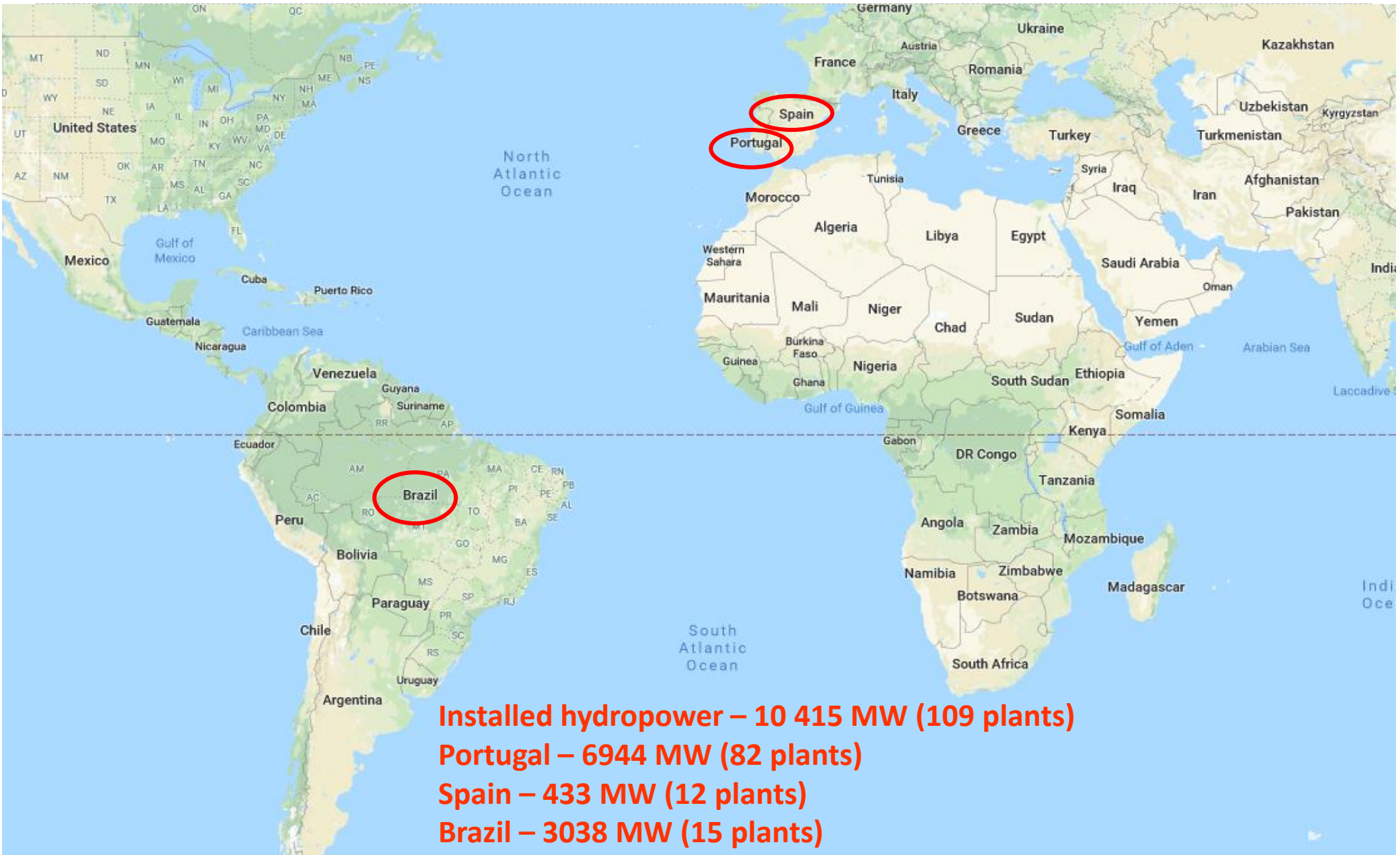
EDP Produção
Dam Engineering Division

International Workshop
Overflowing Erosion of Dams and Dikes
11-14th December 2017
Aussois, France

Agenda

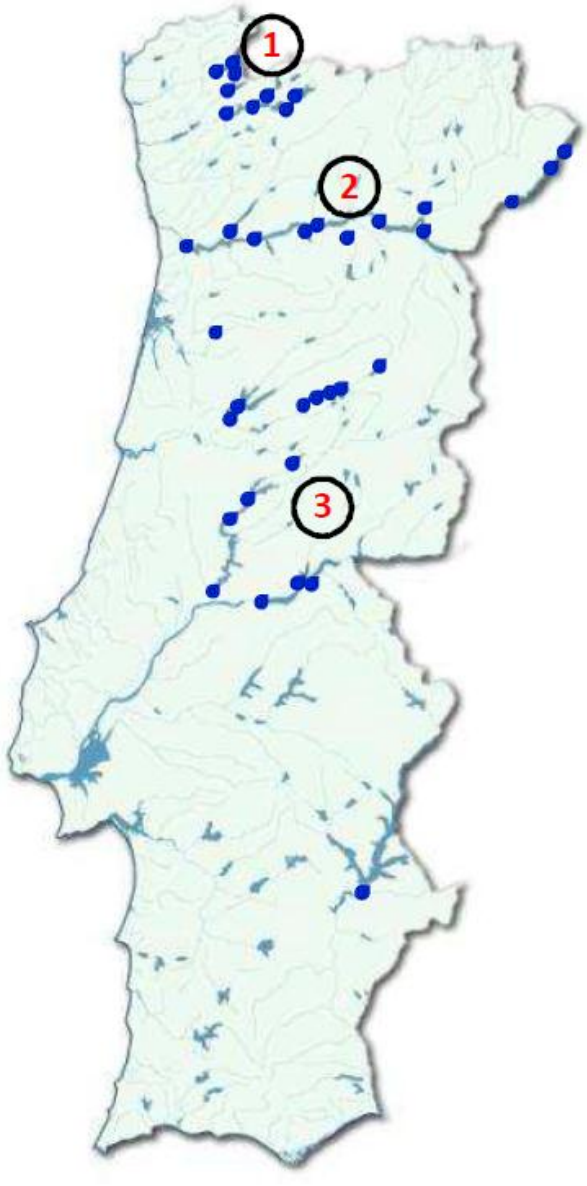
- EDP Hydropower Plants
- EDP Dams in Portugal
- Downstream Spillway Erosion – Problems and Corrective Measures
  - ✓ Caniçada and Salamonde Dams
  - ✓ Santa Luzia Dam
  - ✓ Picote Dam
  - ✓ Paradela Dam
- Recent dams – Adopted Solution
- Final Remarks

EDP Hydropower Plants



EDP Hydropower Plants in Portugal

Hydropower plants (>10MW)



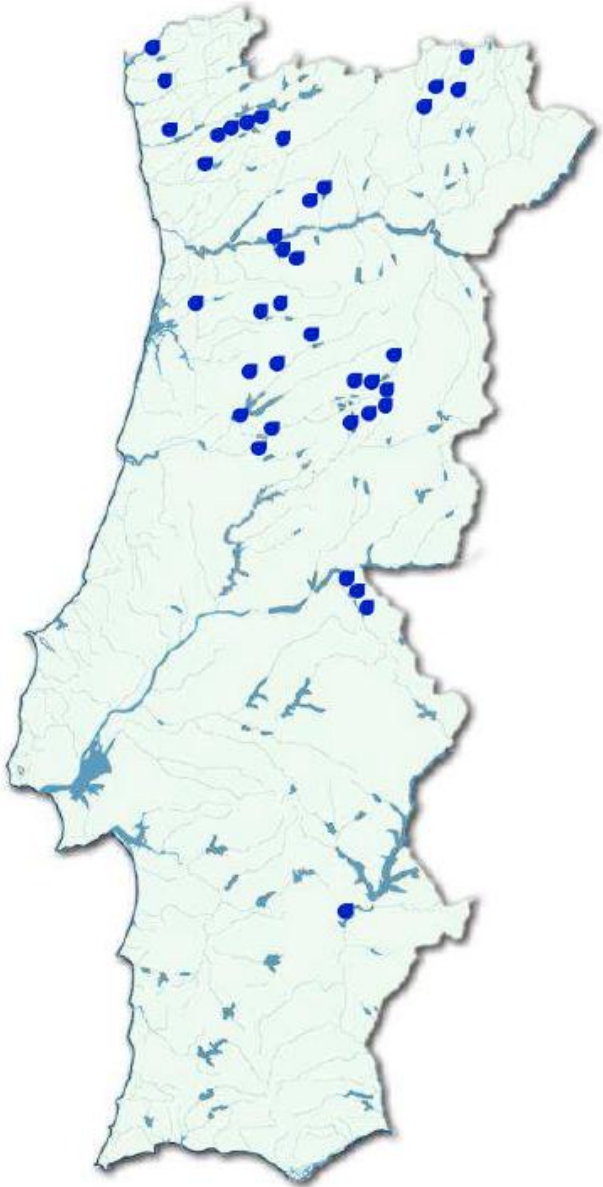
EDP Produção is responsible for the operation of 82 hidropower plants, with a total installed capacity of 6944 MW.

Around 2599 MW are installed in reversible units, allowing the operation in turbine and pump modes.

The power plants are organized in 3 Regional Generation Centers, associated with the respective river basins:

- Cávado-Lima (1)
- Douro (2)
- Tejo-Mondego (3)

Small hydro (≤10MW)



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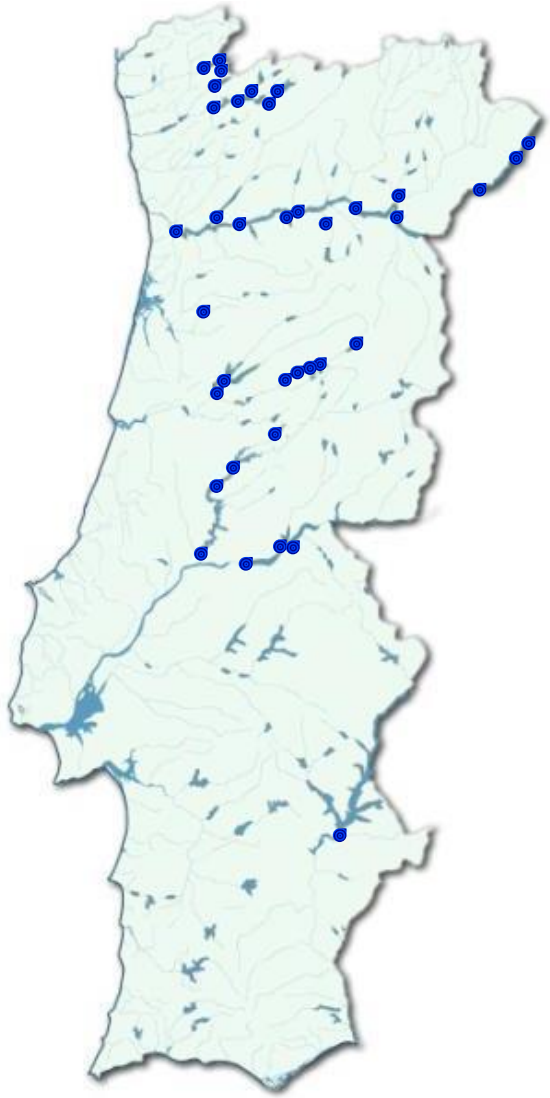
EDP Dams in Portugal



- Around 50 large dams
- 12 dams in international rivers
- Oldest dam completed in 1927
- Most recent completed in 2017
- Wide range of heights (max. 132 m)
- All structural types, with the exception of earthfill
- All dams in concrete, except 3 (rockfill)
- All dams founded in bedrock, except 1 (partly in alluvium)

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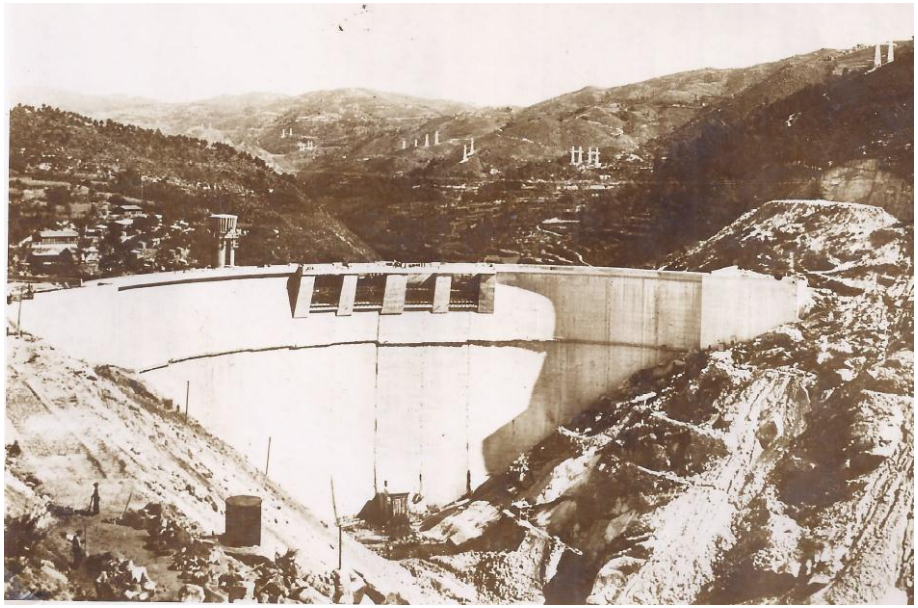
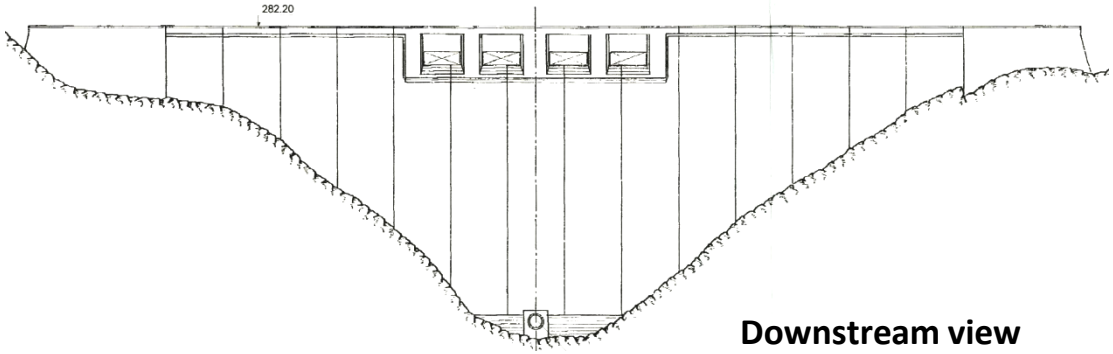
Caniçada and Salamonde Dams

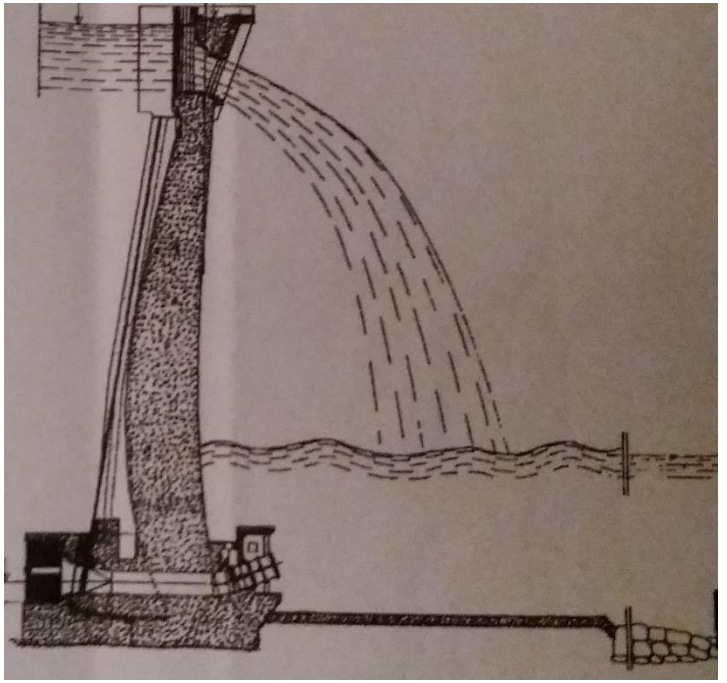
Caniçada Dam - Original Situation





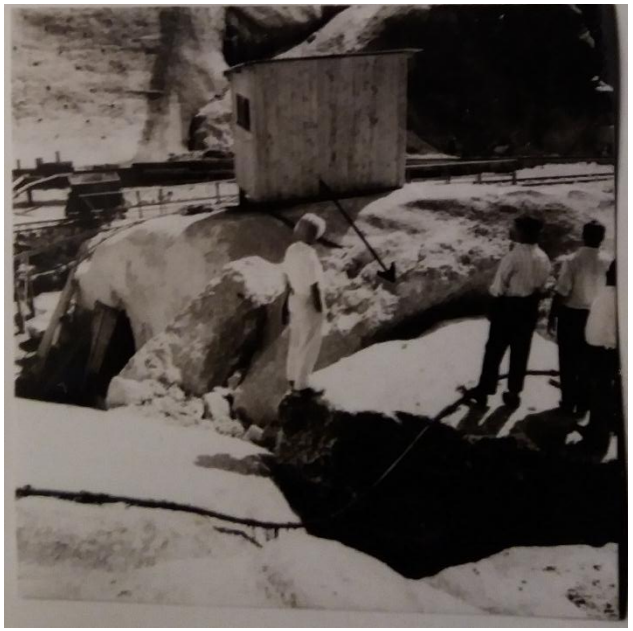
Downstream view

- Year of completion: 1955
- Dam type: Thin arch
- Height: 76 m
- Foundation: Granite
- Spillway type: Controlled; free falling jet
- Maximum discharge capacity: 1700 m^3/s

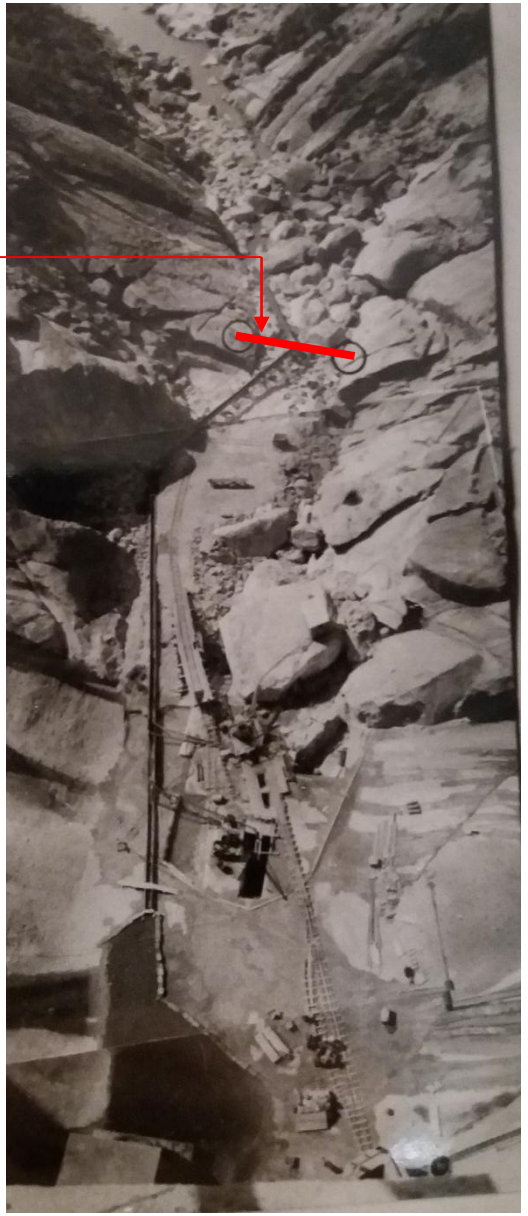


Cross section

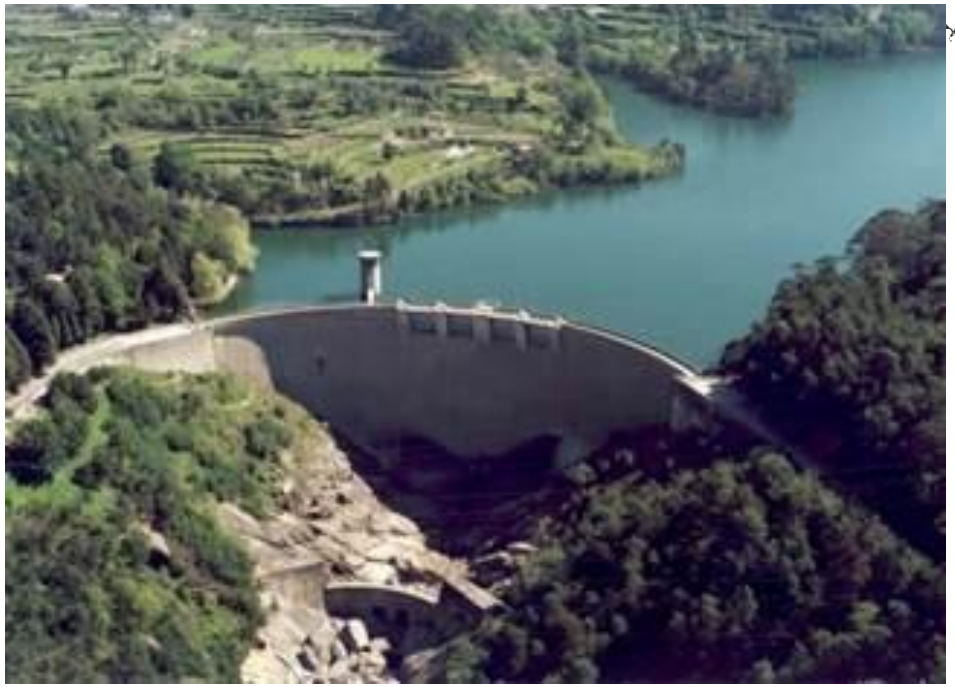
Caniçada dam – Repair Works in 1960-61

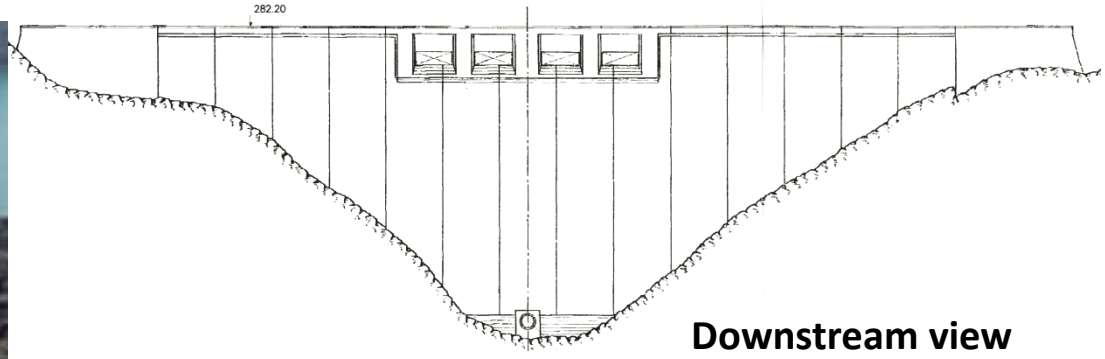


Weir: 115 m downstream the dam



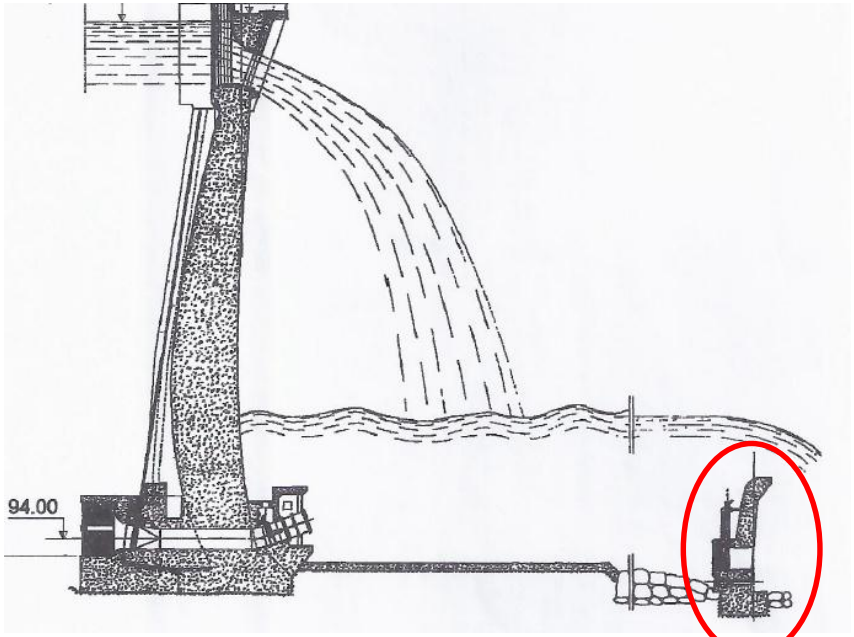
Caniçada Dam – After the Execution of the Downstream Weir





Downstream view

Free falling jet discharging into a plunge pool



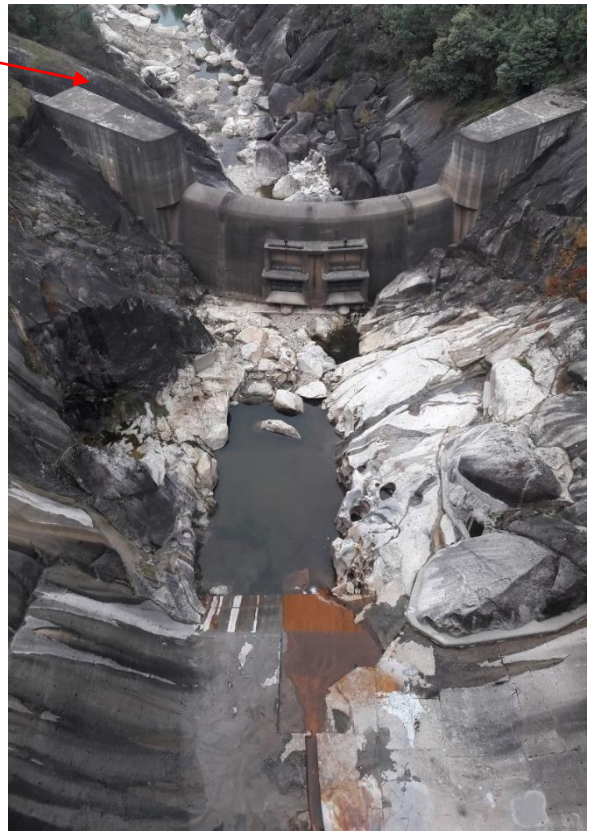
Cross section

Caniçada Dam – Downstream River Bed

Weir

1970

2004



2017

Caniçada and Salamonde Dams

Complementary spillways

Caniçada dam

1700 m³/s + 2000 m³/s

Salamonde dam

1700 m³/s + 1000 m³/s

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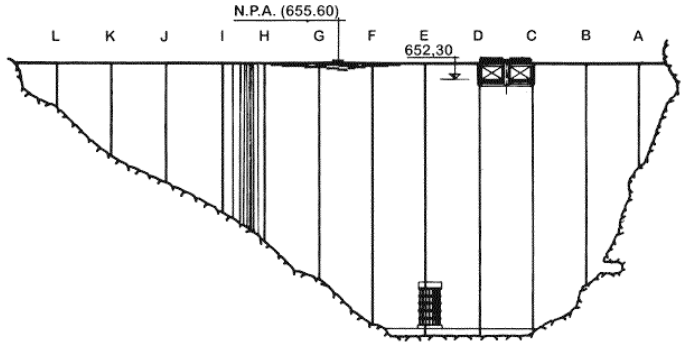
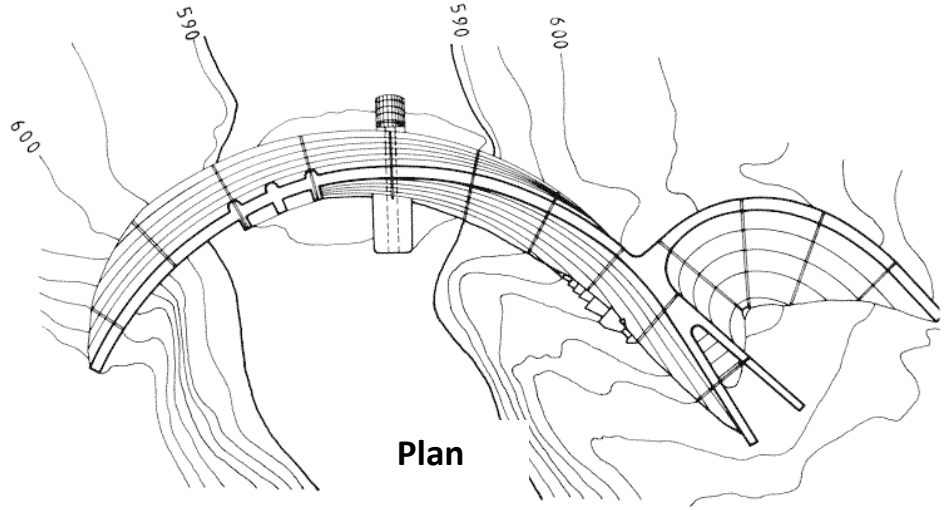
Santa Luzia Dam



Upstream view

- **Year of completion: 1942**
- **Dam type: Thin arch**
- **Height: 76 m**
- **Foundation: Quartzite**
- **Spillway type: Controlled; free falling jet**
- **Maximum discharge capacity: 120 m³/s**



Plan

Santa Luzia Dam – Downstream Spillway Erosion

- **Until 1997: scour depth 3m**
- **Between 1998 and 2001: scour depth 7m**

Santa Luzia Dam – After Repair Works in 2003

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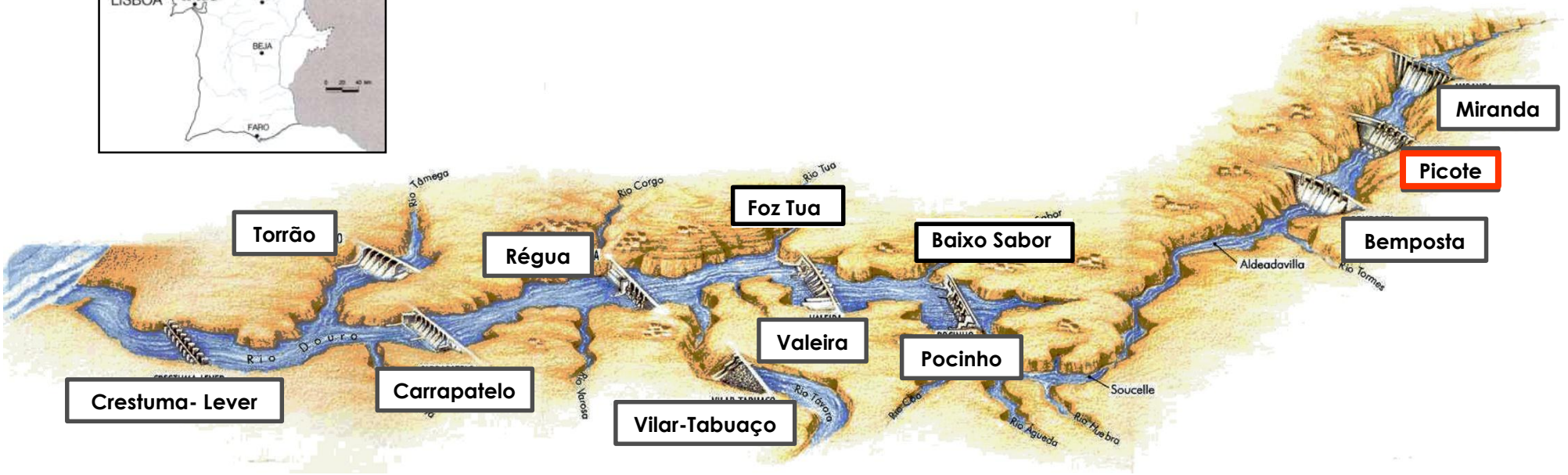
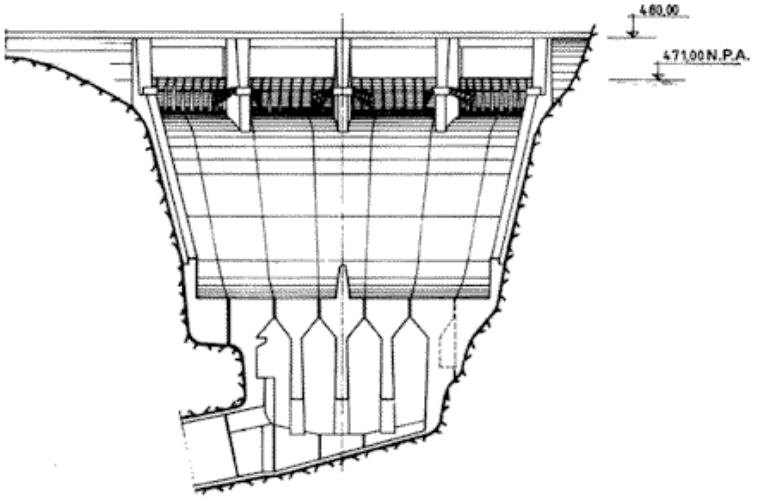
Picote Dam

Picote was the first dam built in Douro River (1958)



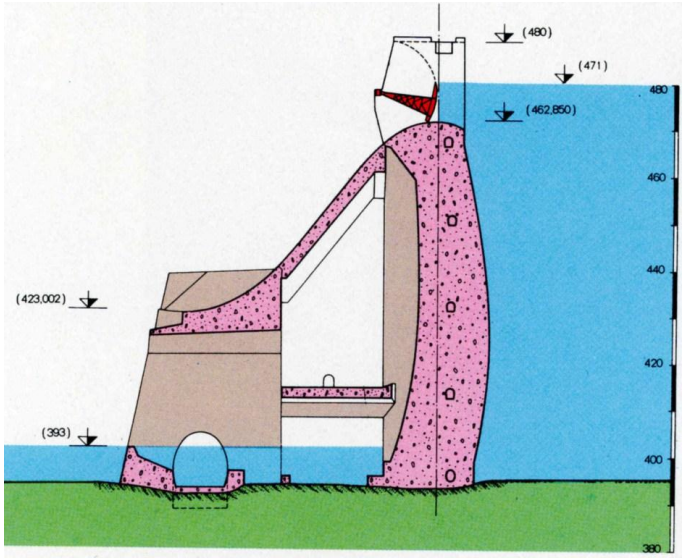
Douro – Portuguese Hydropower schemes

Picote Dam



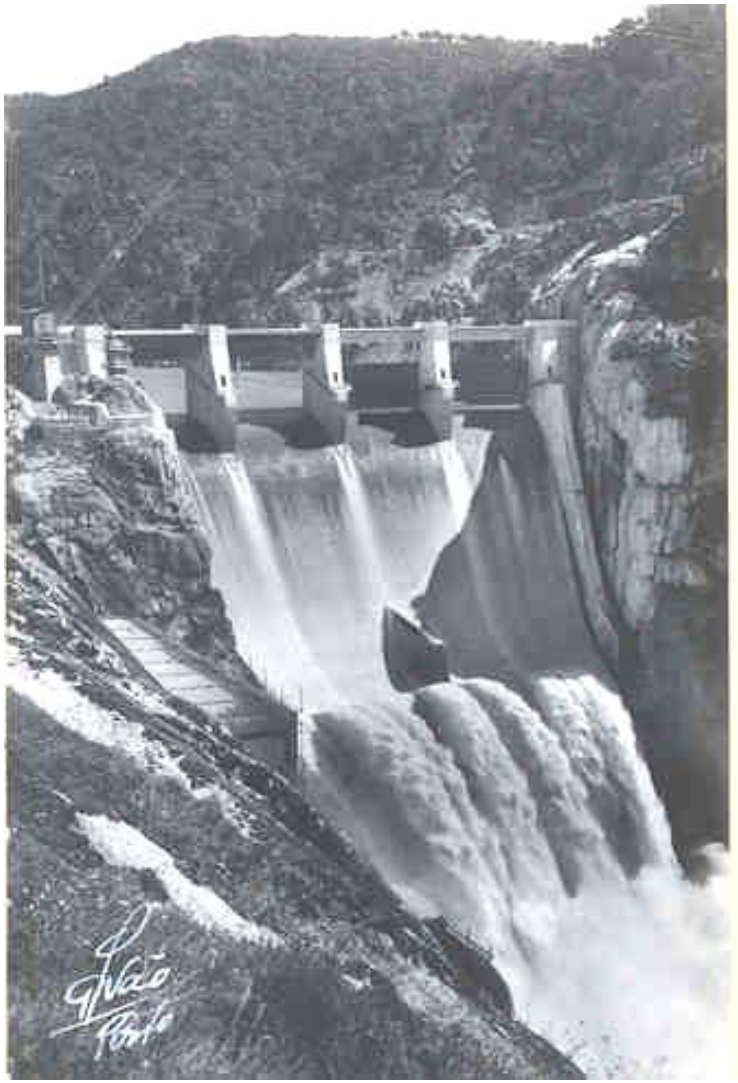
Downstream view

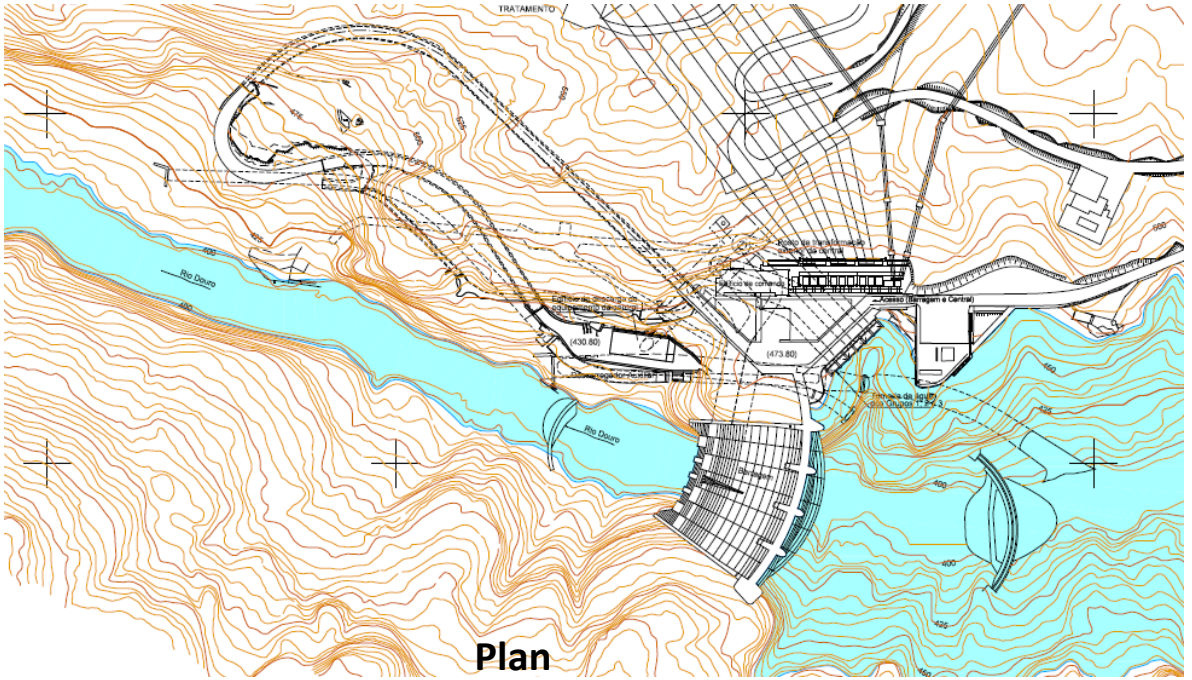
- Year of completion: 1958
- Dam type: Arch
- Height: 100 m
- Foundation: Granite
- Spillway type: Controlled; sky jump
- Maximum discharge capacity: 11 000 m^3/s



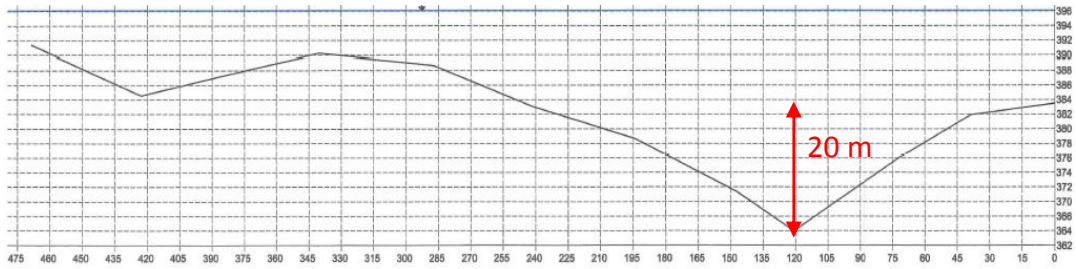
Cross section

Picote Dam – Before Repowering (2007)





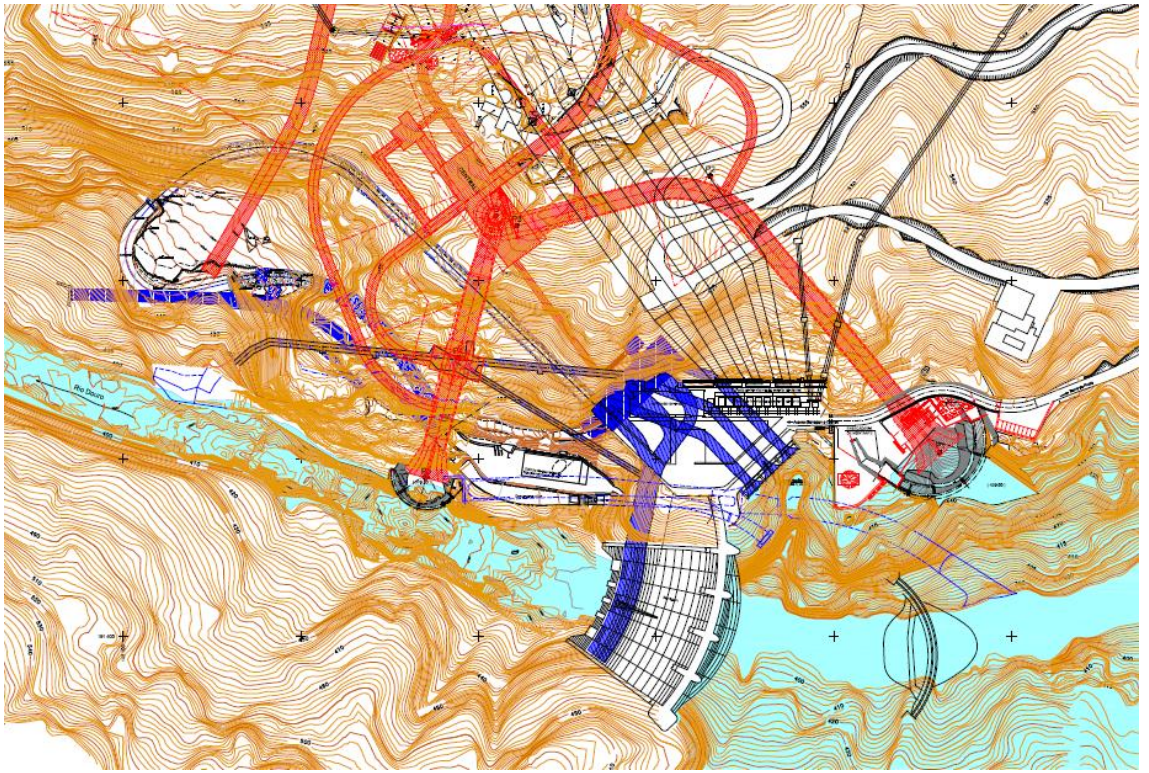
Plan



Longitudinal profile of the river

Sky jump

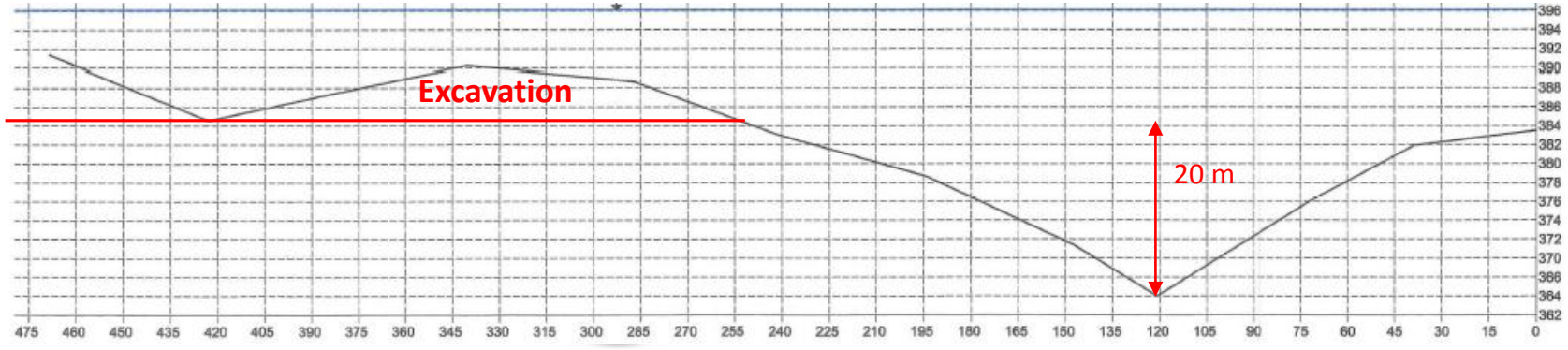
Picote Dam – Repowering (2007-2011)



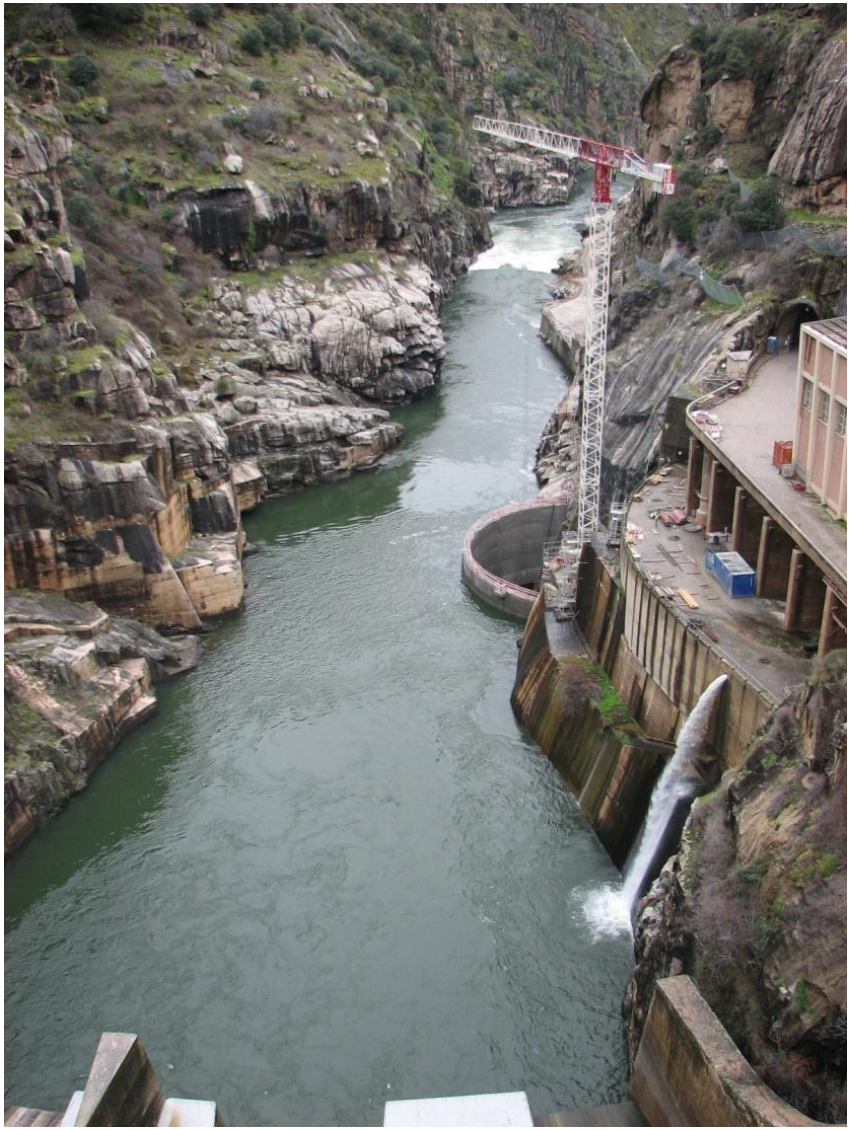
Original scheme

Repowering

Longitudinal profile



Picote Dam – Repowering (2007-2011)



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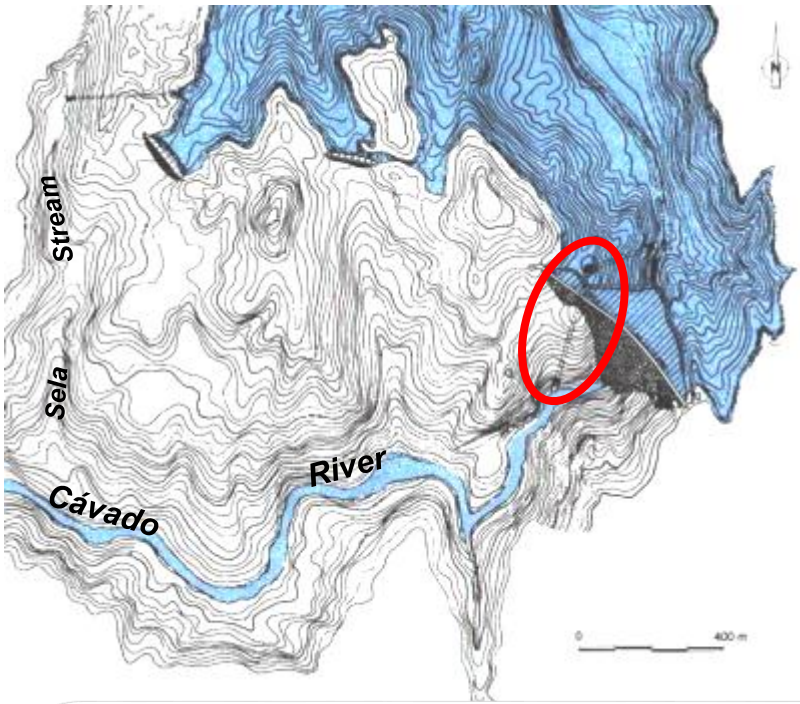
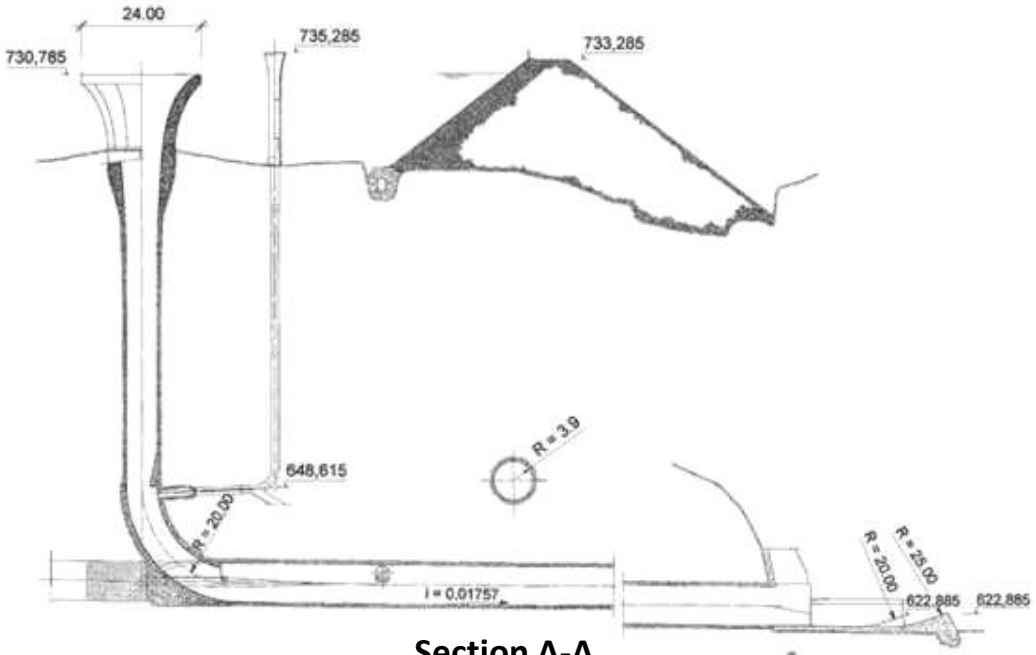
Paradela Dam – Original Situation

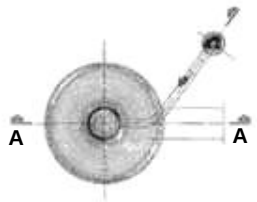


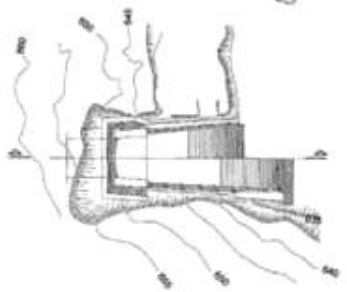
- Year of completion: 1958
- Dam type: Rockfill
- Height: 112 m
- Foundation: Granite
- Spillway type: Uncontrolled + Controlled
- Maximum discharge capacity: 600 + 340 m³/s

Uncontrolled spillway



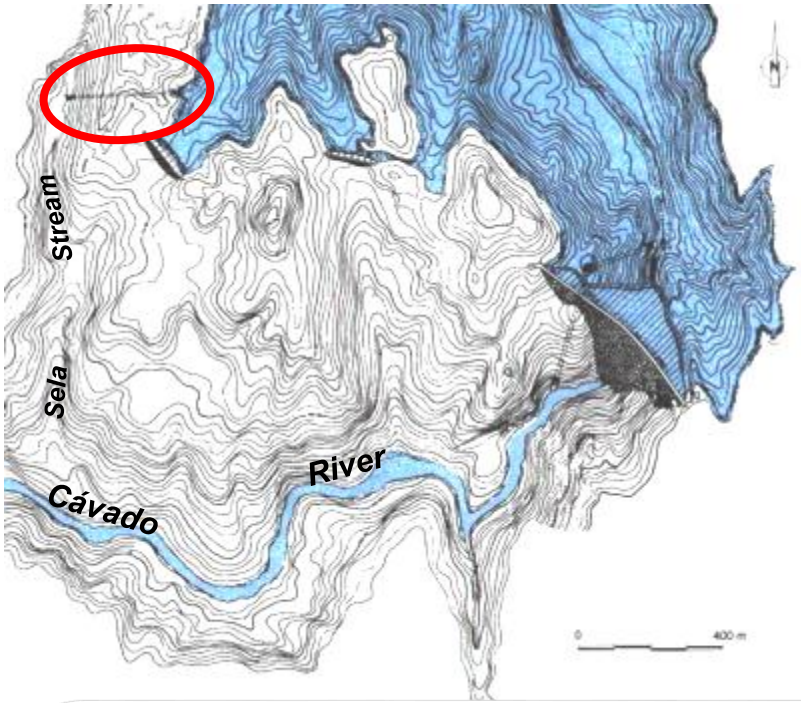
Section A-A





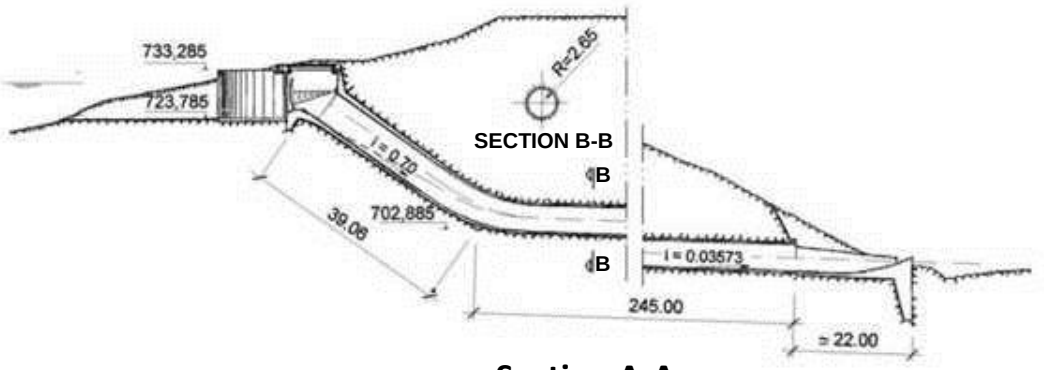
Plan

Paradela Dam – Original Situation



- Controlled spillway
- Located about 1 km far from the dam
- One bay equipped with a radial gate
- Tunnel: 285 m long
- Ski jump discharging into Sela small stream
- Maximum discharge capacity 340 m^3/s

Controlled spillway – Morning Glory



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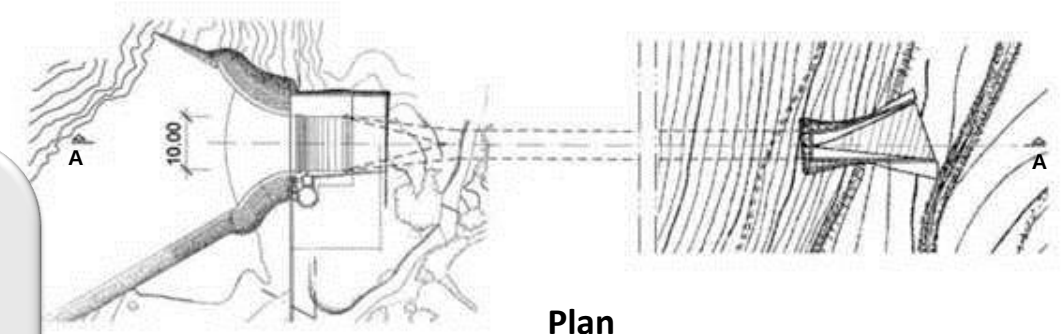
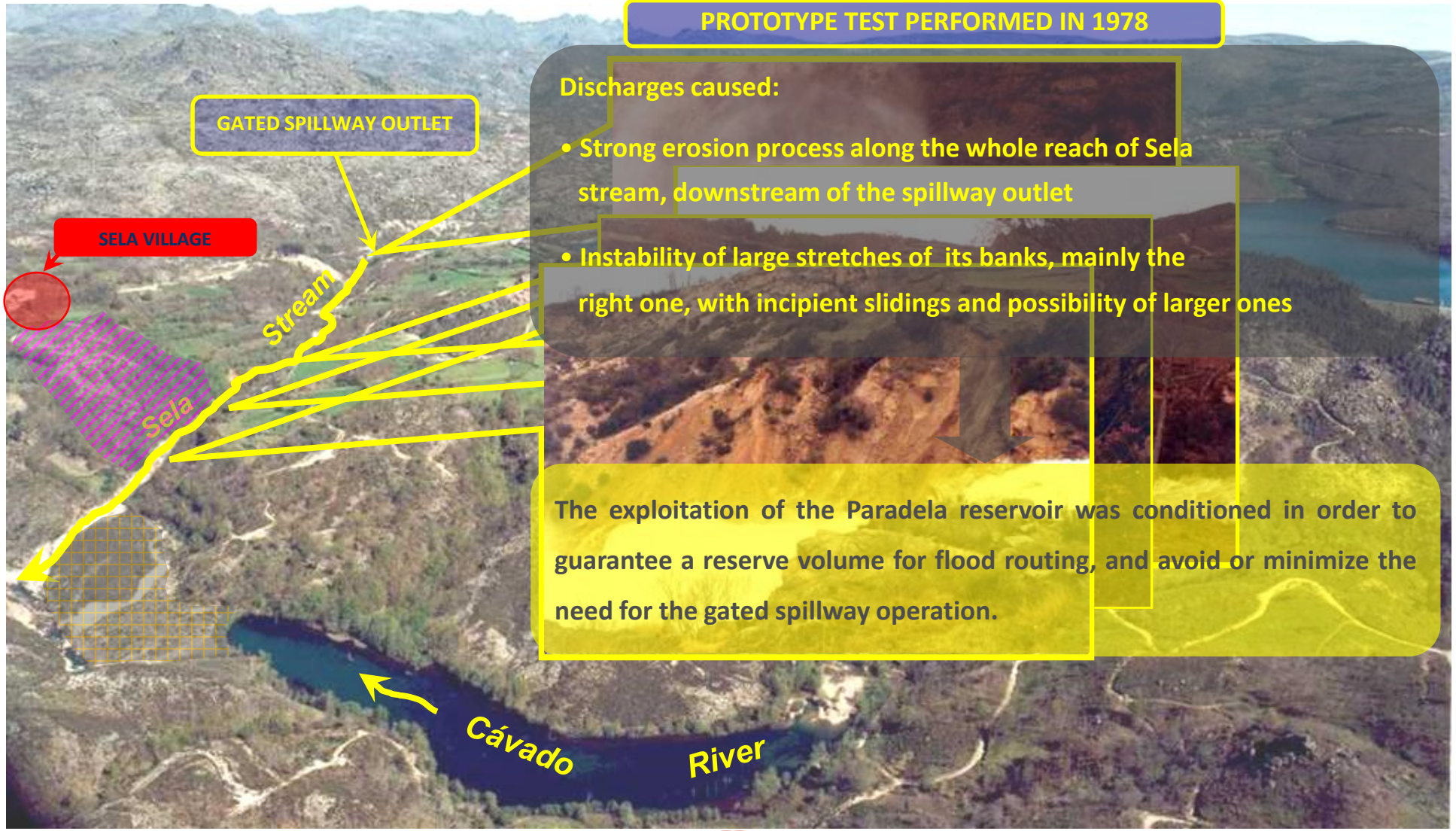


Plan

Paradela Dam – Original Situation

DISCHARGES THROUGH GATED SPILLWAY



Paradela Dam – New Spillway

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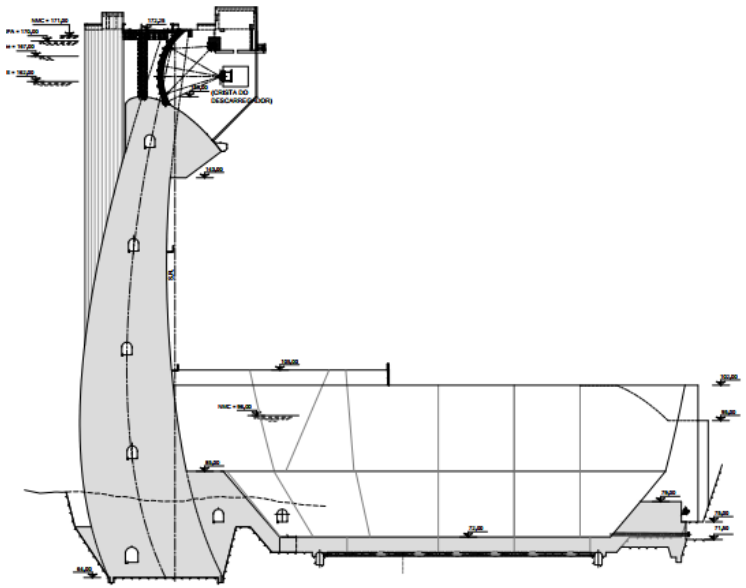
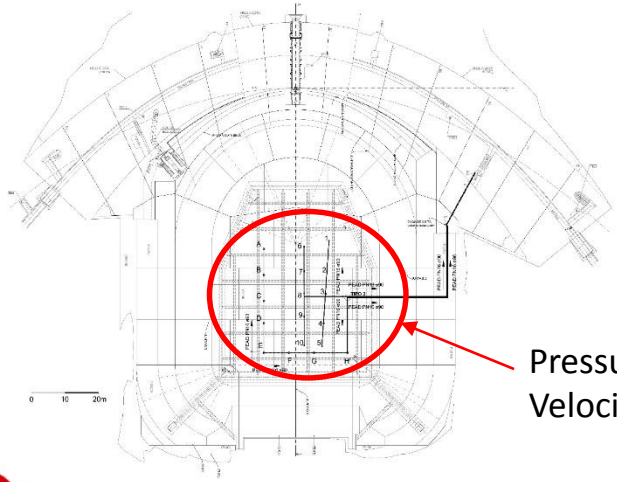
Recent Dams – Foz Tua and Baixo Sabor



Cross section

- Year of completion: 2017
- Dam type: Arch
- Height: 108 m
- Foundation: Granite
- Spillway type: Controlled; free falling jet
- Maximum discharge capacity: 5500 m^3/s



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Final remarks

- **Systematic river bed observation and survey data analysis** have been **key to safety control procedures**, allowing for the effective management of situations in which actual behavior deviates from expectactions.

- A **multidisciplinary approach**, involving the areas of hydraulics, geology, geotechnics and structures, has allowed the definition of **corrective measures**.

- **Hydraulic model tests**, performed by the **National Laboratory for Civil Engineering**, have been essential for the definition of suitable solutions.

- In **recente dams**, despite careful studies, design and construction, what kind of **erosion problems can be expected in the impact stilling basin**? Would it be possible to **optimize** this type of solution? Is there any **experience of pressure and velocity measurements in prototypes**?

- The **challenge** is to define and implement the most suitable solutions regarding **efficiency and economy.**

Thank you for your attention