



# TOUS DAM REVISITED

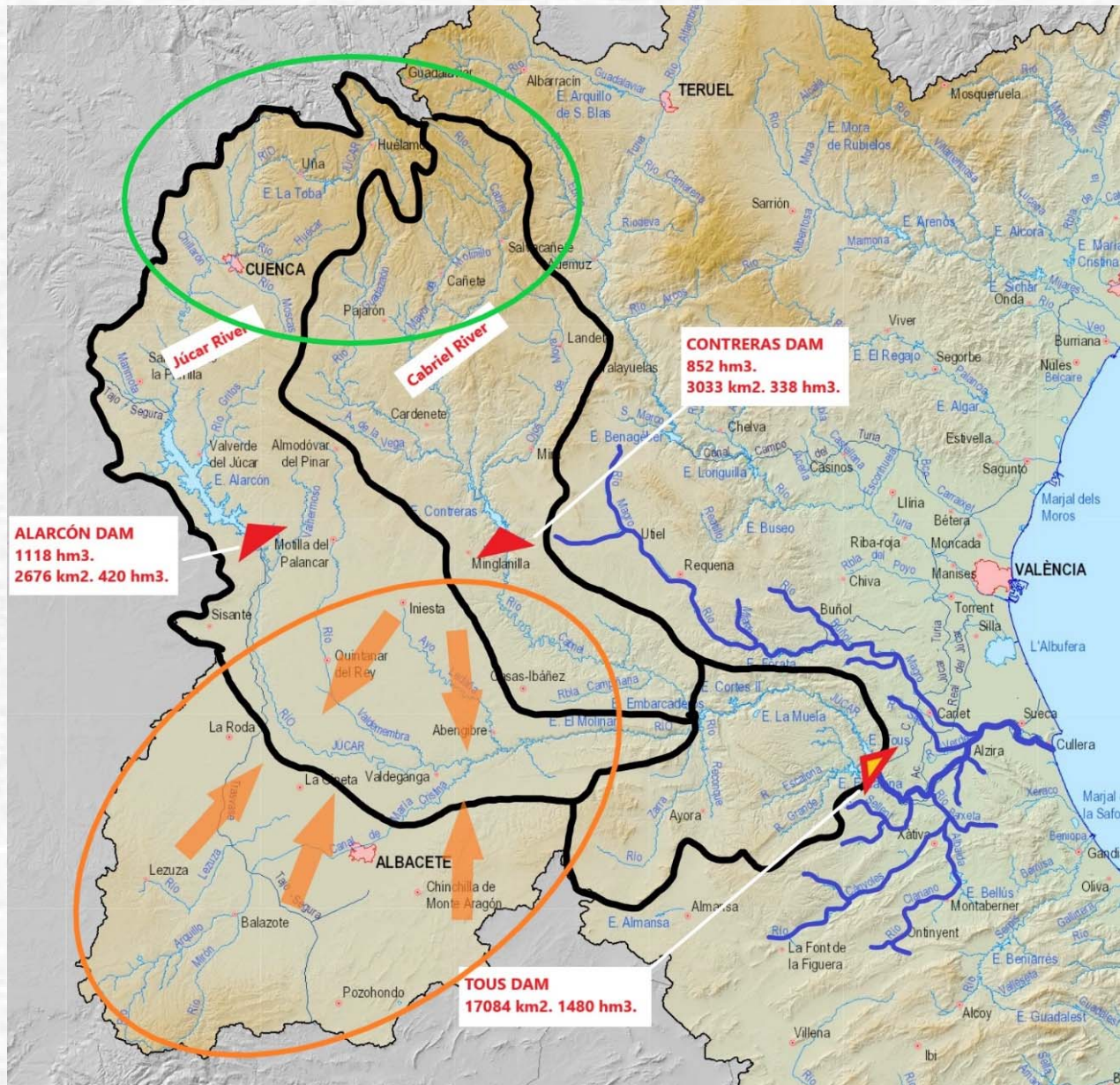
## A Common Sense Disaster

Stockholm  
October, 19th., 2022

Dr. Juan B. Marco  
Professor "Ad Honorem"  
Universidad Politécnica de Valencia



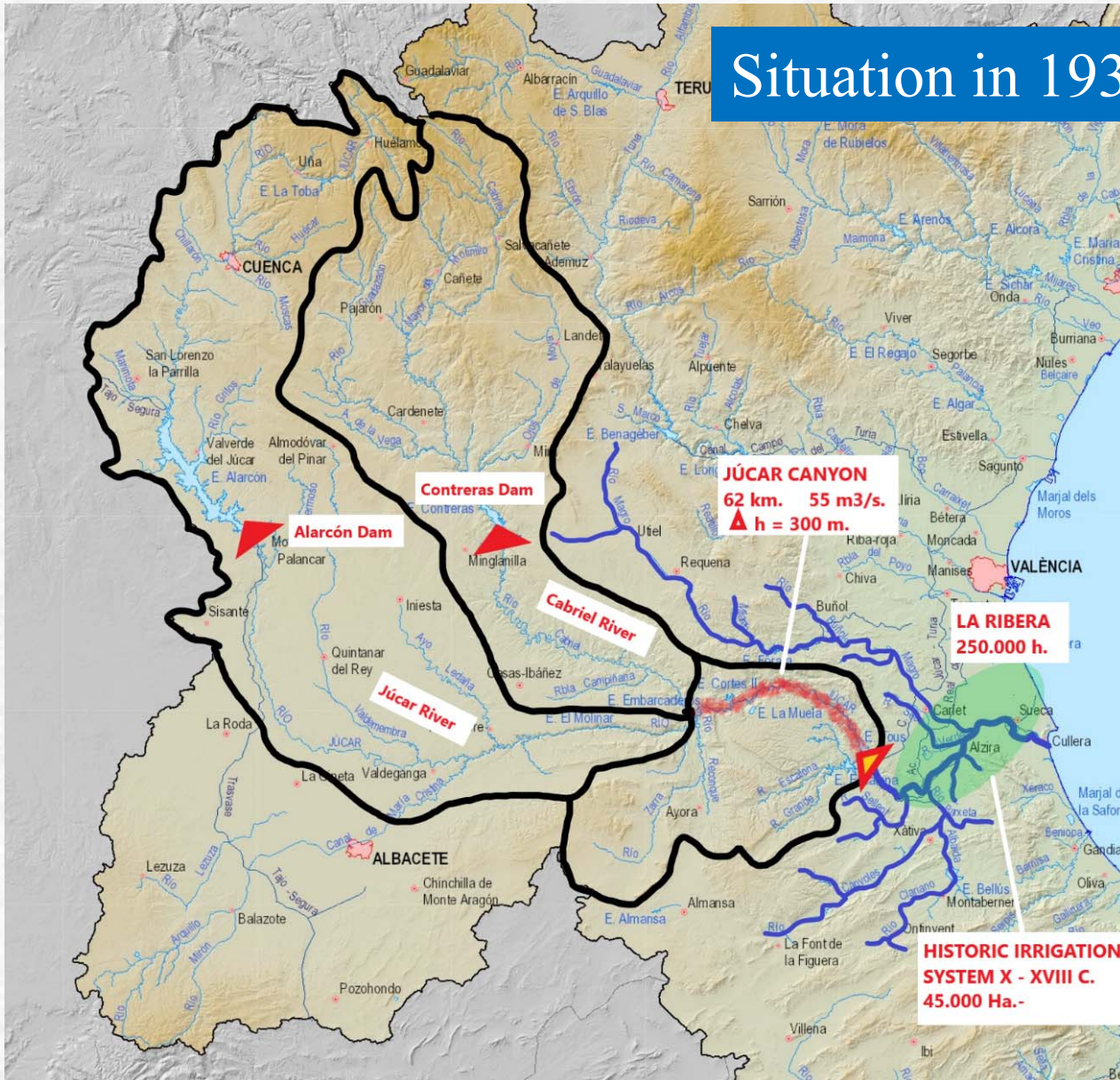




- Two similar basins, controlled by two high capacity reservoirs, Alarcón (1955) and Contreras (1968)
- Most runoff generated at the mountains
- Important aquifers. Eastern La Mancha Aquifer discharges 320 hm<sup>3</sup>
- Both rivers, upper Júcar and Cabriel, join at Cofrentes



## Situation in 1930



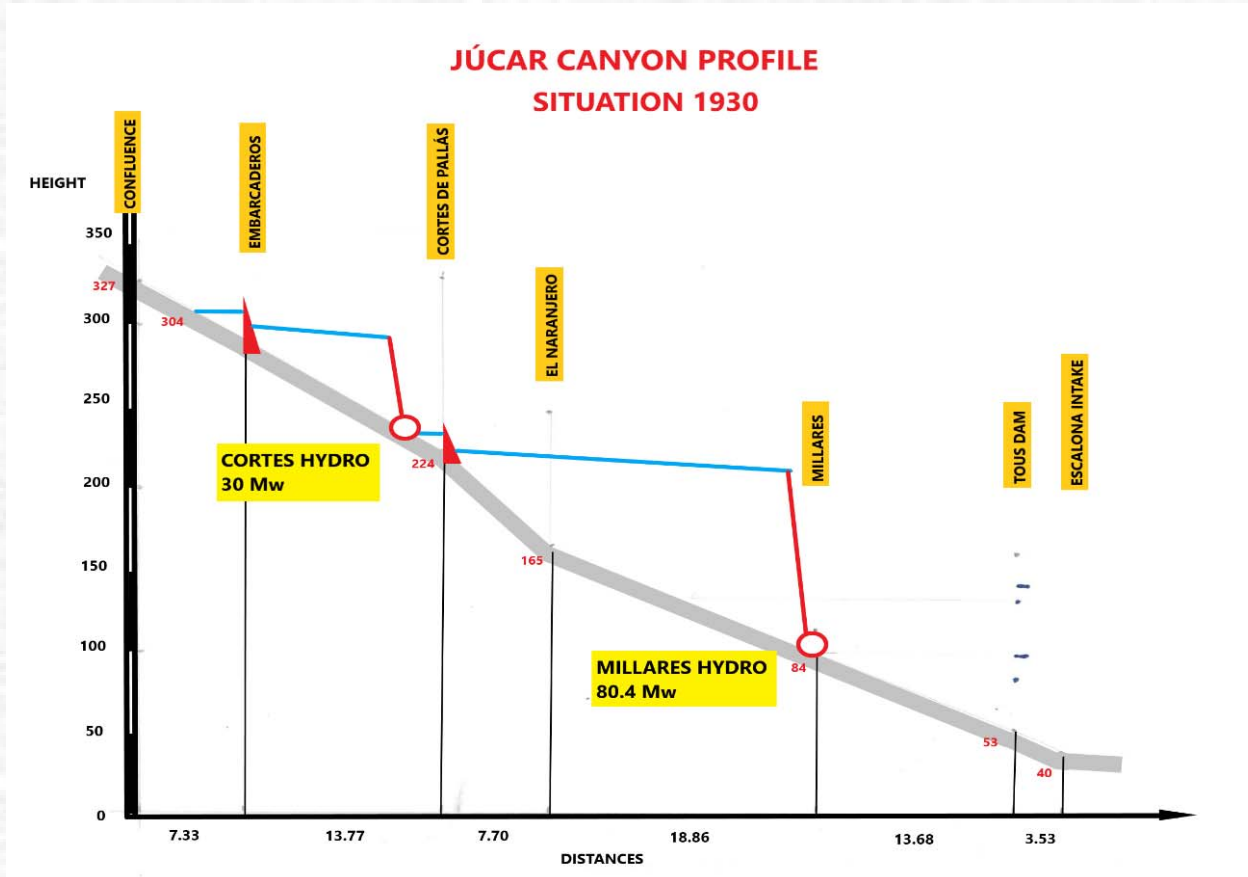
- **Historic Irrigation System (X-XVII C.)** Very old water rights.
- **45.000 ha.** Oranges, vegetables, rice
- **Acequia Real del Xúquer (XIII C.)**

- **Flat area between Tous dam and the sea: La Ribera**
- **250.000 people**

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## Situation in 1930



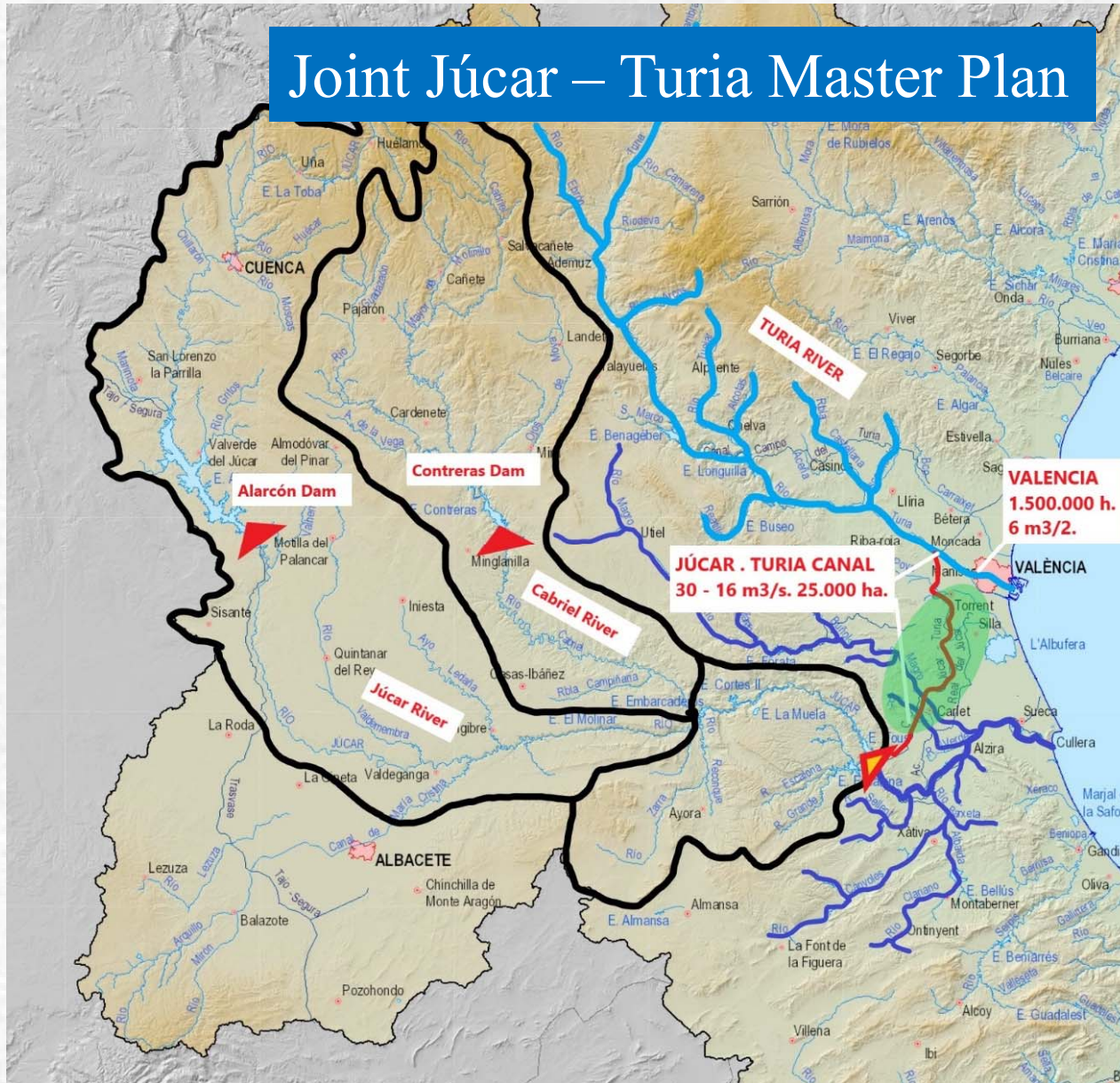
- Júcar Canyon
- In 62 km. the river has a drop of 300 m. with a regular flow of 55 m<sup>3</sup>/s.

- Two large run – off – the –river hydropower facilities were created.

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## Joint Júcar – Turia Master Plan



- Contreras Dam
- Júcar – Turia Canal  
30 – 16 m<sup>3</sup>/s.

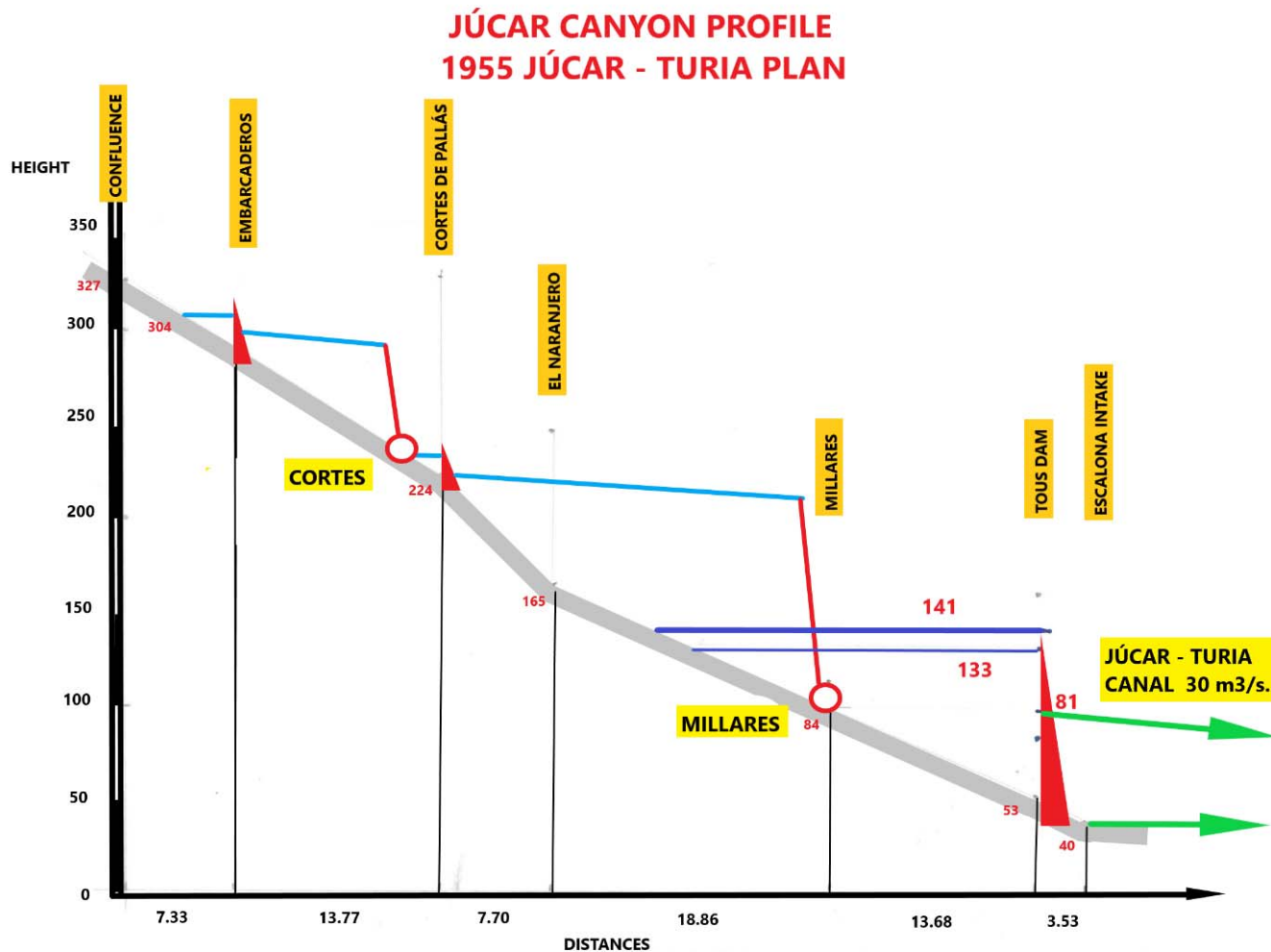
- Water Supply for Valencia
- 25.000 ha. New irrigation
- Supplement for Turia irrigation

- It needed a big Tous Reservoir to readapt the flow for consumptive use downstream of the hydropower system.

1st. TOUS PROJECT  
1955 (S. Aznar)  
412 hm<sup>3</sup>. 141 m. height



## Joint Júcar – Turia Master Plan



- Intake for the canal is placed at level 81, slightly under Millares return.
- Millares hydropower facility loses 50 m. of height

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## Millares Hydropower

- 1956 A comisión is set to fix economic compensation.
- It lasted 40 years !!!



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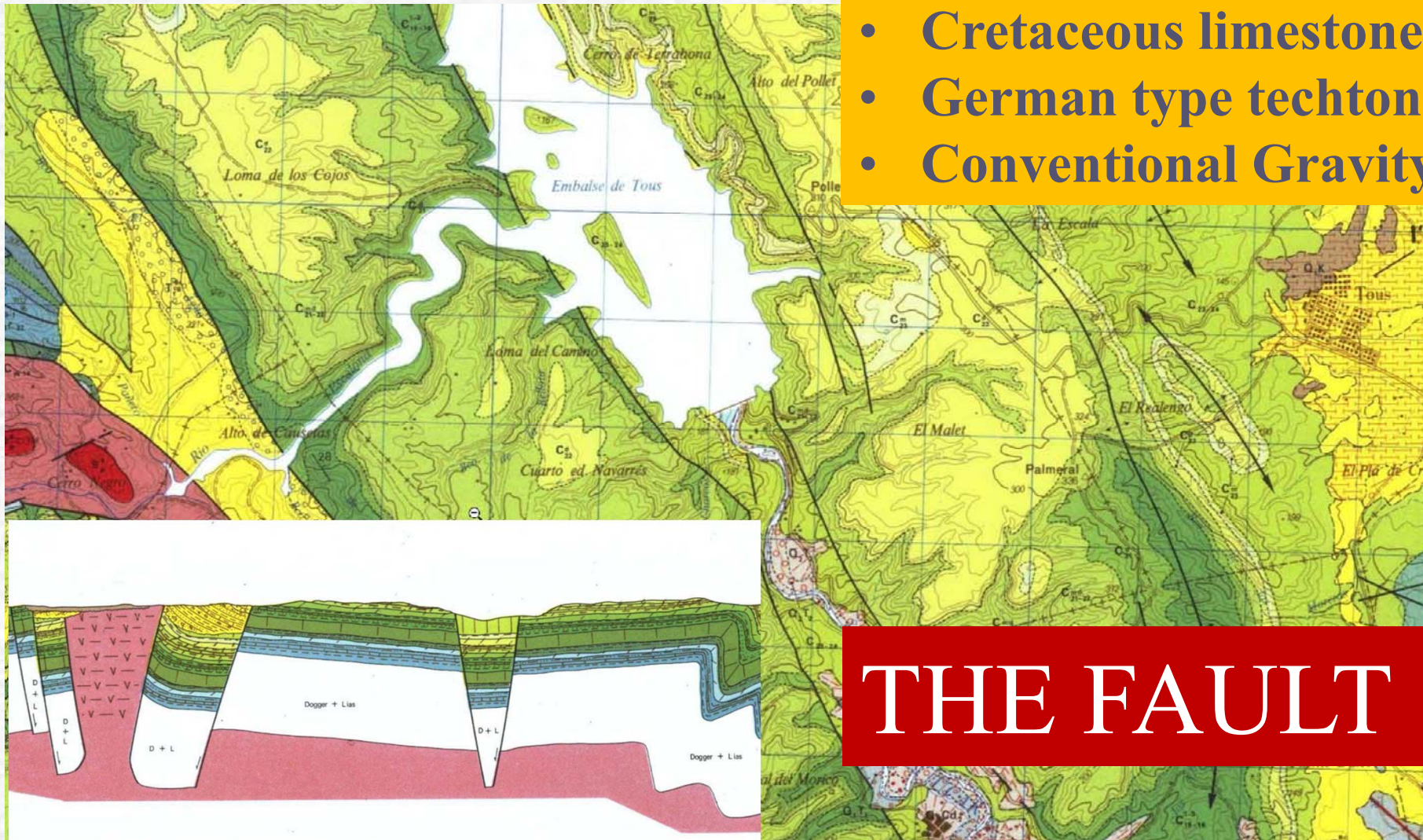
Big opposition by stakeholders:

- Historical Irrigation Canals
- Electric Company
- Social opposition by the cities downstream

PLAN FULLY DEVELOPED WITHOUT  
CITIZENSHIP PARTICIPATION

## Geological Framework

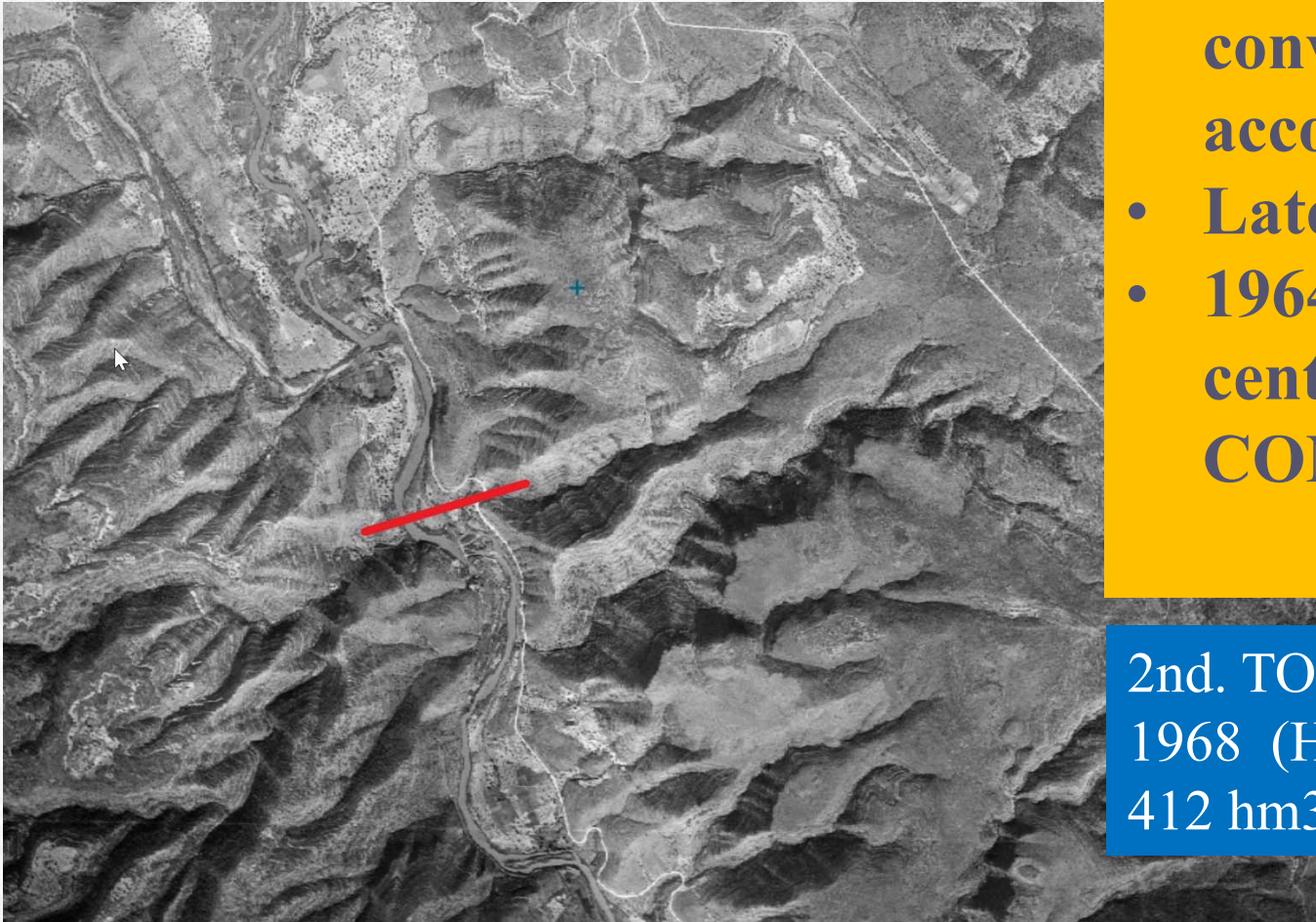
- Cretaceous limestones
- German type tectonics
- Conventional Gravity Dam



**THE FAULT !!!**



## 1956 Aerial Photography

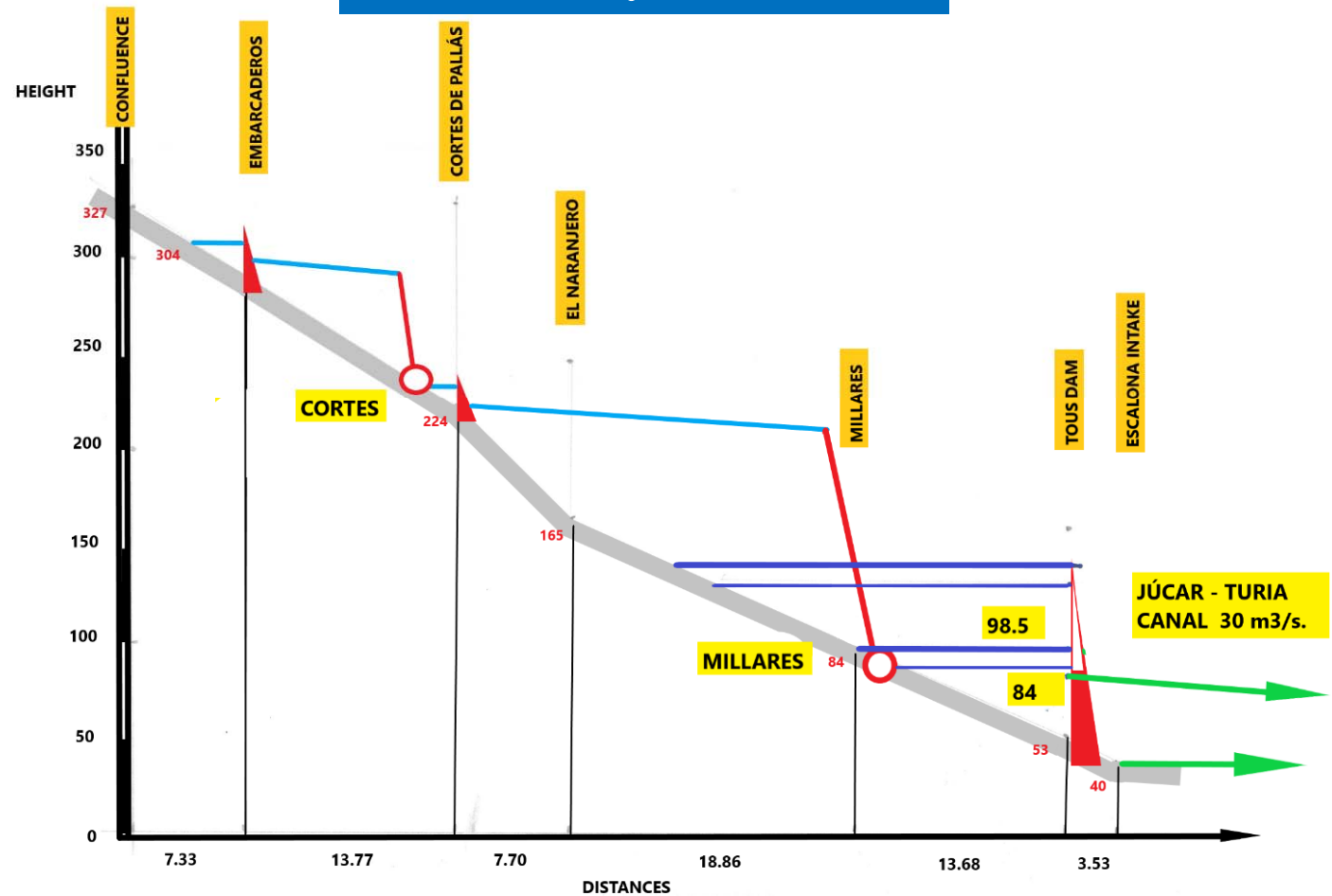


- 1958 Construction begins as conventional gravity dam according to 1956 Project.
- Lateral blocks are built.
- 1964 After foundations for central blocks are excavated, **CONSTRUCTION STOPS.**

2nd. TOUS PROJECT  
1968 (H. Corbí)  
412 hm<sup>3</sup>. 141 m. height

- The Júcar – Turia Canal was already built
- TO DELAY ECONOMIC COMPENSATION FOR MILLARES HYDROPOWER FACILITY.

## 1968 – 1982 Júcar Canyon Profile



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## 1967 Aerial Photography



2nd. TOUS PROJECT  
Adapted for 2 phases  
(S. Madrigal)

- **MIXED DAM:  
ROCKFILL  
EMBANKMENT  
WITH CLAY  
CENTRAL CORE**
- **Complete Concrete  
Gravity Lateral  
Blocks.**
- **SPILLWAY  
DISPLACED ON  
ALREADY BUILT  
RIGHT BANK  
BLOCKS.**



## CONSTRUCTION IN TWO PHASES FOR “ TESTING THE FAULT “

1st.Phase: Top + 98.5 m.	80 hm <sup>3</sup> .
MWL + 84 m.	50 hm <sup>3</sup> .
2nd.Phase: Top + 142 m.	427 hm <sup>3</sup> .
MWL + 133 m.	300 hm <sup>3</sup> .





# TOUS DAM 1982



## TOUS DAM REVISITED

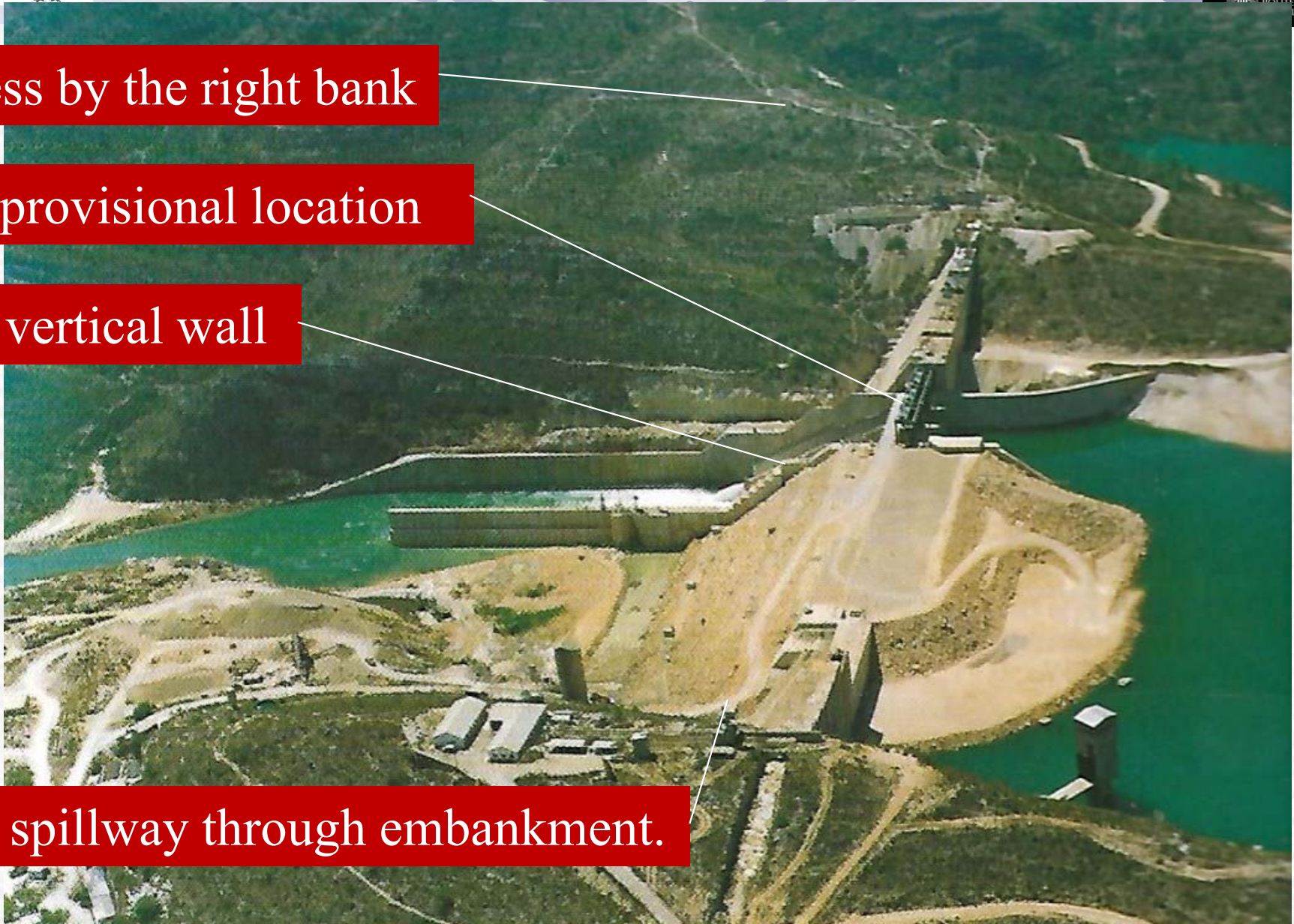


No Access by the right bank

Gates at provisional location

Flexible vertical wall

Acces to spillway through embankment.



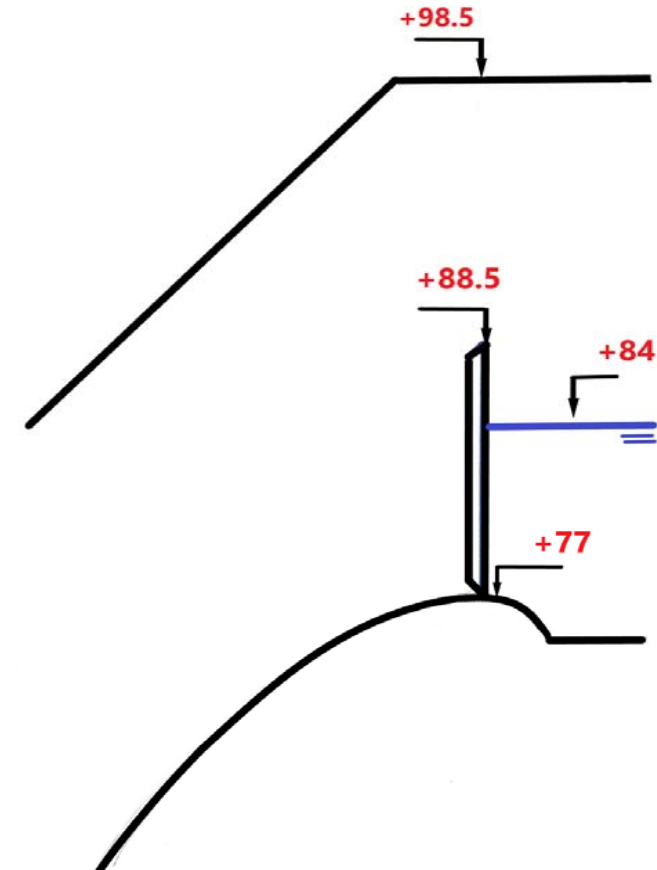


## The Spillway

$$Q = 4500 \text{ m}^3/\text{s.}$$

**POOR HYDROLOGICAL DESIGN !!!**  
Modified Fuller Empirical formula

- **First design:**  
6 x 25 m. free flow.  
Threshold at +84 m.
- **Modified design:**  
3 x 15.333 m. gated.  
3 vertical gates 15.333 m. x 10.5 m.  
Threshold at +77 m. Top at + 87.5



- **TALL RETAINING WALL ALONG THE SPILLWAY**
- **VERY HEAVY GATES DIFFICULT TO OPEN**

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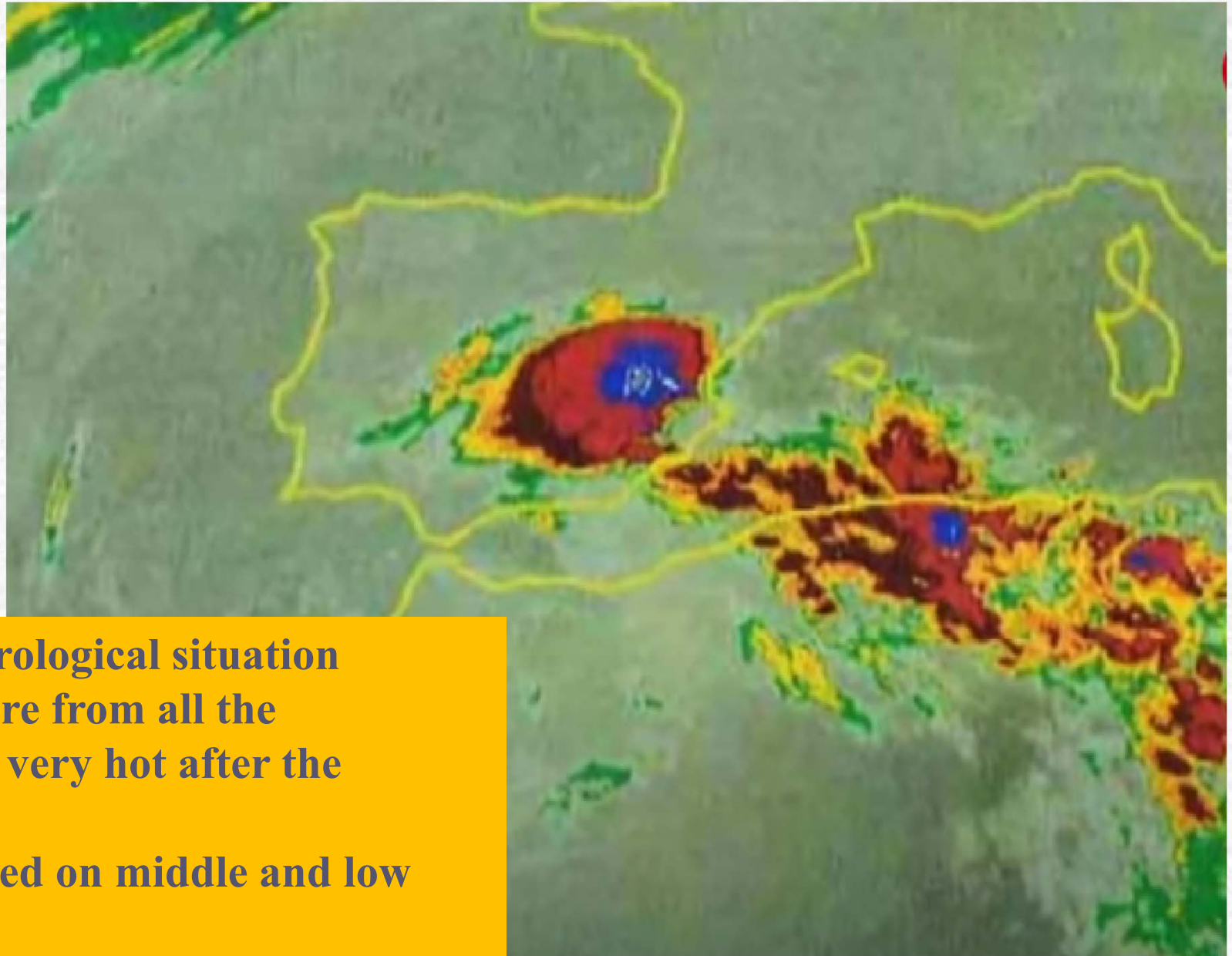


- THE DAM WAS OFFICIALLY UNDER CONSTRUCTION
  - But it had to serve the Júcar – Turia Canal
  - A special permit by the Council of Ministers under Franco Dictatorship allowed entry to service
- 
- **As a Dam under construction the management and responsibility belonged to the Central Large Dam Construction Service at Madrid.**
  - **But since construction stopped in 1970, nobody was there.**
  - **Basin authority had no responsibility and also did not have there any staff.**
  - **Only a security guard by the construction firm was there, with a gun and without pone !!!**



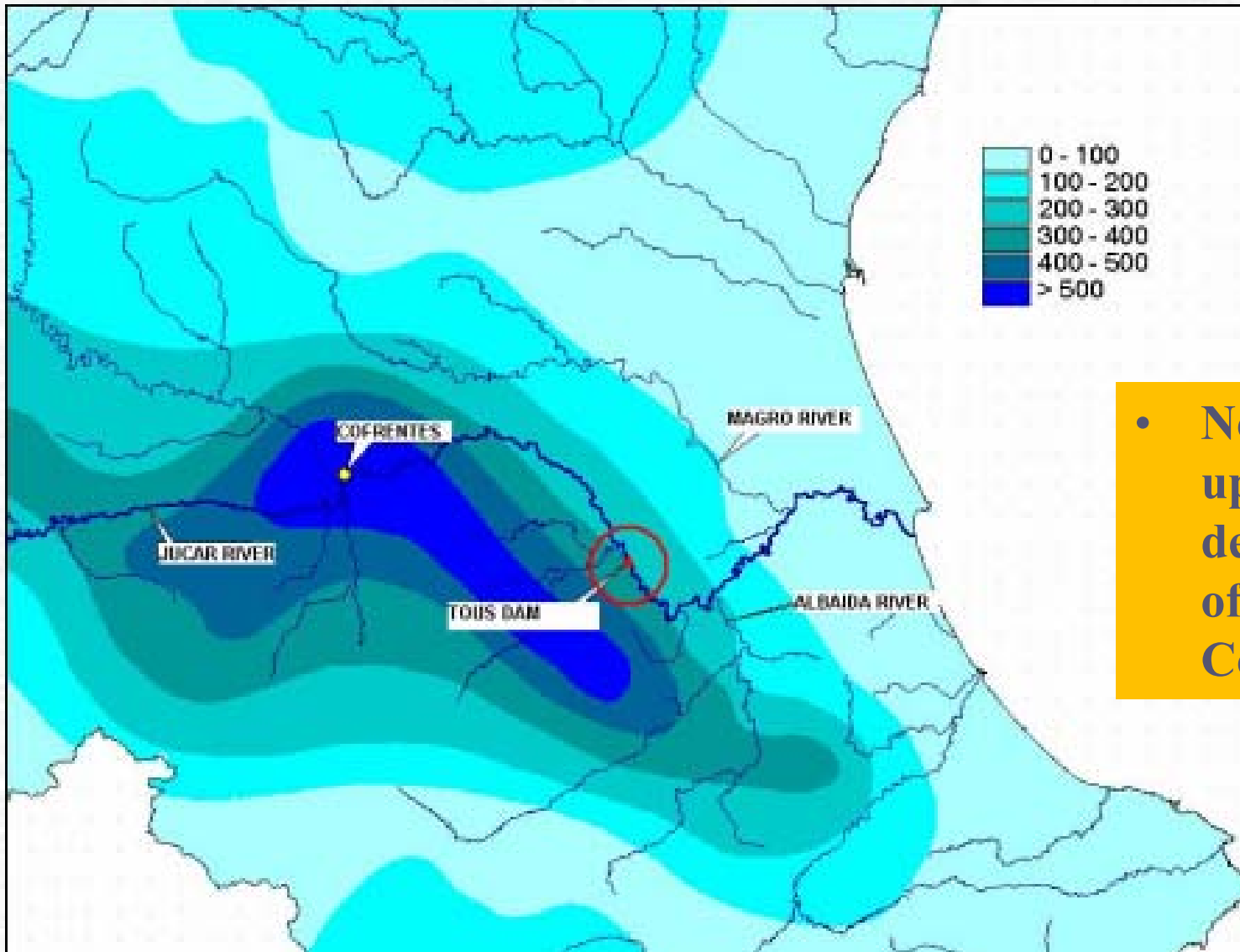


THIS “TEMPORARY” SITUATION  
LASTED 14 YEARS !!!  
1968 - 1982



- Inverse meteorological situation attracted moisture from all the mediterranean, very hot after the summer.
- Cold drop located on middle and low Júcar Basin

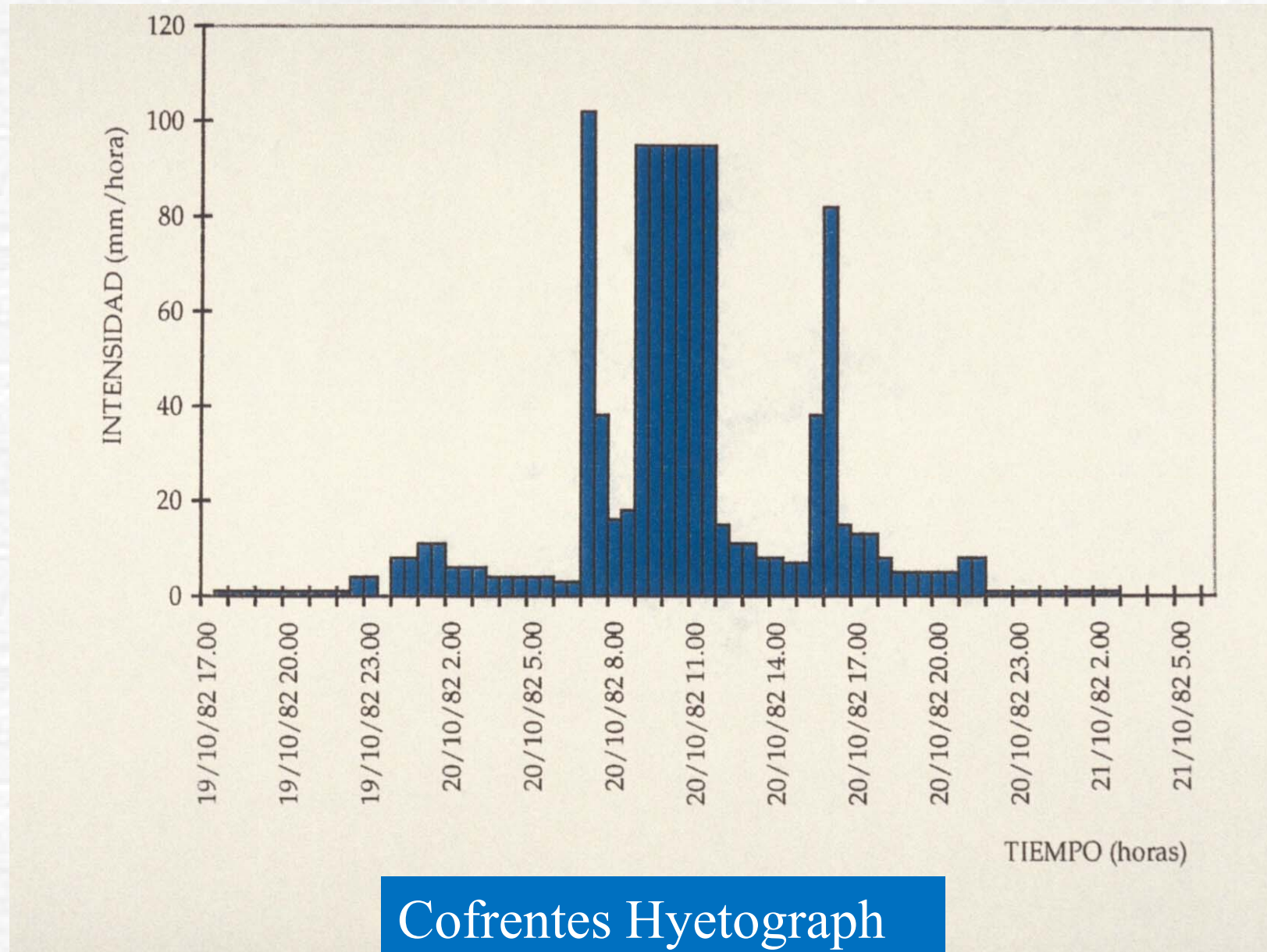




- No rainfall registered at upper basin. Everything developed downstream of the large Alarcón and Contreras reservoirs.



# THE EVENT OCTOBER 20th. 1982



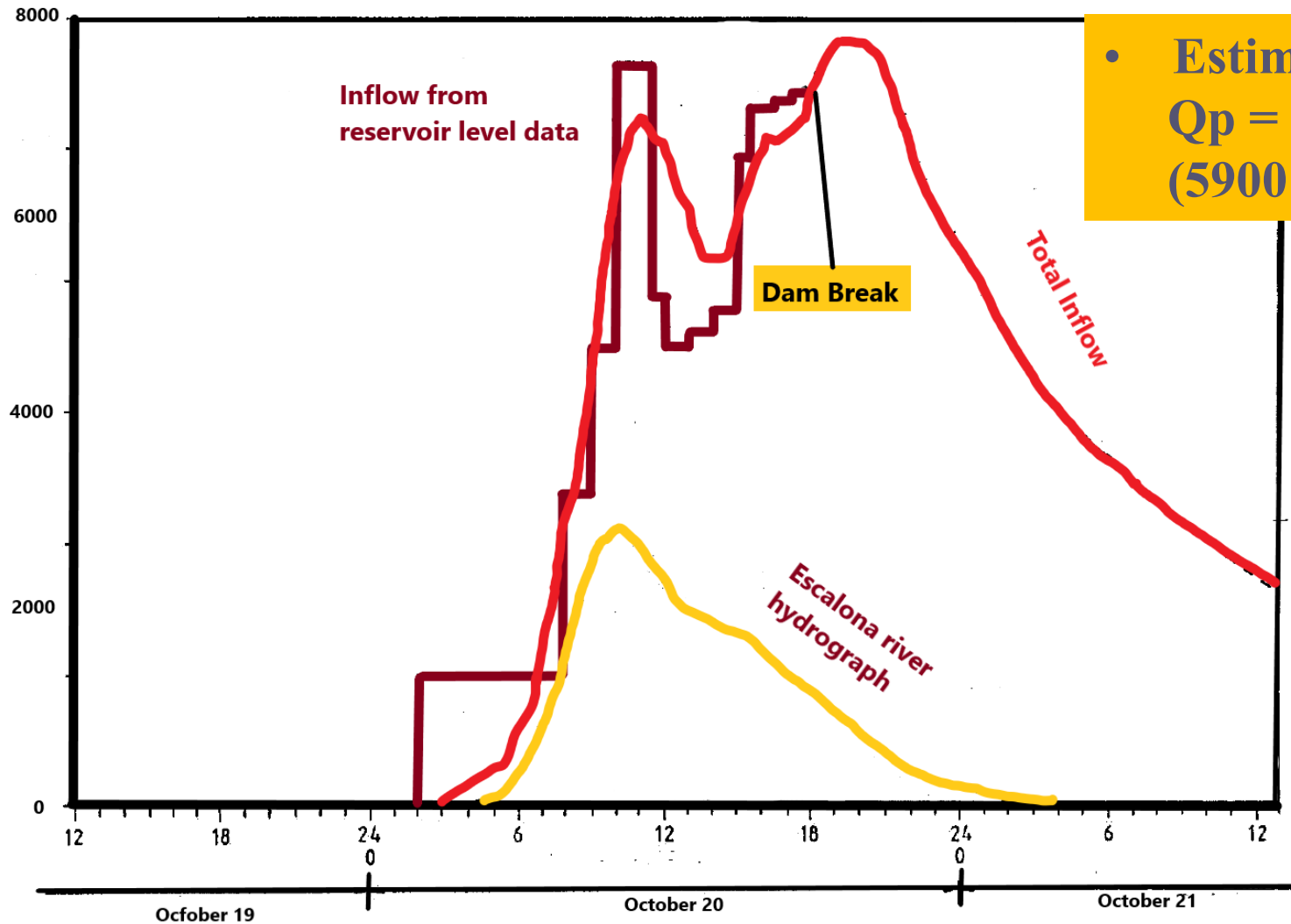
Cofrentes Hyetograph

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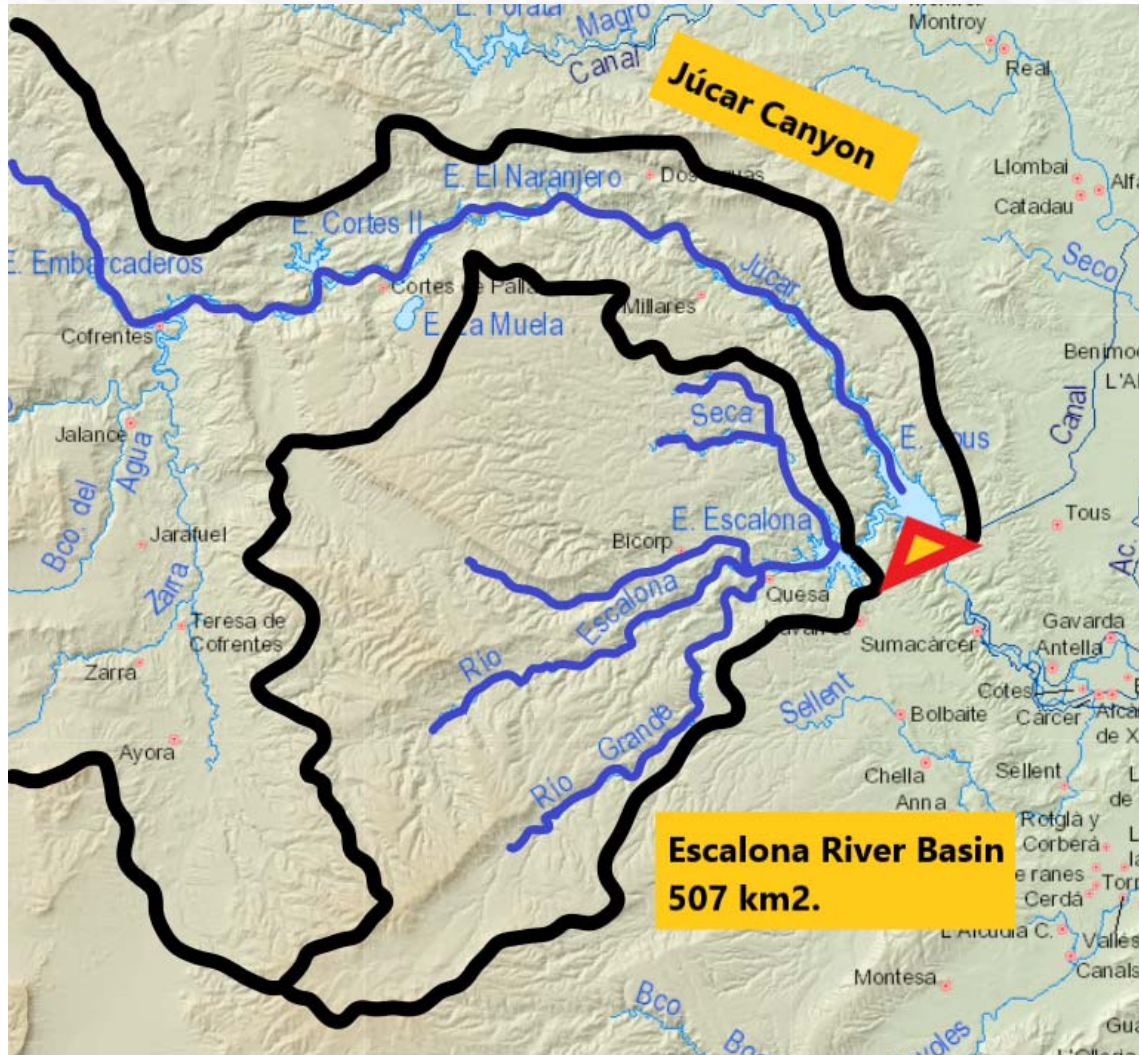




## Incoming Hydrograph at Tous Dam



- Estimated flood peak  
 $Q_p = 7850 \text{ m}^3/\text{s}$ .  
(5900 – 9000 m<sup>3</sup>/s.)



- It started raining strongly at 6 a. m.
- The dam is out of power
- At dawn the Escalona river flood filled up the reservoir spilling over the closed gates. Technicians arrive, and try to open the gates.
- Out of two emergency fuel electric generators, one was out of order, the other at a gallery for repairing a valve. The gallery entrance was flooded.



- It is decided to go to Tous village to get a new group. When returning, the road is cut by a landslide.
- They try to open manually the gates but the mechanism brokes.
- Strong rainfall resumes at 10 a. m. At 11 a.m. the dam starts to spill over the earth embankment.
- Access to the gates is cancelled. There is no road through the right bank.
- Helicopters tried unsuccessfully to fly.





# THE EVENT OCTOBER 20th. 1982



- At 19: 15 the gate closest to the embankment is blown out.
- Piping has developed behind the flexible spillway wall, and collapses along all its length and height.
- A breach 17 m. high develops almost instantly generating a big wave.
- Erosion of the dam progressed during all night.

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# THE EVENT OCTOBER 20th. 1982



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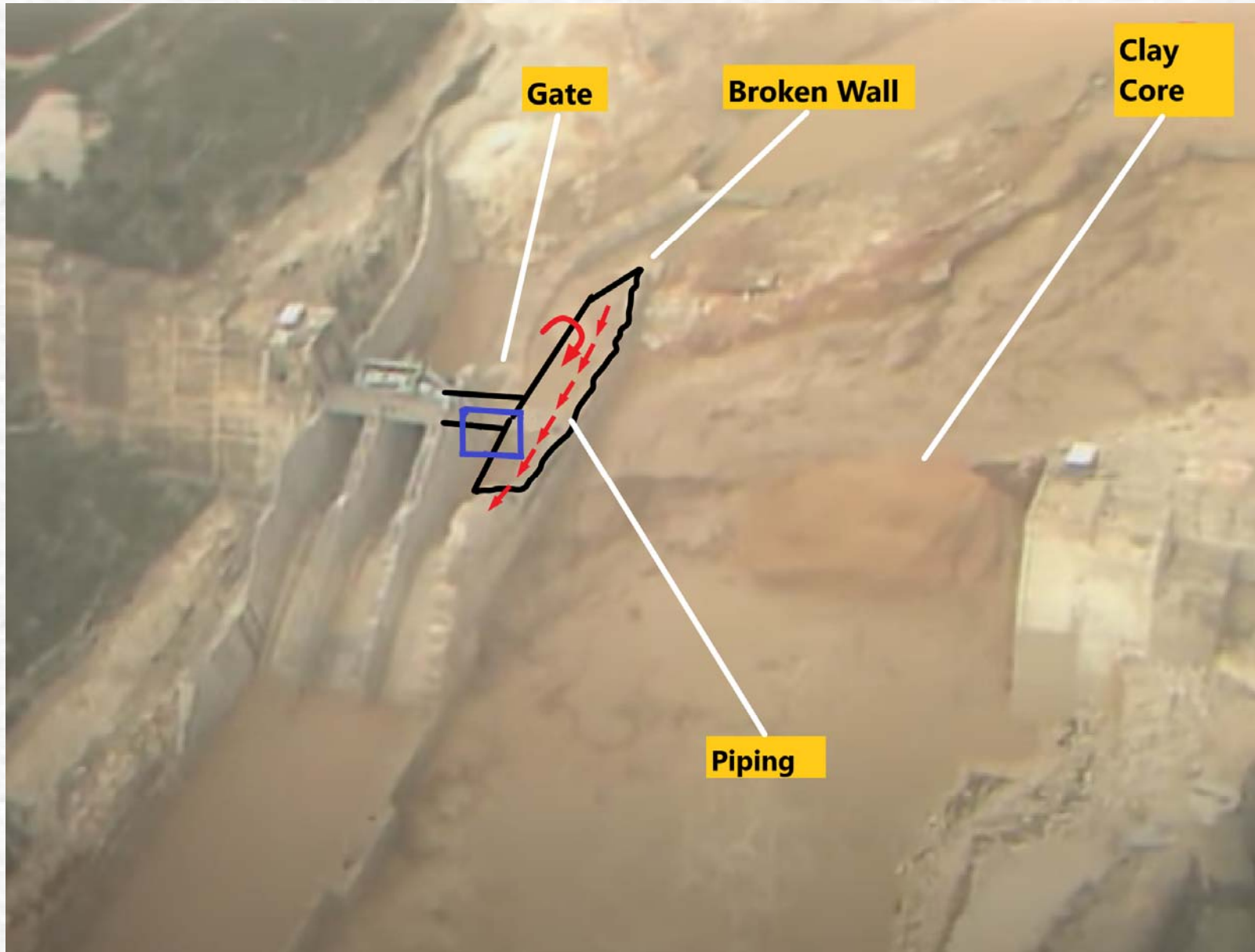
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# THE EVENT OCTOBER 20th. 1982



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- An important part of the central clay core, remained.
- No construction defects were detected.
- Failures were design (flexible wall, hydrology) and logistics

**WHAT ABOUT THE FAULT ???**

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## TOUS DAM REVISITED

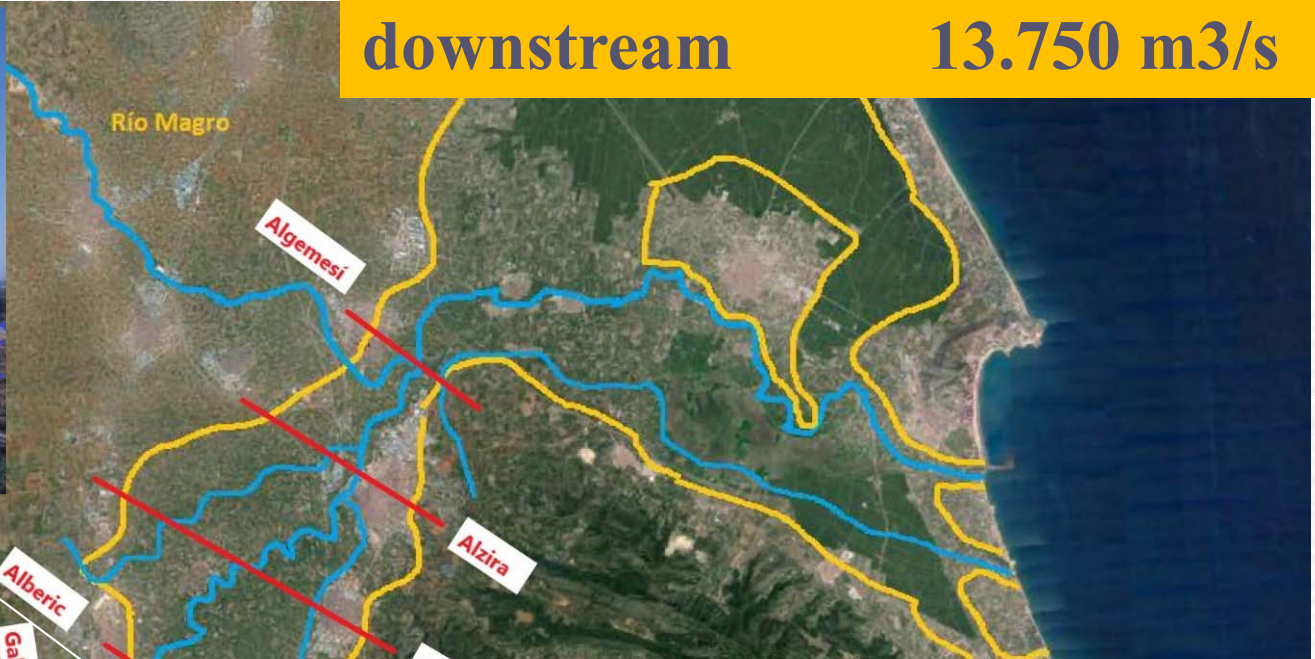




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A dam break wave propagated  
downstream **13.750 m<sup>3</sup>/s**

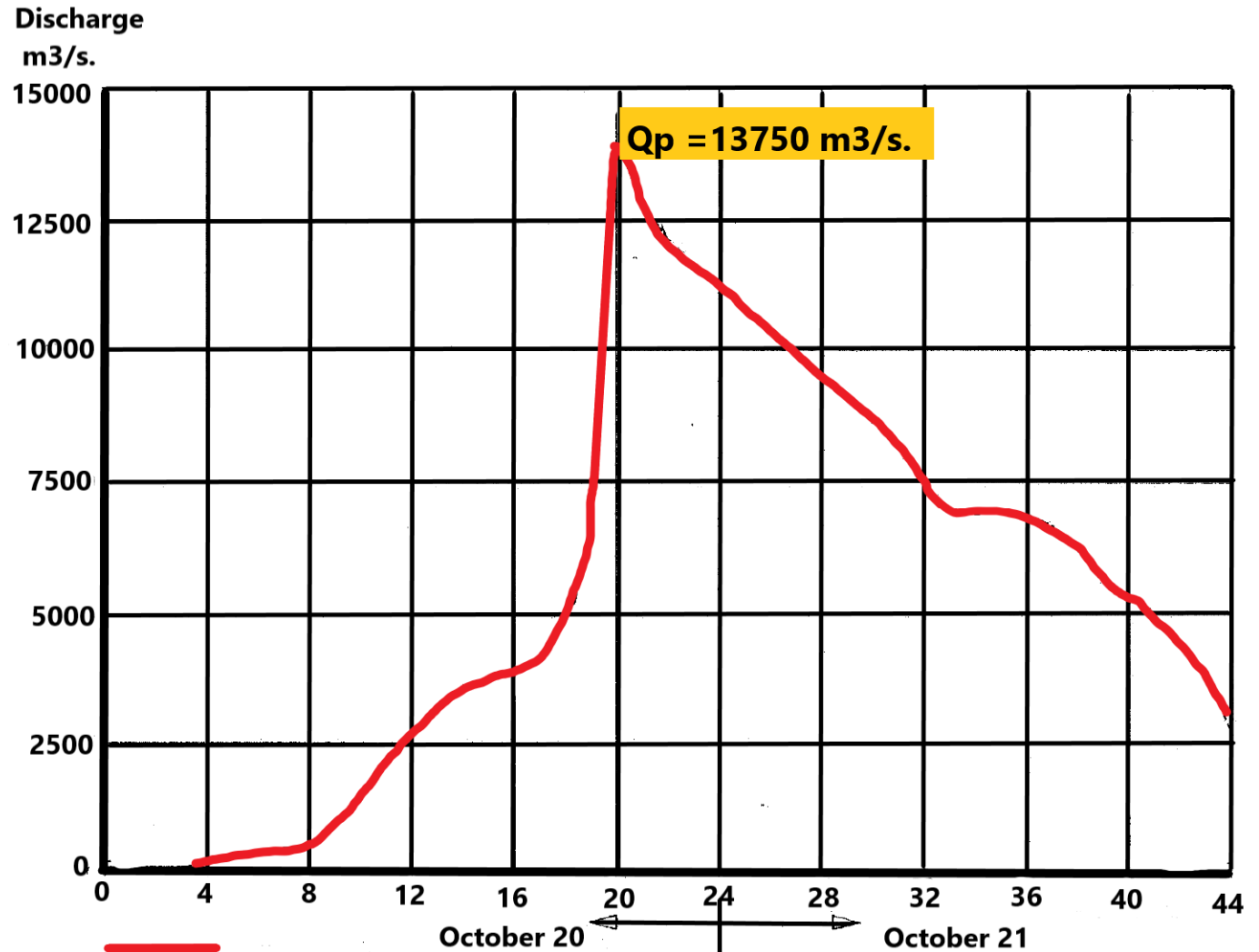


Village	Time	Height
Sumacàrcer	19:25	6 m.
Gabarda	20:15	2.6 m.
Vilanova	20:30	1.4 m.
Alberic	20:45	1 m.
Carcaixent	21:10	0.6 m.

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## OUTFLOW HYDROGRAPH

- Estimated flood peak  
 $Q_p = 13750 \text{ m}^3/\text{s}$ .  
(12900 – 15000  $\text{m}^3/\text{s}$ .)
- 1600 – 2000  $\text{hm}^3$ .  
2 days flood

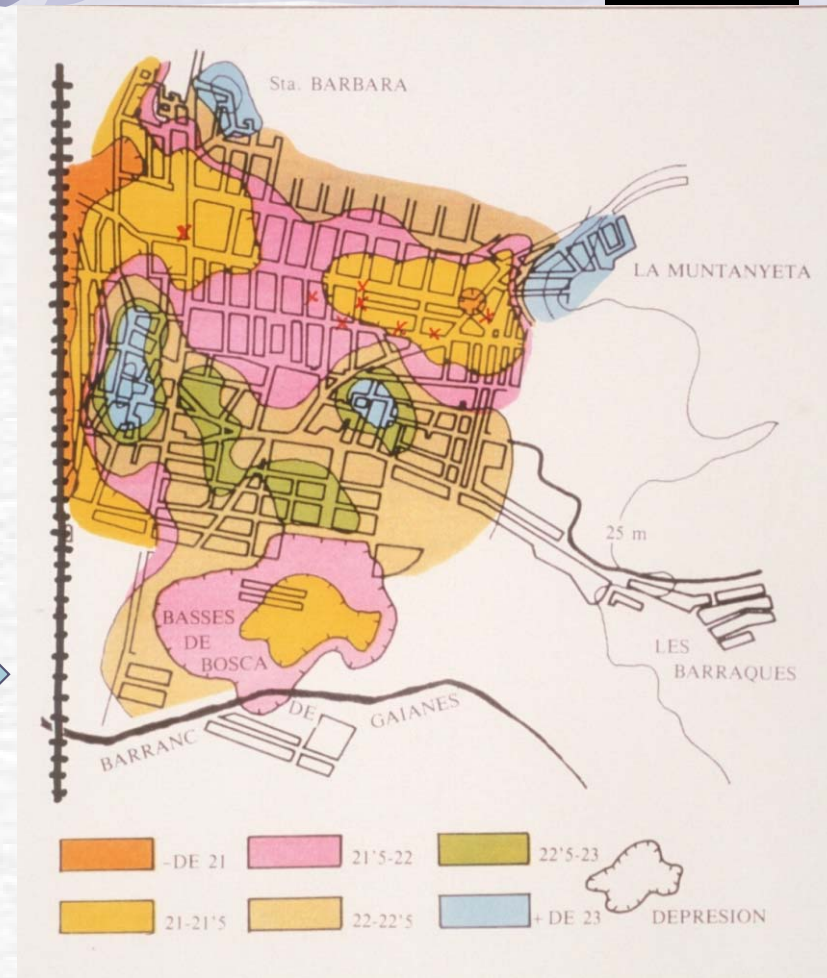
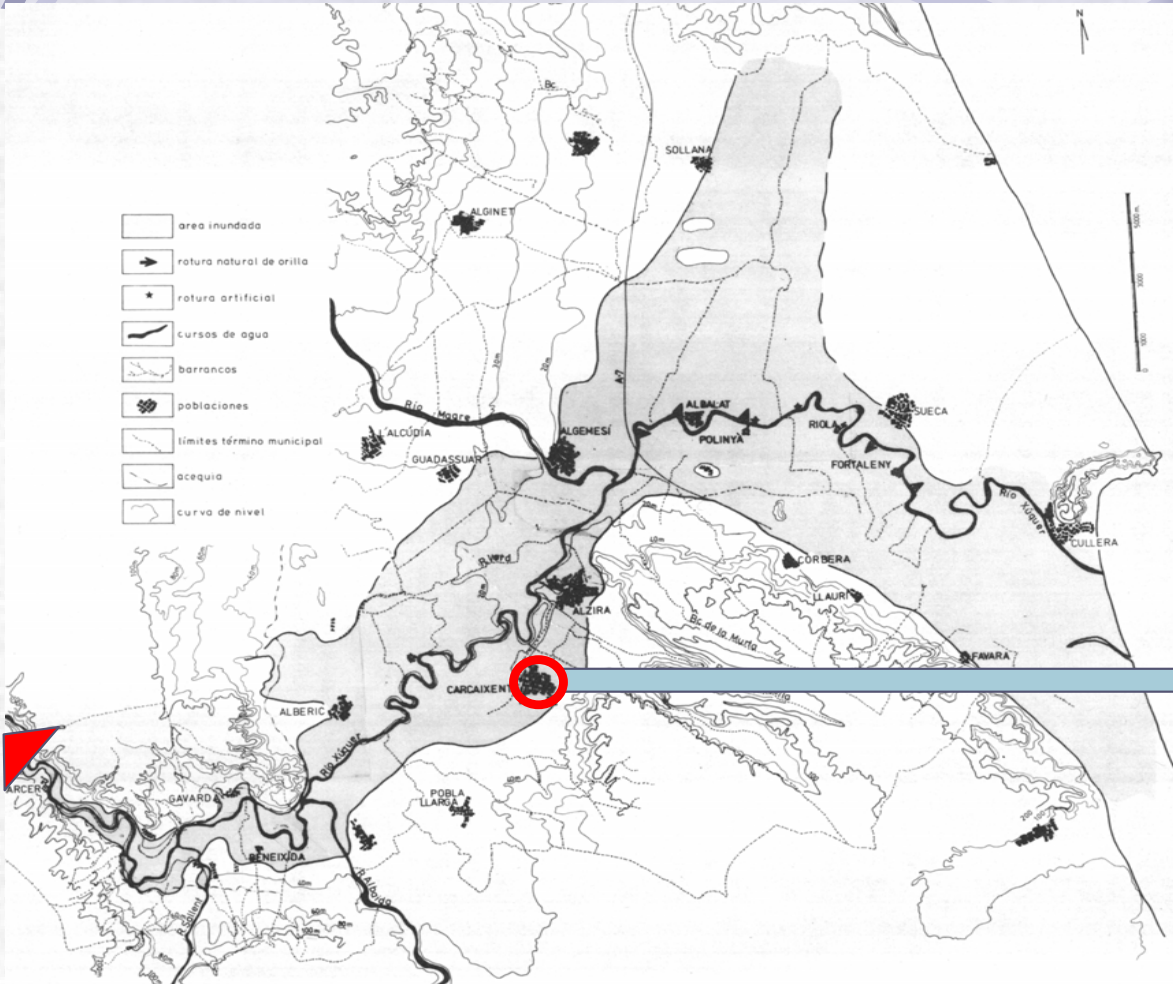


## TOUS DAM REVISITED







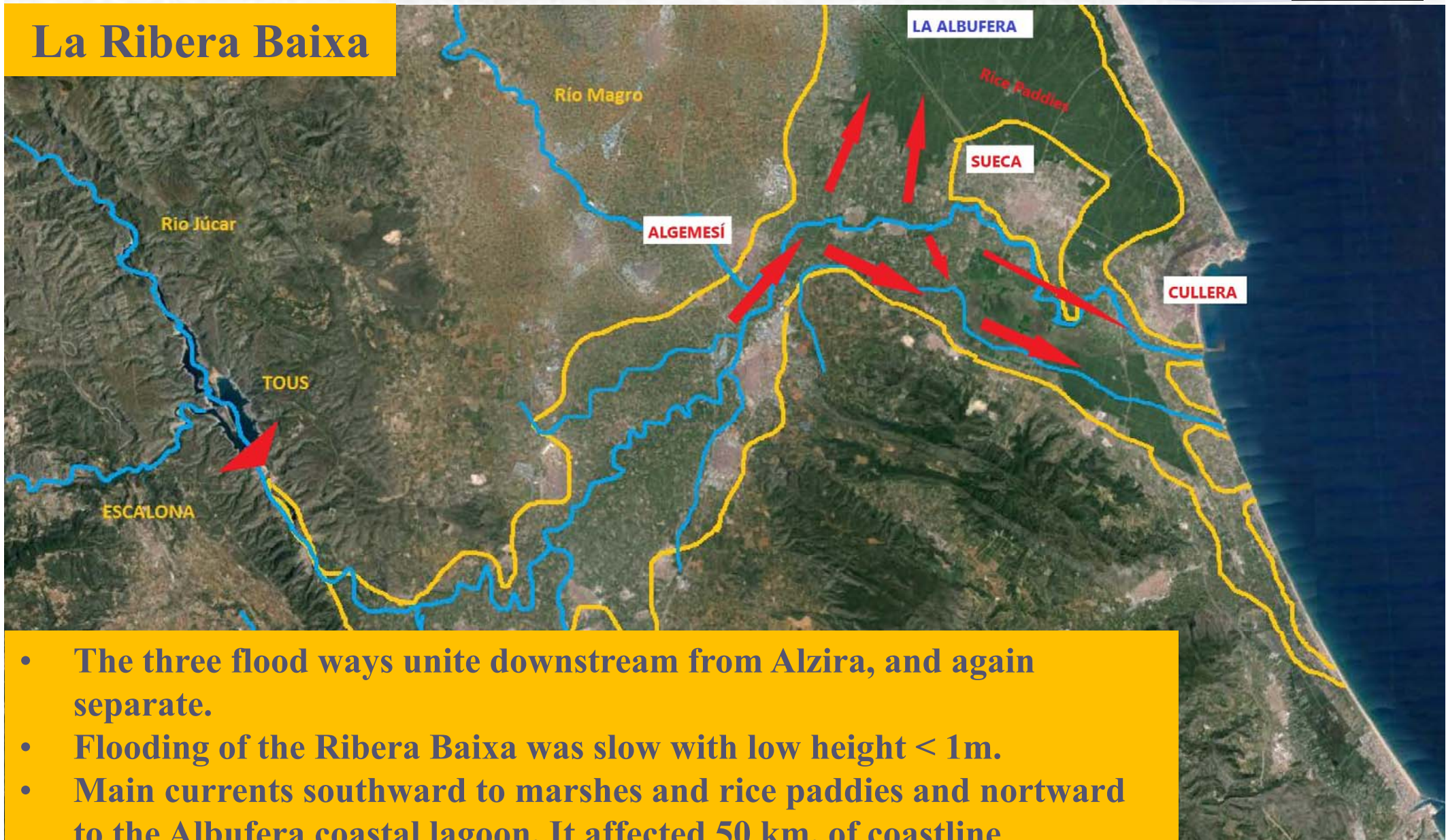


- 16 people died at the very same neighbourhood at Carcaixent
- It is not clear if they died from the dam break wave at 10 p.m. or the flood entrance at 4 p.m.
- This place is quite downstream from the flood

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## La Ribera Baixa



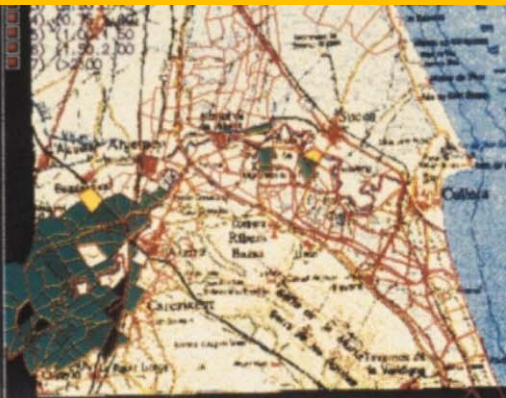
- The three flood ways unite downstream from Alzira, and again separate.
- Flooding of the Ribera Baixa was slow with low height  $< 1\text{m}$ .
- Main currents southward to marshes and rice paddies and northward to the Albufera coastal lagoon. It affected 50 km. of coastline

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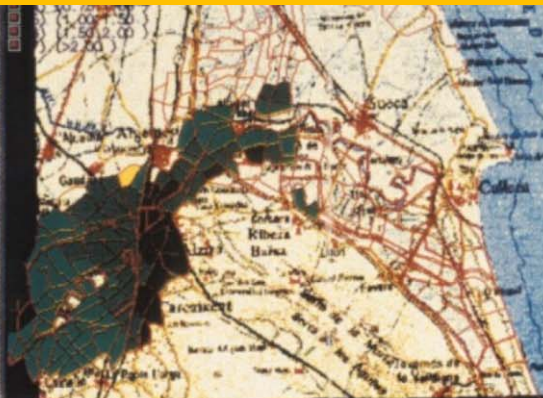


## A NEW HYDROLOGY ERA IN SPAIN

- Connection with world scientific community
- Introduction of hydrological and hydraulic computer modeling.
- Introduction of hydrological forecasting.
- Flood risk mapping



Contraste ficheros h12cp.com - h12sp.com



Contraste ficheros h15cp.com - h15sp.com



Contraste ficheros h18cp.com - h18sp.com



Contraste ficheros h21cp.com - h21sp.com



Contraste ficheros h24cp.com - h24sp.com



Contraste ficheros h27cp.com - h27sp.com

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## ADVANCES IN REAL TIME FLOOD CONTROL

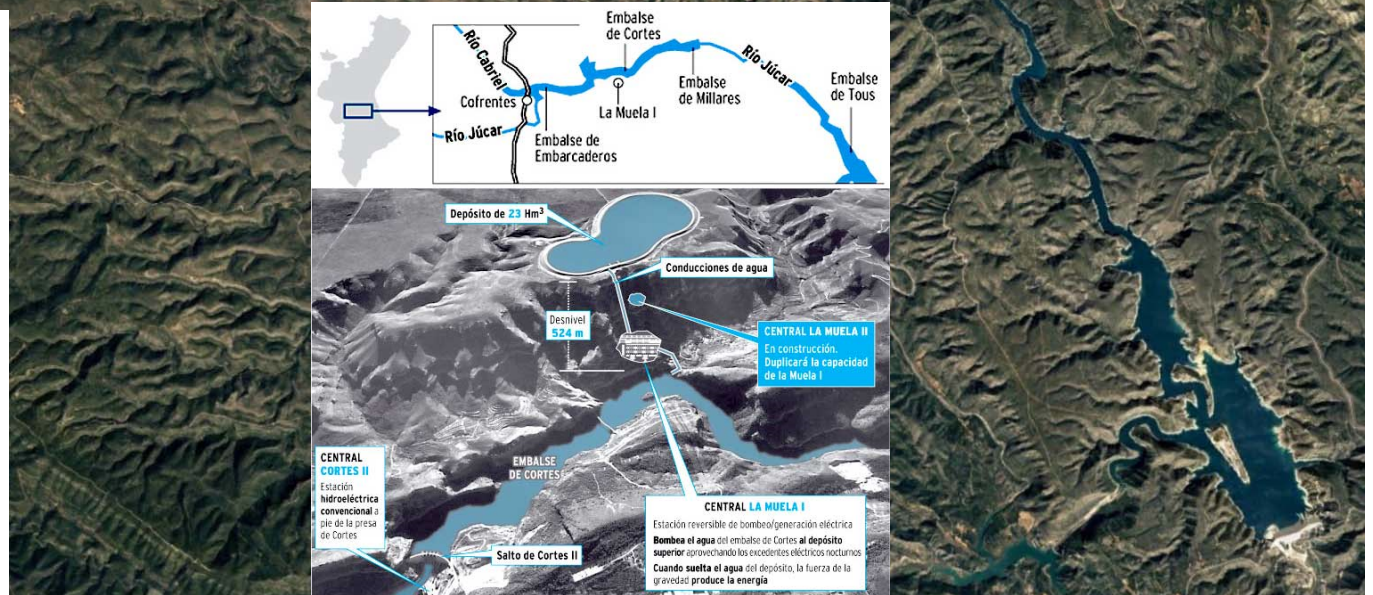
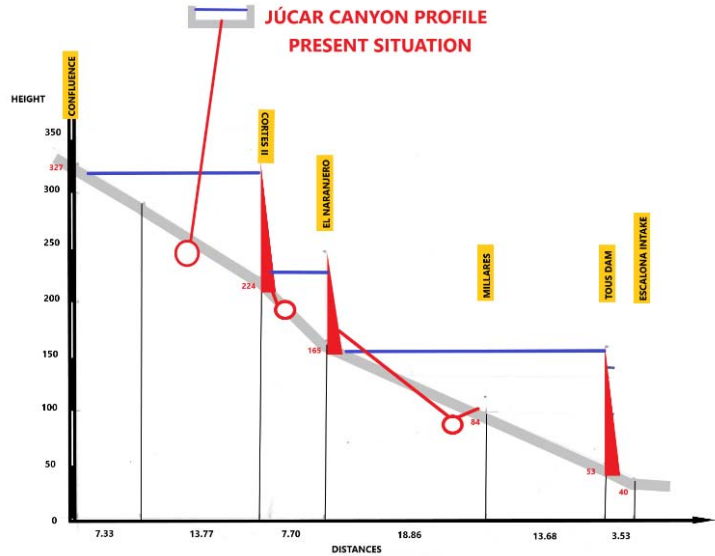


- The SAIH (Automatic System of Hydrological Information)  
**SCADA**  
**Telemetered rain and flow gauges.**  
**Meteorological Radar for rainfall mapping**
- New Dam Safety operation, documentation and maintenance program.
- Civil defence creation

## NEW REGLAMENTS FOR DAM DESIGN AND CONSTRUCTION

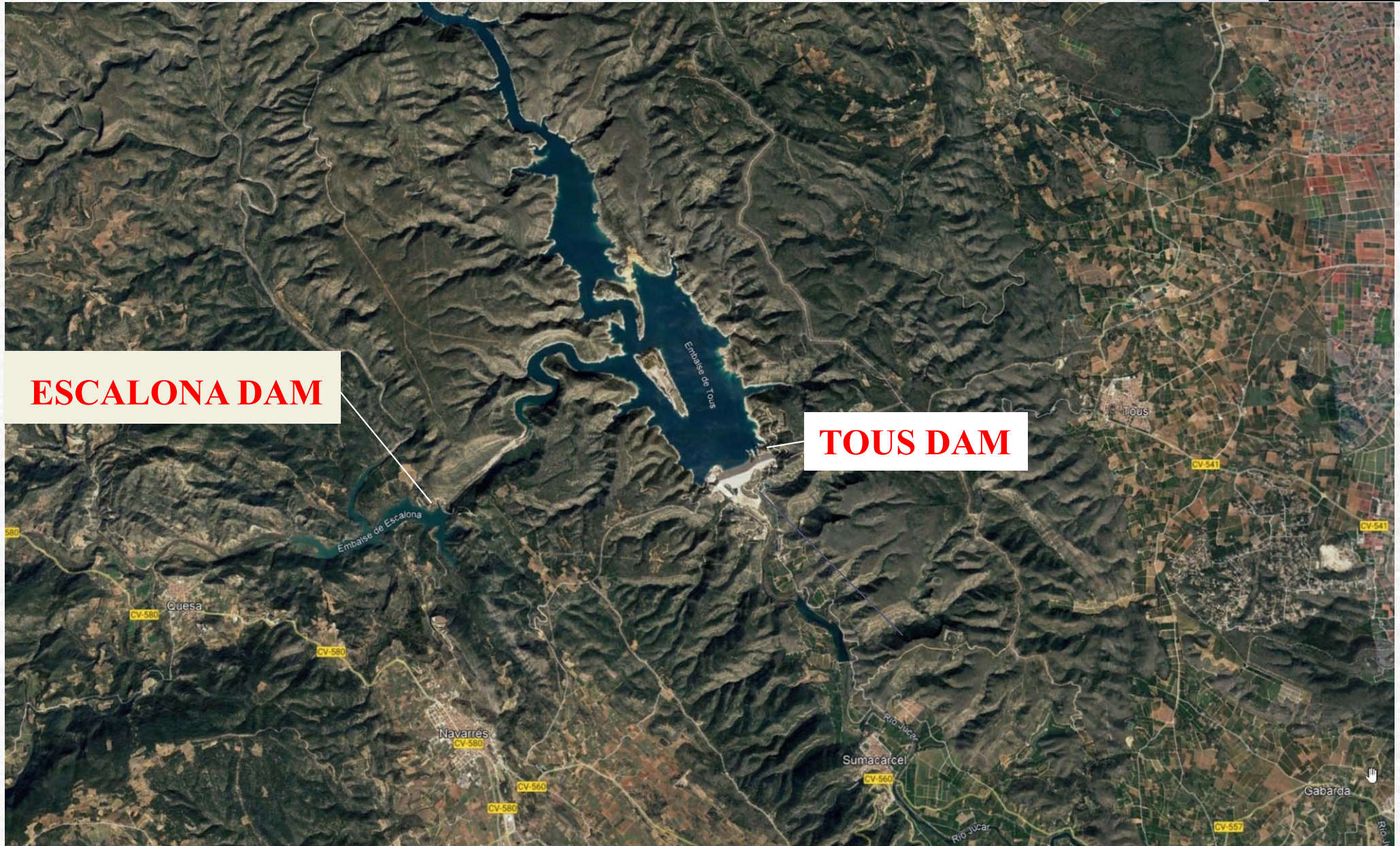
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## TOUS DAM REVISITED





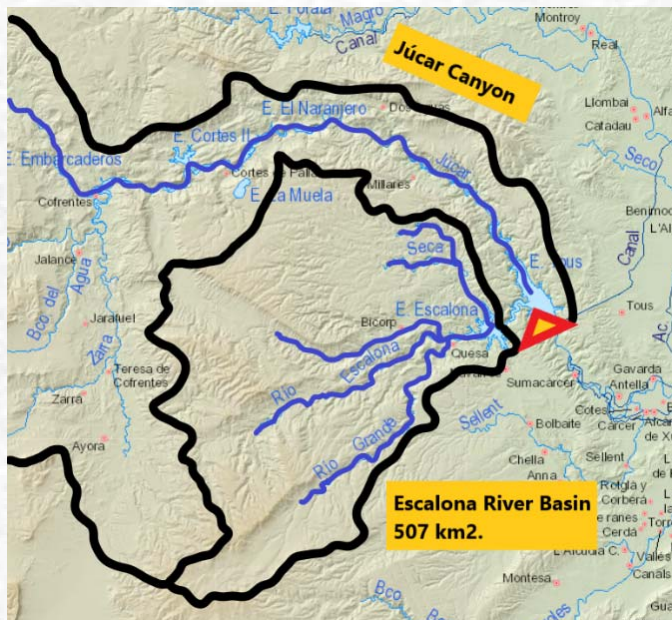
**ESCALONA DAM**

**TOUS DAM**



## ESCALONA DAM

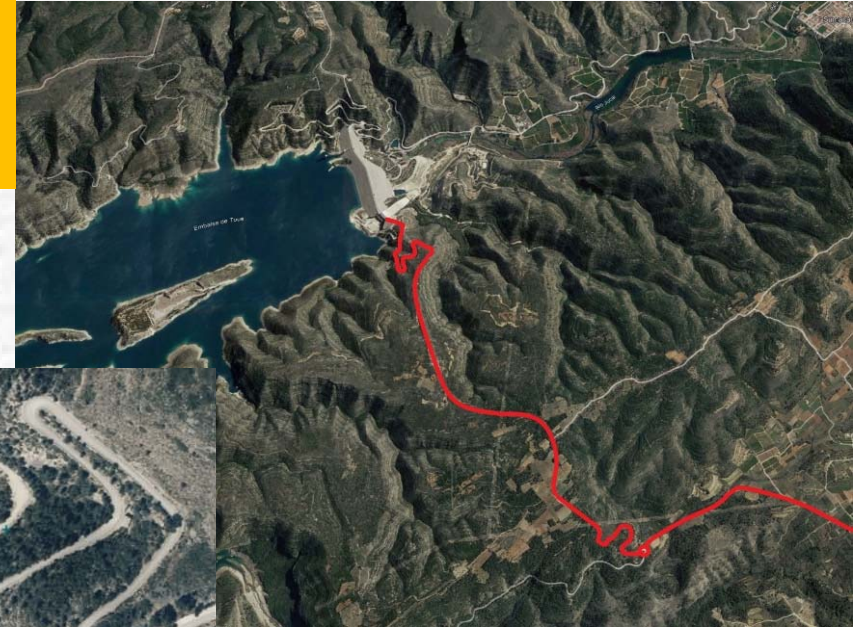
- 70 hm<sup>3</sup>
- Arch concrete gravity dam 100 m. high.
- Protection of Tous Dam under its construction
- Avoid quick response of the Escalona river





# THE NEW TOUS DAM

## NEW ACCESS ROAD FROM THE RIGHT BANK



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# THE NEW TOUS DAM

- 
- **Rockfill Dam with central clay core.**
  - **Old dam remainings were imbedded.**
  - **Concrete contact surfaces with clay materials had a slope.**
  - **627 hm<sup>3</sup>. capacity.**
  - **300 hm<sup>3</sup>. minimum empty capacity.**
  - **Reservoir completely empty by September 1st.**
  - **156 m. high. 133.5 m. from river bed.**
  - **Old clay foundations were not removed (26 m. Deep)**

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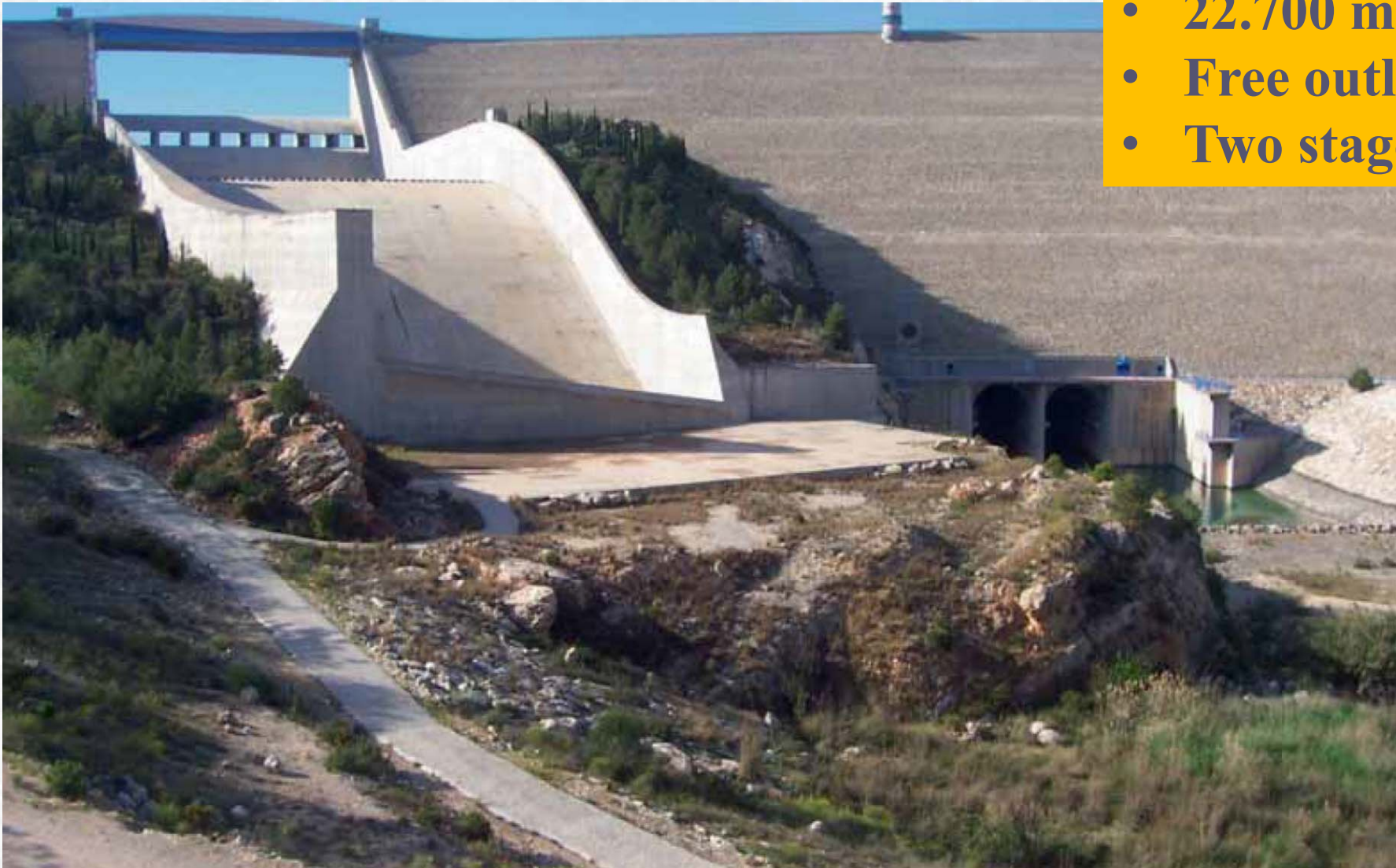


**OLD SPILLWAY  
WAS ADAPTED AS  
INTERMEDIATE  
OUTLET**

- Gated outlet
- 1500 m<sup>3</sup>/s.

## NEW SPILLWAY

- 22.700 m<sup>3</sup>/s.
- Free outlet
- Two stage







## FULLY INFORMATIZED INSTRUMENTATION AND CONTROL

- Linked to SAIH (Real Time Hydrologic Information System)
- SCADA 24 h. 365 d. Staff to control the dam



**Old clay foundations were not  
removed (26 m. Deep)**

**What about the fault ??**

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**Tous Dam disaster was a  
consequence of:**

- Poor hydrological design.
- Lack of logistics, organization, emergency protocols.
- Adaptation to “temporary” service, without being really finished.

**Construction failures were not  
important**

## COMMON SENSE DISASTER



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