12th ICOLD European Club Symposium 2023

Role of dams and reservoirs in a successful energy transition

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Flood control across hydropower dams: The value of safety

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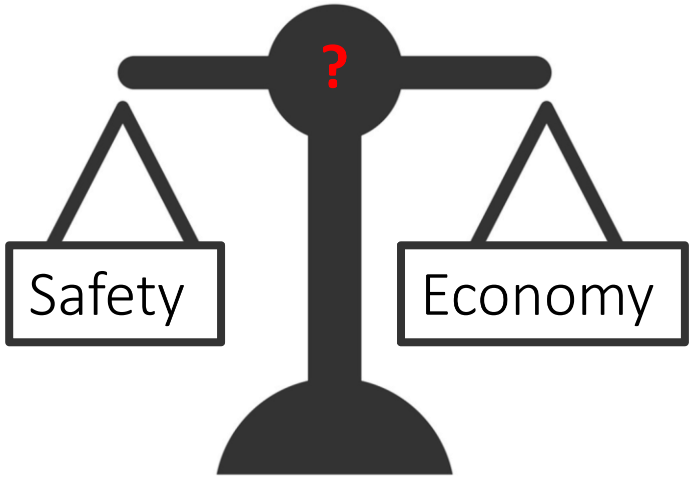
Hydroelectric dams with a gated spillway

Advantages

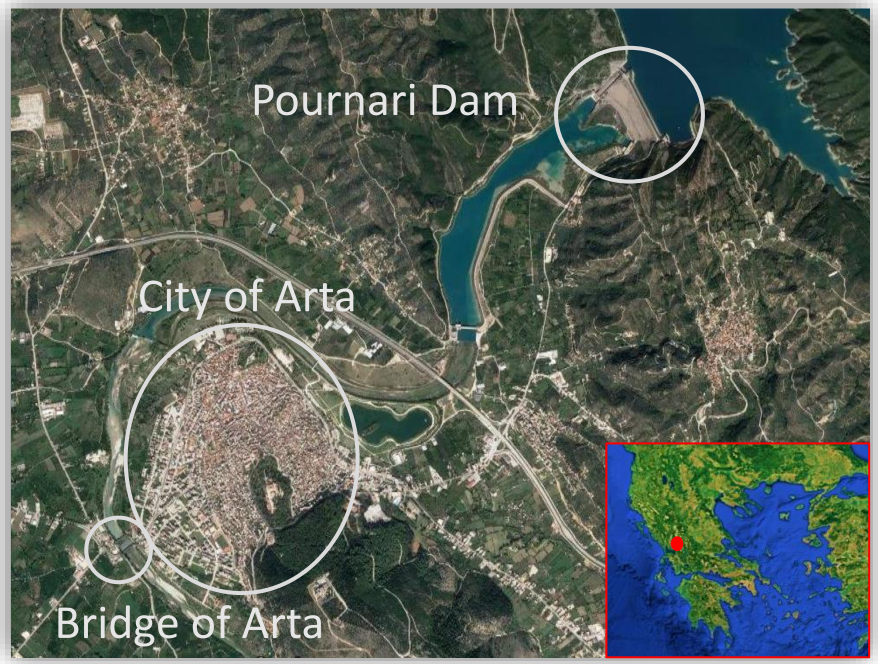
- Increased storage capacity
- Increased head
- Flexibility in water-energy management



Disadvantages

- Subject to human manipulations under stressed conditions
- Too early opening → hydrodynamic losses
- Too late opening → risk of dam overtopping

Pournari Dam, Arachthos River, Epirus, Greece



Google Earth

- Earth dam (1978)
- Dam height: 107 m
- Upstream drainage area: 1794 km^2
- Spillway width: 37.5 m (3 x 12.5 m)
- Spillway capacity: 6100 m^3/s
- Turbine capacity: 500 m^3/s

Why this case study?

- One of the largest hydroelectric works of Greece (300 MW)
- Located just upstream of Arta (25000 residents)

Historical bridge of Arta, 17th century (Source: Wikipedia)

Typical section and characteristic levels

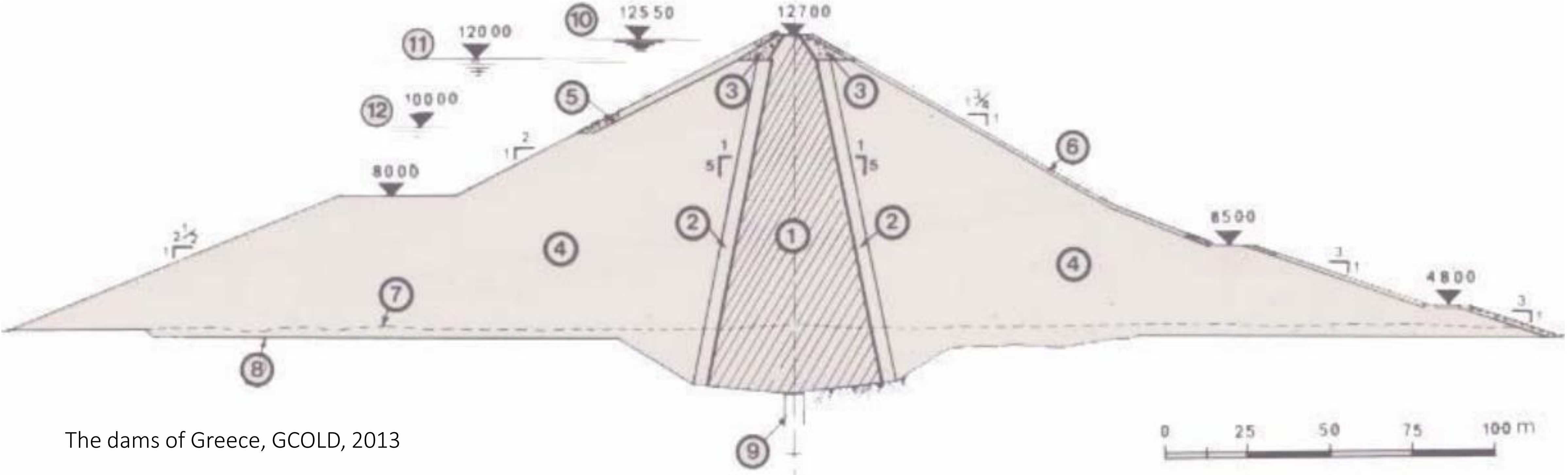
Spillway crest: +107.5 m

Top of gates: +120.0 m

Max. flood level: +125.5 m

Dam crest: +127.0 m

Storage capacity increased from 505 to 885 hm³



The dams of Greece, GCOLD, 2013

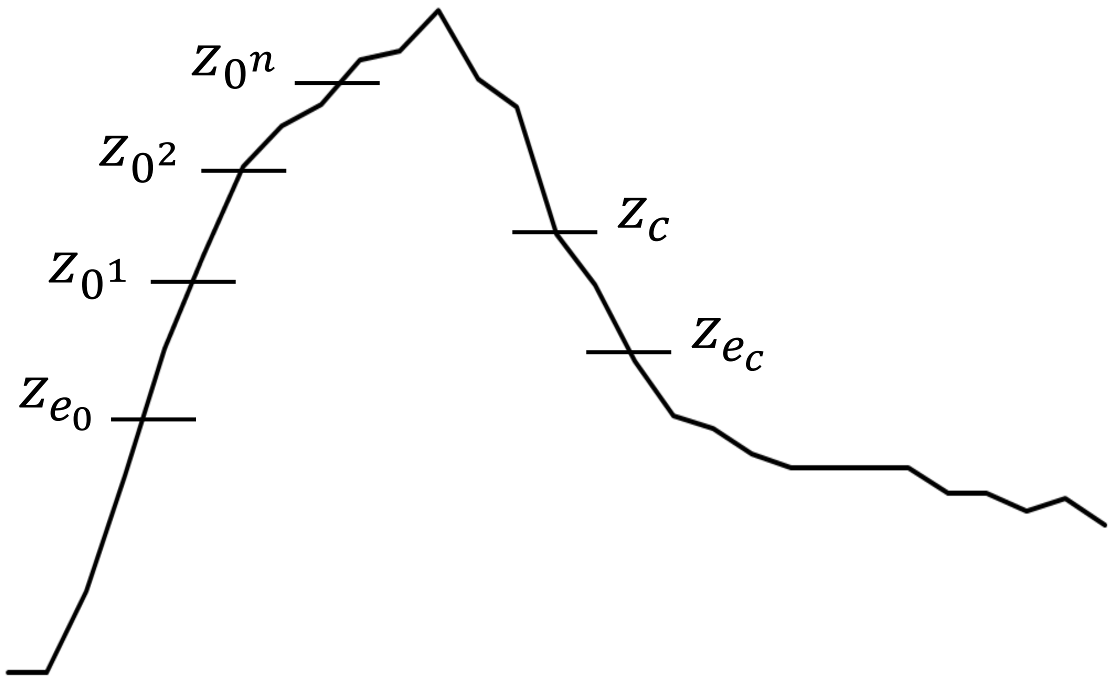
Flood management concept

Regarding turbines operation:

- $z \geq z_{e_0}$ → Emergency → Maximum capacity
- $z \leq z_{e_c}$ → Normal → Standard energy production schedule

Regarding the gate control:

- Progressive opening of gates → release of specific ratio a_k of spillway capacity
- z_0^n → threshold for full gate opening
- z_c → threshold for closure of all gates



Simulation

Inputs

- Geometrical, hydraulic and hydrodynamic properties of system elements (reservoir, spillway, gates, turbines)
- Inflow hydrograph
- Power production schedule (normal mode)
- Operational rules of gates and turbines

Outputs

- Simulated timeseries (reservoir stage, outflow from spillway & turbines, power production)
- Performance metrics (safety and economy)

Performance metrics to optimize

Aspects	Criteria	Quantification
Aspects of *safety*	Protection of dam and associated infrastructures	Distance of max. reservoir stage from characteristic levels (dam crest, MFL)
	Minimize flood risk of downstream floodplains	Maximum outflow through the spillway system (ratio of its discharge capacity)
Aspects of *economy*	Loss of storage due to gate opening	Potential energy to be produced by the overflowing water
	Turbine operation in contrast to their schedule	Deviation of actual vs target power production (small penalty)

Setting up optimization

Control variables - Parameters

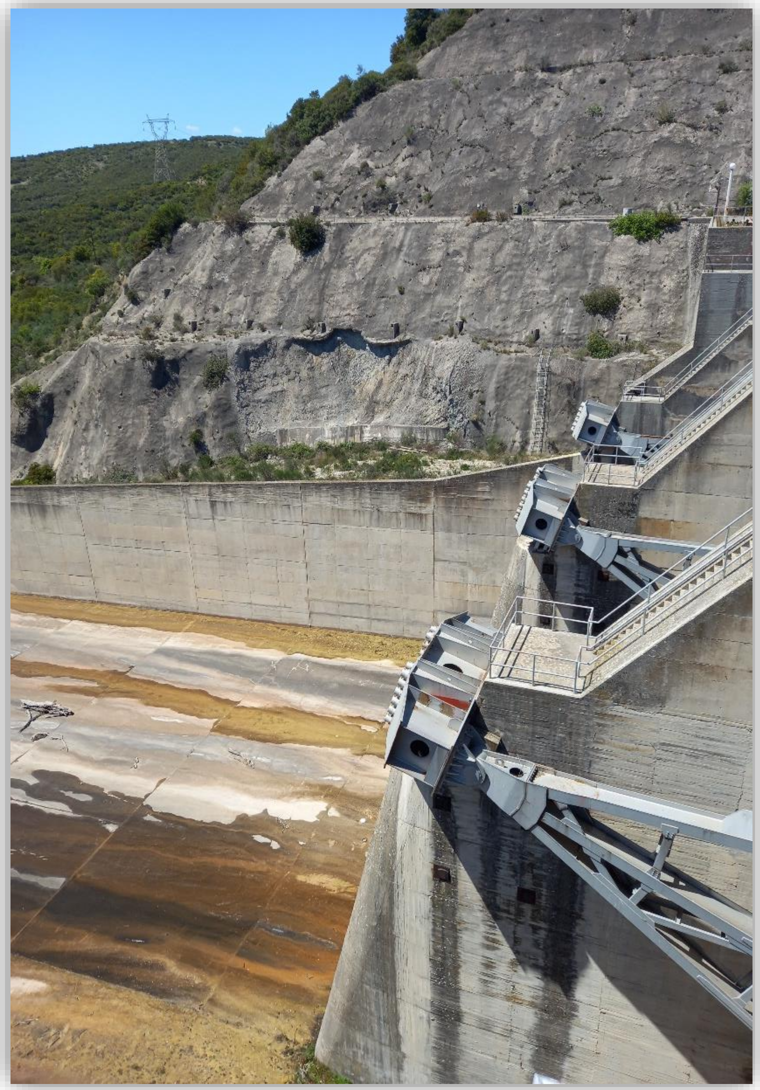
- Turbine control thresholds
- Gate opening thresholds
- Spillway capacity ratios
- Gate closure threshold

Multiobjective function

- Performance metrics
- Weighting coefficients (economy vs safety)

Scenario based approach

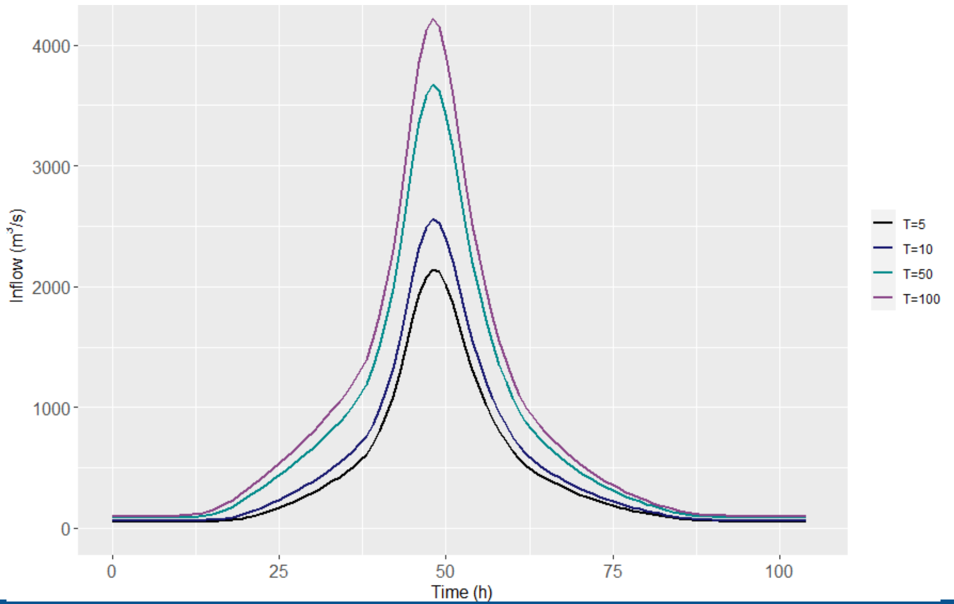
- Inflow hydrographs
- Initial reservoir conditions



The case of Pournari Dam

- Synthetic hydrographs for characteristic return periods (5, 10, 50, 100 years)
- Power plant scheduling:

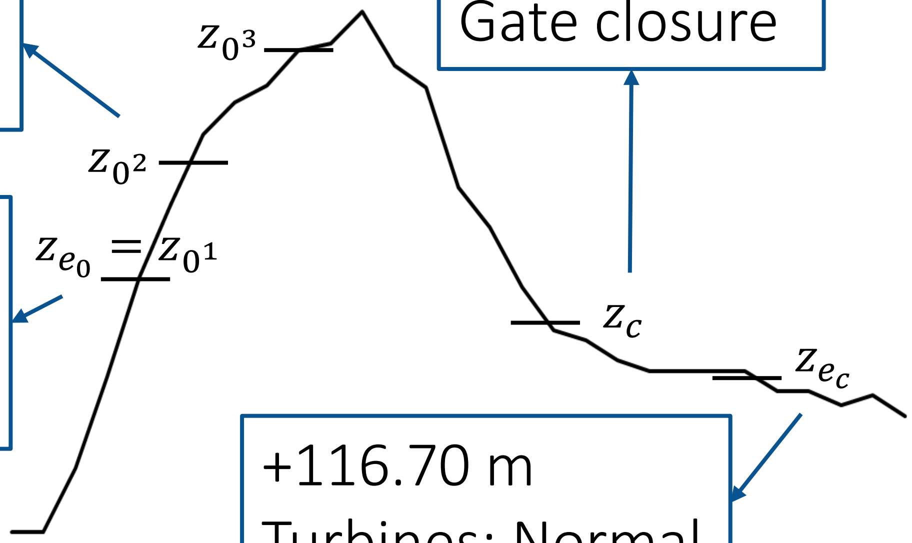
  8:00-12:00 a.m. & 18:00-22:00 p.m. → 500 m³/s (max capacity, peak hours)



+119.20 m
Gate opening: 100 %

+118.45 m
Gate opening: 17.7 %

+117.84 m
Turbines: Emergency
Gate opening: 3.3 %

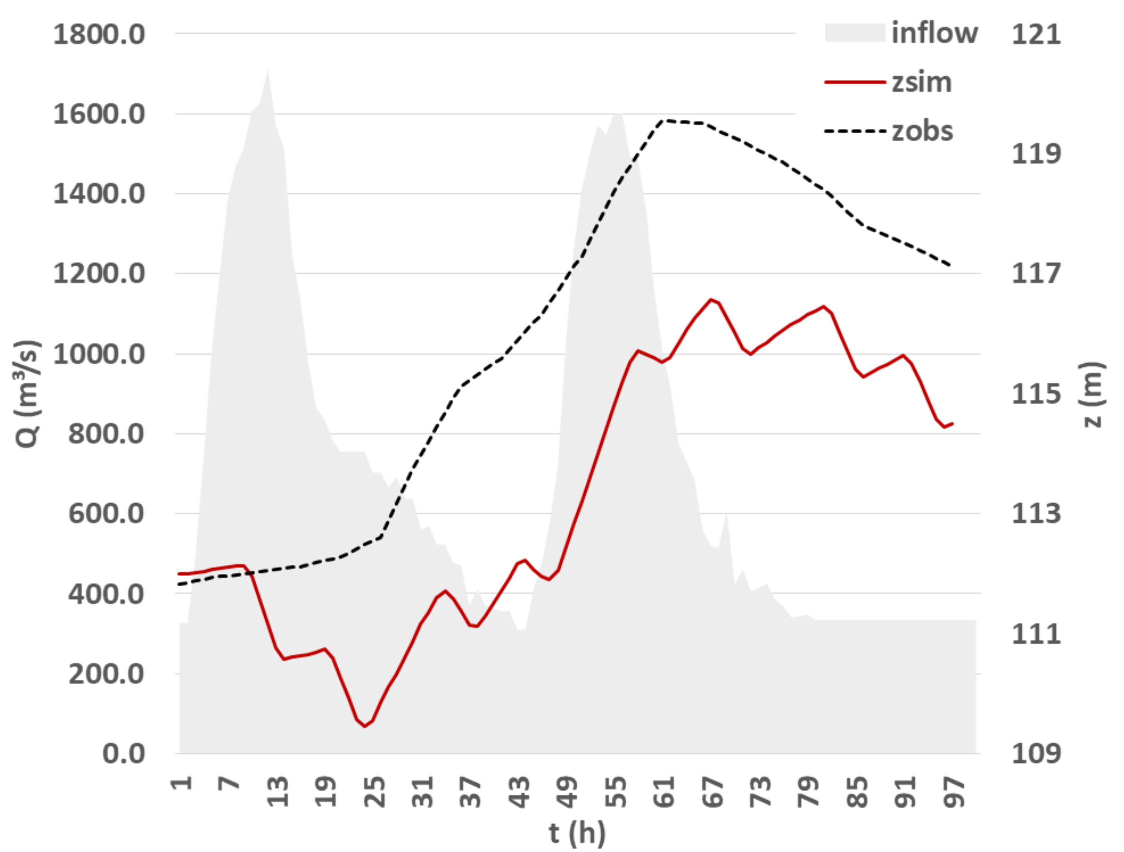


+117.65 m
Gate closure

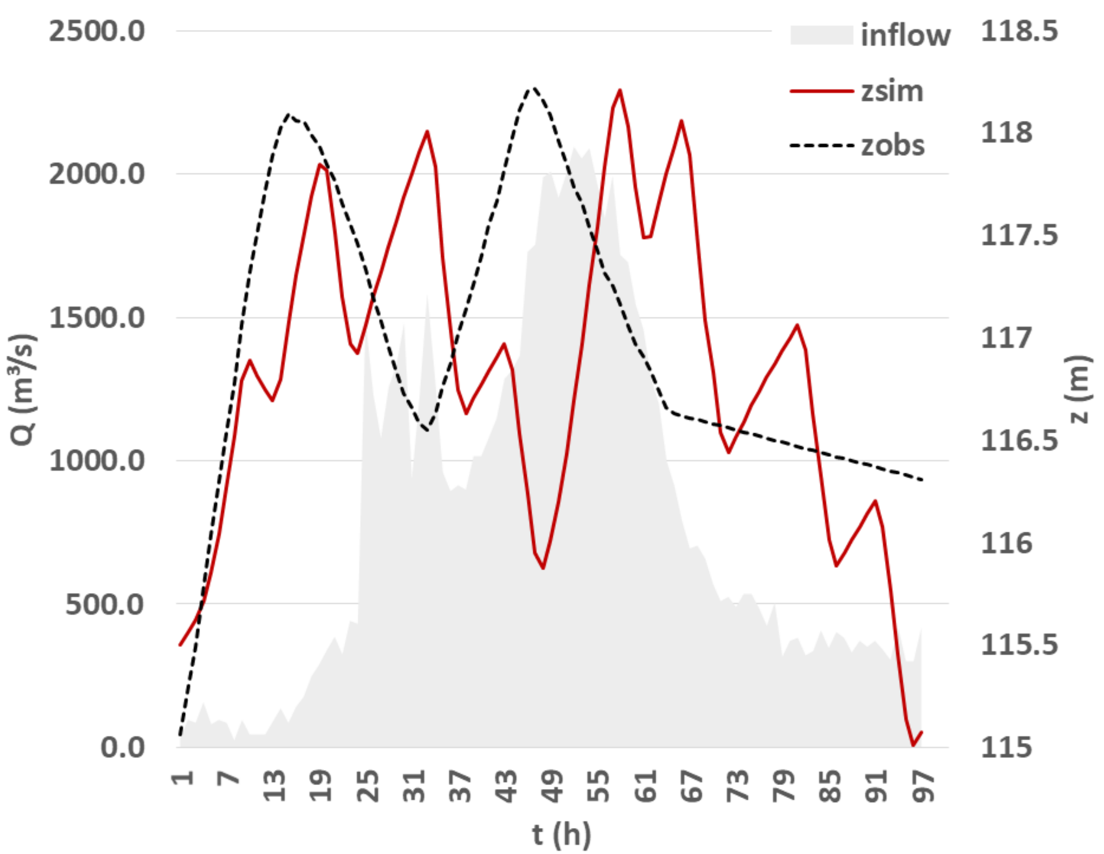
+116.70 m
Turbines: Normal

Alarm stage of dam operator (PPC): +118.0 m

Floods of 2005 & 2015: Actual vs theoretical stage management



28/12/2005 - 1/1/2006



30/1/2015 - 2/2/2015

Summary data

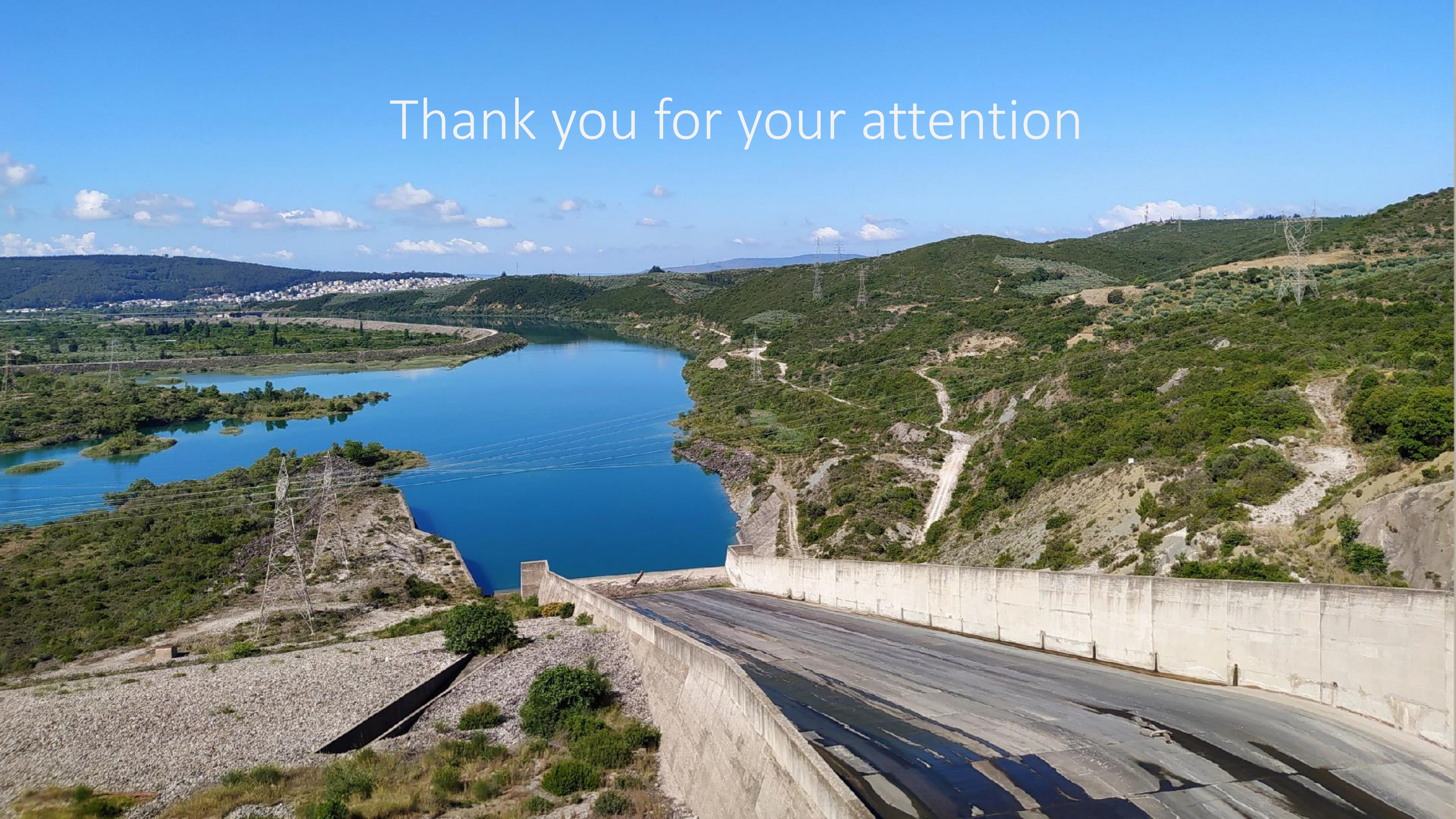
	2005	2015
Accumulated inflow (hm^3)	222	262
Maximum observed inflow (m^3/s)	1712	2095
Initial reservoir level (m)	+115.5	+111.8
Actual operation (PPC policy)		
Maximum reservoir level (m)	+116.8	+119.6
Loss of energy (GWh)	12.0	6.4
Theoretical operation (optimized rules)		
Maximum reservoir level (m)	+118.2	+119.7
Loss of energy (GWh)	3.3	1.0

lakesnetwork.org

Dealing with Flood Events at Hydroelectric Plant areas in Western Greece, Roilos C.

Conclusions & perspectives

1. Generic simulation-optimization method for establishing effective rules for the conjunctive control of turbines and gates during severe flood events
2. Control policy expressed in terms of level thresholds and discharge ratios
3. Multiobjective approach against multiple flood hydrographs to ensure equilibrium between safety and economy goals
4. Key advantages
    - Minimal and easily retrieved real-time data (reservoir stage)
    - Easily formalized in Monte-Carlo setting (stochastically generated flood events and reservoir states)
5. Potential improvements
    - real-time monitoring data over the upstream river basin
    - short-term hydrometeorological forecasting products


Thank you for your attention