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Hydroelectric System Scheduling by Simulation

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Content

Introduction (i)

- Hydro scheduling is very important:
  - Very low variable cost of energy (only O&M)
  - Large regulation capability
  - Allows the storage of energy for reliability purposes
- Hydro production in Spain ranges from 15 % to 20 % of the energy demand of the ordinary regime (except renewable resources)

Introduction (ii)

- Objective:
  - – Analyze and test different management strategies of hydro plants

- Simulation is the method chosen to model them

Introduction (iii)

- Key features of simulation models:
  - Time: Static vs. Dynamic
  - Stochasticity: Deterministic vs. Stochastic
  - Time step: Continuous vs. Discrete

- This hydro simulation model is
  - Dynamic (up to one year)
  - Stochastic hydro inflows
  - Discrete (one day)

Introduction (iv)

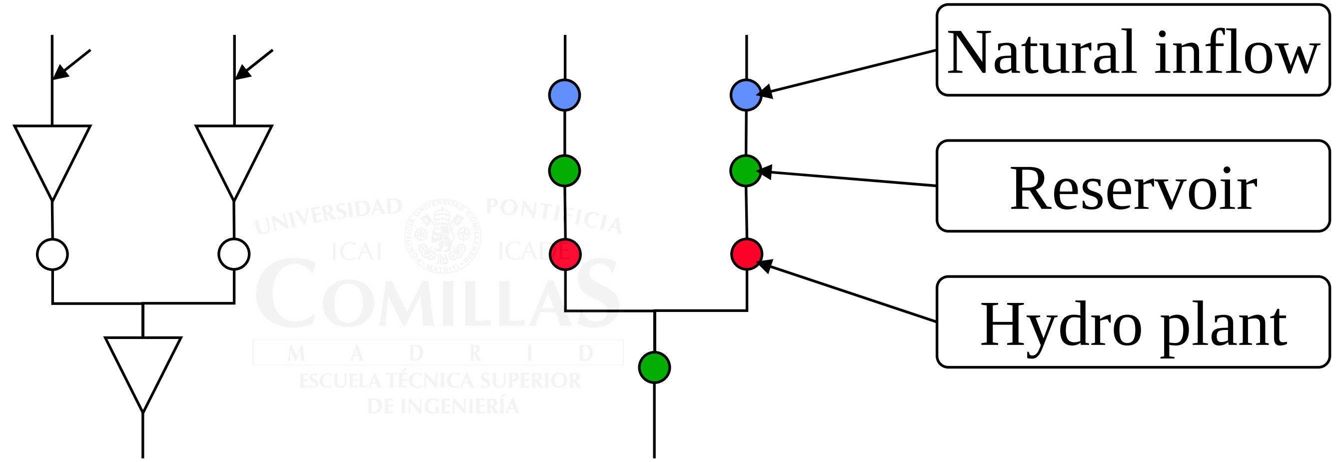
- Model functions:
  - Economic planning of hydro operation:
    - Yearly and monthly planning
  - Update the yearly forecast:
    - Operation planning up to the end of the year
  - Short term detailed operation:
    - Detailed operation analysis of floods and droughts, changes in irrigation or recreational activities, etc.

Content

- Introduction
- **Data representation**
- Simulation method
- Results
- Conclusions

Data representation (i)

- Basin topology is represented by a graph of nodes where each node is an element:



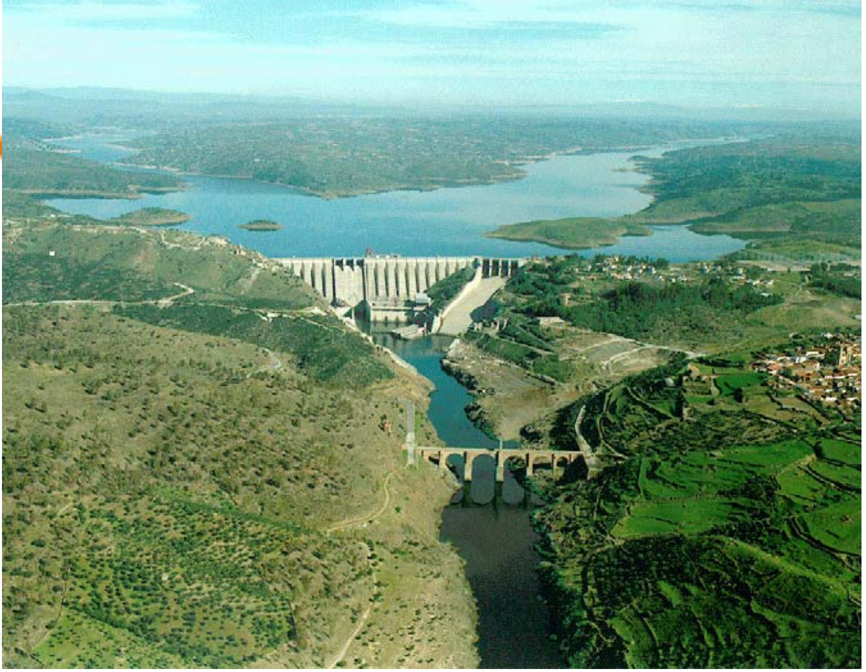
- Connections among nodes are physical junctions through the river.
- This structure induces the use of
  - Object Oriented Programming

Data representation (ii)

- Five types of nodes (objects) are needed:
  - Reservoir
  - Channel
  - Plant
  - Inflow point
  - River junction

- Each node is independently operated although it may require information from other elements

Data representation (iii)



- **Reservoir**:
  - – Manages the water
    - One or more natural inflows
    - One outflow
  - – May have associated:
    - Minimum outflow
    - Volume curves that guide its operation:
      - – Minimum/maximum target curves
      - – Lower/upper guiding curves
      - – Avoiding spillage curve
    - Minimum and maximum volume
    - Production table (input from long term hydrothermal models)

Data representation (iv)

- **Channel**:
  - Doesn’t manage the water
  - Flow transportation between nodes with a limit

Data representation (v)

- **Plant**:
  - – Produces electric energy from hydro inflow
  - – Coefficient of efficiency depending linearly on the head
  - – May also pump

Data representation (vi)

- **Natural inflow point**:
  - Introduces water into the system
  - Uses historical or synthetic inflows

Data representation (vii)

- **River junction**:
  - Groups elements in a river junction
  - Limits the maximum joint outflow
  - Management determined in tho steps:
    1. Independent initial decision
    2. Reduction of it following a priority order up to the maximum flow

Reservoir operation strategies

1. Optimal outflow decision taken from a precalculated production table depending on:
   - Week of the simulated day
   - Hydrologic index of the basin inflows (type of year)
   - Volume of the own reservoir
   - Volume of a reference reservoir

   – Table calculated by a long term hydrothermal model

   – Usually for the main reservoirs of the basin
2. Outflow equals incoming inflow (usually for small reservoirs)
3. Go to minimum target curve (spend as much as possible
4. Go to maximum target curve (keep water for the future)

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Simulation method (I)

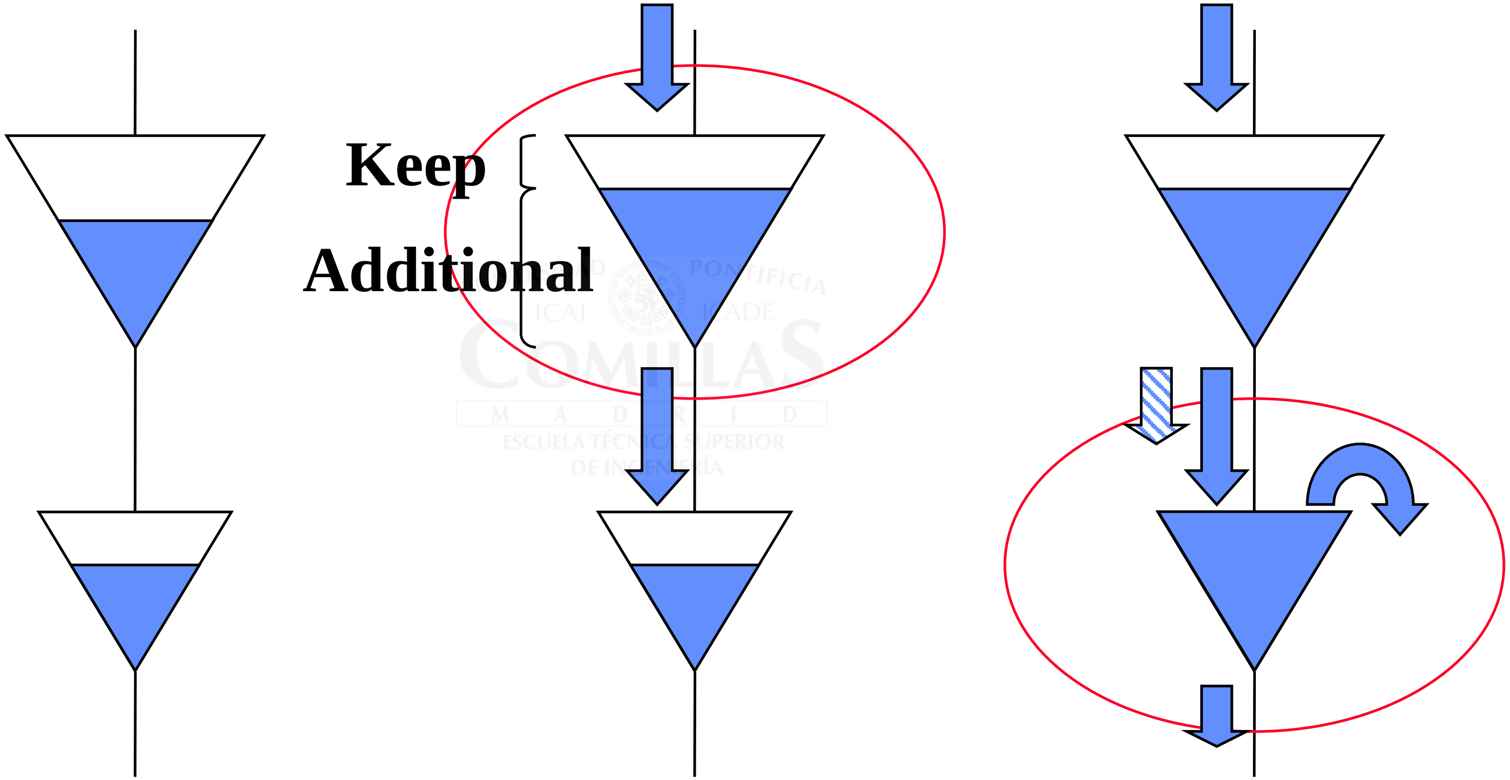
- Main objective:
  - Maximize hydro production following the reservoir operation strategies
  - Other objectives:
    - Avoid spillage
    - Satisfaction of minimum outflow (irrigation)
- Proposed method requires three phases:

1. Decides the initial management
2. Modifies it to avoid spillage and produce minimum outflows
3. Determines the electricity output for previous inflows

Simulation method (II) – Phase 1

- Downstream
- Each element is individually operated according to its own operation and strategies
- Additional information is collected:
  - – In reservoirs
    - Spillage and non served minimum flow
    - Additional volume to spend or to keep
  - – In all the elements:
    - Accumulates those values for the own element and those located upstream

Simulation method (III) – Phase 1



Simulation method (III) – Phase 2

- Upstream from the end of the basin
- Modifies the Phase 1 operation
  - To avoid spillage forces the reservoirs to keep water
  - To serve a minimum flow increases the production of reservoirs
- Splits the changes proportionally to the capacity of each element with respect to all the remaining elements located upstream

Simulation method (IV) – Phase 3

- Determines the plant output
  - By using a coefficient of efficiency
  - Depending on the average water head of the day
- Splits the production between peak and off-peak hours:
  - As much as possible in peak hours
  - The rest in off-peak hours

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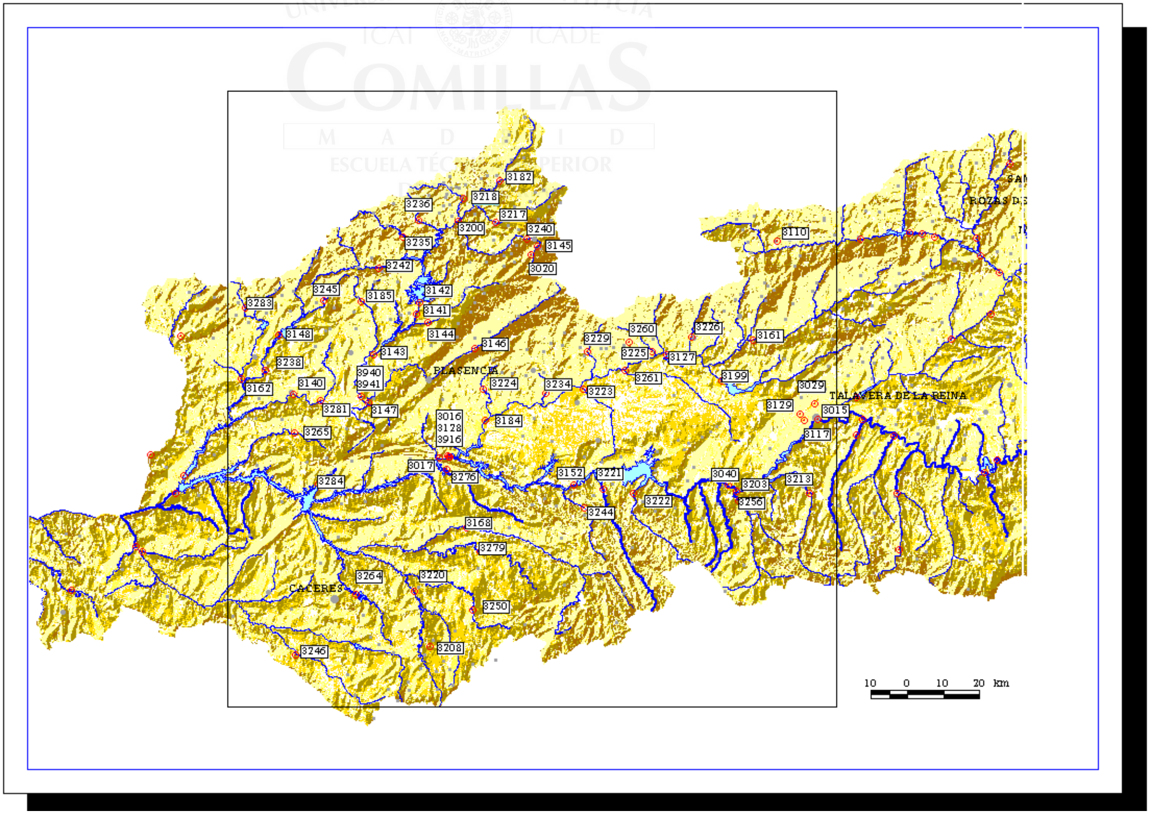
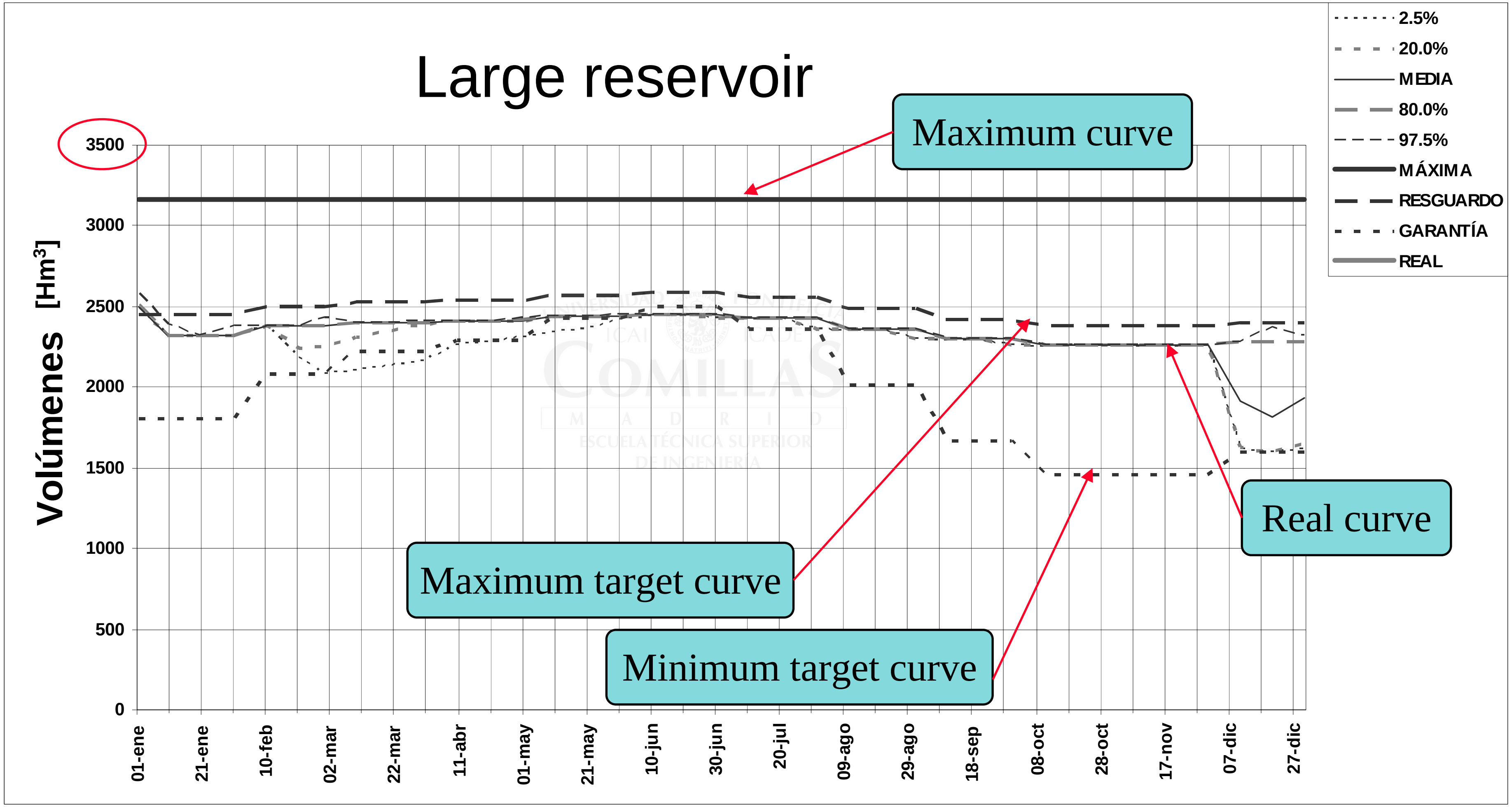
Case study

- Application to the Tajus basin belonging to Iberdrola with:
  - 9 reservoirs of different sizes
  - 8 hydro plants
  - 6 natural inflow points
  - 27 historical series of daily inflows



Results (I)



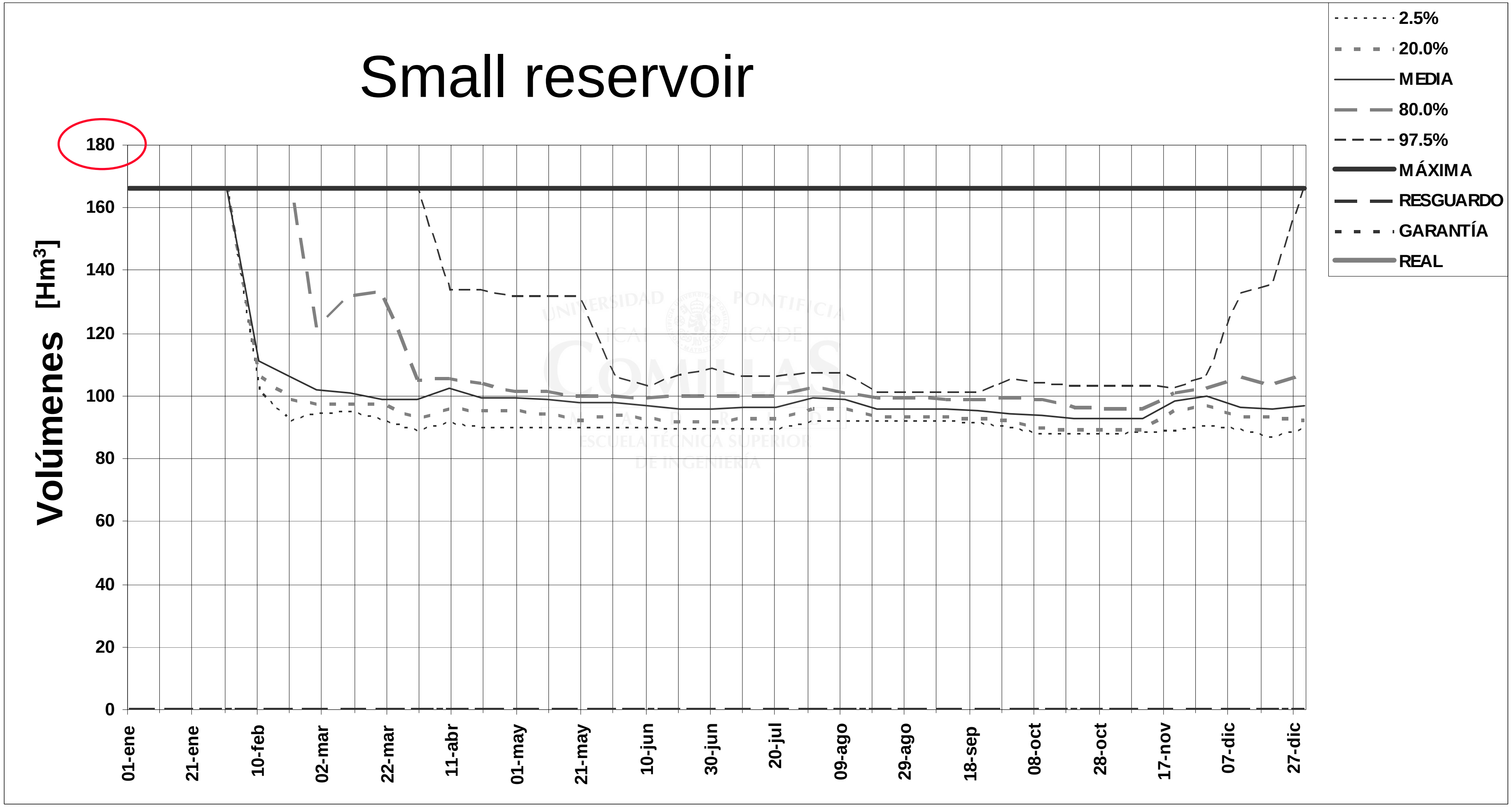
Maximum curve

Maximum target curve

Minimum target curve

Real curve

Results (II)



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Conclusions

- It has been proposed a general simulation method for hydro basins
- A three phase method implements the maximize hydro production objective
- Object Oriented Programming has been used
- A flexible computer application implements this method
- Validated with a case study
- It is currently been used for hydro operation

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