

National Technical University of Athens

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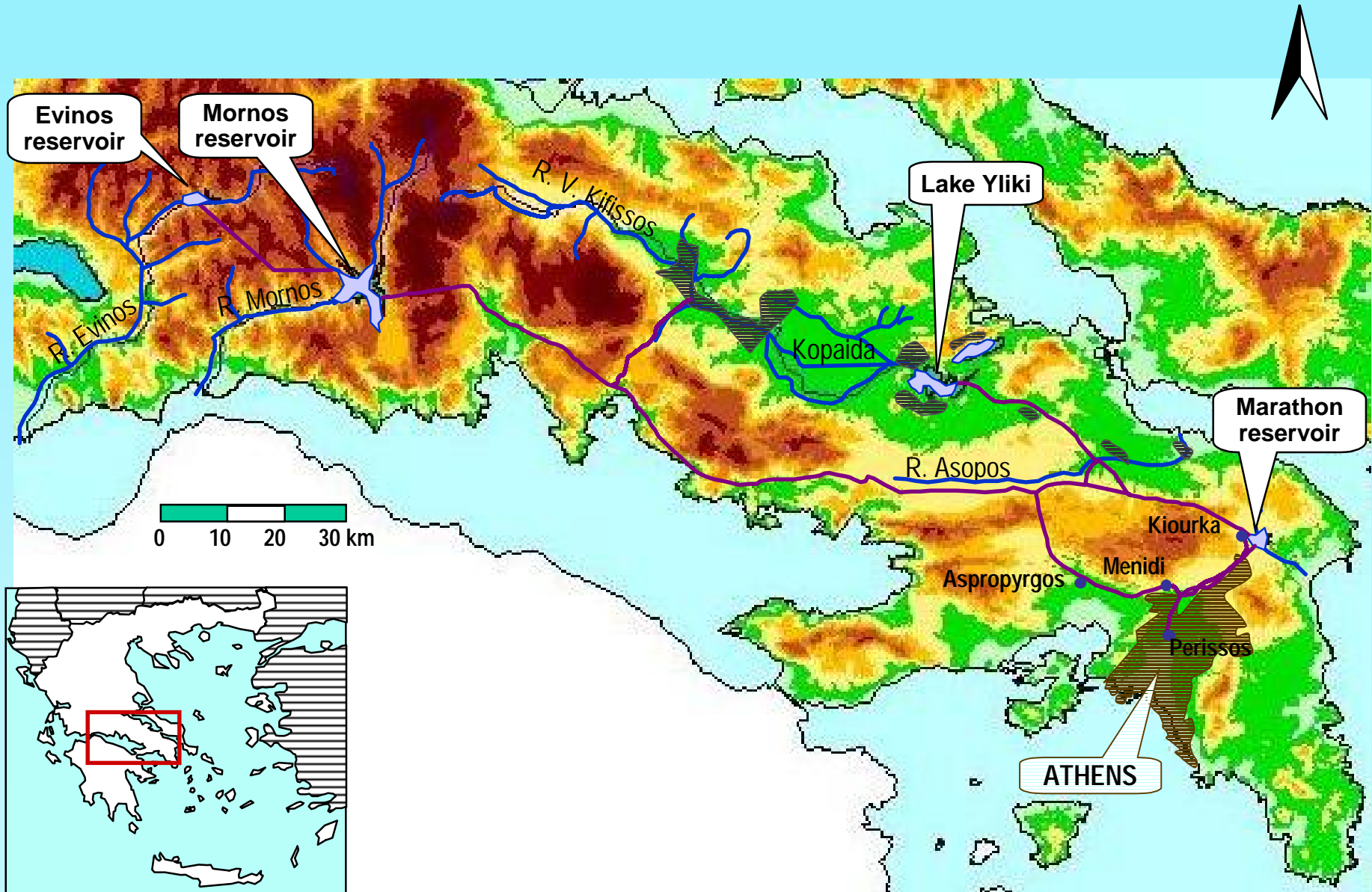
A decision support system for the management
of the water resources system of Athens

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The Athens water supply system



Hydronomeas

A DSS for the Athens Water Supply System

- *Hydronomeas* has been developed by the N. T. University of Athens within the framework of the project “Modernisation of the Supervision and Management of the Water Resource System of Athens”, funded by the Athens Water Supply and Sewage Company (1999-2000).

Critical questions to be answered

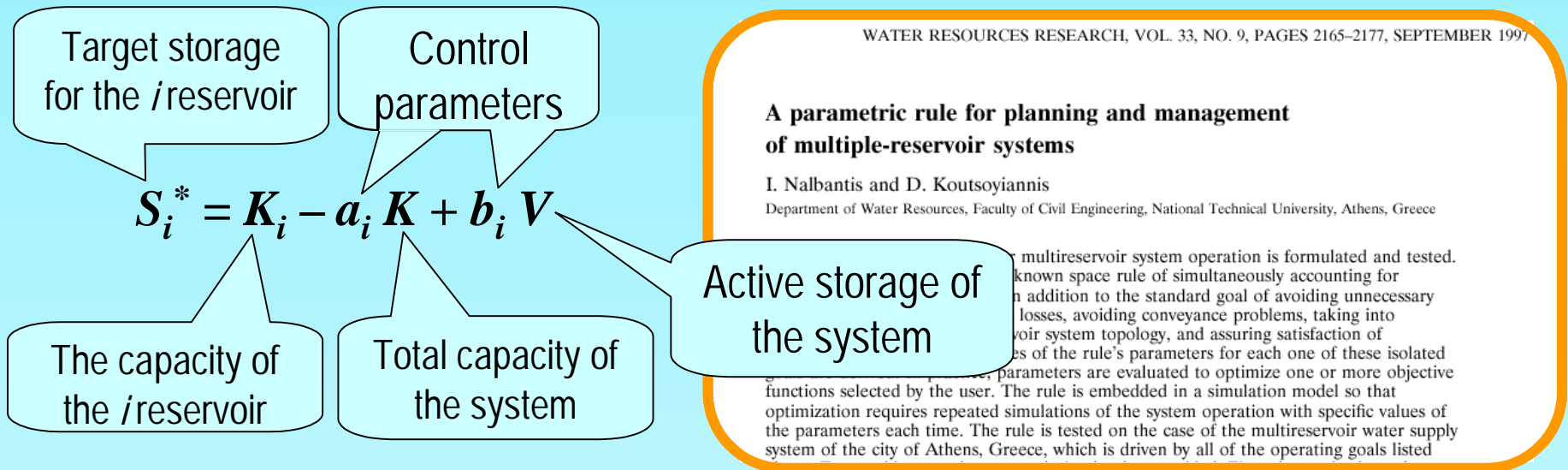
- What is the maximum total withdrawal from the hydrosystem, for a given hydrologic regime and a given reliability level?
- What is the minimum failure probability in achieving a given set of operational goals, for a given hydrologic regime?
- What is the minimum cost to achieve a given set of operational goals, for a given hydrologic regime and a given reliability level?
- What are the consequences of modifications in the hydrosystem (e.g., construction of new projects), and the impacts of different management policies or hydroclimatic scenarios?
- How could the system respond to special occasions such as channel damages or an intense increase of water demand for a specific period (e.g., during the 2004 Olympic Games)?

Characteristics of *Hydronomeas*

- Suitable for simulating complex multipurpose, multireservoir systems and for detecting the optimal water resources management policy
- It applies the parametrisation-simulation-optimisation methodology, keeping the number of control variables small
- The results are given in probabilistic terms
- The software has been developed in an Object Pascal environment (Delphi) and uses a relational database
- Hydronomeas cooperates with the stochastic simulation system **Castalia** for the generation of synthetic hydrological time series

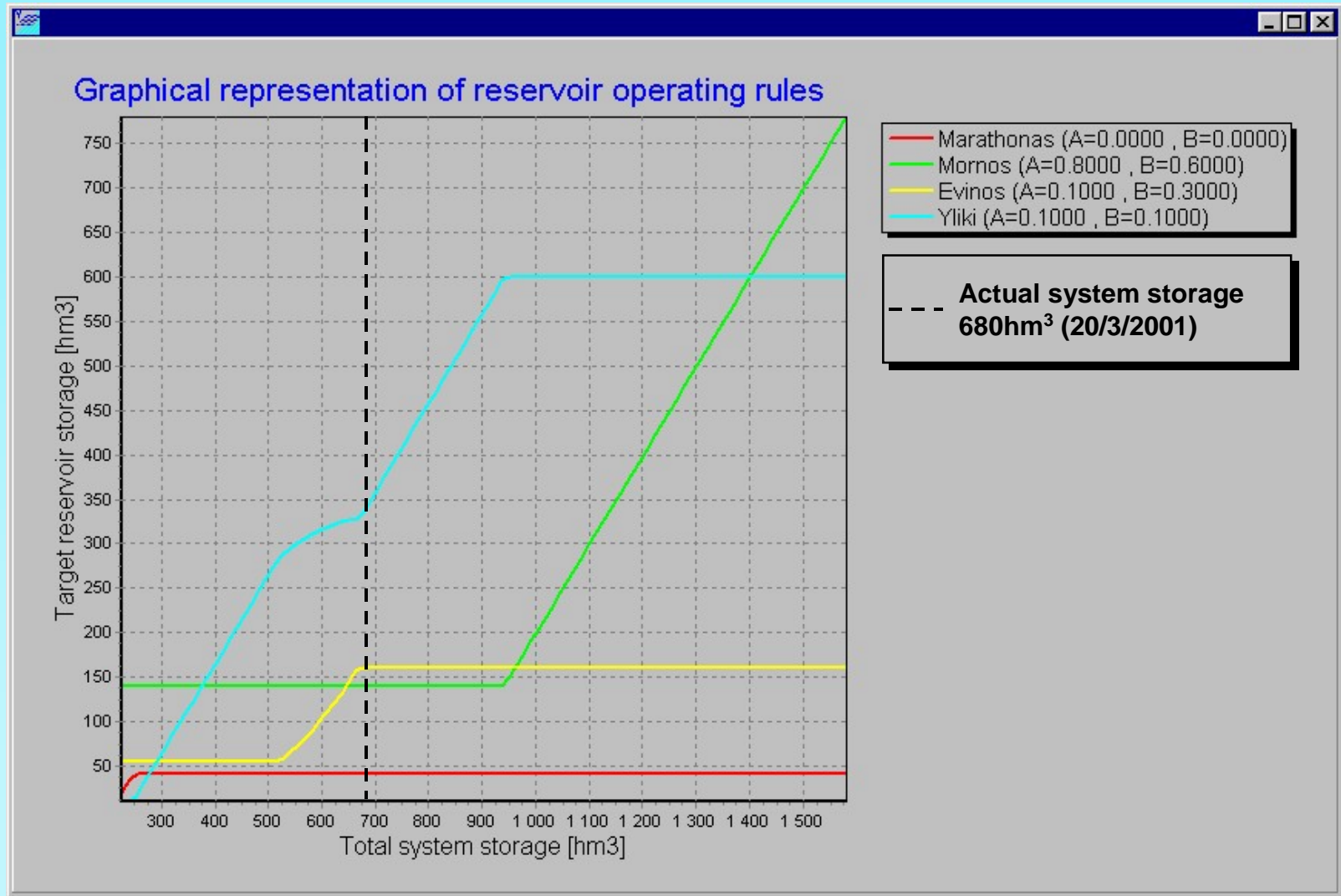
Parametric operating rules

Main idea: Distribution of the total active storage of the system V at each of the N reservoirs according to a simple linear rule:

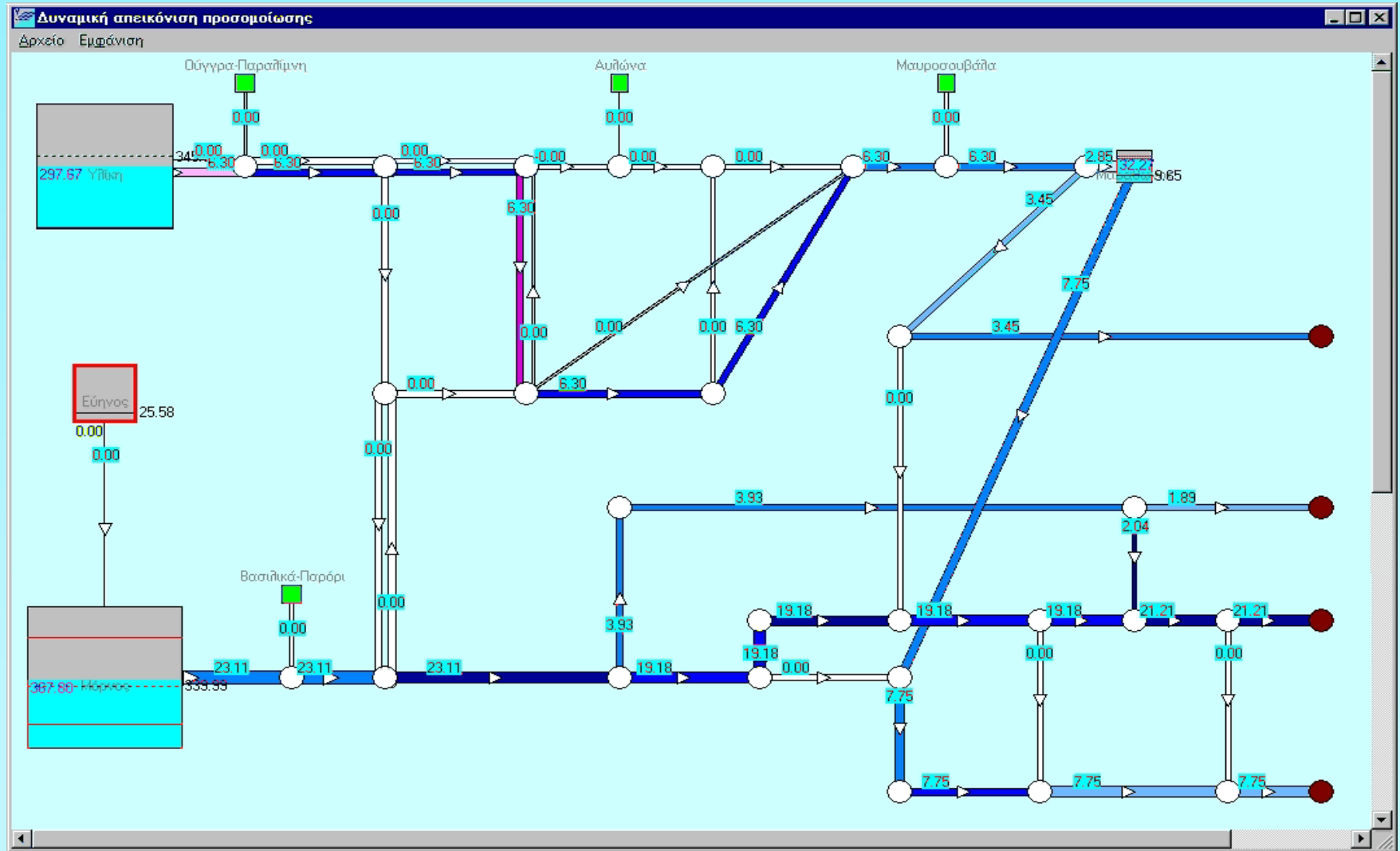


- Initial rules are corrected according to an adjusting procedure, in order to satisfy reservoir capacity constraints, and thus they become nonlinear
- The total number of control variables of the system remains $2N$ and becomes independent of the simulation length

Graphical representation of reservoir operating rules



The visualisation of the simulation process



Calculating the optimal operating rule

- An objective function is formulated, expressing the performance measure of the management
- Types of problems to be solved:
 1. minimisation of the total operational cost
 2. minimisation of the failure probability, for a given set of operational goals (targets)
 3. maximisation of the total annual withdrawal, for a given reliability level
- Operational targets:
 1. water consumption
 2. firm power generation
 3. minimum flow preservation
 4. reservoir storage control.
- The objective function is evaluated through the simulation process
- The optimisation problem is strongly nonlinear
- Advanced techniques are used, particularly the multi-start downhill simplex algorithm (Press et al. 1992) and the shuffled complex evolution method (Duan et al. 1992)

Steady state simulation results

- Reservoir water balance including annual mean value of water runoff, rainfall, evaporation, reservoir leakage, aqueducts inflow, outflow, losses, consumption
- Aqueducts flow balance
- Targets failure probability
- Optimal reservoir operating rules

Target
1) Meridi Demand - Consumption for supply
2) Galatsi Demand - Consumption for supply
3) Kiourka Demand - Consumption for supply
4) Mandra Demand - Consumption for supply
5) Evinos - Consumption for supply
6) Marathonas - Maximum storage
7) Marathonas - Minimum storage
8) Yliki - Consumption for irrigation

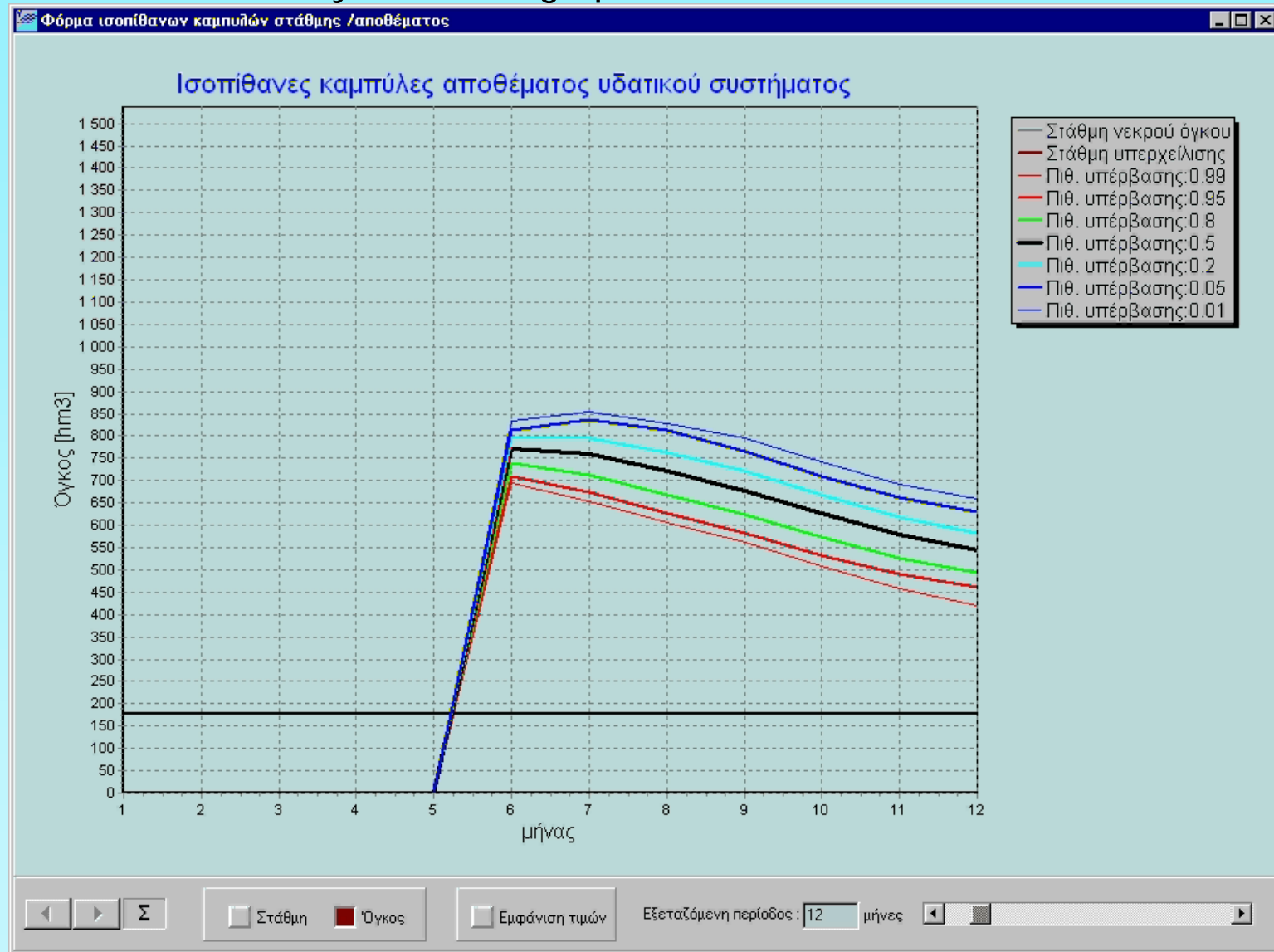
Water Balance
(Annual mean values of the best solution found: 0m³)

Flow balance
(Annual mean values of the optimal solution in hm³)

	Viliza-Avlona	Kithairon diversion	Kleidi channel	Bogiati tunnel	Momos channe	Mouriki pump	Viliza-Kakosales	Mandra A	Kiourka-Meridi	Mandra B
Normal flow	3.541/3.8	84.190/10.8	84.858/9.9	42.179/7.6	356.470/15.1	15.106/20.1	7.895/10.0	32.938/2.4	6.645/6.2	19.800/0.0
Reverse flow	-	-	-	-	-	-	-	-	-	-
River flow	-	-	-	-	-	-	-	-	-	-
TOTAL	3.541	84.190	84.858	42.179	356.470	15.106	7.895	32.938	6.645	19.800
Energy consumed	0.000	0.000	0.000	0.000	0.000	7.251	2.447	0.000	1.595	0.000
Energy consumed in the rev	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy generated	-	-	-	-	-	-	-	-	-	-
TOTAL [GWh]	0.000	0.000	0.000	0.000	0.000	7.251	2.447	0.000	1.595	0.000
Cost [million drachmas]	0.000	0.000	0.000	0.000	0.000	101.512	34.264	0.000	22.327	0.000

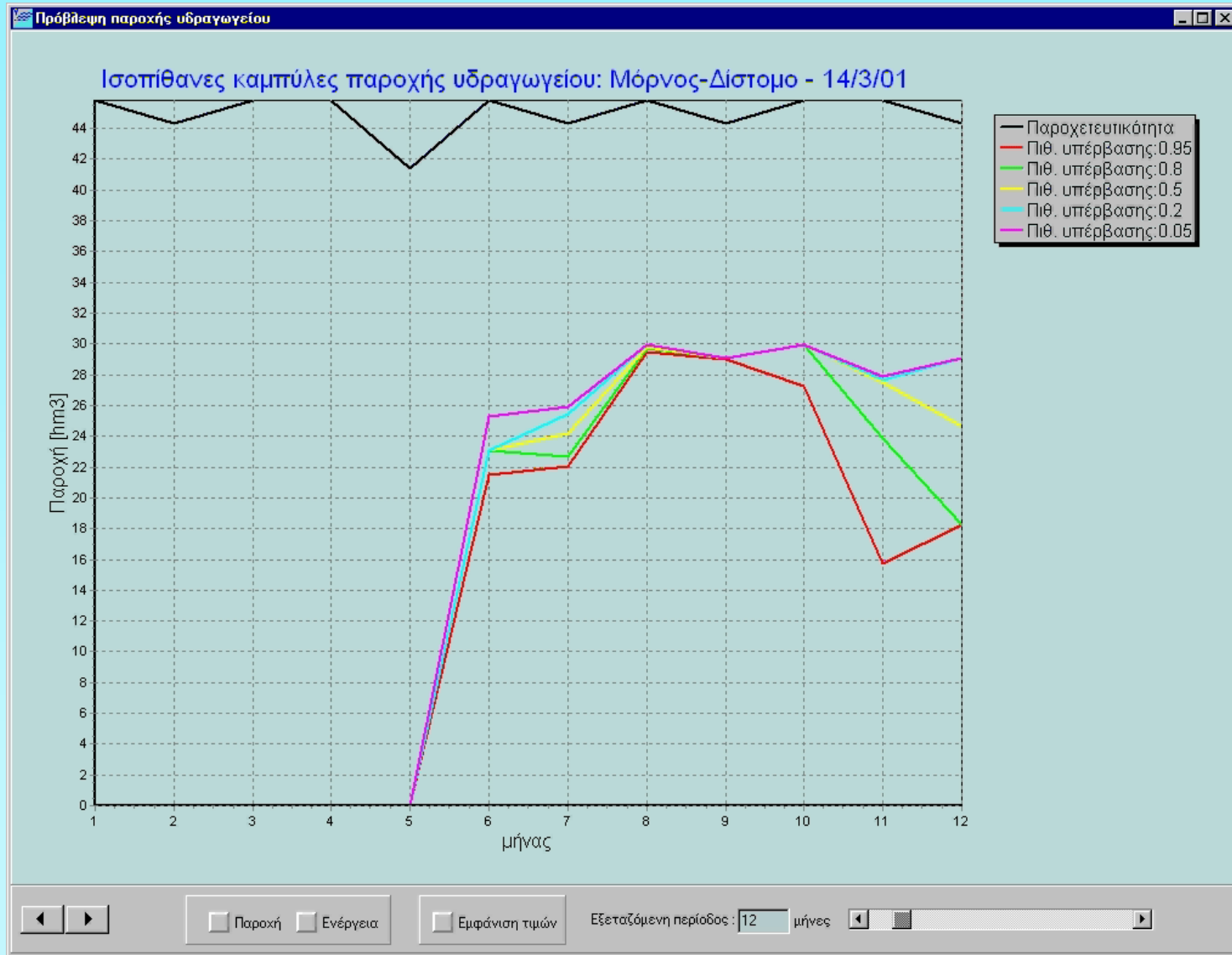
Terminating simulation results (1)

System storage prediction curves



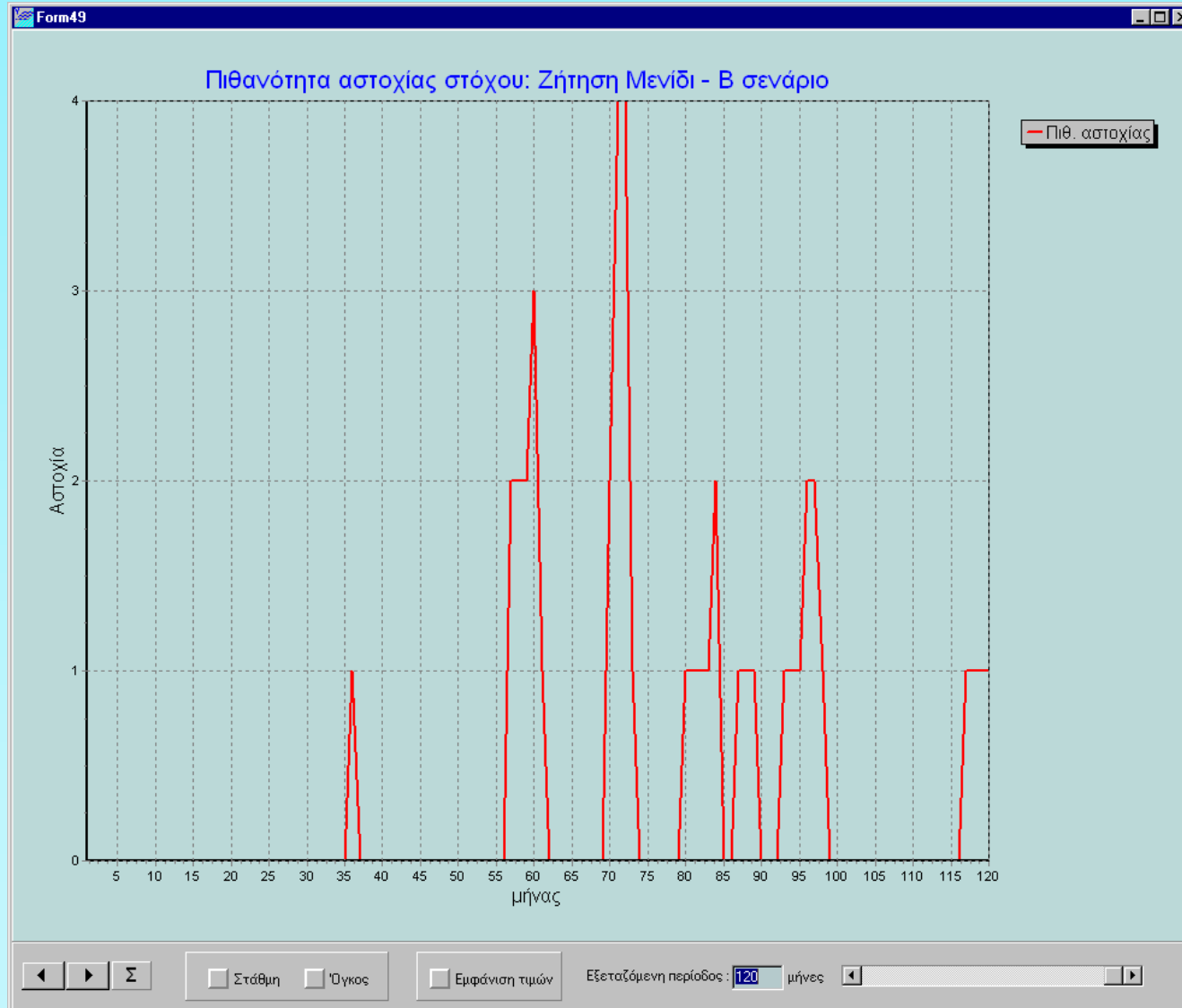
Terminating simulation results (2)

Water flow prediction curves



Terminating simulation results (3)

Target failure prediction curves



Answers to questions

- The mean total annual runoff of the 4 river basins is **860 hm³**
- The annual safe yield of the system, ignoring all aqueduct capacity constraints, is **480 hm³** (failure probability of 1%)
- The annual safe yield of the system, taking into account the current aqueduct capacity constraints, reduces to **420 hm³** (failure probability of 1%)
- Assuming a moderate increase of water demand over the next 10 years, the failure probability (management risk) is **1.3%**
- The energy needed in order to comply with the estimated demand of the actual hydrologic year is **94 GWh** (with a standard deviation of 35 GWh)