National Technical University of Athens

Department of Water Resources, Hydraulic & Maritime Engineering,
Faculty of Civil Engineering

DETERMINING MANAGEMENT SCENARIOS FOR THE WATER RESOURCE SYSTEM OF ATHENS

G. Karavokiros

A. Efstratiadis

D. Koutsoyiannis

HYDRORAMA 2002

- Introduction to water resources management (WRM) scenarios
- Categories of information comprising a scenario
- Scenarios and simulation results of the Athens Water Resources System (WRS)
- Conclusions

Water Resources Management (WRM) Scenarios

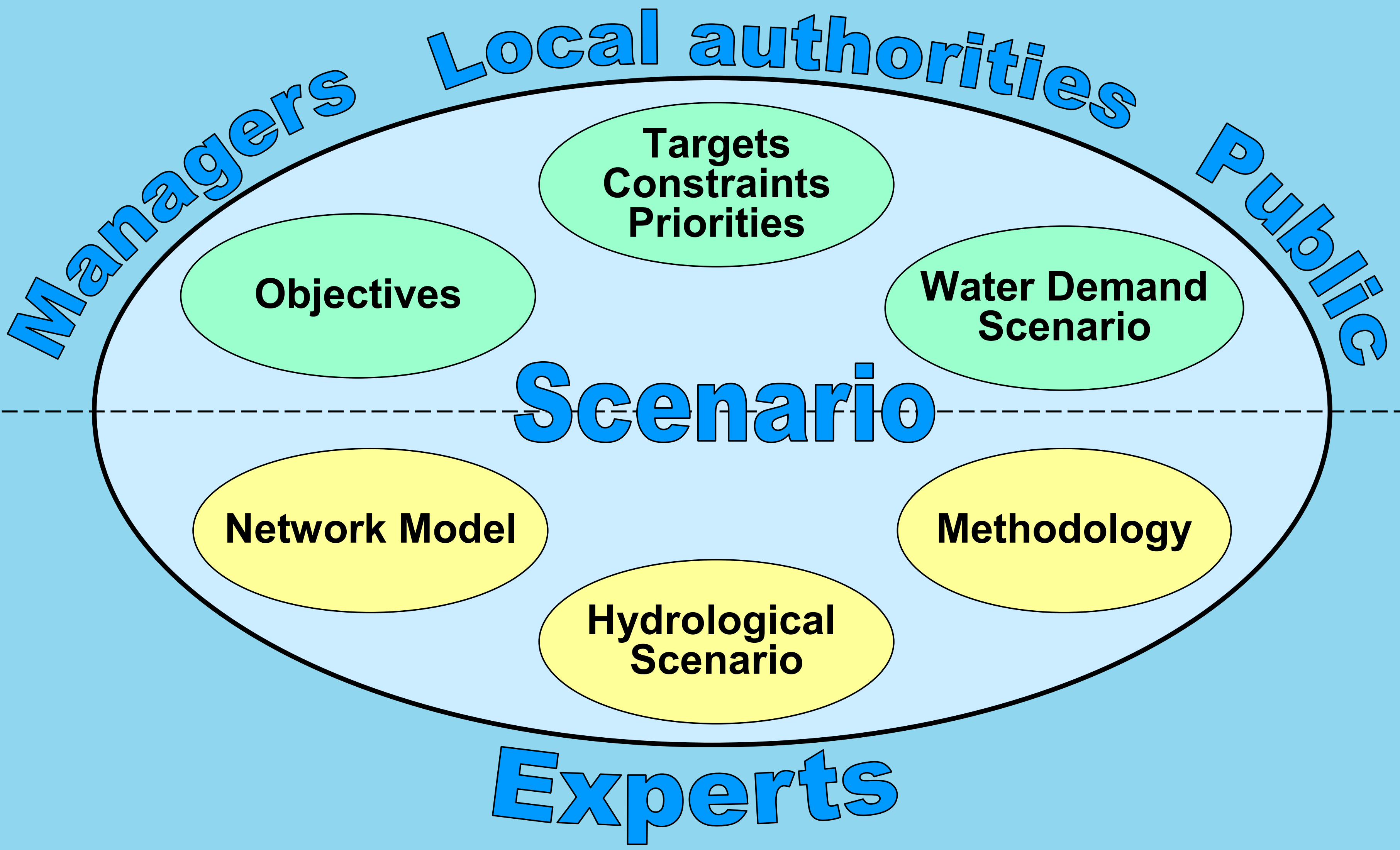
- A scenario is "*a concept for a hypothetical or projected chain of events*" (Grigg, 1996)

In WRM, scenarios are created in order to project certain decisions to the future through simulation models

A WRM scenario is defined as a set of assumptions (information) needed for modelling and simulating a hydrosystem

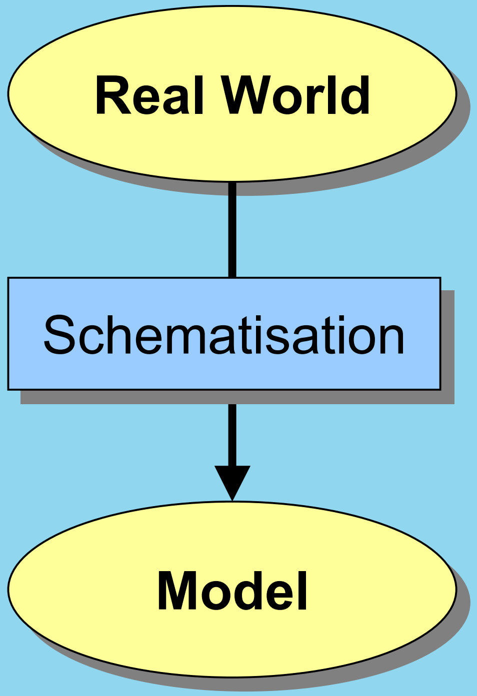
- Common scenarios refer to the following management policies:
  - The current most probable scenario (including the present state, planned future modifications and the expected water demand for the next years)
  - Expansion of the hydrosystem including new water resources and supply regions
  - Application of a certain water demand management policy
  - Emergency scenarios in case of failure of some crucial system components

Categories of Information Comprising a WRM Scenario



The Model Schematisation of the Hydrosystem

- The schematisation of the hydrosystem transforms a part of the real world into a model
- Main elements of a schematisation are:



Abstraction

- reduces complexity of the real world
- eliminates insignificant information

Classification

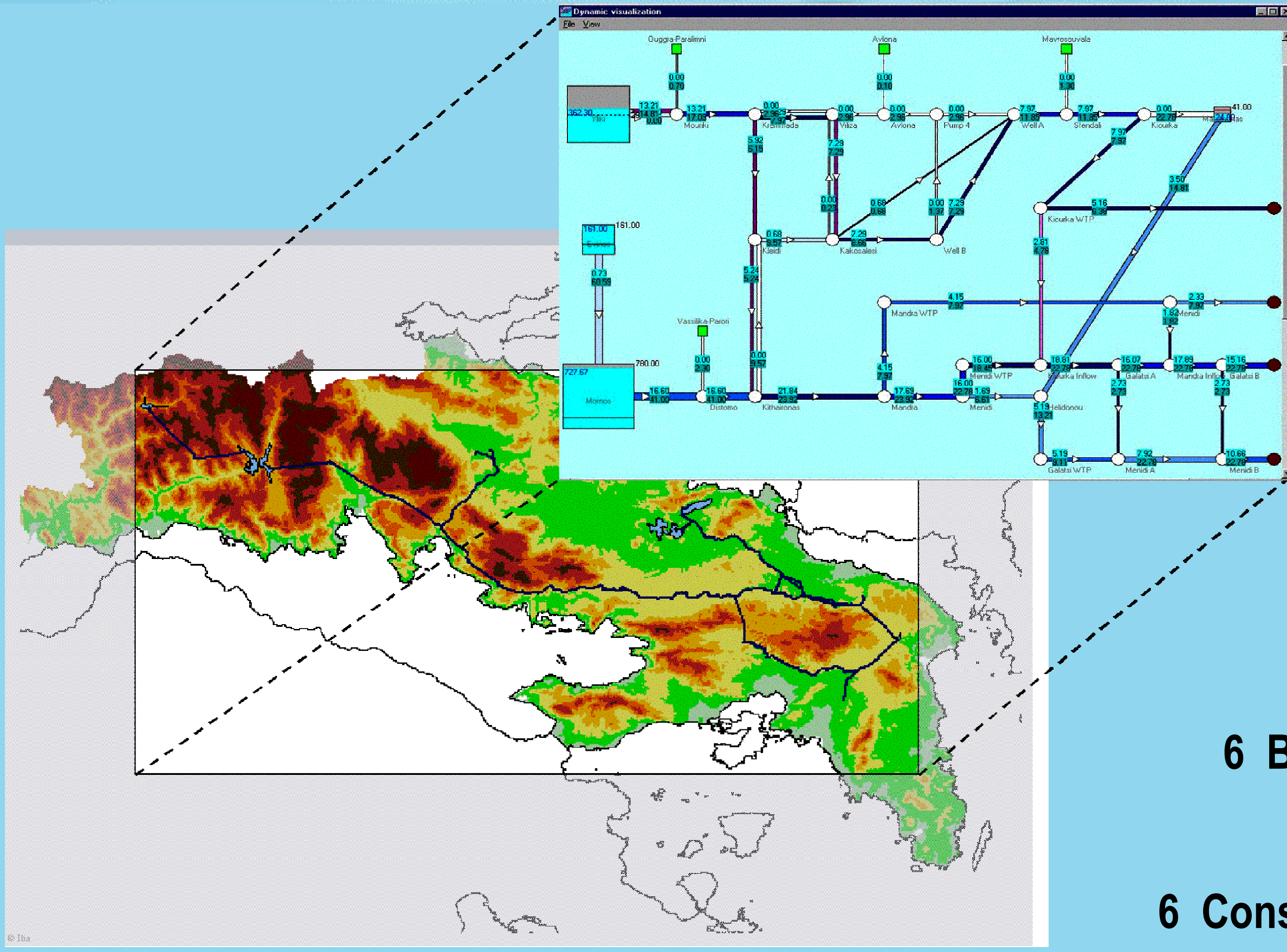
- reduces polymorphism
- gives a common view and handle of objects

Simplification

- saves resources
- reduces computational effort

- The schematisation approach is dependent upon the purpose of the application and the capabilities of the mathematical model used
- The core of most WRM models is a network consisting of nodes and links

Schematisation of the Athens WRS



36 Nodes

47 Pipes

4 Reservoirs

6 Borehole groups

4 WTP

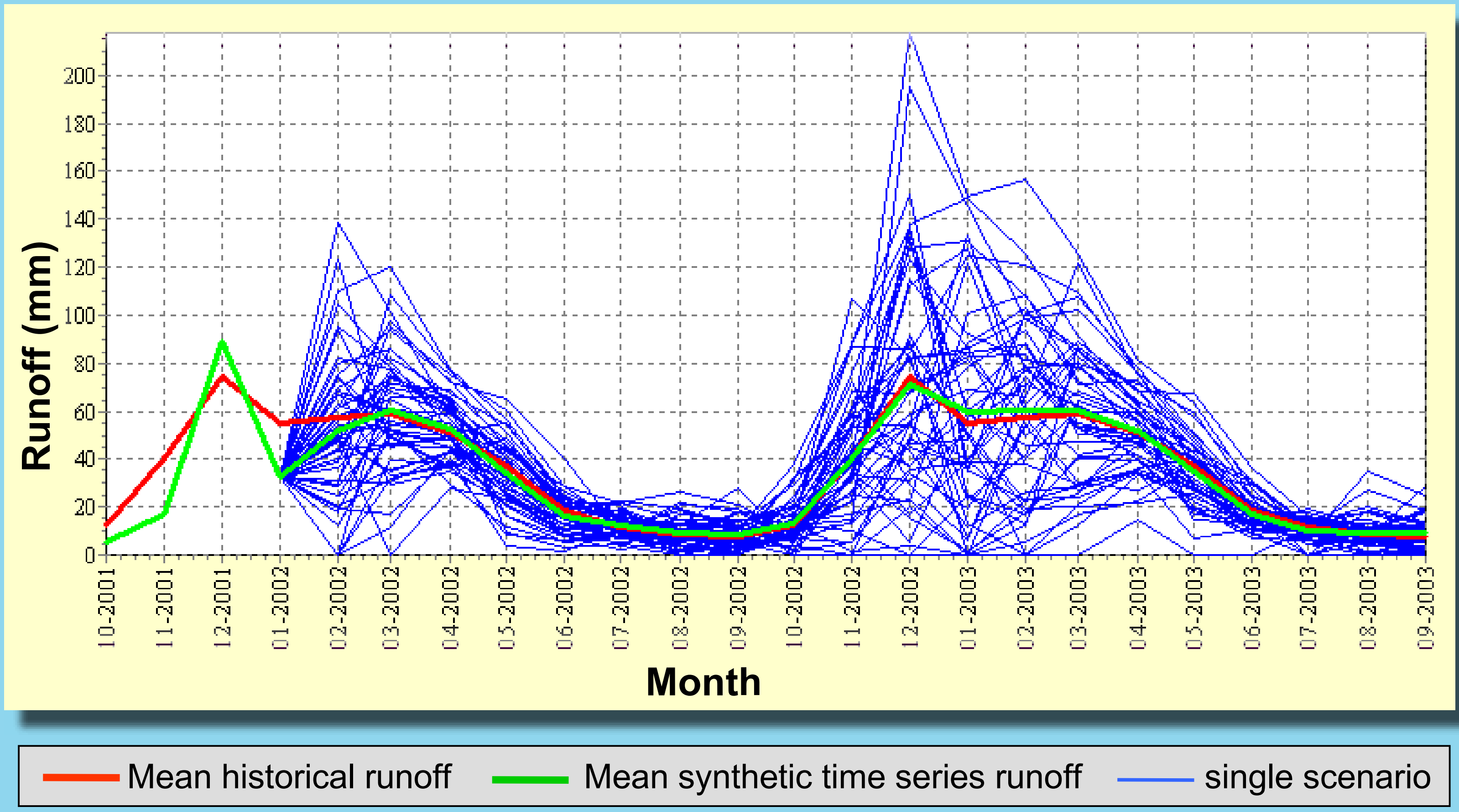
6 Consumption nodes

Hydronomeas is used as the main decision support tool for WRM

Hydrological Scenarios

- Hydrological scenarios include runoff, precipitation, and evaporation time series, derived from historical hydrometeorological data
- Corrections and transformations of the original data include:
  - Data validation (homogeneity test, screening, double mass analysis etc.)
  - Data compilation (aggregation/disaggregation, series transformation, spatial interpolation etc.)
  - Data filling-in (interpolation, regression analysis etc.)
- Selection of historical time periods (drought, normal, wet period)
  - Strongly dependent on the historic period
  - The results refer only to the selected conditions
- Generation of synthetic hydrological time series, based on the statistical properties of all available data
  - The hydrological scenario becomes independent of user decisions
  - Provides the ability to measure the uncertainty associated with hydrological conditions by means of probability

Hydrological Scenarios for the Athens WRS



Runoff scenarios into the Mornos reservoir

Synthetic hydrological time series for the Athens WRS are generated by the stochastic simulator *Castalia*

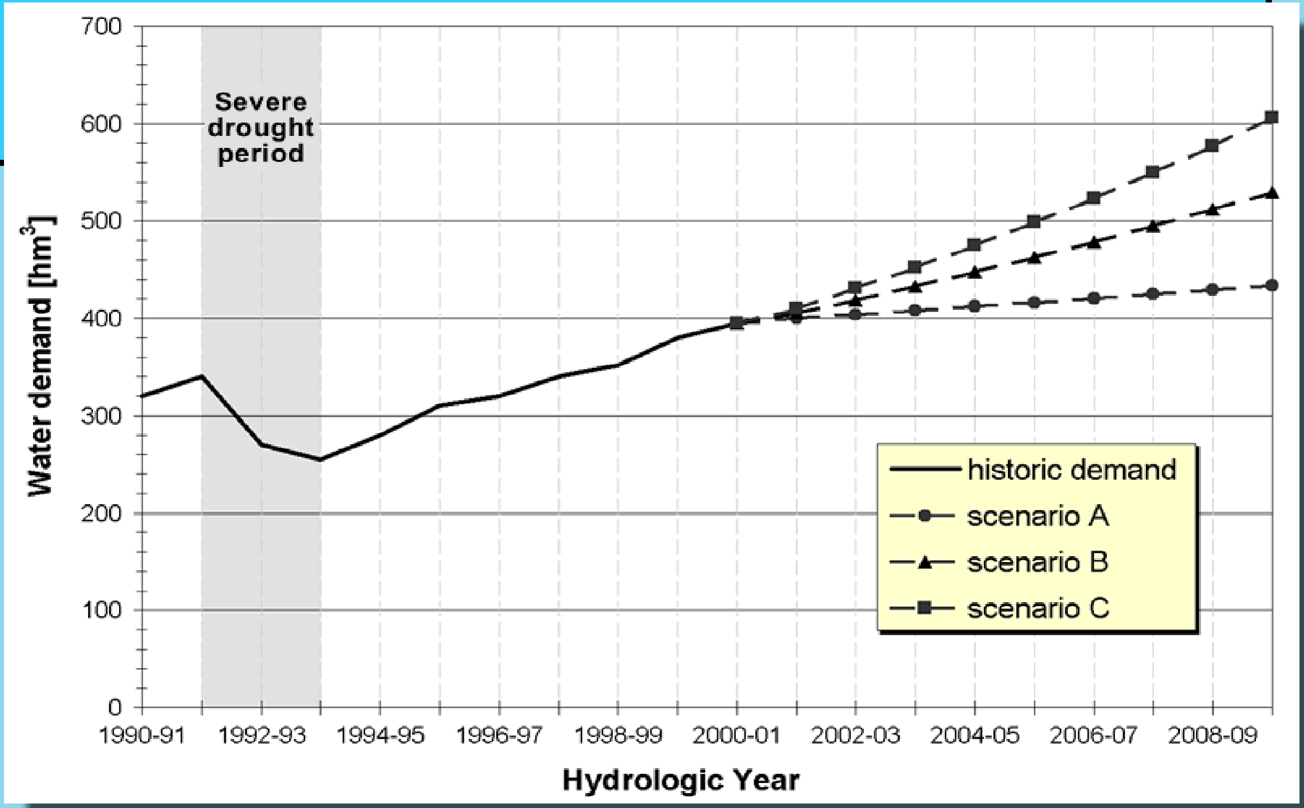
Water Demand Scenarios

Estimation of the water consumption in urban areas

- Population and industrial growth
- Living standard
- Land use in urban areas

Major influence factors

- Expansion of the water supply system
- Water charging policy
- Information campaign



Urban water demand scenarios for the metropolitan area of Athens

Targets, Constraints and Priorities

Water uses and operational requirements are modeled as **targets** and **constraints** from the following categories:

- water consumption (water supply, irrigation, etc.)
- discharge control (minimum, maximum or fixed flow in aqueducts)
- storage control (minimum or maximum water storage level in reservoirs)

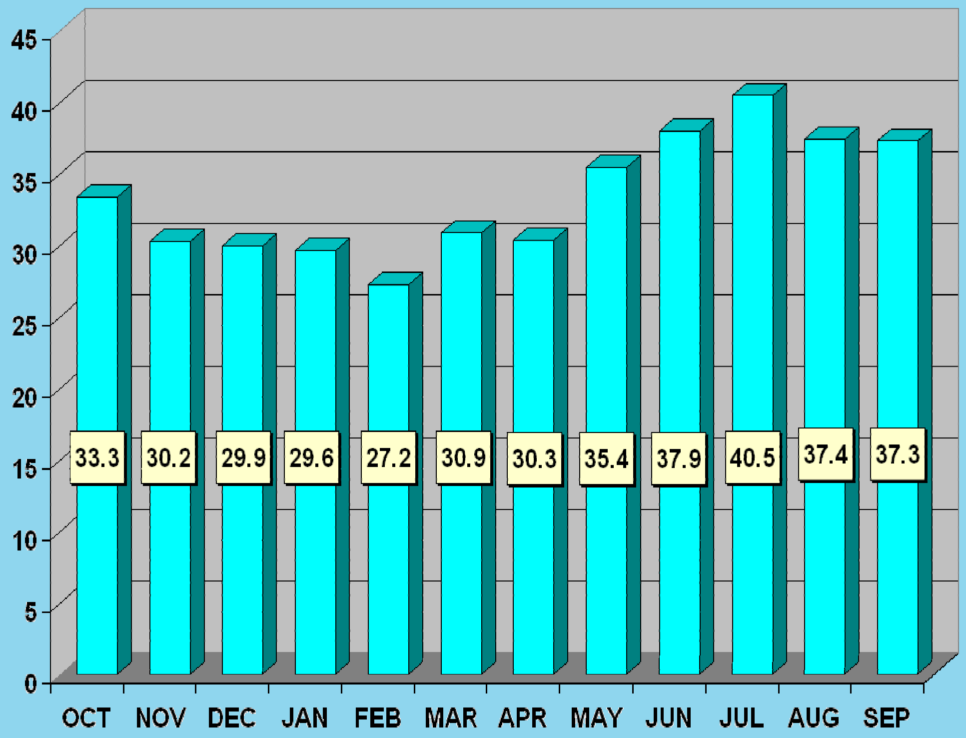
Physical constraints imposed by the hydrosystem may prohibit the realisation of all predefined targets simultaneously. Typical reasons are:

- The exhaustion of water resources
- The exhaustion of the system discharge capacity

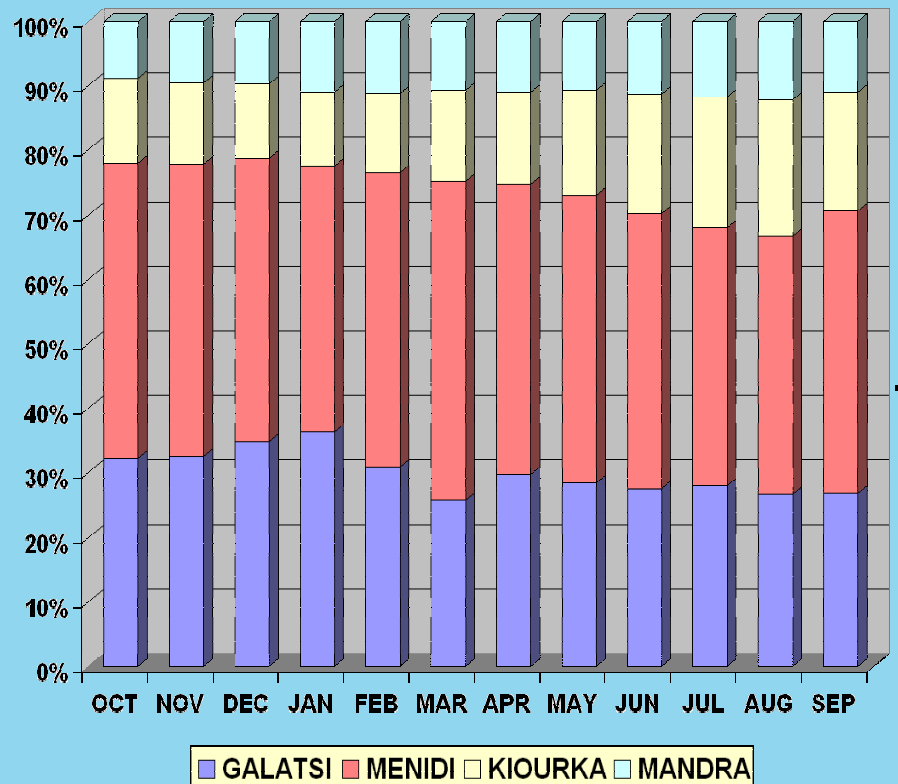
The targets are sorted in a **priority list**, in order to ensure that, in case of water shortage, water uses of high importance (e.g., water supply) are fulfilled first.

Water Consumption Targets of the Athens WRS

The water consumption of the Athens Metropolitan area in the year 2001 has been **400 hm^3** (measured at the WTP)



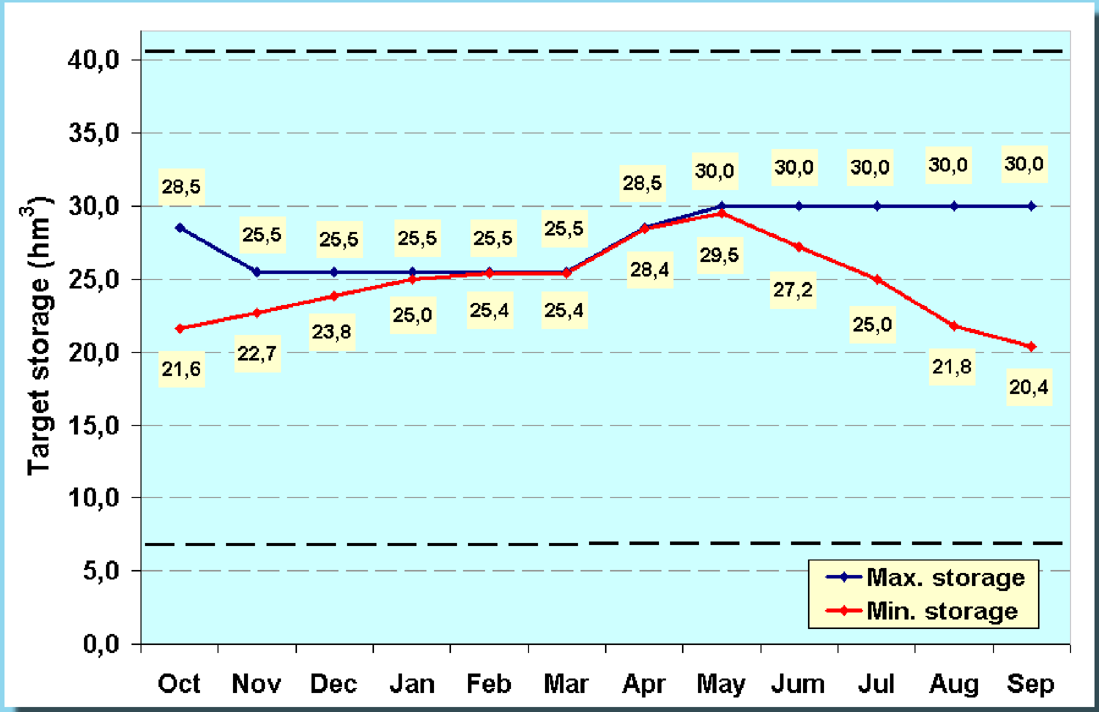
Monthly distribution of the total water consumption



Spatial distribution of the water consumption

Stage Control Targets for the Marathon Reservoir

- Marathon is used mainly as an auxiliary water resource
- During the summer season part of the stored water is used for the water supply of Athens
- Water spills are not allowed due to the urbanization of the downstream coastal areas

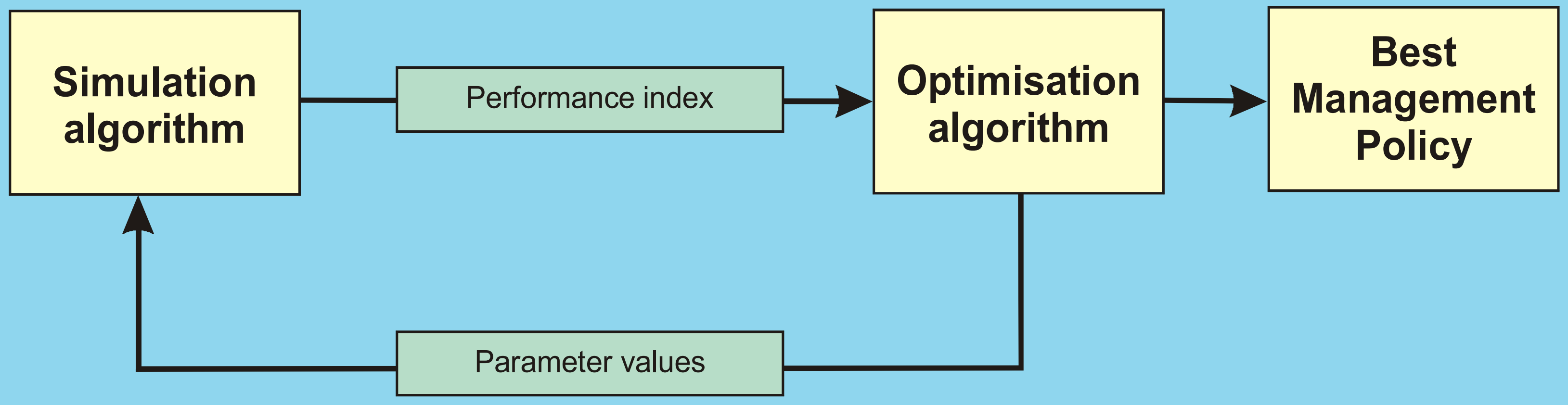


Other Targets and Constraints

- Maximum storage targets for the Evinos and Mornos reservoirs for prevention of water spills
- Environmental preservation flow of 1 m^3/s in the Evinos river, downstream of the dam
- Irrigation demand of the Kopais plain 35 hm^3 /y from the lake Yliki

Methodological Assumptions for the Athens WRS

- A step-by-step flow allocation methodology is applied to allocate the available water resources through the hydrosystem, in order to satisfy the system's targets, constraints and priorities (network optimisation model)
- Groundwater releases are regulated according to the ratio of the active storage of the reservoir system to its total active capacity
- Parametric reservoir operation rules are applied. The simulation procedure is driven by an optimisation algorithm to determine the optimal parameters of reservoir operation rules



The Management Objectives

Management Objectives refer to the long-term operational goals of the WRS

In the Athens WRS the following three management objectives have been used in several scenarios:

- Maximisation of the total annual withdrawal of the Athens WRS, for a given reliability level
  - What is the operation policy for the theoretical potential of the WRS regardless of the limitations imposed by the discharge capacity of aqueduct?
  - What is the actual potential of the WRS?
- Minimisation of the water supply failure probability (risk) for a given set of targets
  - Which management policy ensures the supply of water to the metropolitan area of Athens with the highest reliability level, regardless of any operational cost?
  - Is it feasible to achieve the specified targets in an emergency situation?
- Minimisation of the total operational cost for a given set of operational goals and for a given acceptable (very low) water supply failure probability
  - Applied in scenarios which reflect a normal operation

Terminating vs. Steady State Simulations

Terminating simulations

- Terminating simulations apply a number of hydrological scenarios, all having the same initial system state
- Terminating simulations are applied whenever the impact of a specific management policy over the next period is examined
- Water resources management decisions have long-term impact. The time horizon of terminating simulations should be at least 5-10 years
- <u>Example</u>: Estimating the energy consumption of the current hydrologic period for a given management policy

Steady state simulations

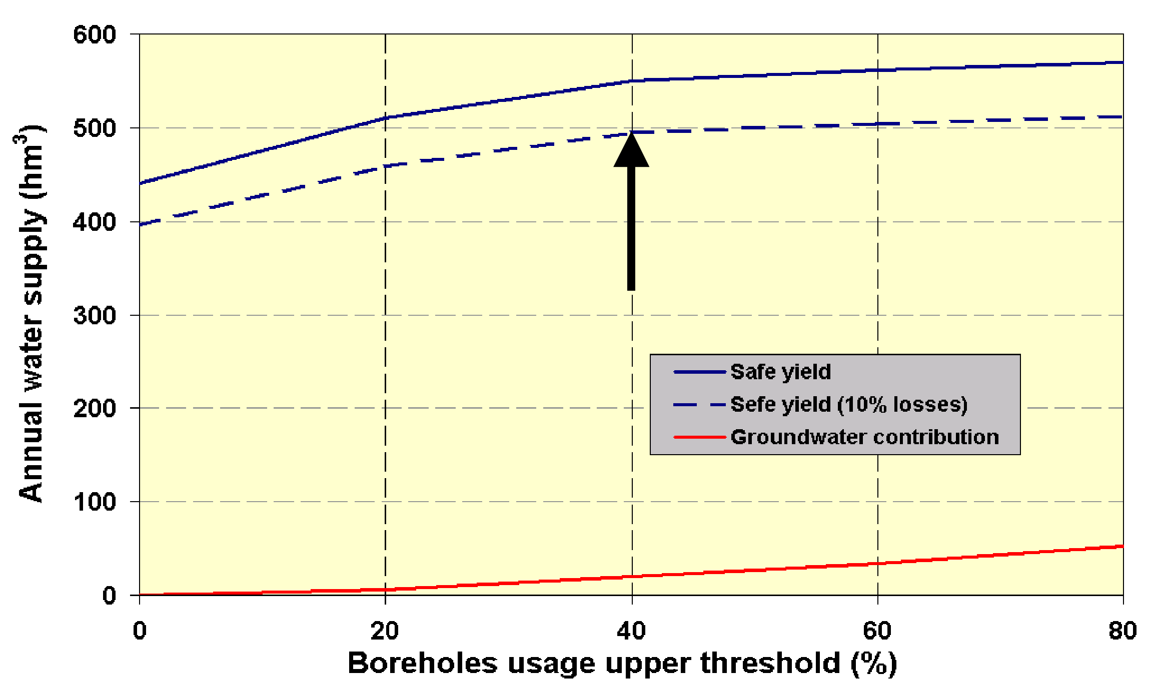
- Steady state simulations use long-term synthetic time series in order to reduce the impact of the initial state on the results
- <u>Example</u>: Estimating the system yield

1st Scenario: Assessment of the Theoretical Potential of the Athens WRS

Management Objective: Maximisation of the safe yield of the hydrosystem, regardless of discharge capacity limits of aqueducts

- No restrictions imposed by conveyance capacity limits of aqueducts and no costs due to the conveyance of the water through the network were taken into account
- Groundwater use was forbidden if surface resources exceeded an upper threshold (% of the total active capacity) and enforced if surface resources fall below a lower threshold
- The adopted reliability level was set to 99%, on an annual basis
- Steady state simulation, using synthetic inflow series of 2000 years, which incorporated persistent drought periods

The theoretical potential of the Athens WRS, for sustainable groundwater use, is estimated **495 hm^3**



2nd Scenario: Normal Operation of the Actual WRS

Assumptions

Management Objective: Minimisation of the operational cost (total pumping energy) and at the same time ensuring a very high reliability level for the next 10 years

- An average annual 99% reliability level for the next 10 years was set
- All physical restrictions of the WRS were incorporated as well as all planned facilities and expected modifications
- The assumption of 10% leakages from the WRS was made
- A constant water demand scenario of 415 hm^3/y was adopted
- Same operational policy regarding boreholes was adopted
- Terminating state simulations based on 200 synthetic inflow data sets, each of them having a length of 10 years were used, starting at February 2002

2nd Scenario: Normal Operation of the Actual WRS

Conclusions and proposals

- The actual situation is characterised by a significant increase of water consumption (during the period October 2001 - January 2002, the increase rate was 8%), simultaneously with a severe drought that continues for a third hydrologic period (the total reservoir inflows during the year 2000-01 were as low as in 1991-92)
- The unfavourable actual situation imposes full use of the entiety of backup resources (Yliki Lake and groundwater)
- The only sustainable management policy is to reduce the water consumption, through a wide information campaign as well as via pricing measures

Final remarks

- A careful and systematic development of scenarios is an important step towards an effective and sustainable water resources management
- Only suitable skilled experts should be involved in the process of determining the schematisation of the hydrosystem, the hydrological scenario and the methodological assumptions
- Decision makers, local authorities and the public should be involved in the process of defining the management objectives, the operational targets, their priorities and the water uses
- Computer simulation models must take into account all physical and operational constraints and scenario components of a hydrosystem, and provide detailed information about the impacts of a variety of scenarios
- The Athens WRS utilises powerful state of the art software systems, which not only enables the inspection of different scenarios but also locates optimal management policies