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Implications of sustainability in water resources management at catchment scale

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Palermo, 8-9 October 2004

Traditionally,

Water Resources Planning and Management

have been approached via

Deterministic or Stochastic Optimization

(Maas et al., 1962; James and Lee, 1971; Loucks et al., 1981)

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More recently,

Multi-criteria Techniques

have been extensively used, in order to account for a wider variety of

Commensurable and Incommensurable Objectives

The introduction of the

Sustainability Concept
(World Commission on Environment and Development, 1987)

which aims at fulfilling the so called "3 Es" objectives:

- Environmental integrity
- Economic efficiency
- Equity for present and future generations

radically changed the traditional perspectives.

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SUSTAINABILITY EMERGING CONCEPTS

- Water must be considered as a limiting factor for economic growth and development
- Environmental aspects (especially water quality which may reduce water availability and quality of life) must be taken into consideration
- Socio-economic aspects must be taken into account
- Legal and political (local, national and international) issues (strategies, restrictions) must be considered
- Uncertainty (including hydrological stochasticity, climate change and future demand) has to be accounted for

Planning sustainable resources exploitation requires to take into account:

- the present situation
- the socio-economic context
- the availability of resources
- the environmental carrying capacity

In addition it is also necesary:

- to place special attention on public requirements which implies strong interactions with population.

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EMERGING REQIREMENTS

Sustainability requires studying problems in a comprehensive way at catchment scale.

Furthermore, with the introduction of the sustainability concept classical optimisation in water resources, has lost its leading role with respect to the integrated analysis of

environmental and socio-economical impacts

of pre-defined development scenarios.

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OTHER REQUIREMENTS FOR SUSTAINABLE PLANNING

- Compatibility of technology with nature and the physical, biological, ecological, social and cultural, political and sensual (including visual) environments,
- Use, preservation and protection of renewable resources,
- Equitable allocation and sharing of all benefits and costs,
- Emphasis on service as well as profit and financial feasibility,
- Enhancement of local social institutions and cultural traditions
- Public involvement in all aspects of planning and management and decision-making.

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THE NEED FOR INTEGRTED DECISION SUPPORTING TOOLS

From all these aspects the need emerges for integrated planning and impact verification decision support tools, integrating over a geo-referenced database all the required models and tools to be used by planners to assess the consequences of measures on a multiplicity of aspects, to navigate among the extremely large number of items and possibilities and to produce and implement development measures that will

keep track of the environmental and socio-economic interactions,

of public requirements and of administrative and legal viability.

Existing Decision Support Systems (DSS)

tend to be not sufficiently flexible or too detailed in the single models or restricted to some of the aspects of the problem, without taking into account the

complex interrelations

of all the

physical, socio-economical

and

environmental components

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Examples of Existing Decision Support Systems (DSS)

- **AQUATOOL – Polytechnical University Valencia**
- **BASINS - US EPA**
- **EGYPT DSS – ET&P**
- **ENSIS – NIVA**
- **IRAS – University of Cornell**
- **MIKE BASINS - DHI**
- **RIBASIM – Delft Hydraulics**
- **SPATIAL DSS – NTUA**
- **WATERWARE – Eureka 487**
- **WEAP – Stockholm Institute**

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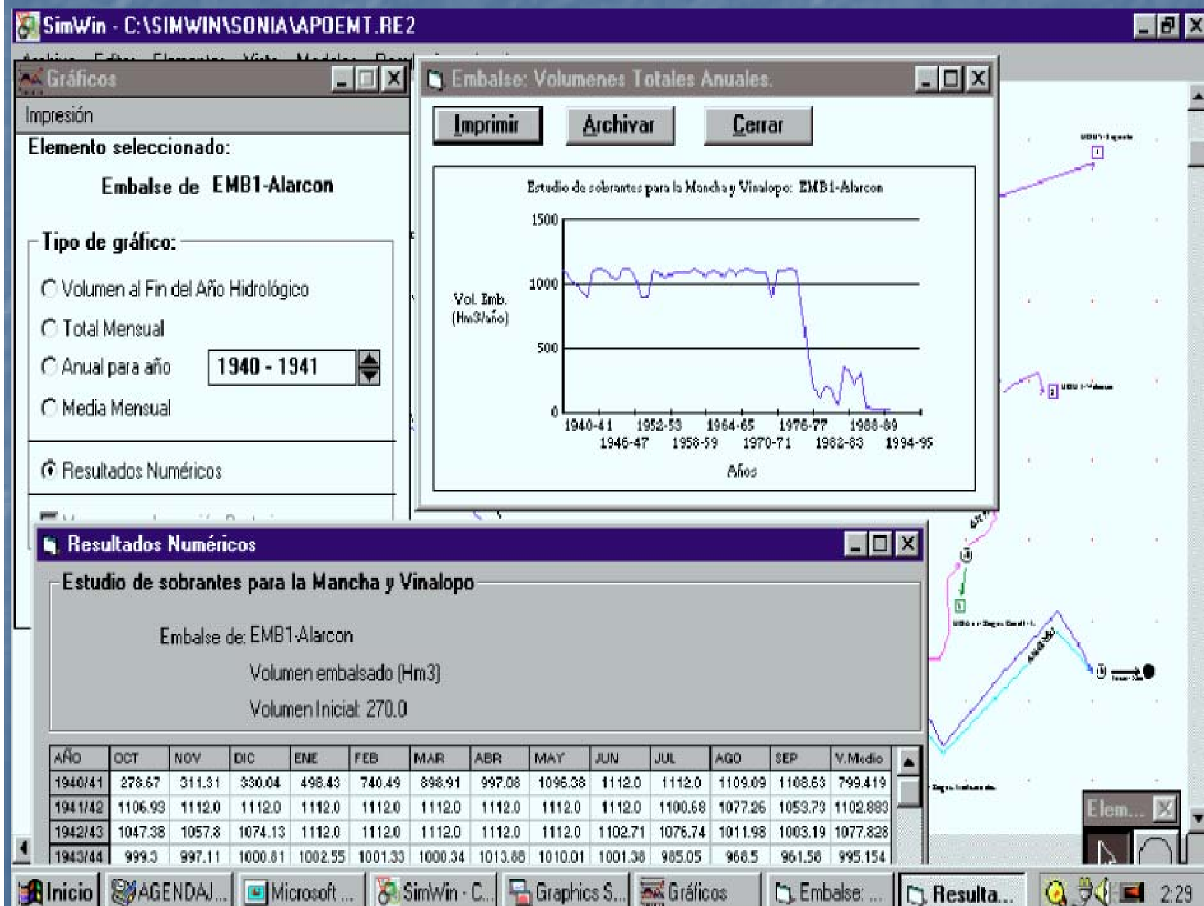
AQUATOOL – Polytechnical University Valencia



PROS

General Water Resources Management at catchment scale

CONS

No economic and environmental aspects

No link with GIS

Does not allow dynamic inclusion of nodes

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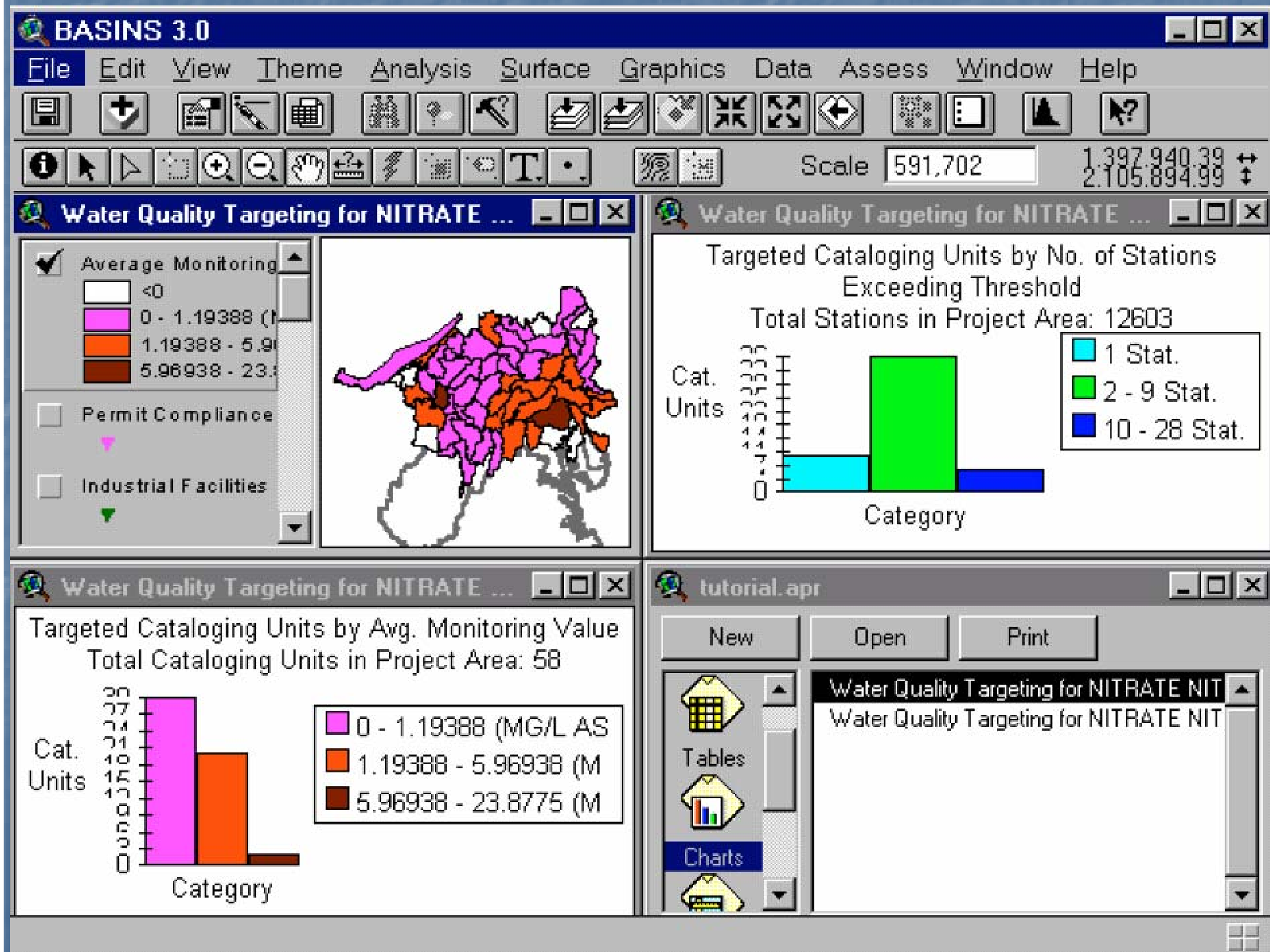
BASINS - US EPA



PROS

Environmentally oriented

CONS

Physical aspects description prevails over socio-economical impacts

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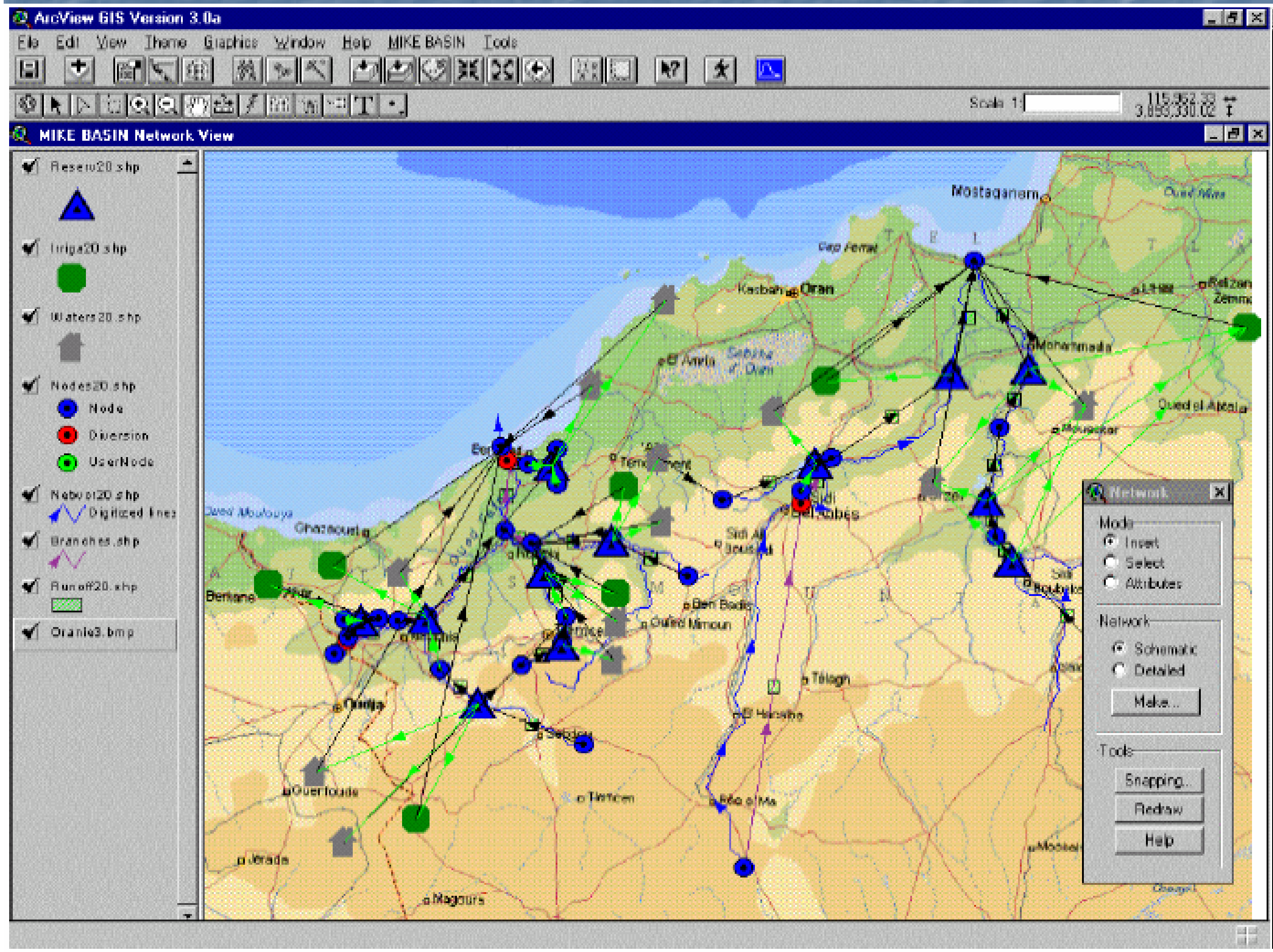
MIKE BASINS - DHI



PROS

Integrated GIS-DB

Physical simulation and optimisation

CONS

No socio-economic and environmental impact

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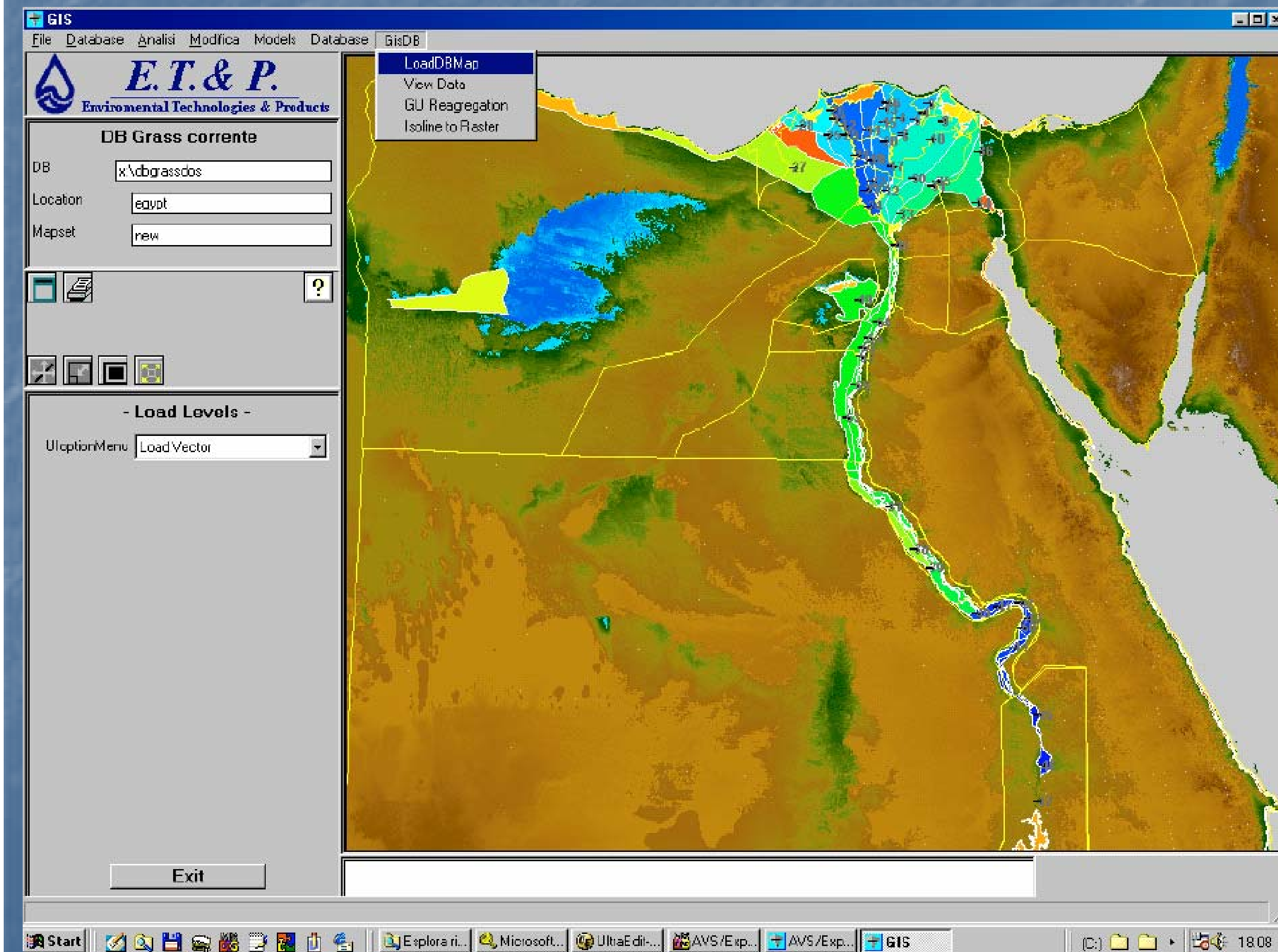
EGYPT DSS – ET&P



PROS

Comprehensive
Includes Socio-economical, Environmental and Quality of Life indicators

CONS

Too complex as a generic tool

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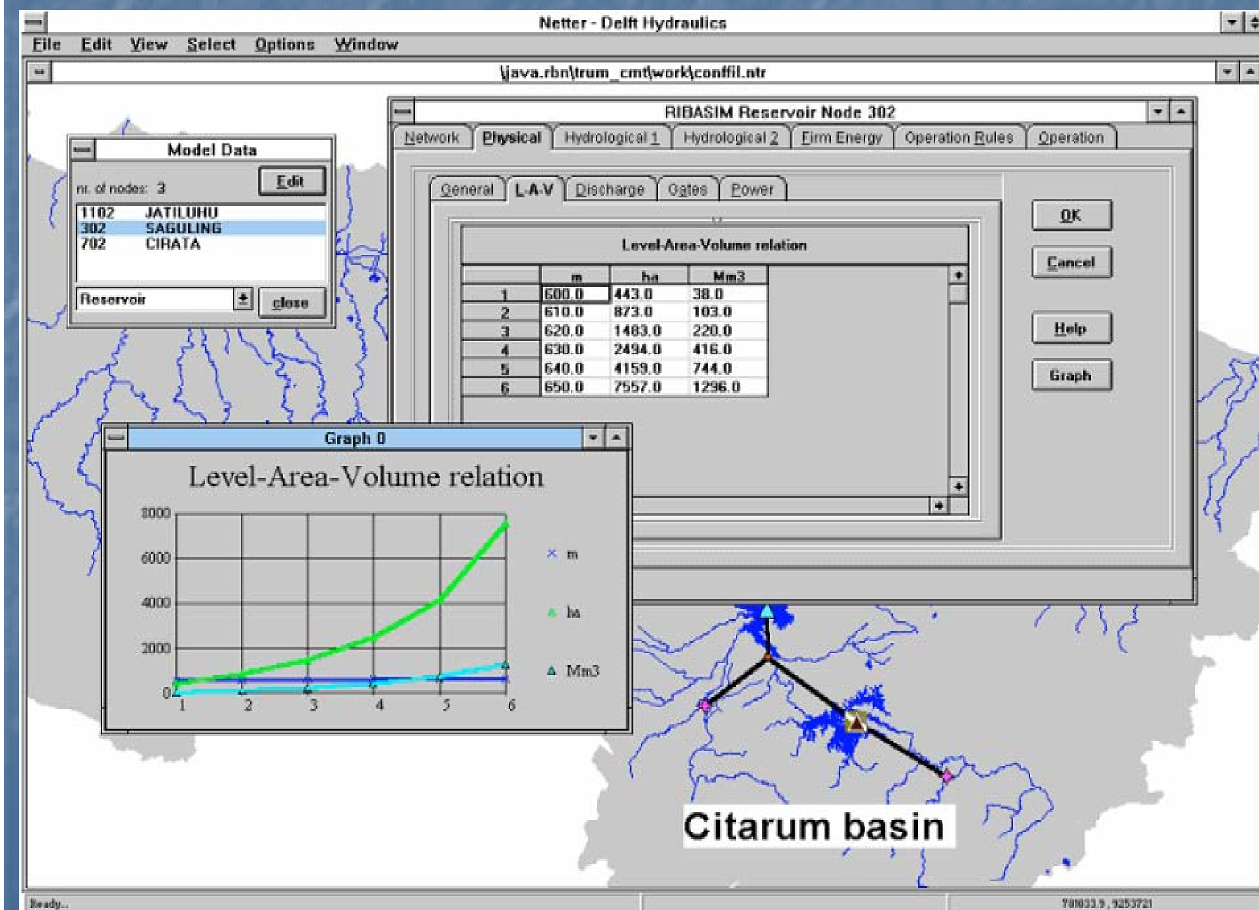
RIBASIM – Delft Hydraulics



PROS

Includes several models

Performs water allocation

CONS

Does not allow for Environmental and Socio-Economical impacts

Can import maps but does not provide GIS facilities

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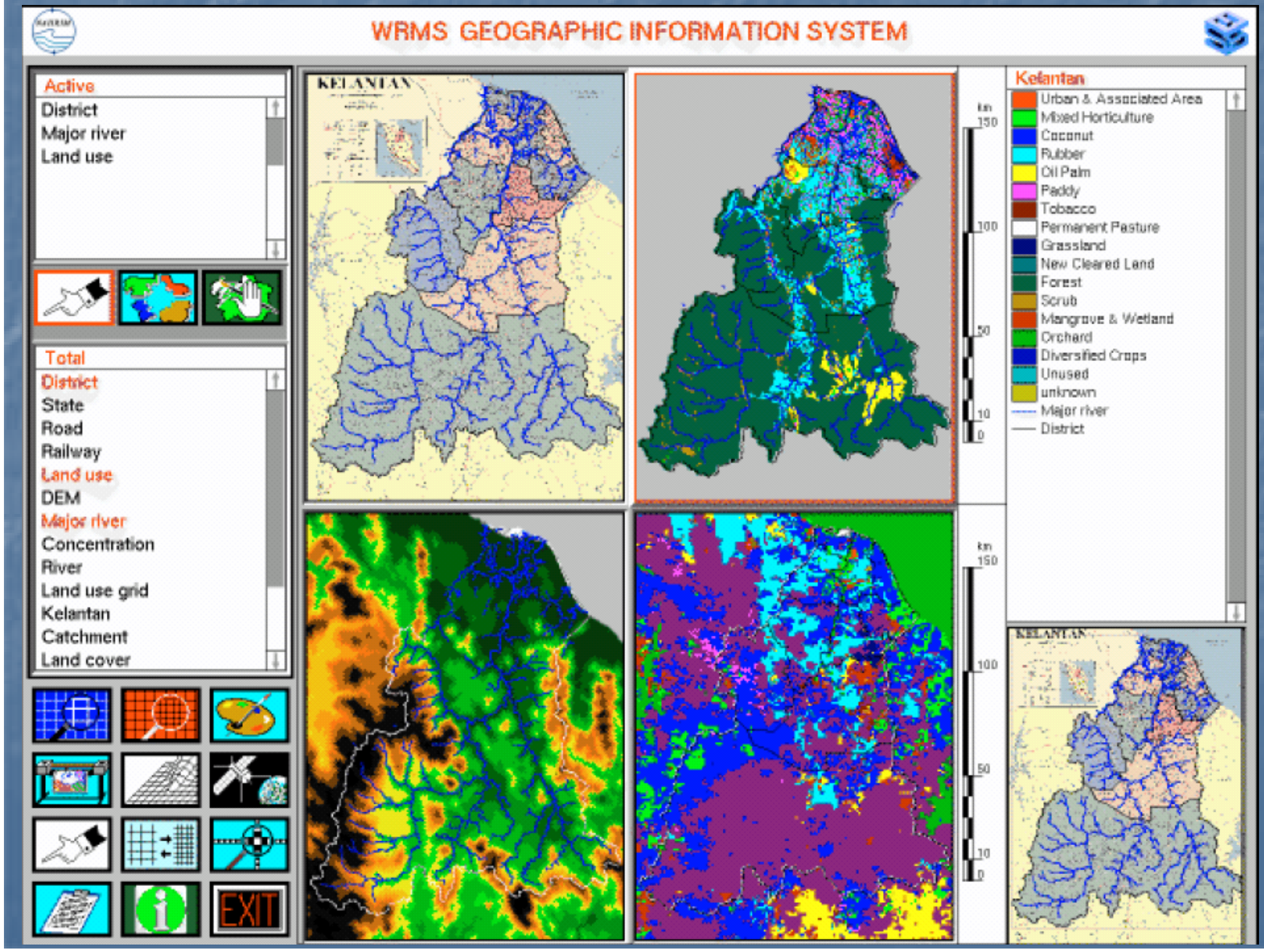
WATERWARE – Eureka 487



PROS
Incorporates GIS and DB
Open architecture

CONS
More information system than DSS

Integration of components very expensive

Scant documentation available

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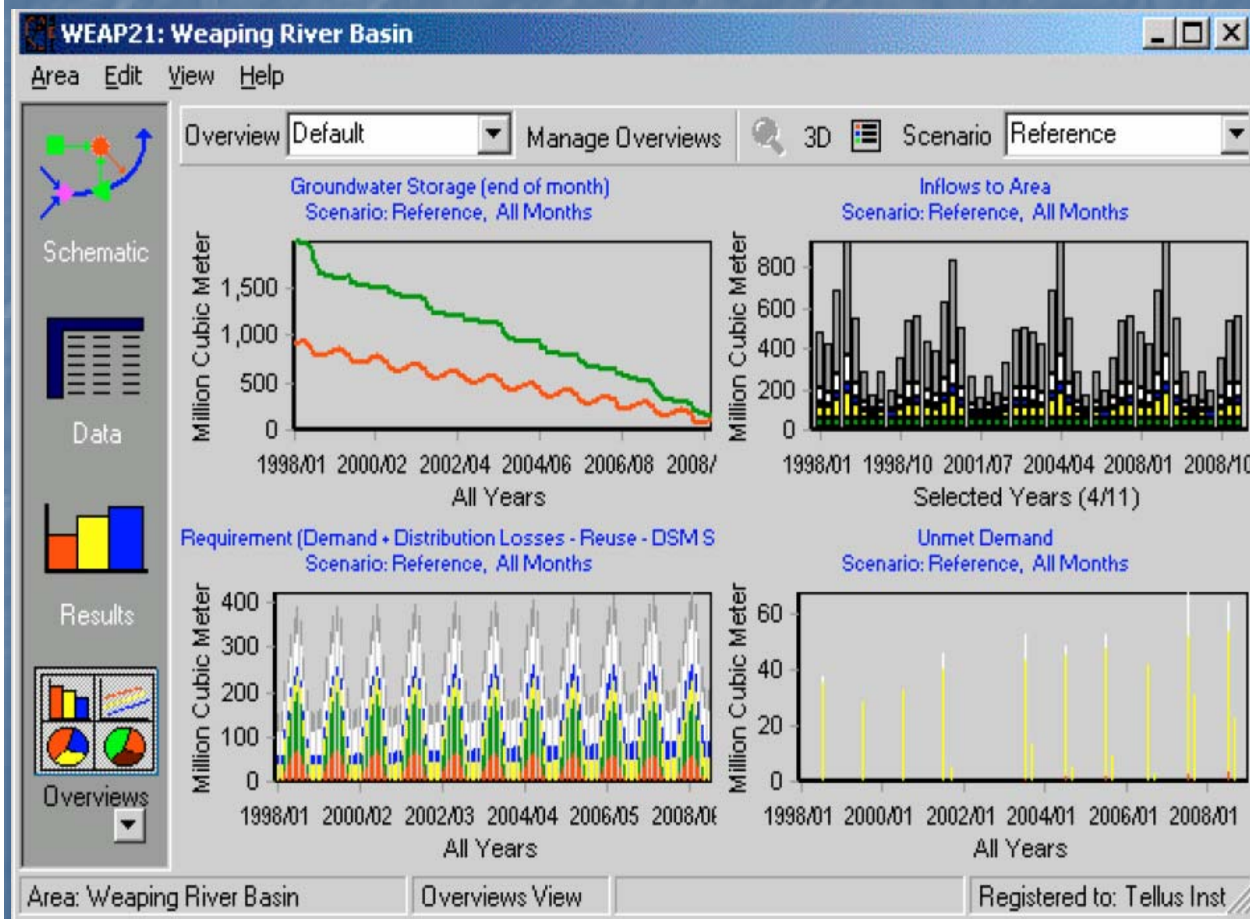
WEAP – Stockholm Institute



PROS
Comprehensive
Based on DPSIR concepts

CONS
Does not include GIS/DB

Water Demand cannot be updated through feedbacks at each time step

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A new tool: the WaterStrategyMan DSS

- A comprehensive Decision Support Tool
- Uses WFD and DPSIR concepts and approaches
- Fully imbedded in ARC-GIS
- Uses the ARC-GIS Geo-Database
- Includes interactive and user friendly graphical tools
- Includes default data, such as:

  1x1 km Geotopo30

  1x1 km FAO Soil Map of the World

  1x1 km Global Land Cover Characteristics Data Base

  10x10 km Monthly average climatology
- Allows for multicriteria analysis of indicators

The Water Strategy Man Team

National Technical University of Athens (Greece)
ProGeA – Protezione e Gestione Ambientale (Italy)
Ruhr University of Bochum (Germany)
Office International de l'Eau (France)
The Hebrew University of Jerusalem (Israel)
The Water Development Department (Cyprus)
INSULA (Spain)
The University of Porto (Portugal)

Objectives of the WSM DSS

- To support the strategy analysis at regional level
- To compare strategies on the basis of different indicators
- To help decision-makers to decide upon the best strategy, taking into account:
  - Regional development priorities
  - Social and economic constraints
  - Environmental constraints
  - Local, national or international legal constraints and directives

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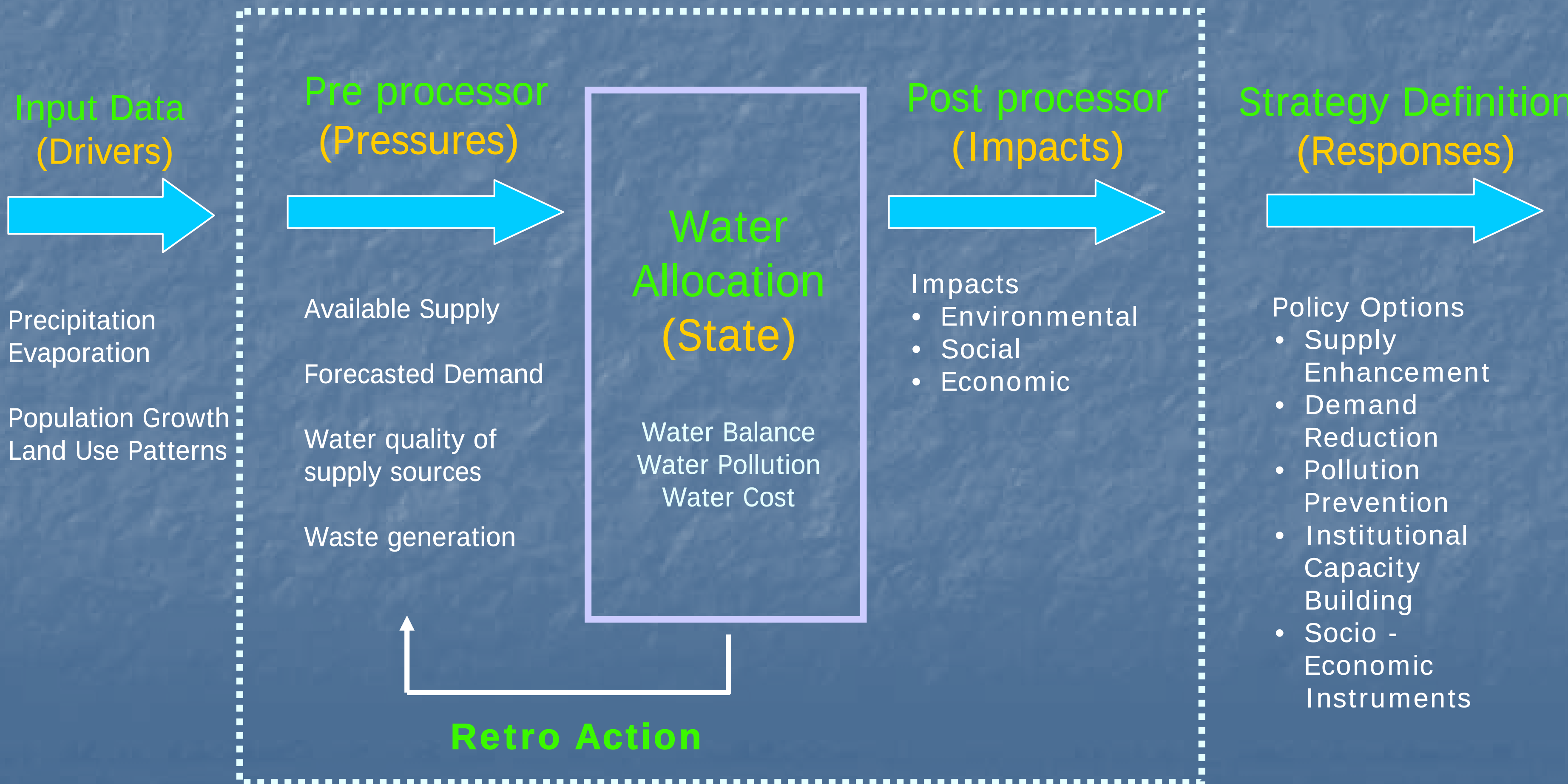
The WSM DSS Framework



The Four Main Functions of the DSS

- Describe the existing state of the water system
- Assess state in terms of:
  - Sources
  - Usage
  - Water cycles
  - Environmental quality
- Forecast state on the basis of:
  - Assumed or envisaged scenarios
  - Technical alternatives
  - Management policies and actions
- Evaluate impacts of actions

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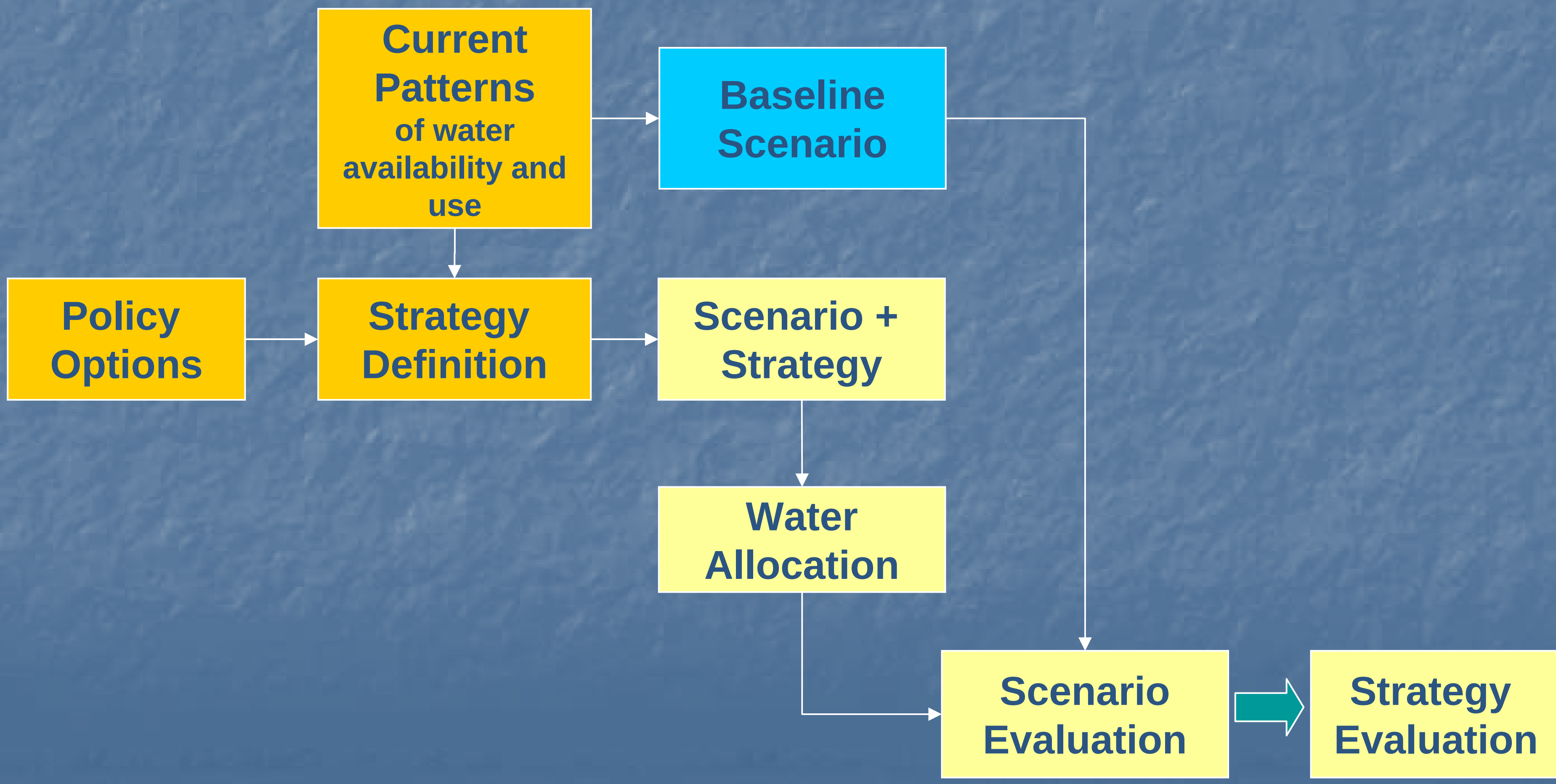
The Analysis Procedure



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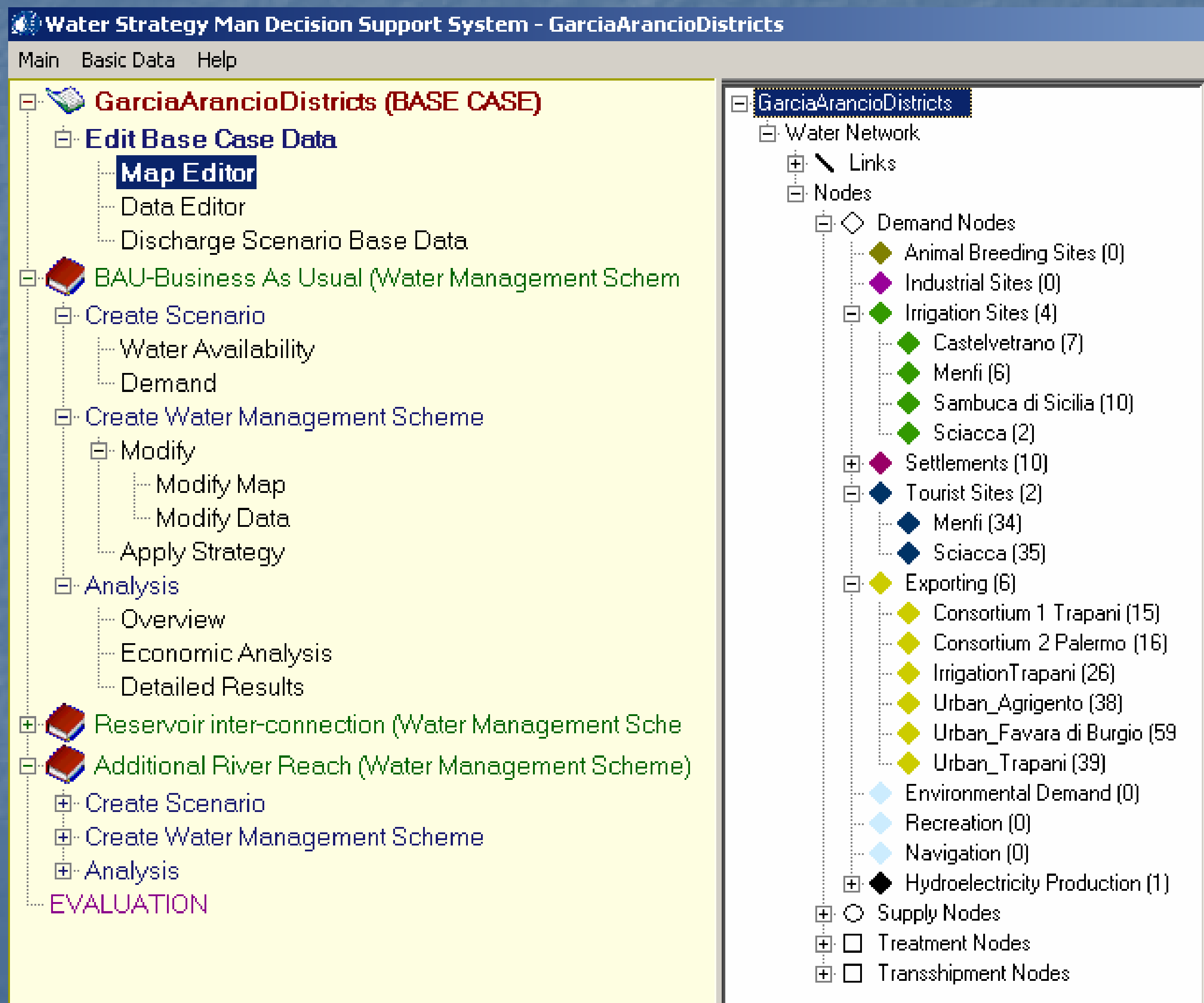

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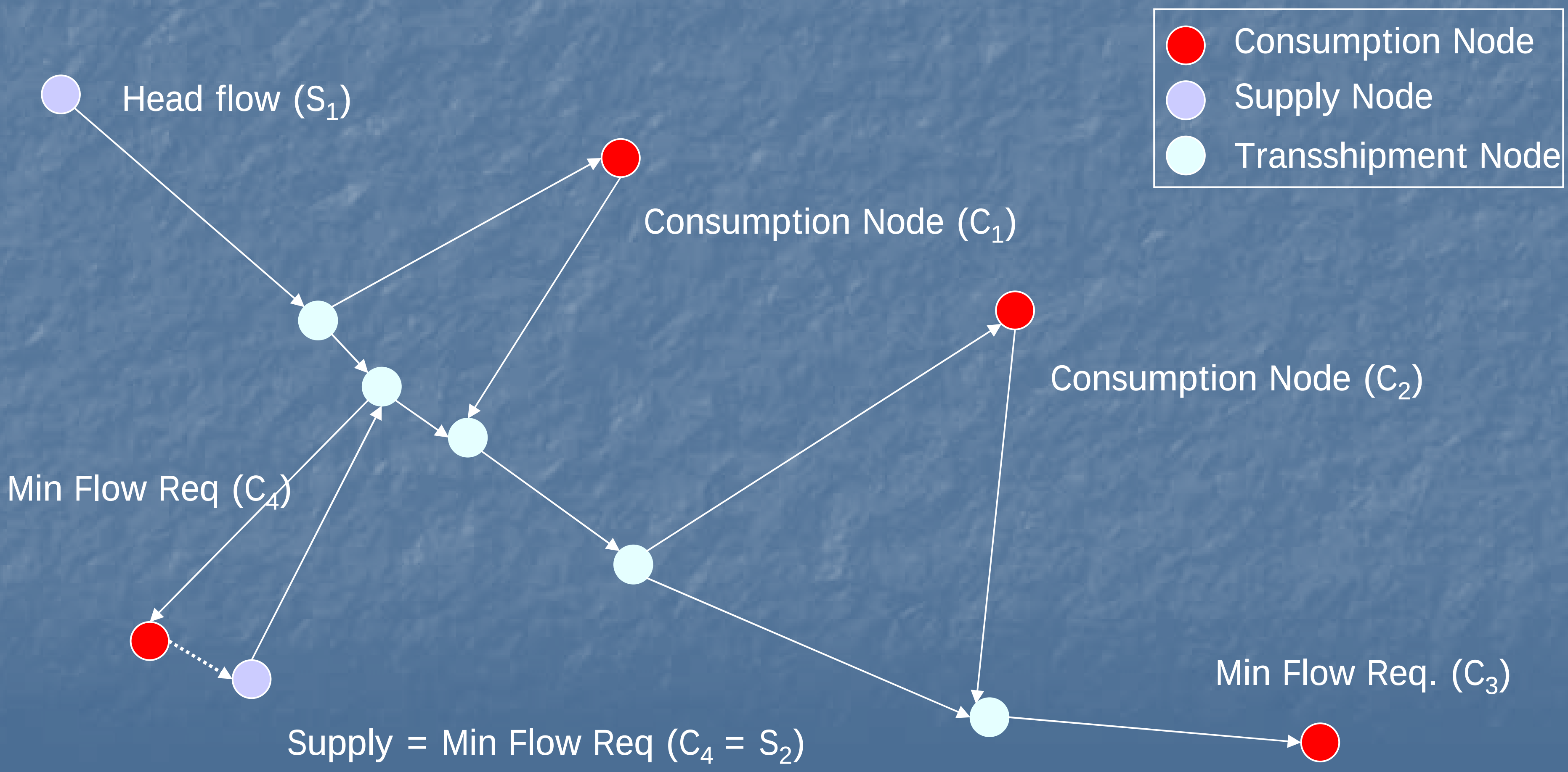
River Basin Schematization



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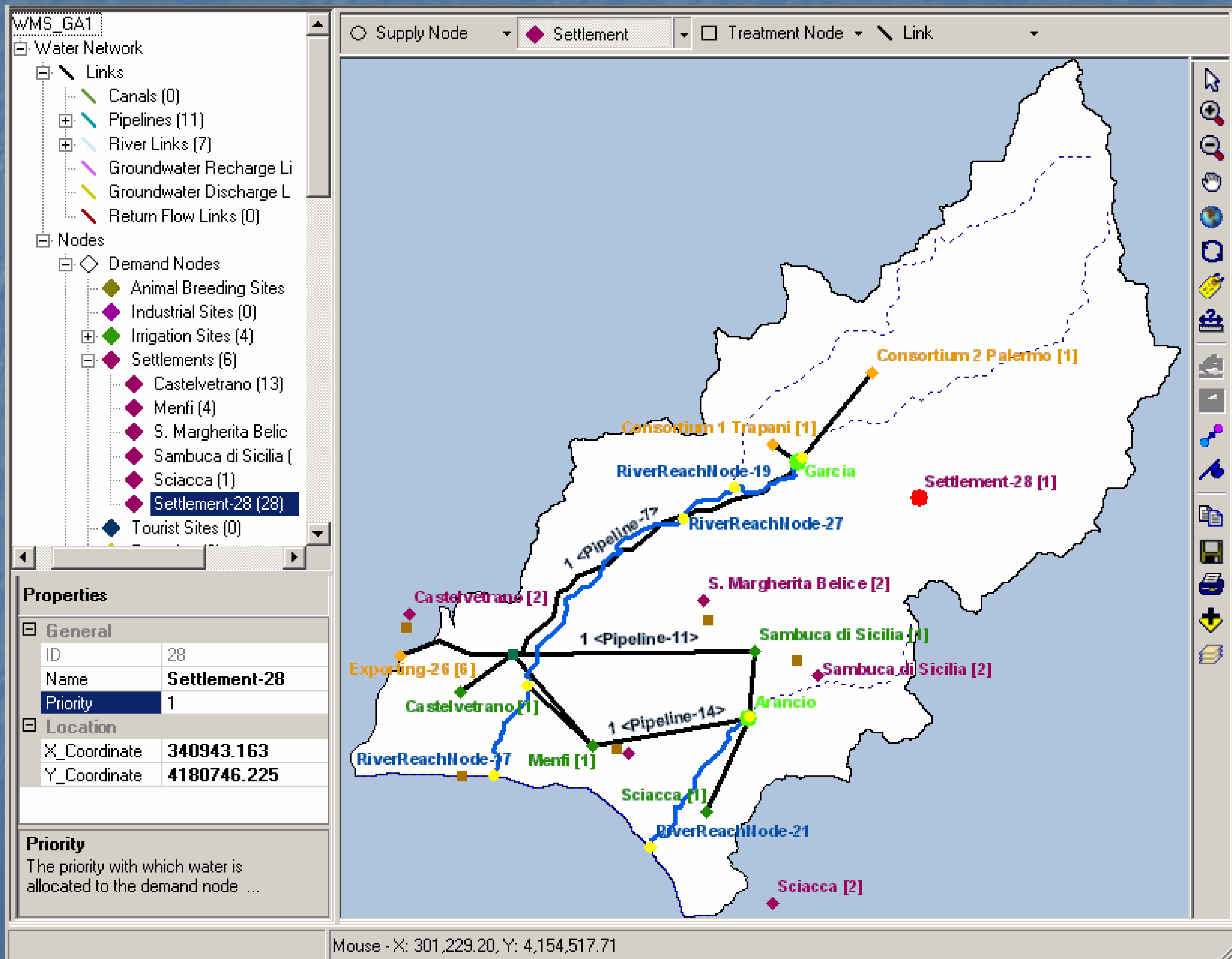

Generating hydrological scenarios

Hydrological scenarios can be directly generated from available hydrological data or by processing hydro-meteorological observations such as rainfall, temperature, evapotranspiration.

Scenarios can then be generated by:

- repeating the base year for the entire duration of the scenario,
- defining a monthly or yearly trend over the entire period,
- building up a sequence of previously created base years.

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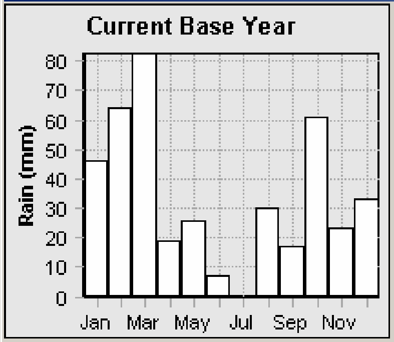
Rain Scenario Generation - Step 3: Selected Mode Parameters - Trend Definition



The third step of generating a scenario of rainfall allows you to specify the parameters for the selected mode.

In this window you can assign a trend in two ways:

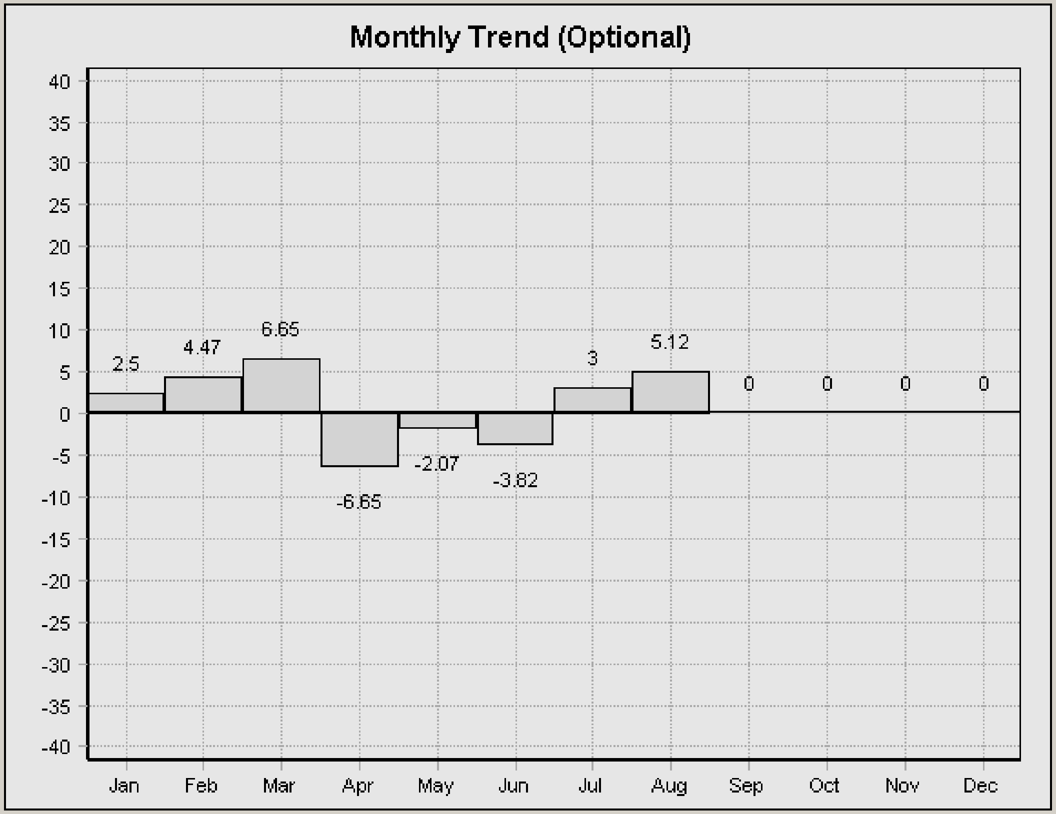
a) Define a total increment of rain (Rainfall Trend) in terms of percentage over the entire duration of the scenario. The monthly variation within the year is derived proportionally.

b) Define directly an increment of rainfall over the period for each month of the base year. In this case the "Rainfall Trend" you may have previously specified is ignored.

In both cases you can change the initial percentage of the base year (optional).

Current base year that has been previously selected is visualised in the top left corner of the window.

Rainfall Trend in the period: +30% **Percentage of base year:** 100%



Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
+2.5%	+4.47%	+6.65%	-6.65%	-2.07%	-3.82%	+3%	+5.12%	0%	0%	0%	0%

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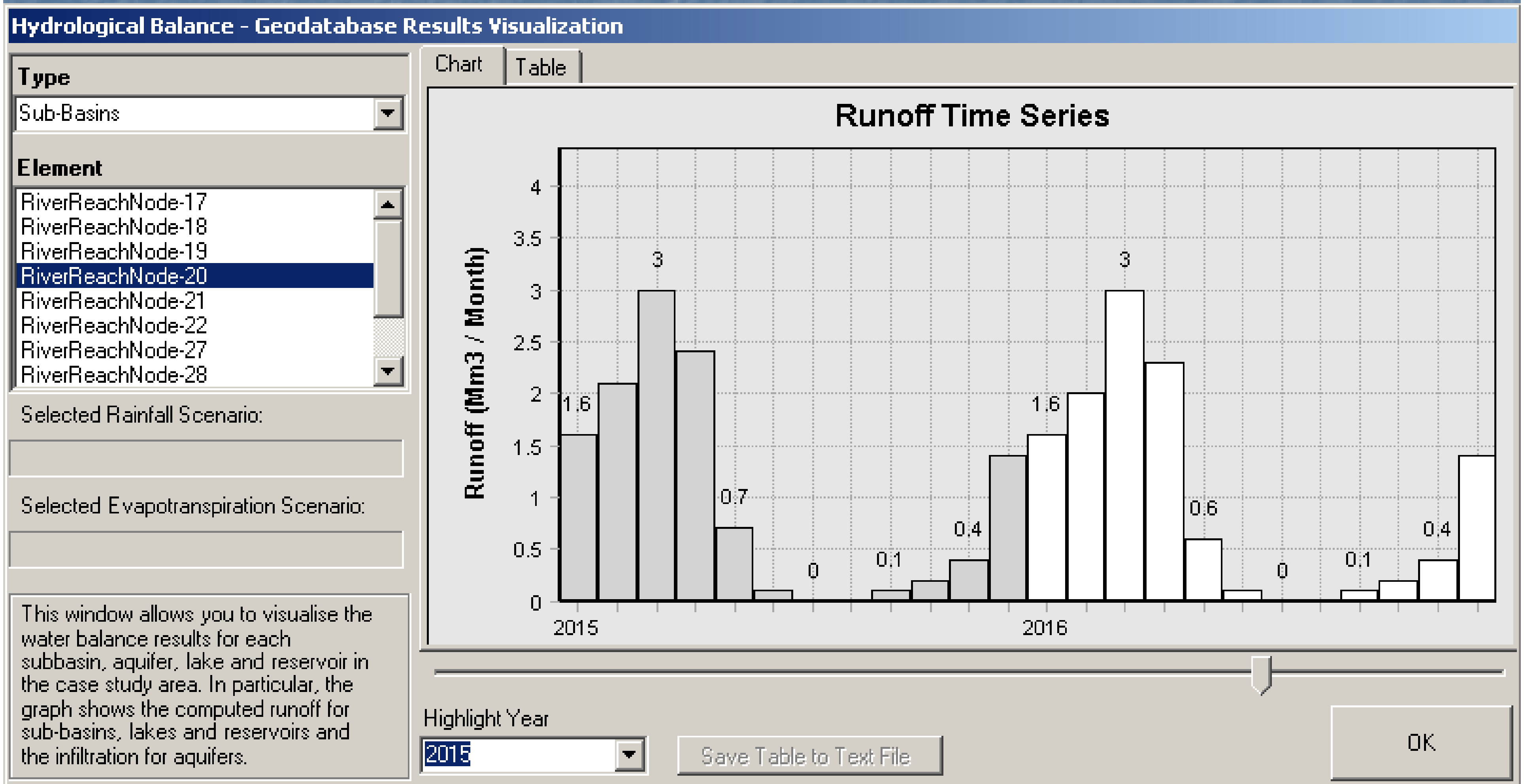

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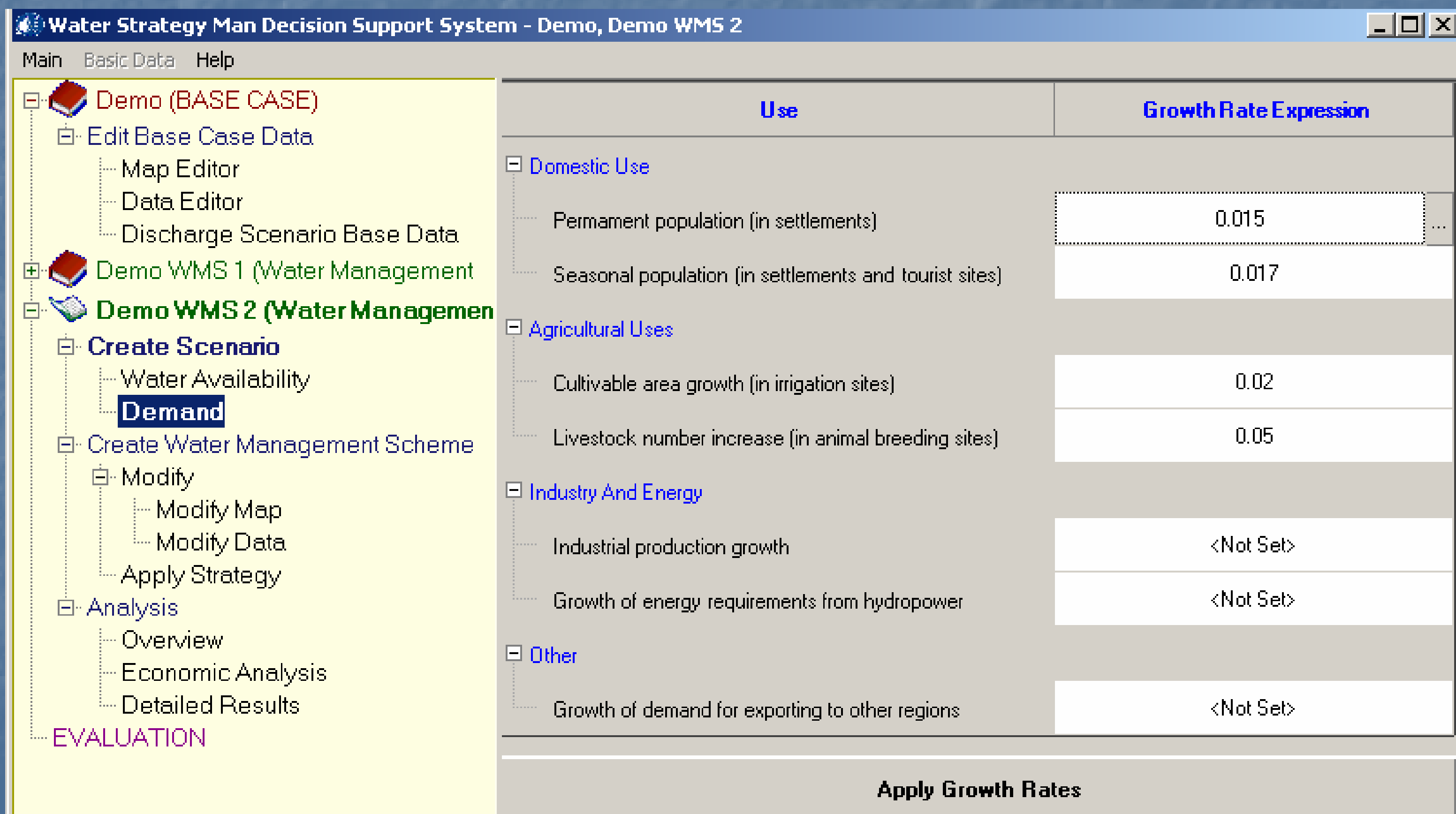
Generation of demand scenarios on population growth rates



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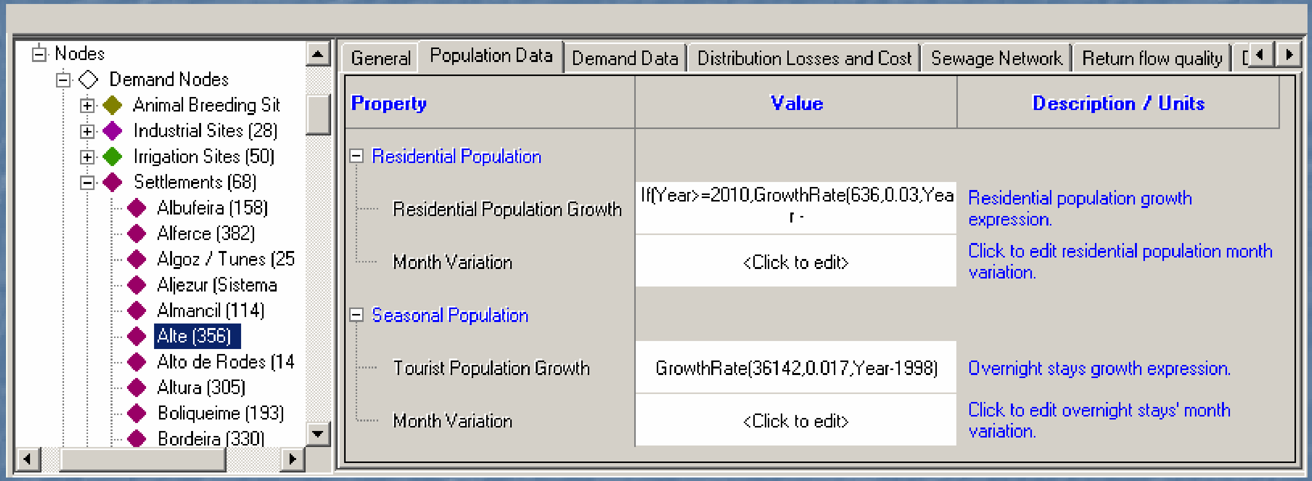
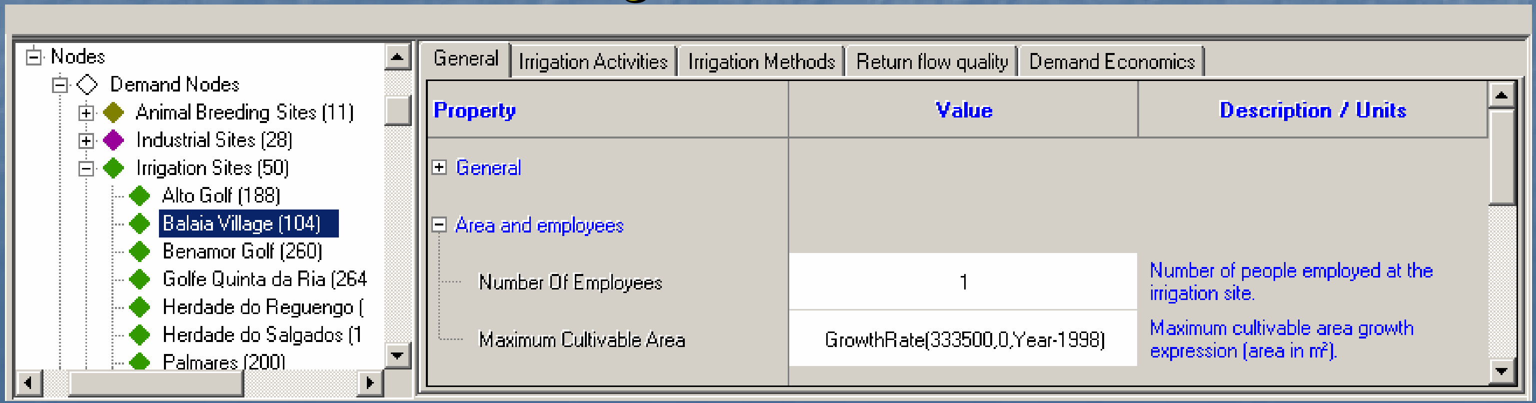
or on seasonal patterns

Settlements



Irrigation Sites



Policy Options and Actions

POLICY OPTIONS	ACTIONS
A. Supply Enhancement	A1. Unconventional/untapped resources A2. Surface Waters and precipitation (direct abstraction, dams, reservoirs) A3. Groundwater (drillings, wells) A4. Desalination A5. Importing A6. Water Reuse
B. Demand Management	B1. Quotas, Regulated supply B2. Irrigation method improvements (drip irrigation, enclosures) B3. Conservation measures in the home (water saving plumbing systems) B4. Recycling in industry and domestic use B5. Improved infrastructure to reduce losses (networks, storage facilities) B6. Raw material substitution and process changes in industry
C. Social–Developmental Policy	C1. Change in agricultural practices (low irrigation crops, genetic improvement) C2. Change of regional development policy (tourism/agriculture limitation)
D. Institutional Policies	D1. Institutional Capacity Building (Education and awareness campaigns, Use of standards, Public participation, Stakeholder involvement, Conflict resolution, Contingency planning) D2. Economic Policies (Water pricing, Cost recovery, Incentives) D3. Environmental Policies (Enforcement of environmental standards and legislation, Monitoring, Penalties and fines, Impact and risk assessment)

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The Strategy Definition

ACTIONS	Strategy OPTIONS							
	Demand Management		Supply Enhancement		Institutional Capacity Building		Socio-Economic Instruments	
1	Household conservation		Importing water		Organizational mobilization		Cost recovery	
2	Losses reduction		Surface storage		Institutional/ Legal amendments		…	
3	…		Reuse		…		…	
…	…		…		…		…	

STRATEGY 1

STRATEGY 2

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Scenario+Strategy Evaluation

- Evaluation is based on indicators for:
  - Sustainability of water resources
  - Social/Economic benefits for water uses
  - Environmental impacts on water resources
  - Compliance with legal, economic and environmental constraints

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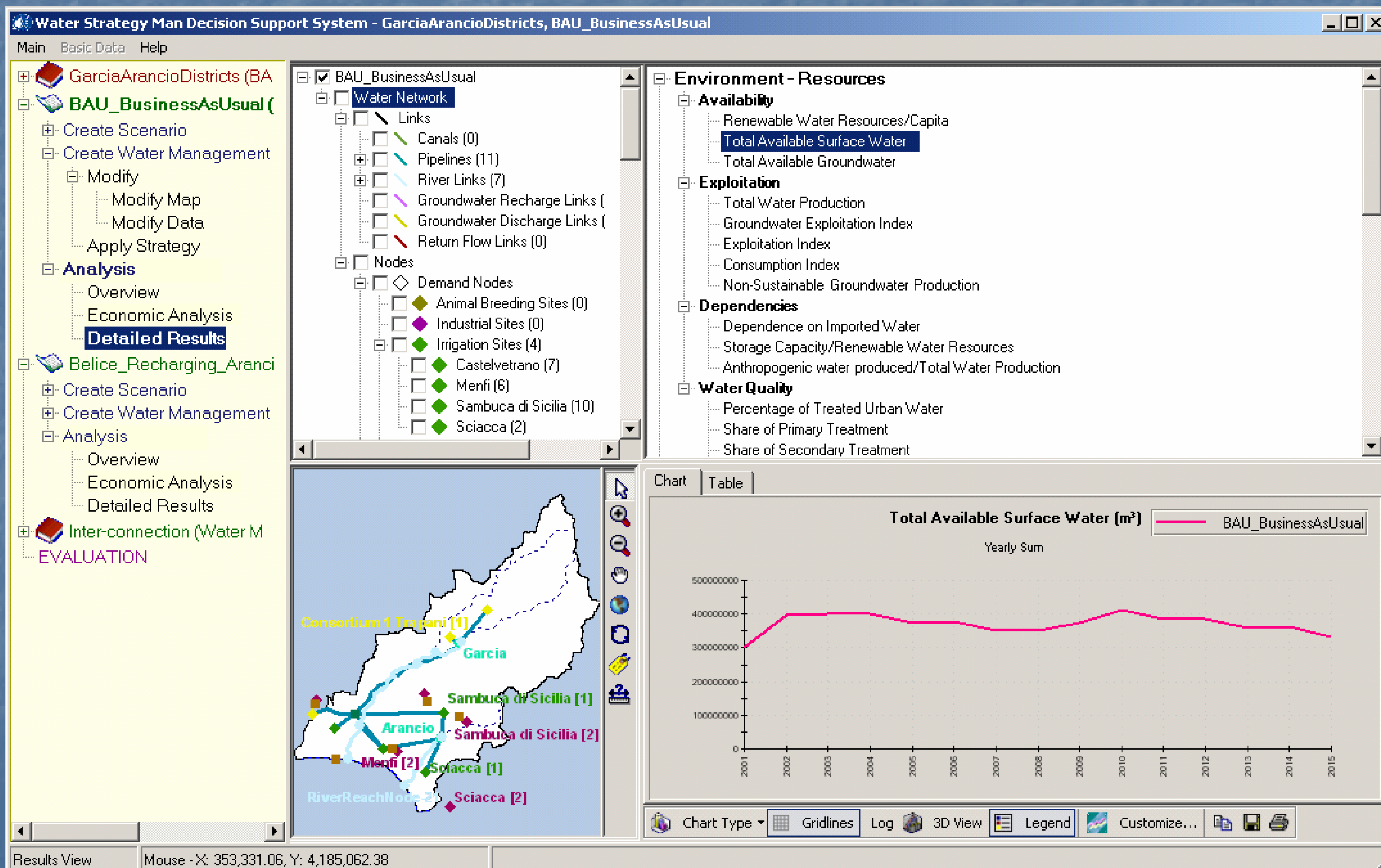
Analysis of results with reference to BAU



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Performance at node level

- Pollution
  - Concentrations of fecal coliform counts in water bodies
  - Concentrations of BOD / COD in water bodies
  - Heavy metal concentrations in water bodies
  - Decrease in effluent volume (%)
  - Reduced pollution levels in water bodies after wastewater treatment
- Demand
  - Increase in potable water (%)
  - Reduction of actual water consumption (%)
- Economics
  - Increase of income (%)

Performance at regional level (1)

- Sustainability of resources
  - Increased water availability with respect to baseline scenario (%)
  - Amount of groundwater reserves vs annual groundwater withdrawals
  - Annual regional water consumption (m3/cap)
  - Exploitation index
- Demand
  - Consumption Index
  - Dependence on importing (%) – on upstream
  - Coverage of water demand per sector
- Water quality
  - Increased amount of treated wastewater (%)
  - Area irrigated with treated effluent (%)
  - Improved drinking water quality (% of population)

Performance at regional level (2)

- Economics
  - Rate of cost recovery
  - Increased tourism revenues (%)
  - Increased revenues from agriculture
  - Increased revenues from industry etc
  - Total Cost
    - Direct Cost
    - Opportunity Cost
    - Environmental Cost
- Environment
  - Average monthly BOD in freshwater resources
  - Average monthly nitrogen in freshwater resources
  - Average monthly phosphorus in freshwater resources

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	Supply Nodes	User Nodes	Treatment Plants
Drivers	x	x	
Pressures			
Supply	x		x
Demand		x	
State			
Shortage		x	
Quality	x	x	x
Availability	x	x	
Impacts			
Social			
Health etc		x	x
Economic Impact		x	
Ecosystems	x		

Scenario

Evaluation

Matrix

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Strategy Evaluation Matrix

Impacts	Baseline Scenario	Scenario 1	Scenario 2
Social Impacts	…	…	…
Health etc	…	…	…
Economic Impact	…	…	…
Ecosystems	…	…	…
OVERALL PERFORMANCE	…	…	…

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CONCLUSIONS

The concept of sustainability radically changed the IWR planning approaches from optimisation to scenario simulation analysis

The WaterStrategyMan Project has produced a new Comprehensive Decision Supporting Tool aimed at coping with the emerging requirements.

It is hoped that the new tool, already tested on several European case studies, will be extensively applied and evaluated over several other catchments for further improvements based on users experience.

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Detailed description of the WSM DSS

was distributed to all the participants

Full project description can be found at

http://environ.chemeng.ntua.gr/wsm/

Thank you for your attention