Red Mediterránea de Organismos de Cuenca - REMOC

Valencia
November 2003

Seminario sobre Planificación y D.M.A.

Los sistemas de apoyo a la decisión en la planificación y gestión

by **Joaquin Andreu**

Water Resources Engineering Research Group
Institute for Water and Environmental Engineering (IIAMA)
Universidad Politécnica de Valencia (SPAIN)

e-mail: ximoand@ upv.es

www.upv.es/iiama/ www.upv.es/aquatool/

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WFD and Spanish Water Laws

EC WATER FRAMEWORK DIRECTIVE

- **Society demands:**
  - **Safe supply of water for drinking**
  - **&Other socio-economic activities**
  - **Alleviation of adverse impacts on floods and droughts**
  - **Protection of environment:**

EC WATER FRAMEWORK DIRECTIVE

- **Objective: Good status of all inland surface and groundwater and estuarine and coastal waters:**
  - **Ecological status of surface waters**
  - **Quantitative status of groundwater**
  - **Chemical status of all waters**

Spanish Water Law

- general objectives of the planning process:
  - to reach a good ecological status of inland waters
  - satisfy the water demands
  - equilibrated development for sectors and regions.
- All this, by means of :
  - water quality protection
  - rational development of the resource
  - rational use in harmony with environment and other natural resources.

Multi-objective Water Conflicts: need for DSS

MULTIPLE OBJECTIVES

- Process to take good decisions needs ADEQUATE INFORMATION:
  - feasible alternatives
  - impact on the multiple objectives
  - tradeoffs among them
  - risk associated with them
- In order to elaborate and analyze such information, sound science, technology, and expertise have to be implicated:

MULTIPLE OBJECTIVES

- policymakers and stakeholders are not prepared to produce and understand such information
- transfer of technology from scientist to decision makers is needed
- effective transfer:
  - decisions makers be able to apply the technology easily and in a repeatable and scientifically defensible manner
- Not an easy task:
  - Many aspects (e.g. physical, hydrological, chemical, biological, socioeconomic, institutional, legal, etc.)
  - all are expected to be integrated in the analysis

INTEGRATED PLANNING & MANAGEMENT

- In modern w.r. development all sources and aspects have to be considered in an integrated way, including the
- Conjunctive Use of Surface and Ground Water:
  - joint planning & management of surface and groundwater resources for the purpose of ensuring that the total benefits of such a system exceed the sum of the benefits that would result from separated management.

TOOLS FOR INTEGRATED RIVER BASIN MANAGEMENT

- Models (traditional)
- Additional effort to make them available to Decision Makers and stakeholders (& public):
  - Better and more user friendly
  - Include most components of extremely complex WS
  - estimate the effect of management alternatives on all the criteria of interest

Take into account:

- UNCERTAINTIES
  - CLASSICAL
    - USES
    - DEMANDS
    - RESOURCES, ...
  - OTHER
    - CLIMATIC CHANGE
    - SOCIETY, ...

Evaluate:

- RISK inherent to our decisions

DECISION SUPPORT SYSTEMS

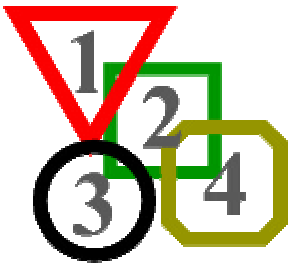
- Suites of computer programs including:
  - design facilities
  - databases handling
  - simulation and/or optimization models
  - capabilities for analyzing and displaying the results
- in a unique and user friendly control framework

DECISION SUPPORT SYSTEMS

- **Many examples in the literature**
- **BUT:**

  "Although this idea (DSS) was a promising one, preciously few of these systems have come to fruition and are actually used on a regular basis" (Rietma et alt., 1996)
- Some applications of DSS in Spain for WRS P&M, and a generalized DSS framework

AQUATOOL:



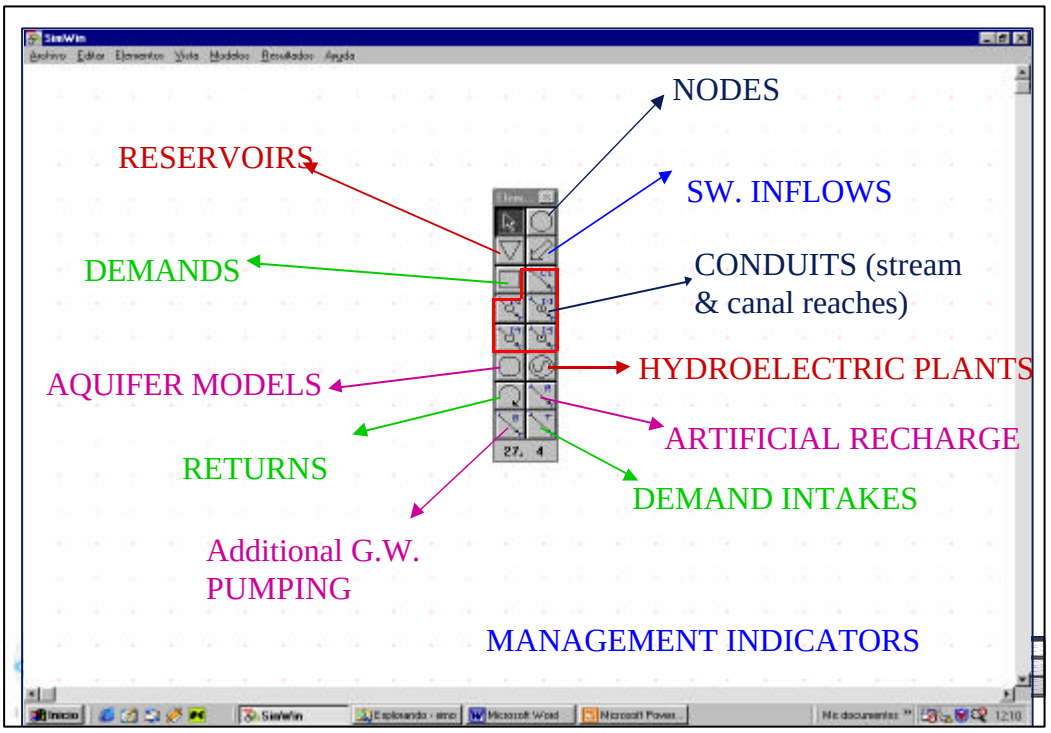
DSS designed for integrated management of complex water resource systems including CONJUNCTIVE USE OF SURFACE AND GROUND WATERS

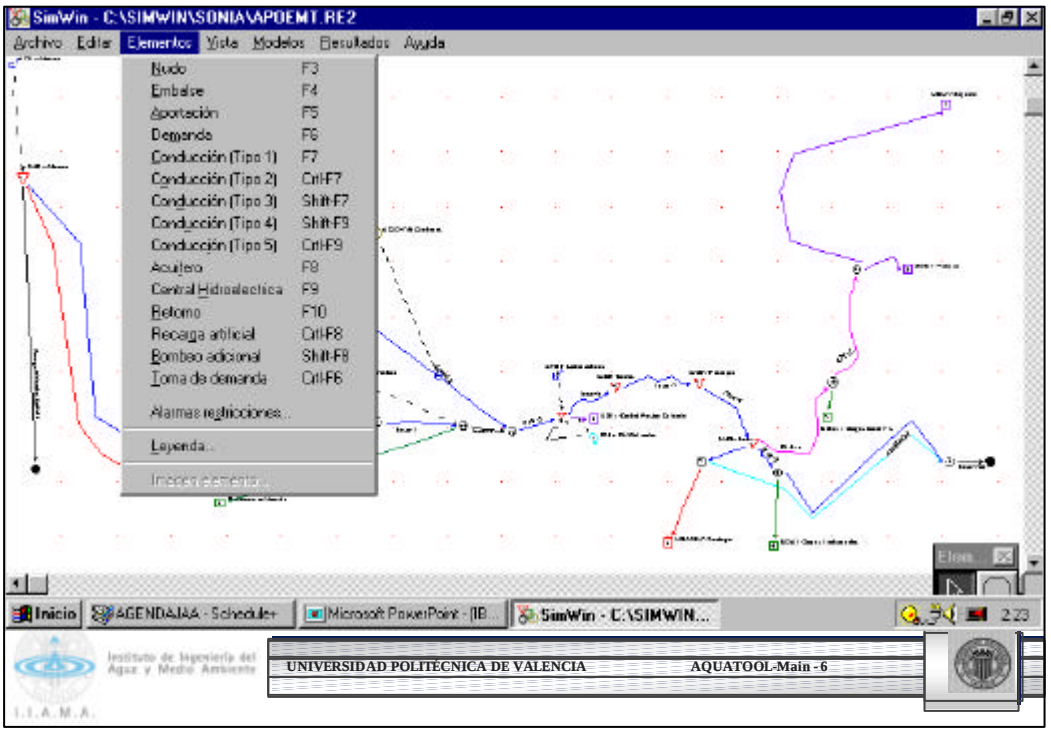
J. Andreu, J. Capilla, y E. Sanchis, "Generalized decision support system for water resources planning and management including conjunctive water use", *Journal of Hydrology*, Vol. 177, pp. 269-291, 1996.

Components and functions:

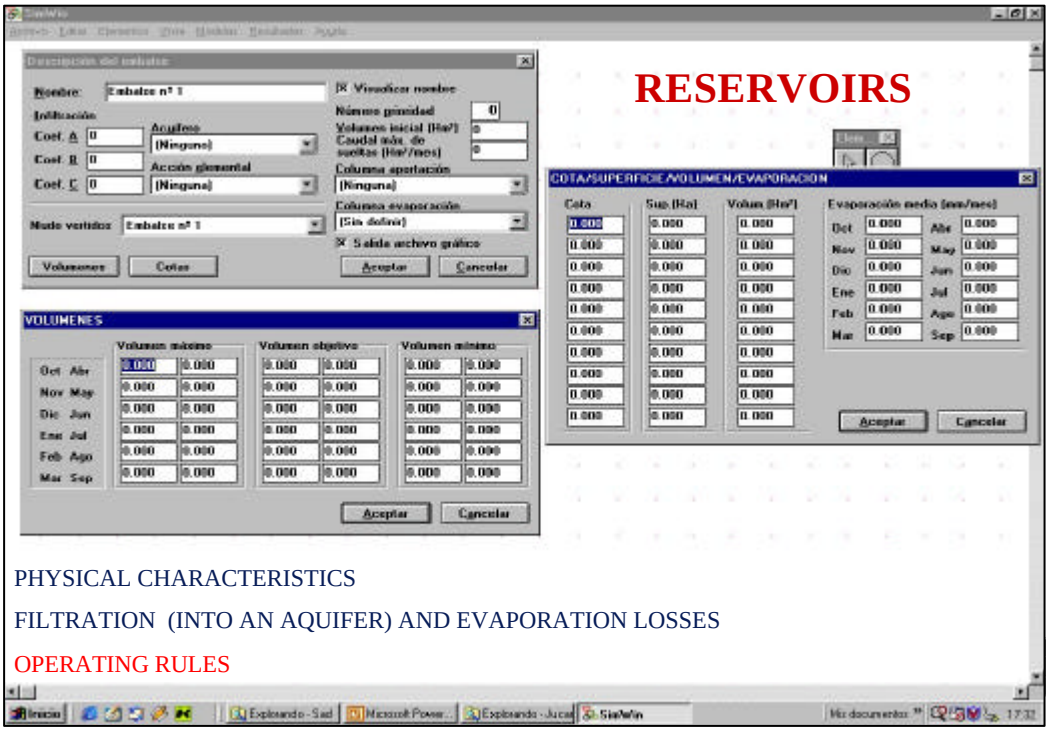
- basin management simulation module
- basin management optimization module
- aquifer flow modeling module
- stochastic hydrological modeling module
- future hydrological scenarios generation module
- modules for risk assessment
- modules for analysis and report of results
- first level control units including:
  - graphical design
  - database management
  - control the execution of the models
  - access to the modules for analysis and report of results
- Microsoft Windows Environment (zero level control unit):
  - coordinates the various components of the system
  - interfaces with users, files and peripheral hardware

- **The DSS allows the user to:**
  - **Input and modify the space configuration of a water resource system**


NODES
RESERVOIRS
SW. INFLOWS
DEMANDS
CONDUITS (stream & canal reaches)
AQUIFER MODELS
HYDROELECTRIC PLANTS
ARTIFICIAL RECHARGE
RETURNS
DEMAND INTAKES
Additional G.W. PUMPING
MANAGEMENT INDICATORS


SimWin - C:\SIMWIN\SONIA\APDEMT.RE2
Archivo Editar Elementos Vista Modelos Resultados Ayuda
Nudo F3
Embalse F4
Aportación F5
Demanda F6
Conducción (Tipo 1) F7
Conducción (Tipo 2) Ctrl-F7
Conducción (Tipo 3) Shift-F7
Conducción (Tipo 4) Shift-F9
Conducción (Tipo 5) Ctrl-F9
Acuífero F8
Central Hidroeléctrica F9
Retorno F10
Recarga artificial Ctrl-F8
Bombeo adicional Shift-F8
Toma de demanda Ctrl-F6
Alarmas restricciones...
Leyenda...
Inicio
AGENDAIAA - Scheduler
Microsoft PowerPoint - [D...
SimWin - C:\SIMWIN...
UNIVERSIDAD POLITECNICA DE VALENCIA
AQUATOOL-Main - 6

- **The DSS allows the user to:**
  - Input and modify the space configuration of a water resource system
  - **Edit and manage geo-referenced data bases containing physical characteristics, management characteristics**



PHYSICAL CHARACTERISTICS

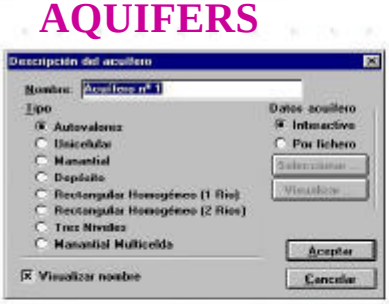
FILTRATION (INTO AN AQUIFER) AND EVAPORATION LOSSES

OPERATING RULES

SURFACE-GROUND WATER INTERACTIONS

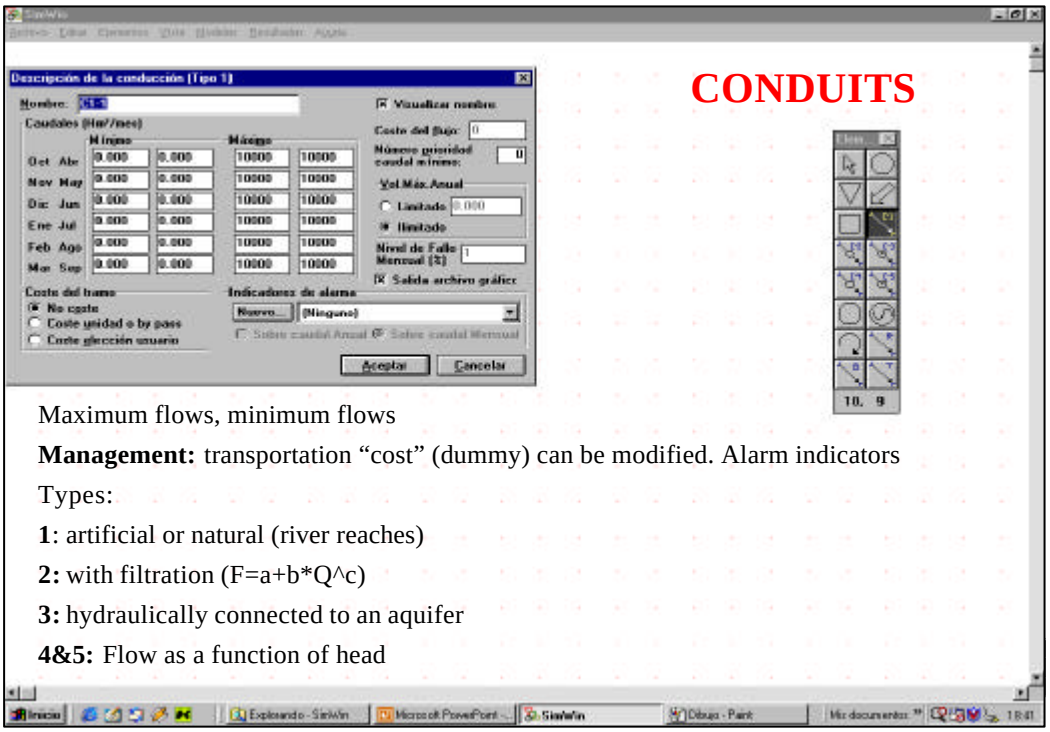
- Pumping from demands
- Additional pumping (drought wells)
- Filtration from streams, canals, reservoirs, irrigation, ...
- Hydraulic connection
- Artificial recharge

AQUIFERS



- Wide range of models available to embed aquifers in the basin model:
  - Lumped approaches:
    - » Reservoir
    - » Single cell connected to stream
    - » Single cell with spring
    - » Multiple cells connected to stream
  - Distributed approaches:
    - » Analytical solution for homogeneous & rectangular shape
    - » Numerical solution for heterogeneous and / or irregular shape:
      - AQUIVAL module

CONDUITS



Maximum flows, minimum flows

Management: transportation "cost" (dummy) can be modified. Alarm indicators

Types:

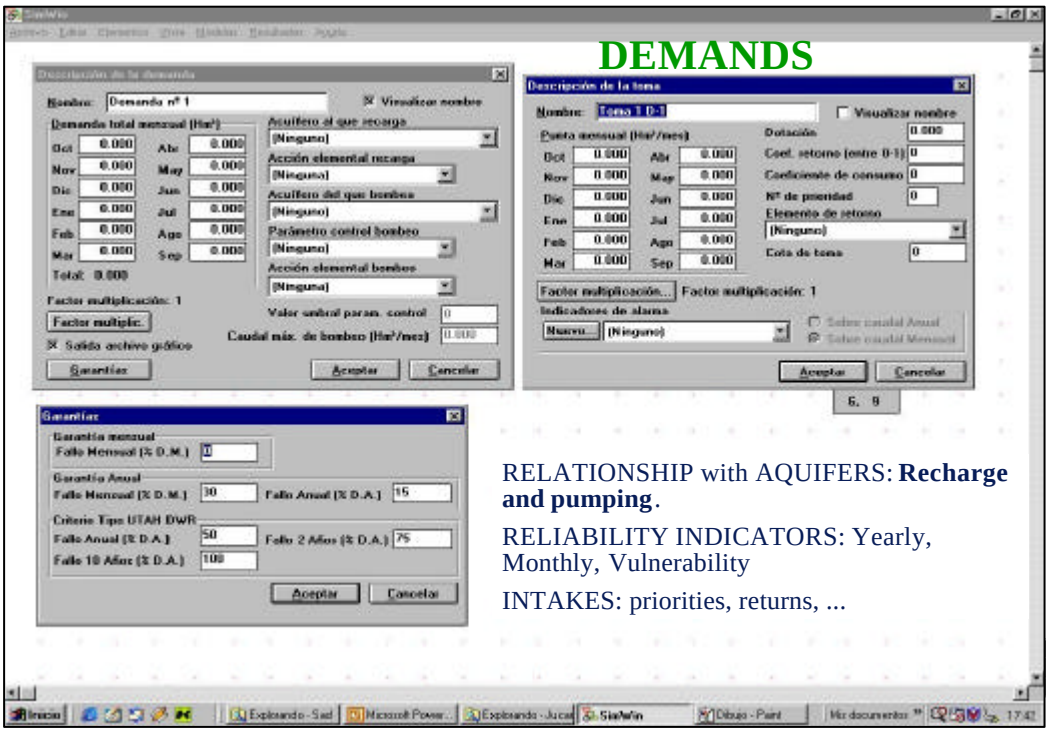
1: artificial or natural (river reaches)

2: with filtration (F=a+b*Q^c)

3: hydraulically connected to an aquifer

4&5: Flow as a function of head

DEMANDS

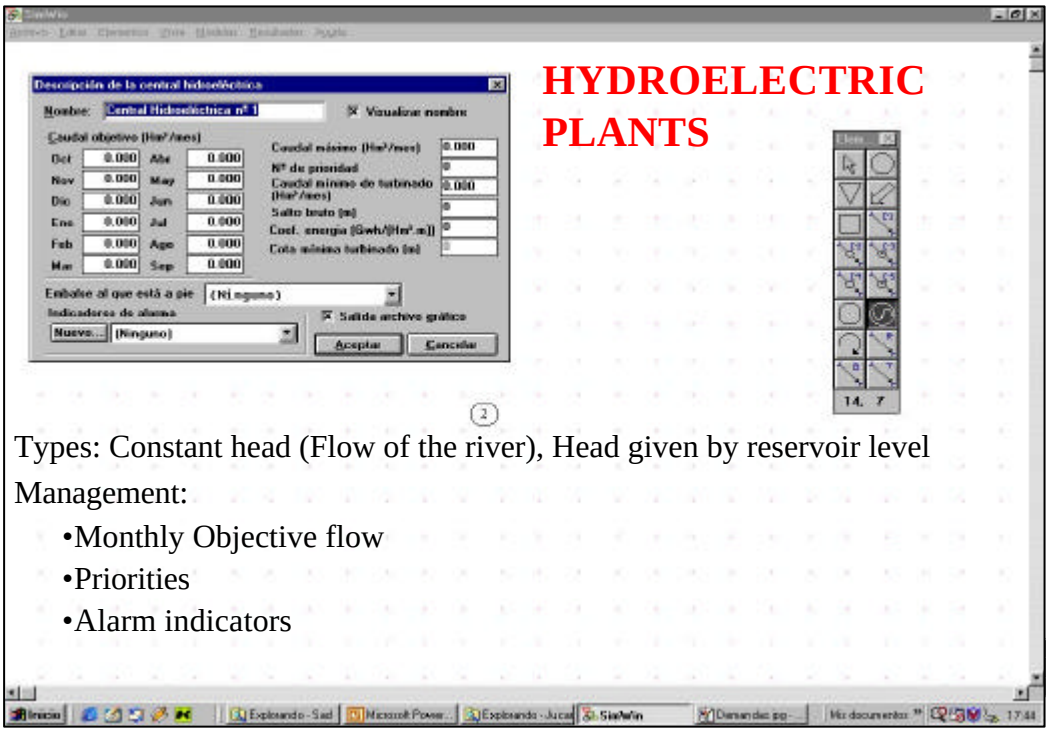


RELATIONSHIP with AQUIFERS: **Recharge and pumping**.

RELIABILITY INDICATORS: Yearly, Monthly, Vulnerability

INTAKES: priorities, returns, ...

HYDROELECTRIC PLANTS

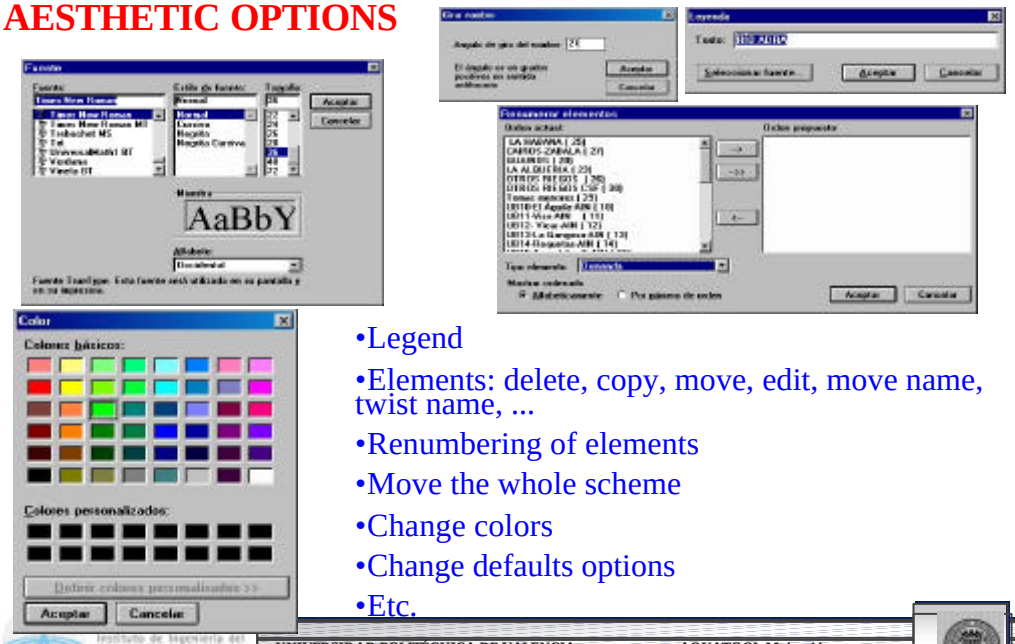


Types: Constant head (Flow of the river), Head given by reservoir level

Management:

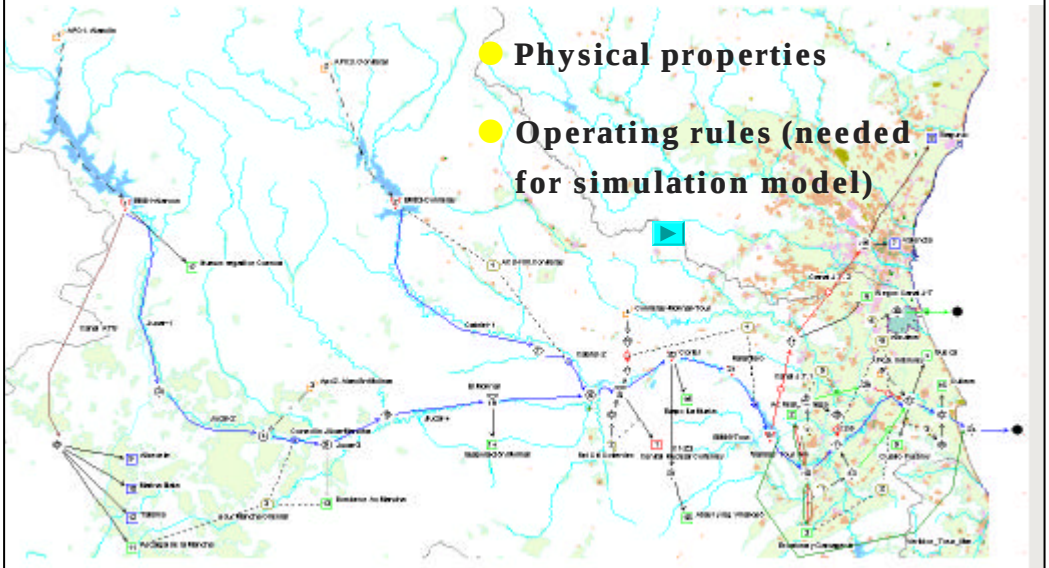
- Monthly Objective flow
- Priorities
- Alarm indicators

AESTHETIC OPTIONS



- Legend
- Elements: delete, copy, move, edit, move name, twist name, ...
- Renumbering of elements
- Move the whole scheme
- Change colors
- Change defaults options
- Etc.

Integrated Basin model: Jucar Basin



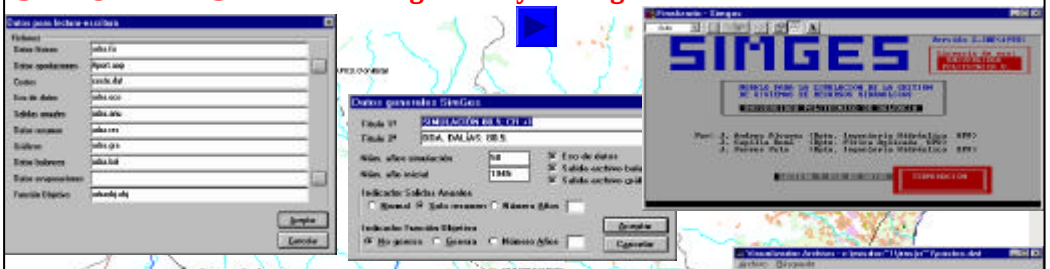
- Physical properties
- Operating rules (needed for simulation model)

The DSS allows the user to:

- Input and modify the space configuration of a water resource system
- Edit and manage geo-referenced data bases containing physical characteristics, management characteristics
- **Simulate or optimize the management for a single hydrological inflows scenario, (historical, synthetic) or for multiple scenarios.**
- **Obtain written reports**
- **Obtain graphs with time series and mean values of the results**

SIMULATION

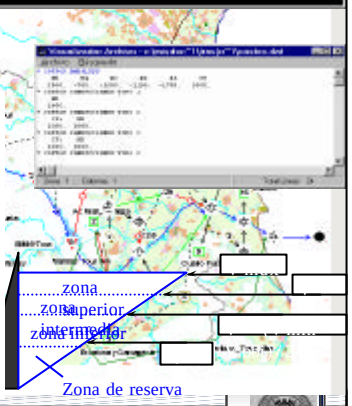
for given hydrologic inflows scenarios



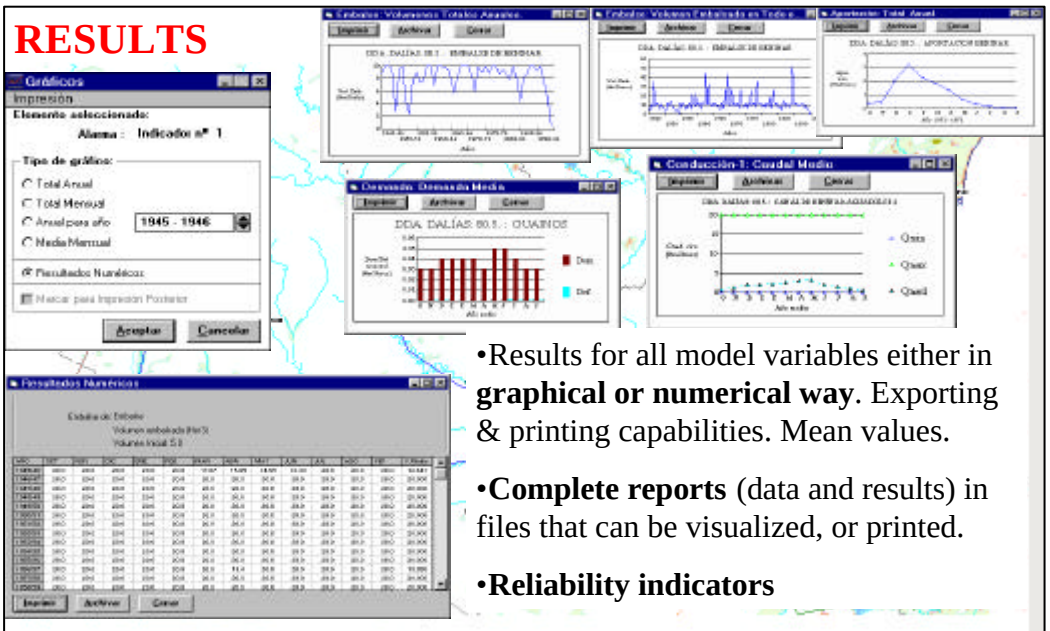
INTERNAL PROCESS:

In every month, a network flow optimization algorithm (Out-of-kilter) finds a flow solution which is compatible with the physical restrictions, and tries to minimize weighted deviations from operating rules (Target supplies, flows, and reservoir storage); respecting priorities.

Iteration is needed to take into account non-linearities and surface-groundwater relationships.



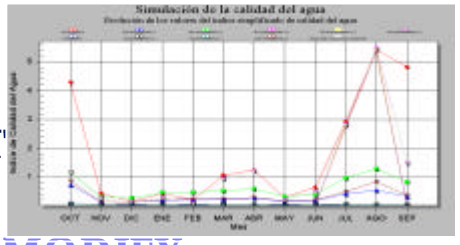
RESULTS



- Results for all model variables either in **graphical or numerical way**. Exporting & printing capabilities. Mean values.
- **Complete reports** (data and results) in files that can be visualized, or printed.
- **Reliability indicators**

WATER QUALITY SIMULATOR

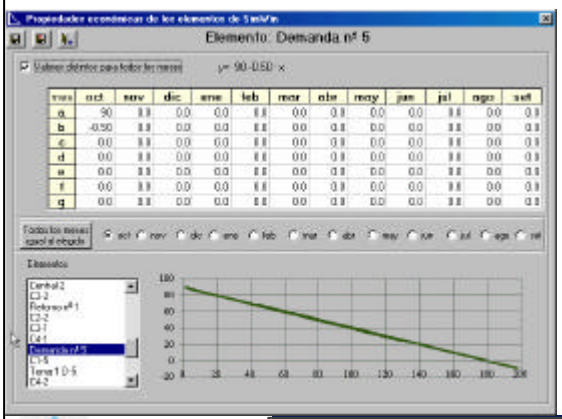
- **ABLE TO SIMULATE W.Q. FOR THE ENTIRE SYSTEM (simplified way)**

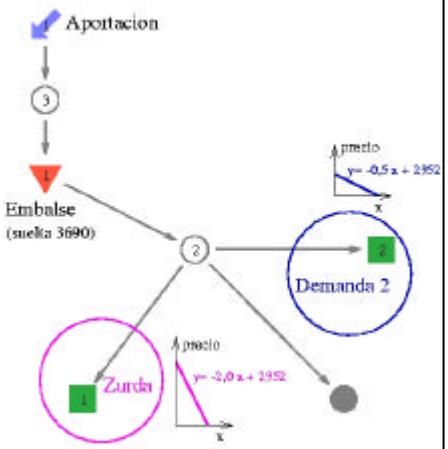


- **LINKS TO THE SIMULAT RESULTS**
- **W.Q. RESULTS USED TO MODIFY CONSTRAINTS IN SIMULATION**
- **CAN BE USED TO PREDICT THE IMPACT OF CORRECTIVE MEASURES IN AN INTEGRATED WAY AT BASIN SCALE**

ECONOMIC EVALUATION MODULE

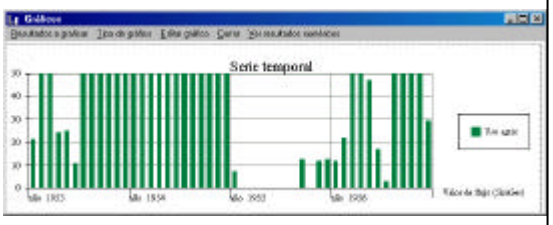
- **ABLE TO ASSESS THE ECONOMIC VALUE OF AN ALTERNATIVE**





ECONOMIC EVALUATION MODULE

- **CAN BE USED AS AN ALTERNATIVE WAY TO ESTIMATE:**
  - **COST OF THE RESOURCE**
  - **ENVIRONMENTAL COSTS**



✓ English manuals

AQUATOOL

OPTIGES

OPTIWIN

SIMGES

SIMWIN

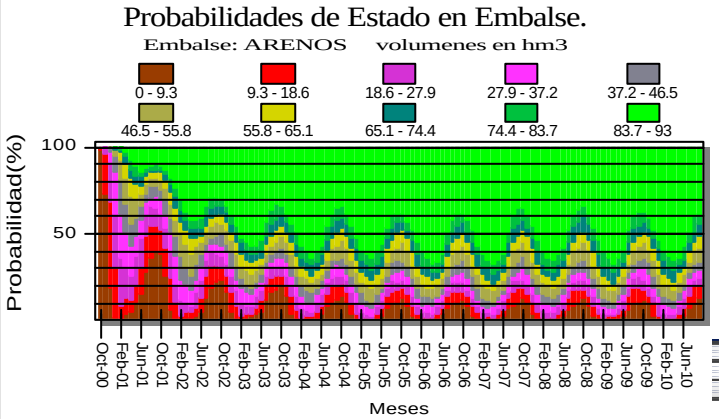
MASHWIN

WAM-ME PROJECT

- Management Simulation and/or Optimization runs using different:
  - **alternatives (e.g. infrastructure)**
  - **time horizons**
  - **demand scenarios**
  - **hydrological scenarios**
  - **operating policies**

- Planning decisions can be analyzed and tradeoffs between alternatives can be determined.

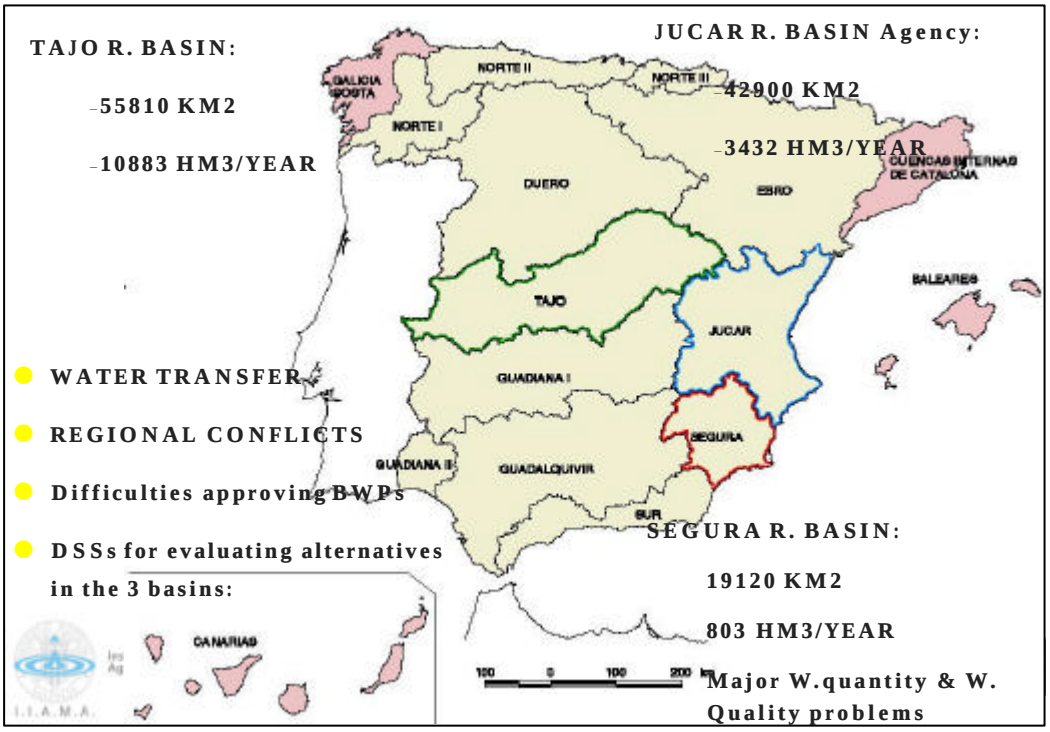
- **Risks associated to planning decisions (design of the system):**
  - **unconditioned multiple future hydrological scenarios for very long time horizons**
  - **after the effect of initial conditions are dissipated, the probabilities stabilize:**



Long term measures

TAJO R. BASIN:

- 55810 KM2
- 10883 HM3/YEAR



JUCAR R. BASIN Agency:

- 42900 KM2
- 3432 HM3/YEAR

- WATER TRANSFER
- REGIONAL CONFLICTS
- Difficulties approving B-WPs
- DSSs for evaluating alternatives in the 3 basins:

SEGURA R. BASIN:

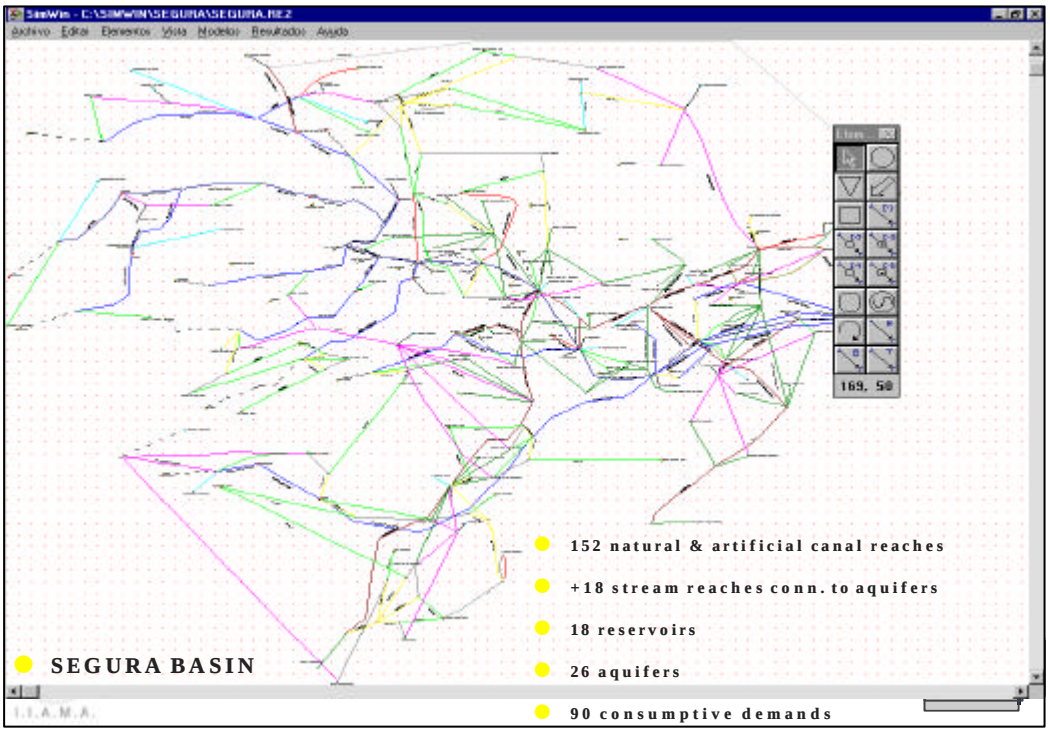
19120 KM2

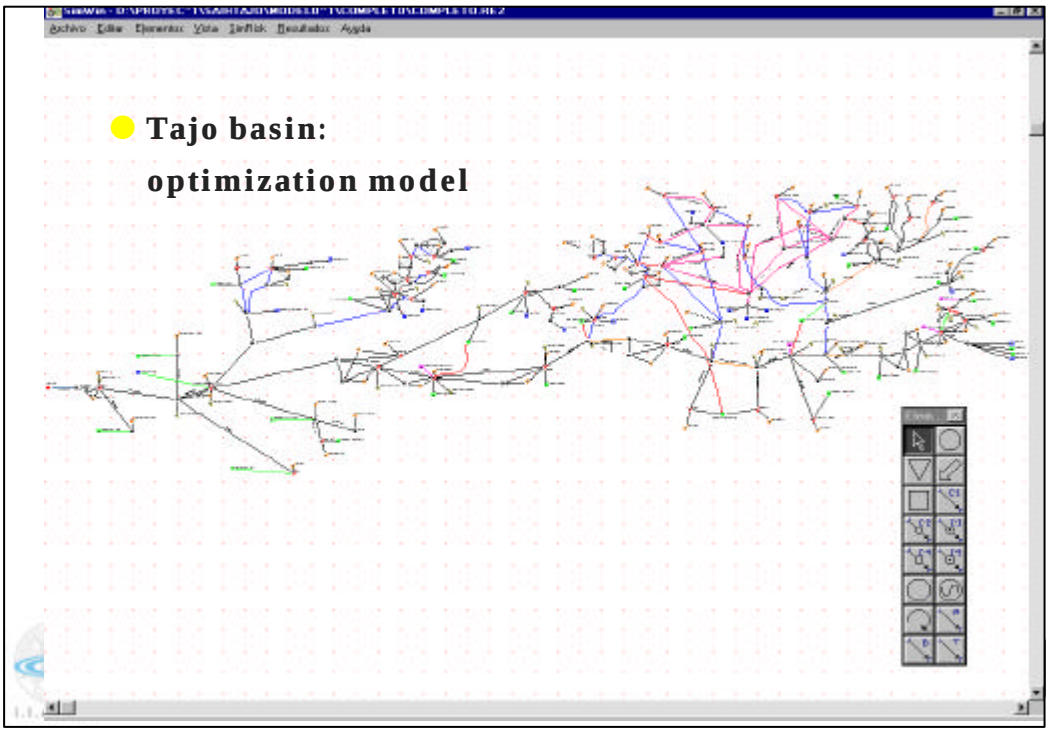
803 HM3/YEAR

Major W.quantity & W. Quality problems

I.I.A.M.A.

- **Integrated Basin model**: Jucar Basin


SIMWIN - C:\SIMWIN\SEGURIA\SEGURIA.RE2
Archivo Editar Elementos Vista Modelos Resultados Ayuda
169, 58
SEGURA BASIN
152 natural & artificial canal reaches
+18 stream reaches conn. to aquifers
18 reservoirs
26 aquifers
90 consumptive demands

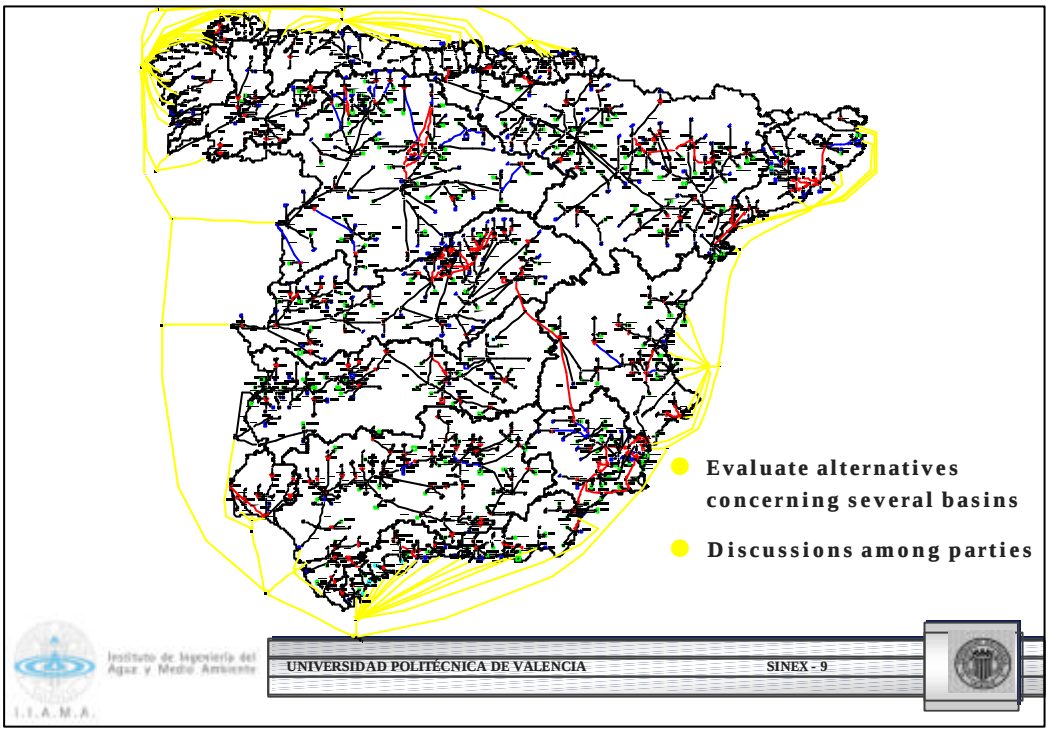

Archivo Editar Elementos Vista Simbolos Resultados Ayuda
Tajo basin:
optimization model

RESULTING DSSs used:

- As tools for the assessment of alternatives, including conjunctive use
- as shared visions of the water system in solving conflicts

- BWPs were approved after CONSENSUS was reached based on the results of DSS
- DSSs are still being used for planning & management issues.

- **Also by many other Basin Agencies, scientific institutions, and consulting firms in Spain and abroad**



- **In the case of the P.H.N., it was very recommendable to use the Optimization module:**
  - No need to specify operating rules, it is possible to concentrate in other aspects (capacity of reservoirs, channels, deficits in the supplies, availability of water for transfer, …)
  - No need to represent in a very detailed fashion all the basins.
  - Analysis of the W.R.S. separately, and
  - Connected in the National Water System scheme

- **... being able to perform easily (thanks to the D.S.S.):**
  - Sensitivity analysis for
    - design variables
    - demand scenarios
    - infrastructure scenarios
    - hydrological scenarios (e.g. Climatic changes)
- **... taking into consideration:**
  - Physical, legal, & environmental factors, as allowed by the objective function in OPTIGES.

Use of Aquatool DSS for real time management and the estimation of risks of operational droughts

RISK ASSESSMENT

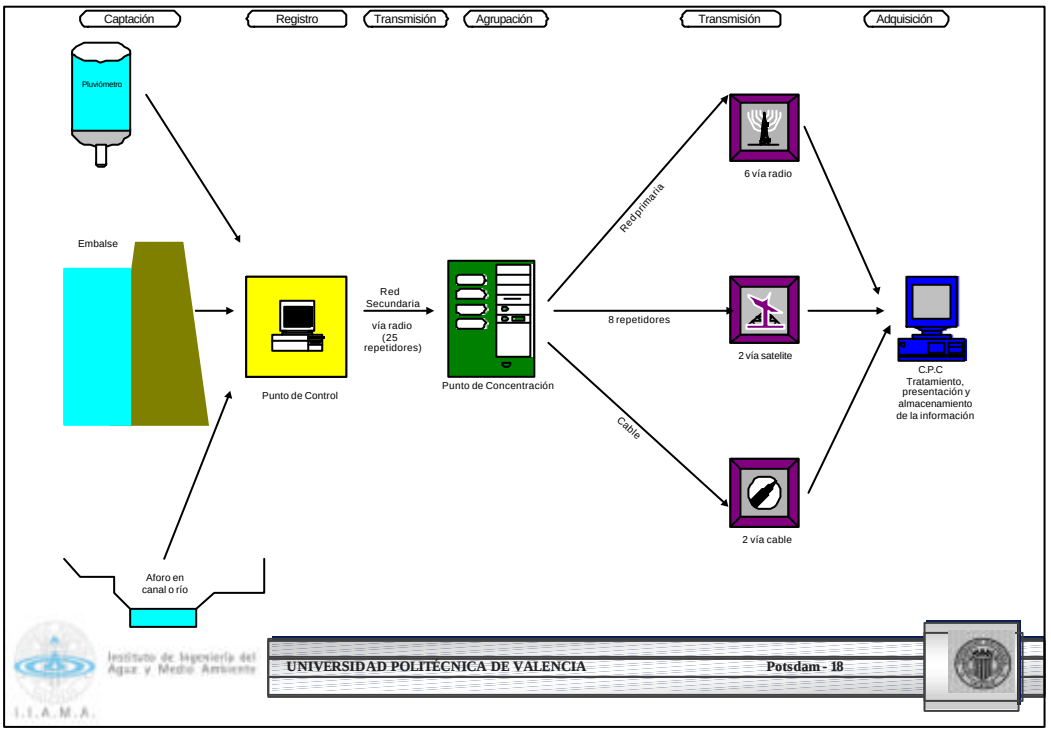
Real time MANAGEMENT

- Permanent measures preventing droughts:
  - **Strict control** of the water stored, the supplies and the efficient use of water
  - **Operating procedures** being able to evaluate the possibilities of a drought occurring, or the expected length of an actual drought, with anticipation measures and decisions in order to avoid failures of great intensity.

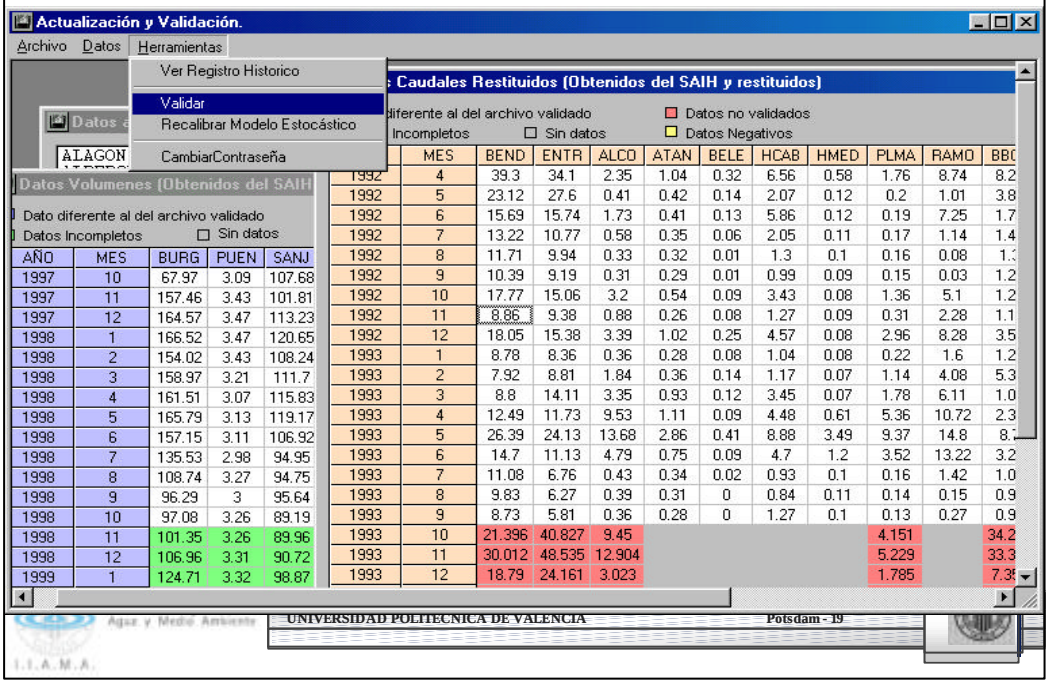
KEY POINTS IN DROUGHT MANAGEMENT

- **When to start applying measures?(anticipation horizon)**
- **Adequate measures? (e.g. degree of restrictions)**
- **What uses have to suffer restrictions? (and different levels for each type of demand)**
- **What are the probabilities of future failures as a consequence of the decisions we are taking?**

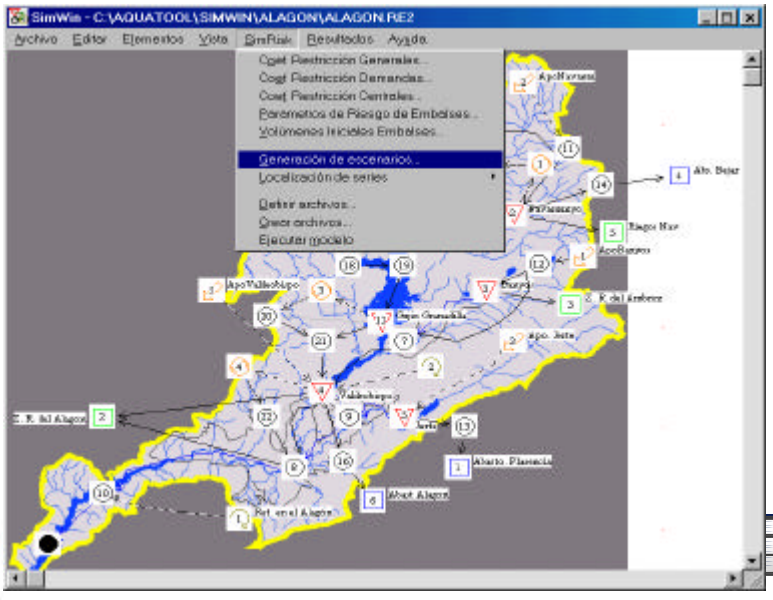
- **Risk of droughts in real time management:**
  - **hydrological scenarios conditioned to the hydrological state of the system at present time (i.e., conditioned to recent flows and aquifers state), and of short time horizon (12-24 months, typically in Spain)**
  - **set initial conditions of present time (reservoir volumes, flow in streams, state of aquifers, …).**



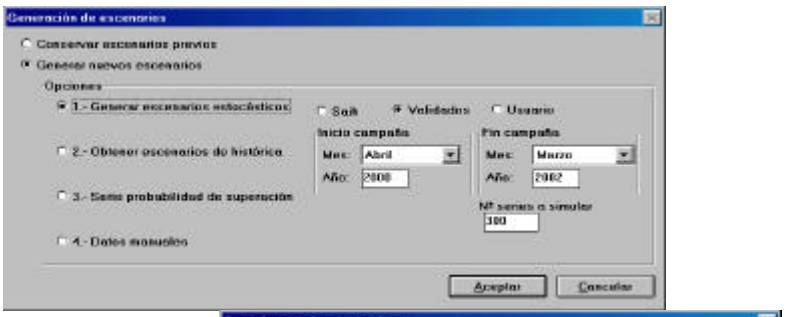
Data Validation

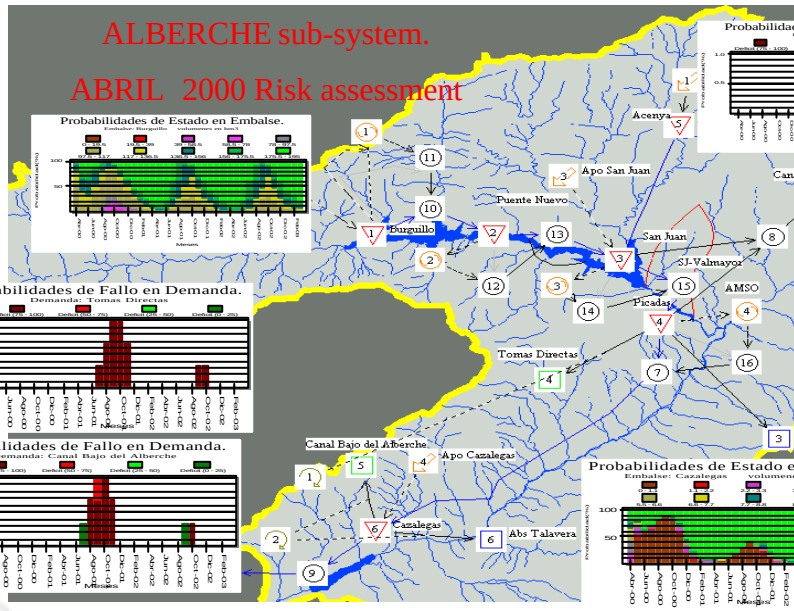


AQUATOOL-TAJO DSS: GENERATION OF SCENARIOS



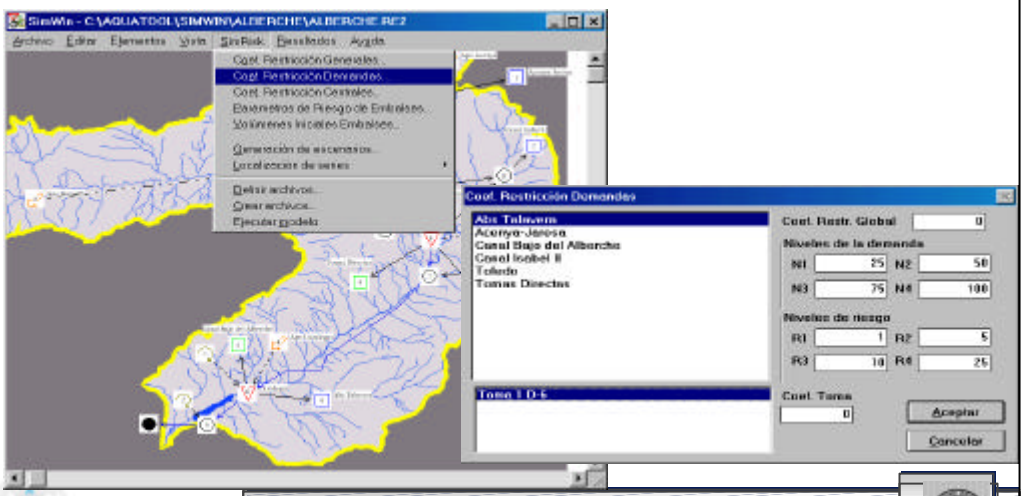
Generation of conditioned scenarios





Mitigation measures:

general or selective restrictions
emergency groundwater pumping
emergency connectivity works

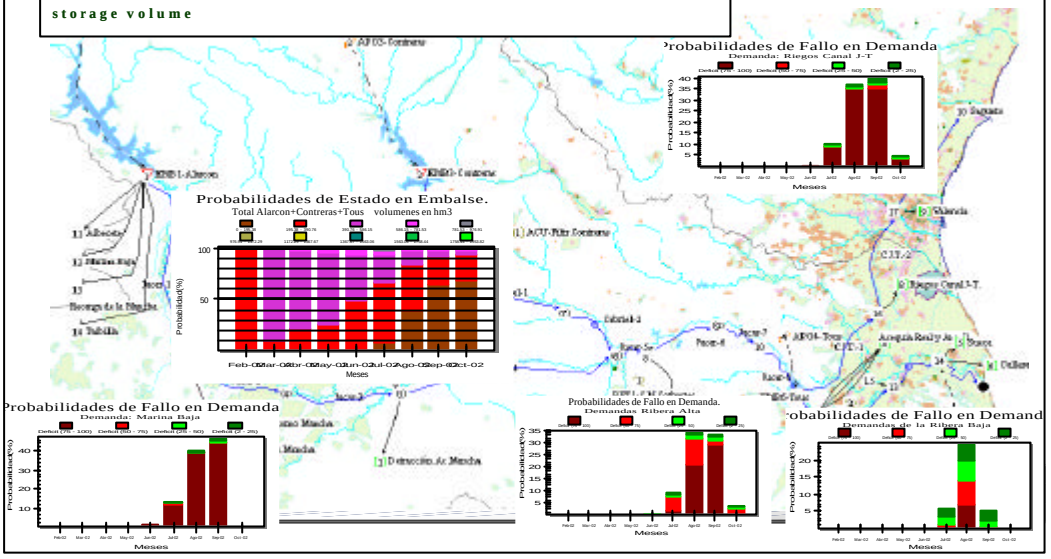


SYSTEM MANAGEMENT UNDER DROUGHT CONDITIONS

AQUATOOL - SIMRISK module for water management based on drought risk

- Applied in all the decision boards for water-releasing in the Júcar basin during the campaign 2001/2002

• Simulation February - 2002. Failure probability in demands and total storage volume



Probabilidad de Excedencia.

Total Alarcon+Contreras+Tous (Oct - 2002)

SIMULATION DATA

- Simulation started: February 2002
- Number of series simulated: 2000

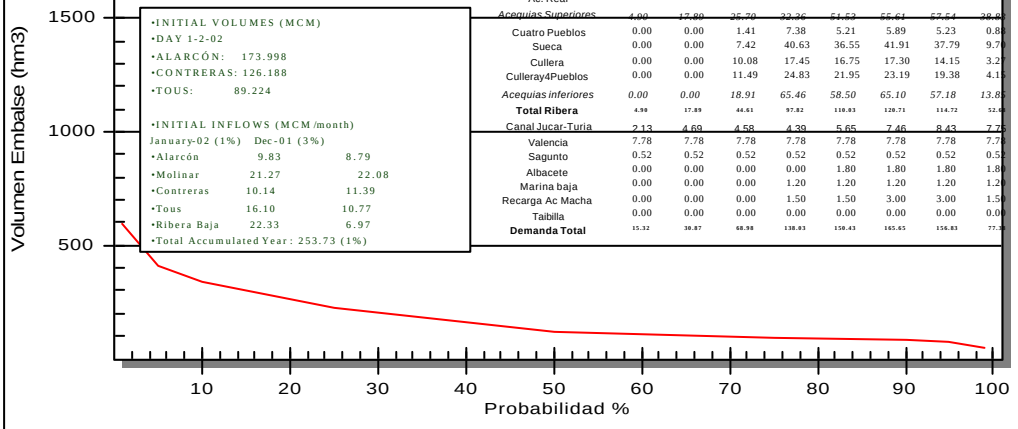
- INITIAL VOLUMES (MCM)
- DAY 1-2-02
- ALARCÓN: 173.998
- CONTRERAS: 126.188
- TOUS: 89.224

- INITIAL INFLOWS (MCM/month)

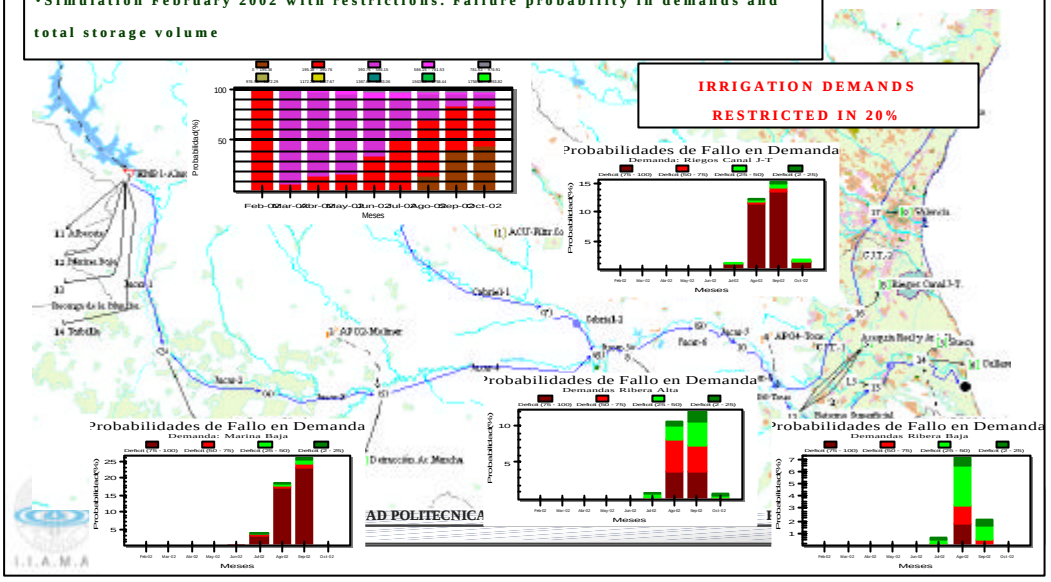
January-02 (1%)	Dec-01 (3%)
Alarcón 9.83	8.79
Molinar 21.27	22.08
Contreras 10.14	11.39
Tous 16.10	10.77
Ribera Baja 22.33	6.97

- Total Accumulated Year: 253.73 (1%)

Demandas hm3/mes	feb	mar	abr	may	jun	jul	ago	sep
Escalona	0.60	1.99	2.27	2.46	5.94	6.70	6.70	5.30
Carcagente	0.24	0.93	1.15	0.99	2.51	2.68	3.21	3.11
Antella	0.39	0.64	0.78	0.86	1.04	1.07	1.07	1.04
Ac. Real	3.67	14.33	21.50	28.05	42.04	45.16	46.56	29.38
Acequias Superiores	*4.00*	*17.89*	*25.70*	*33.36*	*51.53*	*55.61*	*57.54*	*38.83*
Cuatro Pueblos	0.00	0.00	1.41	7.38	5.21	5.89	5.23	0.80
Sueca	0.00	0.00	7.42	40.63	36.55	41.91	37.79	9.70
Cullera	0.00	0.00	10.08	17.45	16.75	17.30	14.15	3.27
Culleray4Pueblos	0.00	0.00	11.49	24.83	21.95	23.19	19.38	4.11
Acequias inferiores	*0.00*	*0.00*	*18.91*	*65.46*	*58.50*	*65.10*	*57.18*	*13.85*
Total Ribera	4.90	17.89	44.61	97.82	110.03	120.71	114.72	52.68
Canal Jucar-Turia	2.13	4.69	4.58	4.39	5.65	7.46	8.43	7.75
Valencia	7.78	7.78	7.78	7.78	7.78	7.78	7.78	7.78
Sagunto	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
Albacete	0.00	0.00	0.00	0.00	1.80	1.80	1.80	1.80
Marina baja	0.00	0.00	0.00	1.20	1.20	1.20	1.20	1.20
Recarga Ac Macha	0.00	0.00	0.00	1.50	1.50	3.00	3.00	1.50
Taibilla	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Demanda Total	15.32	30.87	60.98	138.03	150.43	165.65	156.83	77.33



• Simulation February 2002 with restrictions. Failure probability in demands and total storage volume



Probabilidad de Excedencia.

Total Alarcon+Contreras+Tous (Oct - 2002)

SIMULATION DATA

- Simulation started: February 2002
- Number of series simulated: 2000

- INITIAL VOLUMES (MCM)
- DAY 1-2-02
- ALARCÓN: 173.998
- CONTRERAS: 126.188
- TOUS: 89.224

- INITIAL INFLOWS (MCM/month)

	January-02 (1%)	Dec-01 (3%)
Alarcón	9.83	8.79
Molinar	21.27	22.08
Contreras	10.14	11.39
Tous	16.10	10.77
Ribera Baja	22.33	6.97

- Total Accumulated Year: 253.73 (1%)

Demandas hm3/mes	feb	mar	abr	may	jun	jul	ago	sep
Escalona	0.60	1.99	2.27	2.46	5.94	6.70	6.70	5.30
Carcagente	0.24	0.93	1.15	0.99	2.51	2.68	3.21	3.11
Antella	0.39	0.64	0.78	0.86	1.04	1.07	1.07	1.04
Ac. Real	3.67	14.33	21.50	28.05	42.04	45.16	46.56	29.38
Acequias Superiores	*4.90*	*17.89*	*25.70*	*32.36*	*51.53*	*55.61*	*57.54*	*38.83*
Cuatro Pueblos	0.00	0.00	1.41	7.38	5.21	5.89	5.23	0.88
Sueca	0.00	0.00	7.42	40.63	36.55	41.91	37.79	9.70
Cullera	0.00	0.00	10.08	17.45	16.75	17.30	14.15	3.27
Culleray4Pueblos	0.00	0.00	11.49	24.83	21.95	23.19	19.38	4.15
Acequias inferiores	*0.00*	*0.00*	*18.91*	*65.46*	*58.50*	*65.10*	*57.18*	*13.85*
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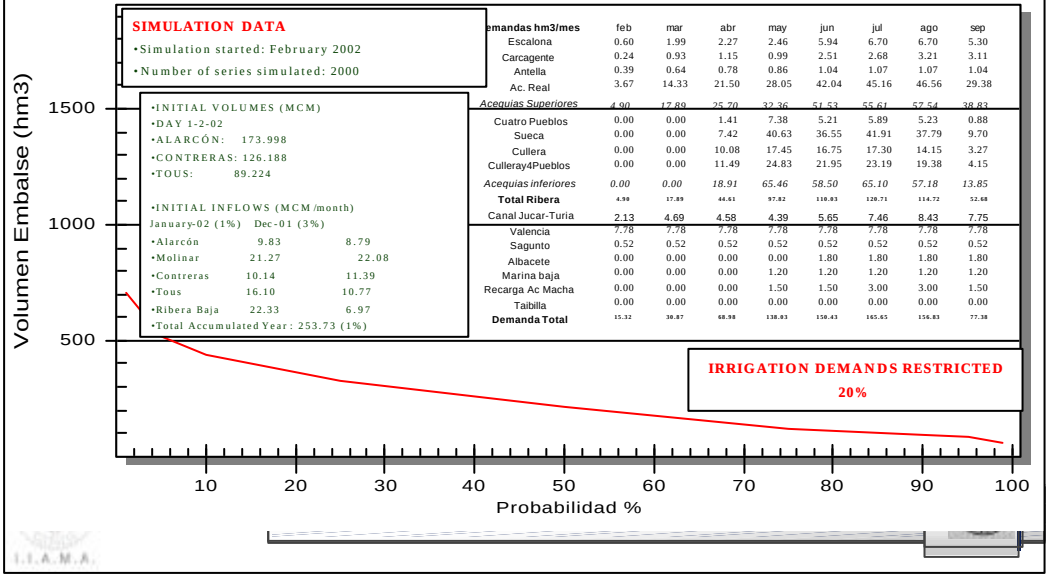

THE RISK ASSESSMENT APPROACH

- Can be applied directly to any complex system thanks to the models included in the AQUATOOL Decision Support System
- It gives a complete vision of the consequences of the decisions (either management or infrastructure)
- It gives indicators that can be used as early warning system for operative droughts
- It can be directly used by the DM thanks to the DSS
- The DSS can be used as a Shared vision model in conflict discussions.

GENERAL CONCLUSIONS & COMMENTS

- **Experiences of application of DSSs in real world w.p.&m. in several places.**
- **This DSS development started in 1987 (Ebro). Then: 1988-89 (Segura), 1990 (DSS), 1996-97 (Tajo), 1998-99 (NWP), 1999-2000 (Management modules), 2000-03 (Júcar). Now (Júcar pilot basin):**

  W. Quality module, Economic module, ecological module, ...
- **Also used in Agencia Catalana Agua, Guadiana, Guadalquivir, Mendoza (Argentina), Flumendosa (Sardinia, Italy), Cyprus, ...**
- **Gap between WRS analysts or modelers and real world practitioners can be narrowed down trough the use of DSS.**
- **Better informed decision making process**

- **having high scientific and technical standards**
- **respond to real necessities of the final users**
- **has be performed in close cooperation with them.**

(In many cases, DSSs are developed by scientists as a kind of academic exercise, and later are presented for use by third parties, discovering that there are substantial differences in problem formulation, data availability and adequacy, and results display and interpretation (for instance, some graphs or figures that are meaningful to the developers, might not be so to the users).

- **Problems have to be solved progressively**. Trials to build from the beginning the "total DSS", covering all aspects of watershed management, frequently lead to frustration.
- Systems with **modular structure**, where each module addresses specific questions and where good coordination between modules is provided, have more probabilities to get successful results.
- This approach is better accepted by the **final users if they are involved in the development**, because they gain confidence on the tools as they are developed.

- Decision makers are not reluctant to use advanced technological tools, but they value the **easiness of use** and the **reliable support from the developers**. If DSS are too complex to use and/or the availability of the developers to solve any problem is not assured, then the **confidence of the user** on the system and on its own capability to use it when needed is reduced, restraining its use.

Seminario sobre Planificación y D.M.A.

Los sistemas de apoyo a la decisión en la planificación y gestión

by **Joaquin Andreu**

Water Resources Engineering Research Group

Institute for Water and Environmental Engineering (IIAMA)

Universidad Politécnica de Valencia (SPAIN)

Thank you!

e-mail: ximoand@ upv.es

www.upv.es/iiama/ www.upv.es/aquatool/