System Dynamics Modelling

AquaStress
Mitigation of Water Stress Through New Approaches to Integrating Management, Technical, Economic and Institutional Instruments

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Iskar Case Study, Bulgaria

<u>Activity 1</u>: Industrial water management - reducing demand and pollution

In brief:

System Dynamics Modelling has been developed and applied to the simulation of the Kremikovtzi plant water system. It has been used for simulating and studying various operational scenarios, under different climatic conditions (Normal, dry and very dry years)

Background

System Dynamics Modelling (SDM) is a methodology for studying and managing complex feedback systems. It is typically used when formal analytical models do not exist, but where system simulation can be developed by linking a number of feedback mechanisms. This type of Systems Modelling, being lower in detail and higher in integration, allows the domain experts and the local stakeholders to explore the relationship between various technical options and the overall system behaviour and to increase their understanding of the interactions and impacts among different water system components.

Application within Iskar case study: Kremikovtzi

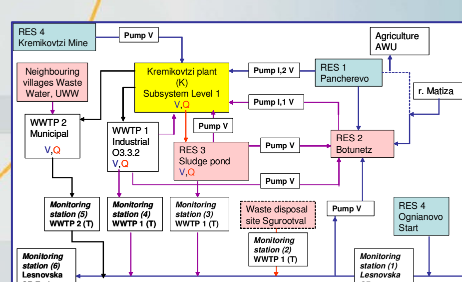
The Kremikovtzi metallurgical plant, near Sofia, Bulgaria, constructed initially in 1963, is one of the largest water consumers in the country (total fresh-water consumption 55×10^6 m^3/year on average - roughly equivalent to the water needs of a city with a population of 600 000). Its water supply system is complex and consists of both freshwater (reservoirs, rivers, groundwater) and reused water sources (treated industrial waste water). It also provides water for a number of smaller satellite plants, sharing the same water resources. Some of the system's freshwater sources are also used by urban and agricultural water users in the Sofia region, leading to regulations for priorities and upper limits to water consumption for industrial use, as well as water stress situations arising in times of drought. SDM has been developed and applied to the Kremikovtzi water system in order to simulate and study future operational scenarios, under varying climatic conditions ("normal", "dry" and "very" dry" years) and operational rules.

SDM in stages

The SDM for Kremikovtzi was built in stages, in participatory context *(Experts→ stakeholders → experts → stakeholders…)*, starting with simpler versions that gradually increased in detail, as follows:

1. Problem/system identification within the case study

2. Development of a dynamic hypothesis explaining the cause of the problem (Conceptual model)



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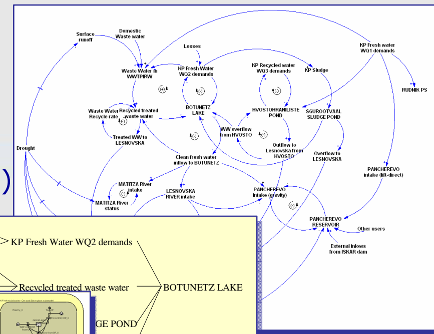
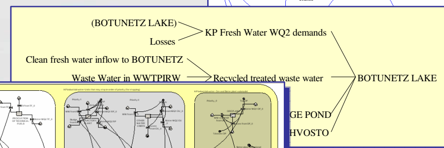
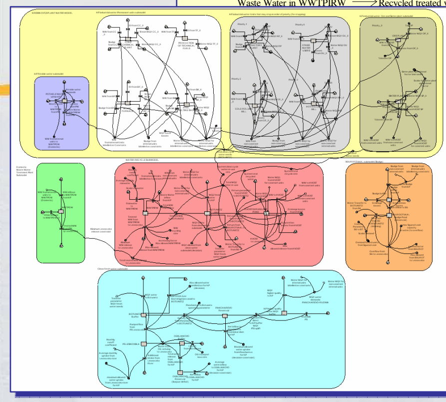
3. Definition of system components, links, interactions and feedback loops (Causal Loop diagram SDM Qualitative model)







4. Development of the numerical simulation model *(Quantitative SDM model)*

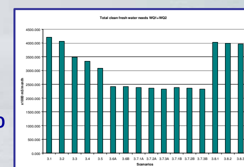
5. Testing the model *(Validation)*

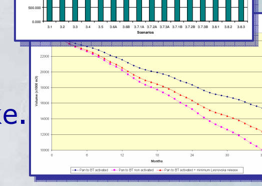
6. Return to Step 3 for changes, if needed

Simulation/Scenarios

The SDM model simulated the system, on a monthly basis, under 23 operational scenarios, corresponding to "normal", "dry" or "very dry" years; varying treated waste water recycling rates, operational rules, priorities and reduction or stoppage of production for specific industrial units.

Results





1. "Normal" year: the system total recycling rate can increase from 44.4% (today) to 53.8% by recycling 75% of treated industrial waste water (instead of 60% today), saving on average 400×10^3 m^3/month of freshwater intake.

2. "Dry year" scenarios: It is possible to keep all units operating normally, if the industrial waste water recycling rate is set at 90%.

3. "Very dry year" scenarios: Hierarchical closure of some units and different recycled and fresh water allocation rules can keep the plant's most important units operating and minimize the deficit at the clean freshwater sources.

Software specifications

SDMs are implemented in special visual environments that enable the user to effectively "draw" the system components and their interrelations and run different scenarios. SIMILE® for numerical and VENSIM® for causal-qualitative diagrams have been used here, together with EXCEL® for pre- and meta-processing. SDM is a software tool of i^{3}S in AquaStress.

Publications

VAMVAKERIDOU-LYROUDIA, L.S. and **SAVIC D.A. (2008).** "*System Dynamics Modelling: The Kremikovtzi Water System*", Report No.2008/01, Centre for Water Systems, School of Engineering, Computing and Mathematics, University of Exeter, UK, 132p

VAMVAKERIDOU-LYROUDIA, L.S., SAVIC, D.A., TARNACKI K., WINTGENS T., DIMOVA, G. and **RIBAROVA I. (2007).** "Conceptual/System Dynamics Modelling Applied for the Simulation of Complex Water Systems", in *Water Management Challenges in Global Change*, Proc. Int. Conf. CCWI 2007 & SUWM 2007, Leicester UK, 3-5 Sept. 2007, Taylor & Francis Group, London UK, pp. 159-167