GESREAU: DEFINITION AND DEVELOPMENT OF A DECISION SUPPORT SYSTEM FOR INTEGRATED WATER MANAGEMENT

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The GESREAU project (GEStion des Ressources en EAU) aims to define a new relevant concept for global and integrated water management adapted to administrations. This globalized approach intends to handle problems at various scales in its geographical context, to understand the dynamics of the system, and to go beyond the traditional administrative approach, which is very sector-related. The integrated proposal requires better communication between the various water management specialists concerned by flood, drought and resources, quality and fauna preservation, and the public domain of the river network. These two aims demand the use of data processing and analysis systems such as Database Management Systems, Geographic Information Systems, simulation models, etc that are gathered in a Decision Support System. The components of the DSS have to suit the responsibilities and the capabilities of the administration, as well as the different levels of land documentation.

1. INTRODUCTION

Surface water management is becoming a complex subject in Switzerland, as in other highly populated countries. The development of activities in our society requires more space. Because this space is often located close to rivers or in potential flood areas, each flood may damage properties or injure people. Furthermore, the natural river space having been largely reduced, the biotope quality is often very much degraded.

Presently, new legislation related to environmental awareness is opening new opportunities to water managers, although they may not always be consistent with the former rules of management. Water administrators have to deal with increasing stress on the river network with reduced means to handle it.

In order to face these new problems, the Water and Environmental Conservation Office, the Fauna Preservation Office and the Agriculture Office, of the State of Vaud, is collaborating with the Swiss Federal Institute of Technology on the GESREAU (GEStion des Ressources en EAU) project. The aim of this project is a global and multidisciplinary approach that is coherent across different decision making levels. This means applying an integrated water management that fulfills the needs of our society according to sustainable development requirements.

The present article shows the constraints on a decision support system (DSS) design for an existing administration. First, the concept of global and integrated management is defined as well as a typology of decisions. These two elements are required for the definition of the DSS. Secondly, this article describes the approach and the means to design such a system.
2. CONCEPT OF GLOBAL AND INTEGRATED MANAGEMENT

Global and integrated water management has a classical analytic step in which each object is examined in the light of a particular concern (fig. 1). The concerns are defined by the various water management stakeholders. This first step is completed with a synthetic approach, where the analytical data of the various concerns are gathered and represented at the global, regional and local scales [1]. Therefore, global means handling a problem in its geographical context at different scales; integrated means gathering and representing the data of each water management stakeholder.

![Figure 1 Principle of global and integrated management](image)

The approach can be illustrated with the management of a river works, a bridge for instance (fig. 1). The first step consists of placing the bridge in the global catchment system (left inside). The purpose is to analyze the surface of the drainage basin to determine the design flow for the bridge. The second step allows to understand the constraints of the existing system for the various management criteria. In this example, the second level concerns the hydraulic behavior of the reaches upstream and downstream of the bridge. The administrators should evaluate the integration of the new bridge in relation to the priorities of land management, flood mitigation, fauna preservation, and public property management. The last analysis (right inside) identifies the impact of the bridge at the local scale. The example of figure 1 shows only four roles: land management, management of water quantity and quality, and management of the public domain. This list should be completed according to the problem.

The results of the analysis have to be integrated and compared to the whole at the different levels. This synthesis is very important to adapt the bridge project to the system constraints and the desires of the various managers. For example, the public property administrator may point out an electric cable on the left bank, while the biologist may draw attention to a natural zone downstream. These two constraints have to be taken into account from the very beginning of the project.
3. DECISION TYPOLOGY

From the former concept, the use of DSS must be defined in accordance with the kinds of administrative decisions.

3.1 According to the finality

Probst distinguishes the strategic decisions from the operational ones according to its finality. Four criteria determine this finality [1] (fig. 2).

![Diagram of decision typology](image)

**Figure 2** Typology of decisions [1]

Analysis of water management shows that the strategic decisions are divided:
- into different levels (political, legislative, administrative),
- into many specialized sectors (quantity, quality, resource management, recreational, etc.), and
- into various administrative levels (federal, state, township).

The GESREAU project is concerned with the regional administrative level, which is a canton in the Swiss political system. The cantonal administration is right under the Federal government and over the township. It is in charge of every problem related to water and land management. The physical limits of a canton are based on historical events; they do not follow the limits of drainage basins. Good collaboration is therefore necessary with the neighboring cantonal administrations.

The water management decisions in a canton are mainly operational (fig. 2). They are related to public property management, to pumping and discharge permits, and to flood mitigation in new construction projects. These decisions are well structured and can be computer-assisted. They stand for most of the job of the administration. One aim of GESREAU is to give rapid and easy access to the data and to provide powerful spatial analysis and representations. The bonds between the data storage and data analysis software have to be very tight (fig. 7).

The strategic decisions, which are more seldom, usually involve the help of consultants, as well as other institutional partners. The decision making approach is less structured; many variants of the project are tested through various scenarios. Thus, the aim of computer assistance is to have an open database for the storage of the variants and to have links with simulation models to design the scenarios (fig. 7).

3.2 According to the stakeholders

The definition of a problem corresponds with a discord between the desire of a stakeholder and his/her perception of reality [1]. The desire is composed of values and principles adopted by the stakeholder and imposed on him/her through social organisms to which he/she belongs. The model of reality made by a person is built on the facts and messages that have been captured. Thériault identifies four situations according to the agreements (or disagreements) about the desires
(principles) and the perception of reality (facts) between the stakeholders of a decision (fig. 3).

Let us pursue the bridge project example. The building of a new bridge is only a technical problem if everybody admits that it will shorten the time of travel (fact) and its construction corresponds to a general interest (principle). The problem is clearly identified and everyone is concerned about it. As the stakeholders agree about the facts and principles, they have to face a technical decision.

If there is a disagreement on the principles, the problem is political. Suppose, the opinion that the bridge shortens the trip is shared, but maybe it has to cross a protected natural zone. Some ecological organizations can not accept any construction in this area. In this case, each group of stakeholders tries to convince the other ones of the validity of their principles.

A third situation is imaginable. Suppose, the principle of putting natural zones under protection is shared, but the one touched by the bridge is not in good shape anymore. It does not deserve its restricted status any more. Then the problem is legal. One has to check if the area deserves its status as a protected natural zone.

In the end, it might not be logical to concede the re-evaluation of a degraded natural zone because this admits that the area has not been properly protected. The disagreement between the bridge promoters and the environmentalists is cultural; the perception of reality (facts) and the desires (principles) of the stakeholders are opposed. The solution has to be found through negotiation.

This example shows that the stakeholders involved in water management have to negotiate their decisions. The conflicts that occur between them are often culturally based. The interpretation of reality is not unique because of the hazard of climatic processes. Each stakeholder has a limited vision of geographic areas according to the principles that he/she defends.

If a negotiated decision is not found, a conflict can continue in a political or legal arena. This example demonstrates also that the technical considerations come only at the end of the process [4].

In land management, as in water management, motivations to negotiate depend on the stakeholders, their open-mindedness and their abilities to share their data (fig. 4). These motivations depend on the power distribution between the decision-making stakeholders. Conciliation is usually a better choice than to go to court or to risk a political referendum.

In the situation of lobbying, the administrative manager has to pay attention to preserve the public interest in the negotiation. Otherwise, he/she may discredit
his/her administrative authority (fig. 4). He/she has to be able to check the fairness of negotiated decisions over time and space. At last, negotiation requires practice. For instance, stakeholders of different opinions will negotiate more easily, if they know each other well [6].

![Diagram](https://example.com/diagram.png)

**Figure 4** Conditions and stakes of negotiation in the administrative context [5]

In the water management context, decision support systems improve the description of the situation and the communication between the various stakeholders. It stores former decisions in their geographical context. Thus, similar problems are more likely to be treated in an equally fair manner, even if the decision-maker changes.

4. GESREAU PROJECT

4.1 Aims

GESREAU is a geographical information system that stores water management related data. It should permit a global and integrated management, as previously defined. It is designed for the support of operational decisions. It also contains the data used for strategic decisions. Some links to simulation models are defined in order to evaluate the dynamic behavior of spatial objects.

The concept of the project is to structure a relational database that should centralize information of each water management stakeholder in an organized structure. This structure allows a synthetic land view and gives the required meta-information for the proper use of the data. It should also be flexible enough to be used with other water management software such as simulation models and time series analysis tools.

4.2 Database structure

The structure of the database follows a systemic analysis of the land. The data model, composed of geographical objects, allows each water management specialist to incorporate his own data. This approach to structuring the database can be compared with the “projective” approach defined by Le Moigne [7]. The two elements of the structuring process are the various managers, with his/her information defining his/her own view of the land, and the geographical space which can be described at different scales (fig. 5).

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1 The entities of the database represent spatial objects, even if the database management system is relational; such a system is composed of entities and relations.
The objects stored in the database are defined according to its semantic characteristics, which are given by each administrator, and to its spatial delineation. The delineation of an object is unique at one scale for every water management specialist. The spatial aspects are therefore capital in the integration process of heterogeneous data [8-11].

In GESREAU, the scale of data integration is 1:10'000. This scale was easily defined because each office of the Vaud administration has to manage the same area. 1:10'000 is precise enough to make decisions on a space of 3000 km² like the state of Vaud; a more precise scale would require too much data management work.

This reference scale determines the storage of every spatial data (fig. 6). Most data are inserted as objects defined at the scale of 1:10'000. Global data are supported by super-objects. These are composed of the objects defined at the reference scale. The properties of super-objects are given to smaller ones. For instance, the super-object 'river' supports an attribute 'name of river'; every reach belonging to the river inherits this name.

Very accurate data are integrated on objects defined at a precise scale (fig. 6). They may be redundant with other data taken at the reference scale. This redundancy can not be avoided because these data exist only at some spots in the spatial database. Also, they are not used in the same way. For example, river geometries can be estimated over the entire database with an existing digital elevation model (DEM). The result of this overlay is not accurate for hydraulic applications. It can only be used for geomorphological analysis. Accurate profiles are taken where serious hydraulic problems occur. These profiles are of course integrated into the database, but they do not exist on the entire river network. The
geometry of the river network can be evaluated by different means at different scales and thus becomes redundant, but this redundancy is required for the different needs of these geometric data. Furthermore, the validity of such accurate data expires more rapidly than the information of the DEM. Meta-information has to describe the validity and the limit of use of every data.

Finally, some parameters are not derivable from one scale to another, because the phenomena are not linear. This is the case for many hydrological processes.

4.3 Data processing means
The aim of global and integrated management requires data processing means. High storage capacity is necessary for centralizing the various information; drawing capabilities are needed for building thematic maps as well as synthesizing information at various scales.

GESREAU is built on a database management system (DBMS) linked with a geographic information system (GIS). The two tools are highly integrated; the user requires both tools simultaneously (fig. 7). He/she can conduct spatial and semantic analyses very easily. Links are also provided with time series analysis tools, like CODEAU and simulation models. The link is made by file transfers. Therefore, the developments of GESREAU and the simulation models are independent. The use of sophisticated simulation models by administrators is not the main objective for their integration into GESREAU because simulations are usually not done by administrators but by specialized consultants. The point is rather to integrate simulation results into the spatial database and to allow the managers to compare them with the geographical situation. The negotiation processes that produce good decisions require good synthetic maps.

The data integrated in GESREAU come from field investigations and archived files of the administrative services of the canton of Vaud and the Swiss Confederation, from reports of private consulting offices, as well as from results of spatial analysis tools like raster GIS. These static descriptions are completed with measured and simulated times series [8].

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2 Examples of data processing are given on the net http://dgrwww.epfl.ch/HYDRAM/gesreau
5. CONCLUSION

The GESREAU project defines a new concept for integrated water management. The core of the project consists of a vector GIS integrated in a DBMS linked with simulation models. Great efforts have been spent on the elaboration of the data structure. Instead of building a DBMS based on the present administrative structure or the structure of any simulation models, it is rather based on a systemic analysis of the geographical space. Therefore, the database is independent of any reforms in the administrative structures or technical advances of the simulation models. It allows the application of a real integrated water management system.

The first module on data management was completed in 1996. It is now used in the offices of the Vaud administration. The second module on water quantity management is in development. It should be finished by the year 2000. A third module on water quality is scheduled.

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6. BIBLIOGRAPHY