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Towards a program of measures in the context of the European Water Framework Directive

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Abstract

In the European Water Framework Directive [1] the concepts underlying the management of the EU-waters are described. Attention is paid to many aspects such as the administration, emissions, objectives and monitoring. For each river basin these topics should be condensed in a river basin plan. The contents of such a river basin plan are described in Appendix VII of the EU Water Framework Directive and contain 11 topics. One of the topics is the plan of measures. In this paper the coherence between the topics of a river basin plan and the plan of measures is explored and is applied to the Elbe River in Germany.

Towards river basin management plans for all European rivers

In 2000 the European Commission accepted the European Water Framework Directive [1]. This directive formulates that plans for River Basin Management should be developed for each of the European Rivers. For the contents of these plans 11 requirements are formulated. The first part of the plan should be finished by 2004 while the plans should be operational by 2012.

The requirements for a River Basin Management Plan, mentioned in the next paragraph, serve a number of administrative, legal and technical purposes. Each of these purposes requires different data and information. In the present paper the coherence between the 11 requirements is investigated from the point of view of one of the EU requirements "*a summary of the programme of measures, including how the (environmental) objectives must be achieved*". To that extent first the 11 requirements will be subdivided into 9 requirements which have a technical nature and 2 requirements which serve the consultation with the public. It will be shown that the 9 requirements with more technical nature can be fitted into elements or questions of a problem solving approach:

- What are problems in the river basin and who are the actors?
- What is the present state of the river basin
- What is the desired state of the river basin
- What are feasible measures?
- What are the impacts of the measures on the present state of the basin?
- Which set of measures approaches the desired state satisfactorily?
- What are external factors influencing the state of the river basin?
- Is there sufficient administrative and public support for the selected measures?

For the program of measures, the 9 EU requirements should not be regarded independent from each other, but the accuracy as well as the spatial and temporal resolution of data and models related to each requirement should be coherent. This point is elaborated in the paragraph on the design of the information system.

In addition to the necessity of being coherent, the degree of accuracy also depends on the phase of the systems analysis, see e.g. Miser and Quade [2]: problem definition, development of feasible measures, building and using models to analyse the effectiveness of the measures and ranking and selection of a set of measures. For instance in the problem definition phase the data and know-ledge is less detailed than in the phase of using models to analyse the effects of a set of measures.

As the development of a River Basin management plan for the Elbe River is very complex, the development of a Decision Support System was envisaged. An important by-product of the development of such a system is that it helps to structure the discussion between the actors. The Decision Support System presented in this paper is designed for impact assessment and evaluation, i.e. two steps in the systems analysis. The definition of Decision Support Systems has called for many discussions (Mallach [3]). We will use the term DSS in this paper as defined by Keen [4]: a computer system with the aim to assist managers in their decision processes in semi-structured tasks, support, rather than replace, managerial judgement and improve the effectiveness of decision making rather than its efficiency. Such a system should support the following functions:

analysis of management alternatives
communication among scientists and decision makers as well as the public
management function
library function

The design of the DSS should be open and sufficiently flexible to allow for the incorporation of more complex models if necessary. Furthermore, a pilot DSS should be generic and applicable for the management of other river basins in Germany and abroad.

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The EU requirements and information demand for a problem solving approach

Appendix VII of the EU water provides information on the 11 requirements, which the river basin management plans should contain. These requirements are grouped in this paper under headings related to a problem solving approach, as presented above. Differences between a problem solving approach and the EU requirements for a river basin management plan will be analysed in the discussion.

Present state of the river basin (contained in the database)

- General description of the characteristics of the river basin district
- Overview of the significant loads and effects of human activities on the conditions of surface- and groundwater
- Maps with the protected areas and laws on basis of which these areas are selected
- Maps with monitoring networks and the results of monitoring programmes with the condition of the surface- and groundwater and the protected areas

Desired state of the river basin

- The (environmental) objectives for surface- and groundwater and for the protected areas

Measures

- A summary of the programme of measures, including how the (environmental) objectives must be achieved
- Register of all more detailed programmes and management plans related to the river basin districts

Decision making; satisfying and/or ranking of alternatives

- List of the relevant authorities
- Providing an economic analysis of the water use

Administrative and public support (consultation of the public)

- Summary of the measures for information and consultation of the public, their results as well as the resulting changes in the plans
- Points of contact and procedures for obtaining documentation for information and consultation of the public, and information about the measures envisaged and the monitoring data.

The interaction between some of the elements of the problem solving approach is presented in Figure 1. The (environmental) objectives for surface water and ground water and for protected areas for a part of the "Desired State" are shown on the right hand side of Figure 1. The general description of the characteristics of the river basin district and an overview of the significant loads and the effects of human activities on the condition of surface water and groundwater will form a part of the database as well as the socio- economic and technical model base. A summary of a program of measures is found in the element Measures. The answer on the question "how the (environmental) objectives will be achieved" can be derived from the interaction between the elements in Figure 1.

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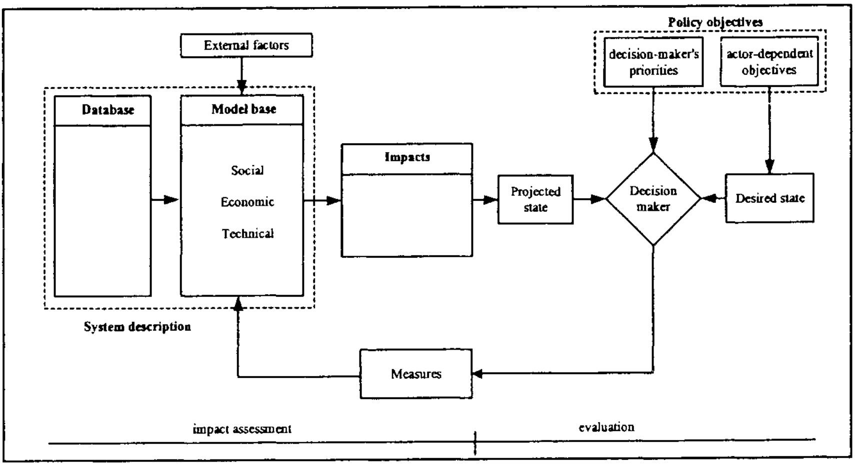

Figure 1: Interaction between some of the EU requirements for the development of a river basin management plan.

as follows. A set of measures affects the river basin, represented by the socio-economic and technical system leading to a projected state. This projected state can than be compared with the desired state. If the projected state differs too much from the desired state, the set of measures must be adapted until the difference between projected state and desired state is acceptable for all partners. To identify all relevant actors, also the list of the qualified authorities is relevant. A DSS can also be used for the requirements of the EU "information and consultation of the public, their results and the changes in the plans as a result".

Results of the feasibility study of a DSS for river basin management, with application to the river Elbe

Introduction

As explained in the introduction, the problem definition phase is the first phase of the systems analysis. The purpose of this phase is to identify the end-users of the model (i.e. persons or institutes that can be considered as problem owner), make an inventory of relevant problems, determine the objectives to be achieved, identify tentative measures, and determine the spatial, temporal, economic and other boundaries of the system. In short: the problem definition delineates the scope of the study.

For the problem definition, initially use has been made of policy documents and interviews with the decision-makers, the public and institutions responsible for the implementation. At a later stage, when the overall picture of the problem became clearer, three joint meetings with representatives of all actors were held.

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For details on the results of the problem definition study for the Elbe, which was carried out by M. Verbeek (Infram bv) and H. van Delden (RIKS bv), we refer to http://elise.bafg.de/?3473 where an English version of the reports and a German summary can be found.

Decision-maker and the identification of problems and -owner

It was not possible to identify a single problem owner for the Elbe catchment shown in Figure 2. Instead a number of potential decision-making institutes, each having their own objectives and measures, were identified: Bundesanstalt für Gewässerkunde (BfG), Arbeitsgemeinschaft zur Reinhaltung der Elbe (ARGE-Elbe), Internationale Kommission zum Schutz der Elbe (IKSE), Wasser- und Schiffsverwaltung (WSV), Bundesanstalt für Wasserbau (BAW), Länder in the catchment area, Biosphärenreservate, Bundesministerium für Verkehr, Bau- und Wohnungswesen (BMVBW), Bundesministerium für Ernährung, Landwirtschaft und Forsten (BMELF), Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU), Wasserwirtschaft. A selection of end-users has been made in view of the consequences for the design of the pilot system.

Desired state of the river basin

The desired state of a river basin is, in the problem definition phase, expressed in terms of management objectives. The management objectives are closely related to the problems. For example, if river navigation is a problem, the objective can

Figure 2: The Elbe river.

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be to make a particular section of the Elbe River navigable. Or, if the chemical state of the river turns out to be a problem, the reduction of the concentration of particular pollutants can be an objective. Achievement of the objectives is measured by means of (usually quantitative) criteria such as a guaranteed water depth of 1.60 m. For the design of the DSS the objectives in Table 1 are of particular importance as they determine which information the model should provide to its users. Referring to the identified problems the following objectives can be discerned:

Table 1. A selection of management objectives and criteria for the river Elbe.

Objectives	Criteria
Improvement of social-economic use	Improvement of the navigability of the Elbe river Maintenance/improvement of the agricultural yield Development of tourism and recreation Improvement of the conditions for fisheries
Flood protection	Reduction of risk of flooding
Improvement of physical, chemical and biological state of the Elbe and its tributaries and increase of the ecological value of the river and its floodplains	River and ground water quality Soil quality of the river bed and the floodplains Improvement of the ecological functions of river and its banks Improvement of the ecological functions of floodplains Improvement of the ecological functions of the catchment area

For a full inventory of objectives and a list of the criteria corresponding to the objectives stated above we refer to the problem definition report.

Measures

A measure is a technical or non-technical action by the actors, with the aim to change the present state of the river basin towards the desired state. Suggestions for promising measures can be made by the end-users themselves, or the team of researchers designing the model. Although the measures are tentative their selection should be made with care. There is no point in analyzing measures that are too expensive or unacceptable for other reasons. Furthermore, one should be aware of the models and data that are needed to analyze the consequences of the selected measures. For the prototype model it is recommended to select a limited number of measures. These measures address the four themes in Table 2.

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Table 2. Selection of measures for the Elbe River.

Themes	Measures
High water management: dike shifting and other measures	Dike shifting (space for the river); Reduction of buildings and other obstacles in the flood plain; Provide information on high water management.
Water quality	Reduction of point- and non-point-source pollution by improving agricultural practice Reduction of pollution due to hazardous substances Improving/building waste-water treatment plants.
Groyne modification	Groyne modification.
Reduction of erosion	Adding material to the river bed/sand suppletion.

Tourism is also mentioned as an important issue for the future. However, no specific objectives and measures could be identified at this time.

External factors

External factors or future context in the terminology of Miser and Quade [2] are uncertain physical, social-economic, and other conditions that may affect the system under study, but are beyond control of the decision makers. This means that the external factors provide the exogenous input for the model system. Although external factors can be considered as a special class of models , one major distinction with the models in the system itself is that it is usually not meaningful to indicate which external factor is most plausible. For the prototype system, external factors can be introduced for:

Economic conditions;
Demographic conditions;
Land use change in the catchment;
Hydrological conditions;
Climate change;
The Czech input of pollutants into the Elbe River.

The final selection of relevant external factors depends strongly on the system design.

The design of the information system

The phase of "building and using models" in the systems analysis requires the design of an information system. This design process, described below for the

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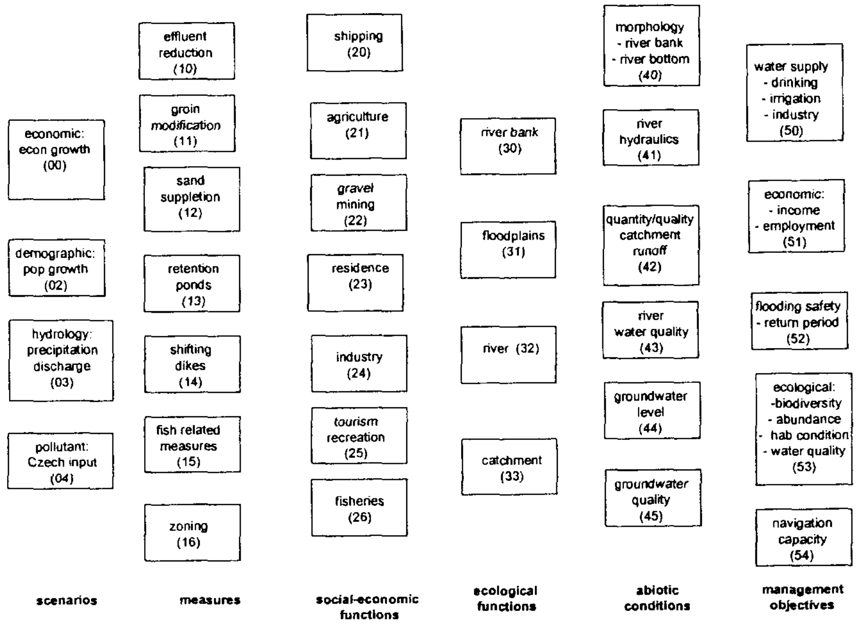

Figure 3: Qualitative system diagram for the river Elbe. For clarity system interactions are not shown here.

Elbe basin, started with a qualitative system diagram followed by a quantitative system diagram.

The qualitative system diagram as a set of word models

A qualitative system diagram provides a conceptual framework for the interaction between management measures and objectives and was developed by scientists using expert knowledge. As a first step a matrix was drawn up with measures and objectives along the axes. The links between measures and objectives were represented by means of +,0,-. This matrix made clear to all participants which group of measures was related to which group of objectives and whether the measure leads to an increase or a decrease of the objective. As a second step, an order-of-magnitude estimate was made of the strength of the links, represented as +++,++,+ etc. As the qualitative system diagram contained a great number of links, initially only the stronger links have been considered. Obviously this assumption is not generally valid (diffusion!) and must be checked in the calibration and validation of the processes in the DSS. The selected processes were represented in the system diagram in Figure 3 in terms of word models based on input and output variables. At the highest level of abstraction (Figure 3) the distinction can be made between social-economic functions, natural functions, and physical processes. Decision-makers can intervene by introducing measures that affect either one of these subsystems, or the interactions between

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them. For clarity the interactions between external factors, functions, measures, and objectives are not shown in the diagram. Instead each element is referred to by a two-digit code. For example, 14-31 is the impact of dike shifting on the floodplain ecology.

The quantitative system diagram on three spatial scales

The quantitative system diagram in Figure 4 contains the scientific concept for each of the processes, an indication of the temporal and spatial resolution of the processes and the data that will be needed. The development of the quantitative system diagram started with an inventory of available models and data mentioned in the qualitative system diagram for the river Elbe, as well as time and costs to acquire them. One of the problems faced in the design of the prototype is that models and data are being collected at a variety of different spatial and temporal scales, ranging from 1000 km^2 sub catchments for land use to 1 m grids for habitat modelling in floodplains. In the former case data are collected for the complete catchment, whereas in the latter case the study sites are limited to a few km^2. The question is then how these different models and data can be incorporated in a common framework of analysis.

The selection of the temporal and spatial resolution was based on the assumption that a chain of models and data, linking measures to objectives, should be of a consistent accuracy and resolution. This was partly carried out by means of a quantitative order of magnitude analysis, but because of a lack of theoretical concepts for this design stage, the argumentation often was rather an art (experience) than a science. This implies that many of the assumptions will have to be validated after the preliminary DSS becomes available. The informatics of this system is open and flexible and allows introduction on new concepts and data.

Figure 4 shows the quantitative system diagram for the Elbe. A distinction is made between three levels of analysis, which exist in the research projects of the Elbe Ecology Program. At the highest level of analysis (Catchment Module) we find the processes studied at the scale of the complete Elbe catchment of 150.000 km^2, i.e. the models describing the impact of land use and hydrology on nonpoint (nutrient) runoff as well as the impact of point discharges. At this scale level the time horizon is long (25-100 years), and the spatial and temporal resolution low (100-1000 km2 and time steps of months or years).

At the second level of analysis (River Module) we find the models pertaining to the Elbe river of 700-800 km in length. This includes, for example, models describing the navigation condition, flood risk, and water quality. Although a variety of models can be used for these purposes, a one-dimensional model would be more appropriate for the prototype DSS. For the river module the spatial and temporal detail will be in the order of 100 m-10 km, and weeks to years, depending on the type of processes studied (bed-level changes will require less temporal resolution than flood-level predictions).

At the third level of analysis (River Section Module) we find the most detailed models that describe the impacts of river engineering measures such as dike shifting and the habitat conditions for different species in the river, its

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banks, and the floodplains. At this scale the level of spatial and temporal detail will be in the order of 10-50 m. This module could be developed for a well-chosen 10-100 km example section of the Elbe river of, which would be representative for the Elbe river in general, and for which the data and models are available or can be collected within the time frame of the pilot study. Preferably the three modules should be linked top-down as shown in Figure 3, by selecting output variables of the higher level modules as input variables for the lower-level modules.

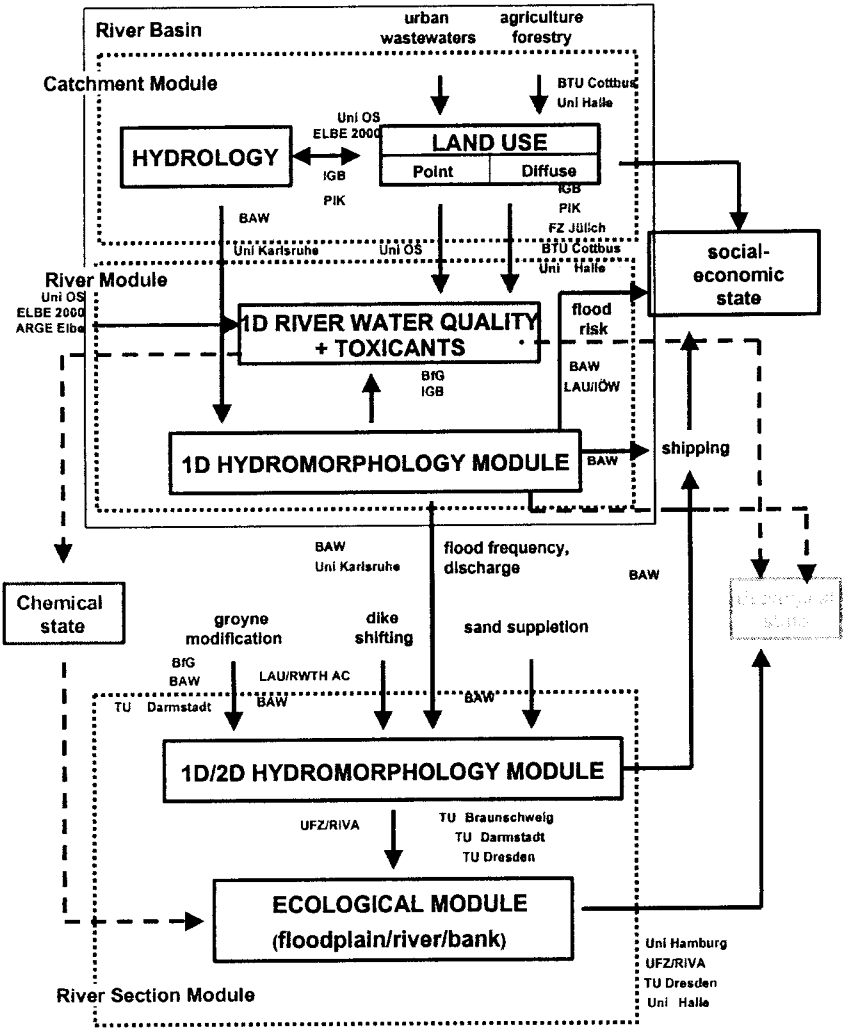

Figure 4: Tentative structure for the prototype DSS for the Elbe with institutes having relevant expertise in the Elbe.

Linking the three modules

For conceptual reasons the three modules should not function independently, but must be linked in some way. Integration can take place in two ways. Top-down integration is the more obvious approach and means that processes at a higher scale will influence the system at a lower scale. For example the water level calculated in Module 2 for a particular section of the river can affect ecological functions at the local level described in Module 3. This could imply that the flooding frequency in all the cells in the floodplain along the section in question depends on one value of the water level in the river, as well as the elevation of each cell. Sometimes the top-down integration will have consequences for the type of models needed. The incorporation of water quality in Module 2, for example, requires a streamline model for pollutant transport in Module 1.

A different approach is to integrate the three modules in a bottom-up way. An example is the influence of molecular diffusion on large-scale transport processes. For the Elbe DSS bottom-up integration could mean that local processes have an impact on a meso (river) and even macro (catchment) scale of analysis. The question however is whether the processes included in the DSS for the Elbe (such as the habitat models) have a bottom-up influence. At least two interactions between the modules can be discerned:
(i) pollutant load of Module 1 as input for water quality model in Module 2, and
(ii) discharge, water quality, and water level calculated in Module 2 as input for the habitat models in Module 3.

Discussion; actors in the river basin management arena

The DSS for the Elbe River is presently being built and results are expected in 2002 and 2003.

In addition to the formal authorities, a number of other actors plays a role in the development of river basin management: scientists, users of the water system, institutions responsible for implementation and maintenance, the general public, NGO's etc. The management processes of the development and implementation of the river basin management plan has been designed such that each actor has the chance to play its own role in the various phases of the process. In the case study the task distribution shown in Table 3 has been used.

There are a number of methods available *to support the decision-maker(s) to determine priorities and help to make a choice* between feasible alternatives. Most common are (spatial) multi-criteria evaluation tools and methods. The question is whether such decision-making tools should be part of the DSS, because in general it calls for a lot of discussion and is relatively little used. On the other hand the large amount of information generated by an integral DSS calls for ways to aggregate, evaluate and present information (e.g. by means of maps). In the problem definition phase the need for such decision-making tools has not become clear. It is therefore recommended to determine the need for these models in the first stage of the development of the pilot DSS.

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Table 3. Task distribution between actors in the policy preparation phases of the Elbe study.

Phases of a Systems analysis	Actors				
	Policy makers	Implementers	Scientists	Users of the basin	Public
Problem definition	*			*	*
Development of feasible measures	*	*		*	*
Building of models			*		
Using models	*		*		
Ranking, selection of measures	*	*	*	*	*

The approach presented in this paper is generic and hence applicable to other rivers. However this approach also shows that the theoretical background of systems design as well as the application in river basin management is rather poor and calls for research to fill up the gaps

In a problem solving approach *knowledge about the impact of measures on the objectives* is a prerequisite. This aspect is elaborated in this paper and is recognized by the scientific community, but is missing in the EU requirements for river basin management plans.

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