# Supporting Multidisciplinary Model-Based Water Management Projects: a User Perspective

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**Abstract:** Multidisciplinary model-based water management is a complex process. Projects that have to follow this process may encounter many problems, related to miscommunication, malpractice, misuse of the model, insufficient knowledge of the modeled problems and overselling of model capabilities. This leads to model projects, which are not transparent and difficult to audit. The knowledge-based system consists of an ontological knowledge base (KB) with 'best modelling practices' for teams, which members have different disciplinary backgrounds and play different roles in a project, and a Modelling Support Tool (MoST). MoST generates and presents guidelines from the KB on what to do. MoST also monitors what team members do in an electronic model journal and facilitates converting model journals into model reports for various audiences and purposes. Water managers can benefit from MoST and its KB in different ways: (1) during project set-up in defining what has to be done and finding a team to do the job, (2) at regular intervals in evaluating what has been done and planning of what has to be done, and (3) to check project progress. Modelers are guided by MoST on what to do, get access to what other team members did and helped keeping records of their work in the project. Auditors can easily follow the audit trail left in a model journal and are helped to appraise modelling projects. Stakeholders and public can be informed and consulted using MoST. In this way MoST and its KB facilitate cooperating in modelling projects and improve their quality. Parts of the technology of MoST and its KB can be reused to support other types of (simulation) modelling or even other types of processes (i.e. not focusing on modelling).

***Keywords***: Multidisciplinary Modelling Support; User Perspective; Quality Assurance Procedure; Scientific Workflow Management; Process Support Technology.

## 1. INTRODUCTION

The first problem, managers of problem solving projects in water management are confronted with, is to arrive at a shared vision on the nature and extent of a modelling project, which supports finding solutions to a stated management problem. That vision entails the scope of the study, the solution approach, expected results, duration, costs and resources used. Thereafter, for a commissioned project, the problem is to execute it in compliance with specifications agreed upon with associated quality assurance. One part of that quality assurance is ensured by transparency of executed activities thus guaranteeing that the work is auditable and reproducible [Scholten et al., 2006].

These current requirements are caused and fuelled by a multitude of problems and bad experiences with model based studies in the past. Refsgaard and Henriksen [2004], Refsgaard et al. [2005] and Scholten et al. [2006] give a several reasons for these problems, including ambiguous terminology, a lack of mutual understanding between key-players, malpractice in regard to input data, inadequate model set-up, insufficient calibration/validation, model use outside of its scope, insufficient knowledge on some processes, miscommunication of the modeler to the end-user, overselling of model capabilities, confusion on how to use model results in decision making and a lack of documentation and transparency of the modelling process.

An additional complicating factor is related to the changing character of model-based problem solving projects from monodisciplinary, single person and academic oriented research model studies into multidisciplinary, decision support oriented projects, in which teams consisting of members with different background and different roles have to cooperate to complete the complex job. Modelling in multidisciplinary modelling teams enables exploring more complex questions, but it also makes cooperation in teams more difficult. Team members with different scientific backgrounds encounter more communication problems, which makes managing multidisciplinary model-based water management projects a cumbersome affair.

The European Commission funded HarmoniQuA project aimed at lowering many of the hurdles encountered in present simulation oriented modelling by providing modelling guidelines, structured in a knowledge base and by developing a tool to support projects that use models for problem solving [HarmoniQuA, 2006]. The context of the HarmoniQuA project, which involves 12 partners in 10 countries and 10 different languages, introduced new problems. These were partly associated with language issues, which were beyond the scope of the project as professional modelers were assumed to understand sufficiently English, and partly because of the variety of modelling cultures in various countries ranging from very professional and mature in northwest Europe to novel and *ad hoc* in some central and south European countries. These discrepancies in expertise were further enhanced by the level of maturity of the scientific disciplines behind the water domain models, ranging from very mature for groundwater modelling to immature for ecological and socio-economic models [Refsgaard et al., 2005].

This paper focuses on how the results of HarmoniQuA's Modelling Support Tool, MoST, and its associated knowledge base with guidelines help solving some of the outlined problems. The tool, the knowledge base and the technology, on which these are based, are discussed from a user perspective.

## 2. MODELLING SUPPORT

To support and facilitate the work of multidisciplinary teams and its project manager in model-based water management the following approach has been chosen. The modelling process has been described and decomposed into elements. The overall *process* is decomposed into *steps*, steps into *tasks* and tasks into *activities*. Furthermore, *methods*/*tools* can be coupled to tasks or to activities. Tasks are related to each other with precedence relations, determining the order of tasks and feedback loops to redo parts of the process, if necessary. There are three types of tasks: (ordinary) *tasks*, *decision tasks* and *review tasks*. Decision tasks have feedbacks to previous tasks and review tasks are decision tasks in which teams discuss progress and decide on continuation. Finally, many details on steps, tasks and activities can be added to the knowledgebase. That means that a generic model of a modelling process has been developed. Based on this decomposition and experiences with other processes, an ontological knowledge base (KB) has been designed with levels of increasing specialization (see Figure 1):

- level 0: meta-ontology with basic terminology;
- level 1: generic process knowledge;
- level 2: modelling knowledge;
- level 3: knowledge for model-based water management.

This leveled structure of the ontological knowledge base facilitates reusing parts of it: a more generic/abstract level can easier be reused for other purposes.

The KB has been implemented in Protégé, a powerful, state-of-the-art, open source ontology editor and knowledge base framework.

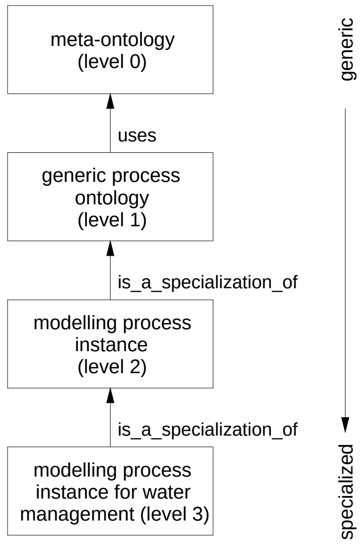


**Figure 1**. A stepwise ontology specialization representing the structure of the knowledge base.

To fill the KB with generic modelling knowledge and water domain specific knowledge, a (web based) KB-Editor has been developed, which acts as front-end between domain experts, unskilled in knowledge engineering, and the knowledge base implemented in Protégé. The KB and the KB-Editor are the backbone of the Knowledge-Based System (KBS) and will be discussed in another contribution to this conference.

Other major components of the KBS are the Modelling Support Tool (MoST) and training material. MoST helps a project manager to filter pieces of modelling knowledge from the KB that are relevant for a specific project and the problem at hand. In this way the project manager arrives at a specification of the work to be done, by whom (experts with different disciplinary background) and using what other resources (models, tools). Subsequently, in the execution phase of the project, MoST monitors what all team members do and helps generating 'smart' reports for various audiences and purposes. Finally, training material has been developed consisting of written material, presentations, exercises that encourage using MoST in a training test case project and many screen-recording movies on MoST, its knowledge base, a case study and some background information. The movies are the core part of the training material and aim at helping users to work with MoST and act as a sort of animated help facility. Elements of the training material are used in the Help System. MoST, its KB, the KB-Editor, the Training Material and the Help System form an integrated product to support multidisciplinary model-based water management projects.

MoST can be optimally used in a setting, in which a (distributed) team, consisting of problem owner / (water) manager, modeler(s), auditor, stakeholders and interested members of the public cooperate in a multidisciplinary model-based water management project (i.e. covering more than one water management domain). What team members do is stored in a model journal. The model journal is shared by all team members and stored on a project server (on Internet or on a LAN). A server application is responsible for managing model journals, enabling that all team members see and work in a model journal, shared by all team members. MoST acts in this way as a client application. The KB is available at a central server to facilitate maintenance and updates. MoST supports updating the local versions of the guidelines from this central server.

Team members get guidance on what to do filtered and customized to their role in a project and the water domain they are working in. A modelling project consists of one or more subprojects. A subproject is typically associated with one or more (water) domains. Subprojects can run with different speeds, but within a subproject with more than one domain the work is executed synchronously.

## 3. A USER PERSPECTIVE

### 3.1. Problem Owner and (Water) Manager

If a problem owner has a water management related problem, which probably can be solved with a (mathematical) model, the problem owner describes the problem, defines objectives of the study, checks the availability of appropriate data, determines the requirements to the study and prepares terms of reference in order to find an organization / team with expertise in the relevant water domains that can do the modelling job.

In the start-up phase of such a project, the (water) manager has to negotiate on who will do what and when. In this phase, MoST can help making the set-up and negotiations explicit and recording it in the model journal. Managers/problem owners can use the defined modelling process in the guidelines of MoST as a template for an agreement with the modelling organization on what has to be done in the project.

During a project, the role of a manager includes: checking the progress of the project (what has been completed, what is in progress and what still has to start) and evaluate (intermediate) results. MoST supports both tasks.

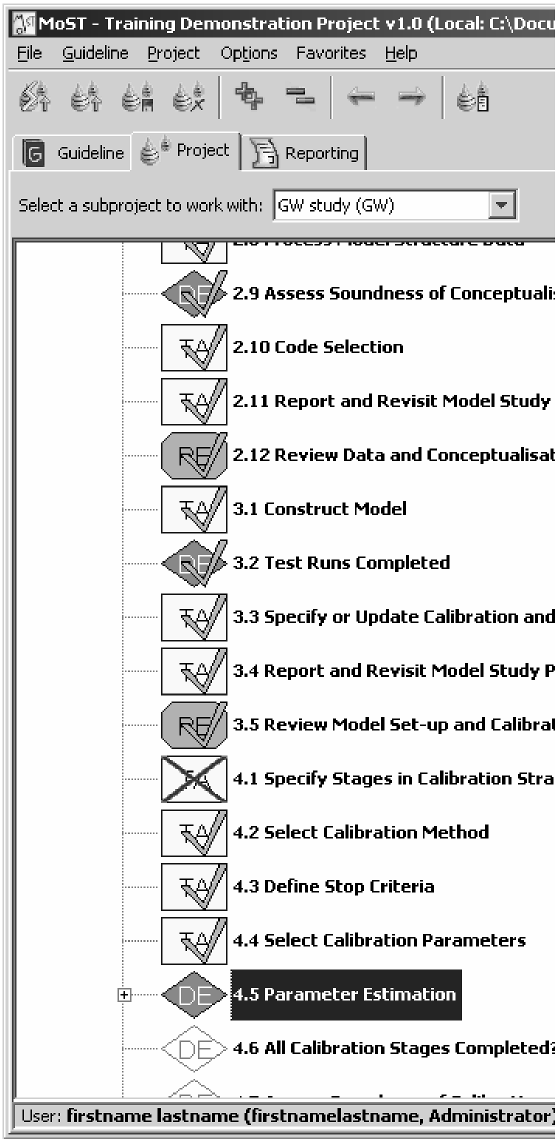


**Figure 2.** Tree view of MoST's monitoring component.

The status of each of the 48 tasks of the standard template can easily be checked in the tree view (see Figure 2). Different icons are used to show this status. A *transparent* icon indicates a task not yet started. A *colored* icon indicates a task that has already started, but not yet finished. If a task is finished, a *green checkmark* is displayed. Skipped task are shown with a *red cross*.

At the end of each step a review task is planned, in which the tasks of the current step are evaluated and the tasks of the next step are planned. This requires an intensive interaction between manager, modeler(s) and team members with other roles. A review task includes deciding on continuation with the next step or redoing a part of the tasks in the current step. In this way managers evaluate at regular intervals (the end of each step) the content of a project.

### 3.2. Modelers

MoST has been designed to support cooperation within a team in modelling projects. Next to the interaction between managers and modelers, cooperation between modelers within a subproject or between subprojects is essential. Modelers working in different domains have to understand each other and all modelers have to be aware of what the other modelers do or did. Therefore MoST facilitates and encourages that all team members and especially modelers keep records of what they do and what the results are of their work. All modelling activities are recorded in a model journal, which leaves an audit trail for reconstructing or auditing model projects. Additional documents e.g. tenders, project plans, model input, result files, acceptance tests, can easily attached to a model journal, facilitating the completeness of project documents.

Furthermore, modelers will be guided through the modelling process following a widely accepted sequence of steps and tasks. Within each task the modeler is presented with a list of activities, which should be carried out, and guidance on their scope and relevance to the modelling task at hand. Where appropriate, MoST presents commonly used methods to support the given activities. Reports may be produced from MoST that contain information appropriate for stakeholders and the public. These reports support their involvement in the modelling process.

### 3.3. Auditors

Auditors can benefit especially from the project's audit trail, left in the model journal. MoST allows auditors to evaluate the work of other team members. Auditors can check the status of all steps, tasks and activities, but also see what has been done, what the results are, decisions taken, which things are not done and why. Furthermore, all other relevant documents, attached to the model journal, are accessible through hyperlinks.

MoST facilitates a transparent evaluation and appraisal of projects by enabling auditors to fill in scoreboards for subprojects. Default scoreboards are provided by MoST and managers can adapt the scoreboards to their own wishes and the character of a (sub)project.

### 3.4. Stakeholders and Public

MoST distinguishes stakeholders and interested members of the public. Stakeholders have a stake in the water management issue, i.e. in exploiting or protecting the resource. Stakeholders include the competent water resource authority and interest groups. The public is a more diffuse group composed of persons that are not directly involved (as modeler, manager or auditor) in a modelling study but that have a legitimate interest in the modelling results. The public may typically be either interest groups or the general public.

The Water Framework Directive (WFD, EU based legislation on river basin management) requires involvement of stakeholders and public. Public participation can have three levels of involvement: (1) being informed, (2) being consulted and (3) active involvement, i.e. discussions, influence on the policy agenda, participatory design of solutions, involvement in decision making and participating in implementation [Pahl-Wostl, 2002, Ridder et al., 2005]. The first two levels are enforced by WFD, the third is recommended.

MoST facilitates informing and consulting stakeholders and public. If members of these groups are added to the team, they can read or write in parts of the model journal within the limits of their authorization. The third level of participation is more active. To facilitate this type of participatory involvement, MoST's KB with guidelines can easily be adapted.

### 3.5. Cooperation in Teams

The multidisciplinary character of MoST's KB facilitates to understand and accept practices and methods of other team members with different disciplinary backgrounds. MoST's KB provides a glossary of 1000 water management terms, which can be used directly or by the hyperlinks added to all glossary terms in the guidelines.

Moreover, MoST allows team members with the appropriate authorization to see what other team members did in a project. This functionality of MoST significantly facilitates cooperation within teams.

### 3.6. The Professional Modelling Community

MoST helps the professional community involved in multidisciplinary model-based water management by focusing on a state-of-the-art-modelling methodology. This methodology is not static, hindering scientific progress, but it is open for comments within the limits of the KB editing authorizations. Ontologies have two fundamental qualities: they enable exchange of knowledge between computers and persons (in all combinations) and they encourage that bodies of knowledge are shared by a group. The latter quality of ontologies requires agreement within the group, which only can be achieved in a continuous process of discussion to come to consensus. In this way the ontological nature of the modelling KB stimulates the dynamics of its content and promotes a wider acceptance.

### 3.7. User Appreciation

How users appreciate MoST and its KB has been tested in 21 case studies, 6 courses, 15 professional workshops and using questionnaires. Some results are summarized here.

MoST helps *water managers* during project set-up, where its guidelines serve as template for an agreement with the modelling organization. Furthermore, MoST enables straightforward project management. Despite these benefits, it was experienced so far that many water managers would not use MoST themselves, but let some project manager play MoST's manager role.

In their first projects, *modelers* feel MoST as a straitjacket that forces them to work according to the guidelines. Just 'overhead' instead of 'help'. Later they experience the ease of use and the benefits of making explicit what they actually did.

*Auditors* perceive the use of MoST as a prerequisite that facilitates their review work. *Stakeholders* and *public* find MoST difficult, but if an expert mediator guides them, they can appreciate it as a tool for real participation in modelling projects.

## 4. TECHNOLOGY USE AND REUSE

### 4.1. Technology

Using the concept of ontological levels in the KB (see Figure 1) facilitates discussing use and reuse of knowledge and tools. We will define here the collection of components consisting of ontological level 0 (terminology), level 1 (generic process knowledge), level 2 (modelling knowledge) and MoST as *modelling support technology* and the collection of components consisting of ontological level 0, level 1 and MoST as the *process support technology*.

### 4.2. Use

The *modelling support technology* (level 0 + 1 + 2 + MoST) is used in combination with ontological level 3 (knowledge for model-based water management) in HarmoniQuA and referred to as MoST and its KB. In addition to generic modelling knowledge, seven water management domains are supported at present (hydrodynamics, groundwater, precipitation-runoff, flood forecasting, surface water quality, biota and socio-economics). There are plans to extend this set of domains with 'activated sludge modelling'. For this purpose ontological level 3 has to be extended with knowledge on this 'new' domain. MoST and its KB are also used in complex, model-based water management projects in Sweden, Denmark, UK, Netherlands and Germany.

### 4.3. Reuse

The *modelling support technology* (level 0 + 1 + 2 + MoST) can also be used for other types of (simulation) modelling, e.g. environmental modelling, crop growth modelling (e.g. in SEAMLESS, www.seamless-ip.org). Such an approach requires a new content of ontological level 3 (knowledge for model-based water management).

Supporting other processes than modelling requires the use of the *process support technology* (level 0 + 1 + MoST). For this purpose ontological level 2 (modelling knowledge) and, obviously, level 3 (knowledge for model-based water management) have to be replaced by structured knowledge on the new process. An example of using the *process support technology* for other processes can be found in the AquaStress project (www.aquastress.net). This project aims at water stress mitigation by providing various water stress mitigation options (technical, management, institutional and others), scientific evaluation of options (multi-criteria analysis, simulation, case based reasoning, etc.) for case studies at specific sites and by supporting participatory processes, in which stakeholders and public participate in selecting and evaluating water stress solutions.

Other examples of reusing parts of the technology include a recent initiative in Denmark to develop a KB for geological modelling, the implementation process of WFD (Water Framework Directive) and supply chain management.

## 5. EXISTING PRACTICES

Recent initiatives to improve quality assurance in model-based water management focus on practices and guidelines [Van Waveren et al., 1999, Scholten et al., 2000, BDMF, 2000, Middlemis et al., 2000, Pascual et al., 2003]. Refsgaard et al. [2005] reviews existing guidelines and classify them according to the following criteria: a public consultation and consensus building process, interaction between modeler and water manager, the scientific maturity of the underlying discipline and the maturity of modelling market. In this way Refsgaard et al. [2005] can explain the state-of-the-art in modelling guidelines for all water management domains and European countries.

Compared to existing guidelines, the HarmoniQuA guidelines are more complete and flexible, support various water management domains, distinguish and serve several user types and allow fine-tuning the modelling process structure to the requirements and character of a modelling project [Scholten et al., 2006]. Moreover, the design concepts and implementation of the modelling support tool MoST is an extra dimension on top of these guidelines.

## 6. CONCLUSIONS AND DISCUSSIONS

MoST and its KB can be fruitfully used in multidisciplinary model-based water management projects. It provides guidance and monitors what team members do. In this way, it facilitates auditing and makes projects transparent.

English is the language used in the tool and in the KB. The lack of support for other languages may hinder a wider use. In order to encourage a wider use, MoST and the KB should be able to cope with more languages. Such a multilingual support requires extra functionalities to guarantee the consistency of all language versions. Future work should enable and facilitate this multilingual use.

The structured approach, in which all process knowledge is organized in ontological levels, facilitates reusing parts of the knowledge base for other processes. The modelling support tool MoST can be used for all processes that can be represented in the format of the KB, i.e. fitting in level 0 + level 1, independent of the content of a process. In this way, the technology, developed in HarmoniQuA, has a wide scope, as it can support all kind of complex processes, in which persons have to cooperate.

## 7. ACKNOWLEDGEMENTS

The present work was carried out within the projects *HarmoniQuA* (partly funded by the EC in FP5 under Contract EVK1-CT2001-00097) and *AquaStress* (partly funded by the EC in FP6 under Contract 511231). The authors thank all HarmoniQuA partners for their constructive and fruitful cooperation. Comments of two anonymous reviewers are acknowledged.

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