

ISSNEW –

A Conception of GIS and Simulation System Cooperation for sustainable groundwater management

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Abstract – The European Water Framework Directive (WFD) came into effect to sustainably protect water resources and to define general objectives in water management. To enable appropriate action planning and to fulfil the obligations to report the status of the water bodies, it is important to use up-to-date spatial data as stored in an information system in combination with well-proved simulation systems. ISSNEW (Information and Simulation System to Evaluate Non-Point Nutrient Entries into Water Bodies) is a project to develop such an integrated information and simulation system. At this the data gathered and maintained in a Geographic Information System (GIS) are used by a coupled system of existing simulation programs for nitrate turnover and transport. In addition the results of the simulation systems will be returned to the information system.

Motive and Design of ISSNEW

The WFD leads to high demands on all parties, but also on the tools to support measure planning and evaluation. The ambition of the WFD is to achieve a good environmental status of surface water as well as good quantitative and chemical statuses of groundwater.

To accomplish these objectives, the following steps must be carried out:

- gathering substantial information about the water bodies,
- qualification and evaluation of the current status,
- defining the nominal status by specifying the obtainable goals and
- establishing and implementing measures and cultivation concepts.

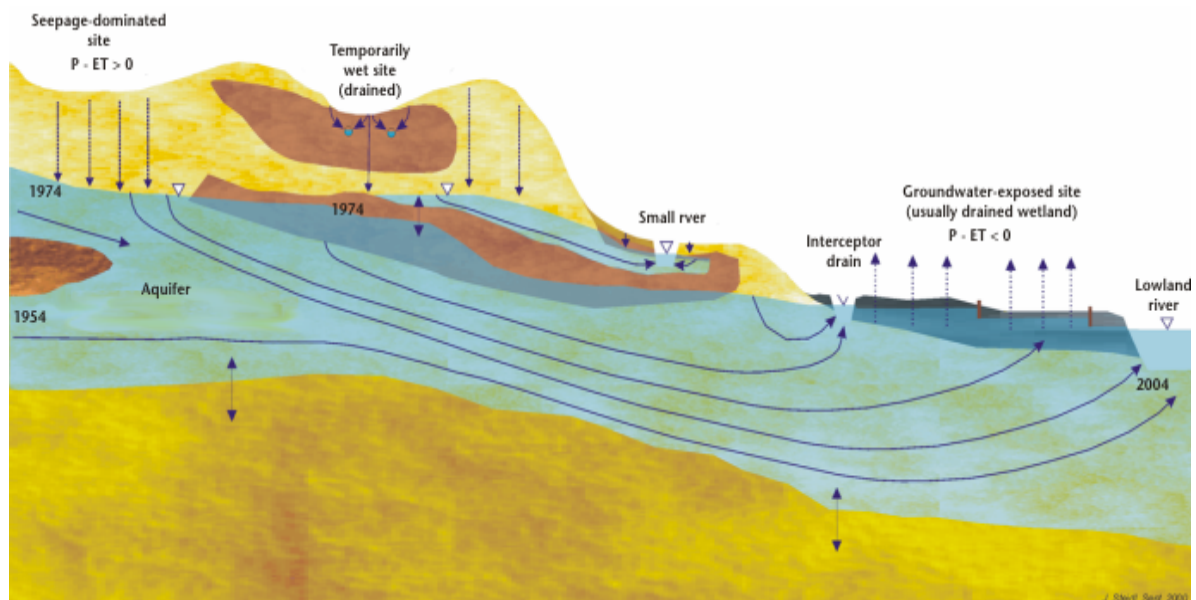


Figure 1: Illustration of possible paths of non-point source nitrogen flow from agriculture, modified acc. to Dannowski et al. (2001).

Still in the year 2004 all water bodies must be qualified. By 2009 measures for improving the status of water bodies at risk must be developed and implemented. Finally not later than 2015 the good status of all water bodies should be accomplished. But as many processes – especially groundwater-related processes – are very complex and longsome, it seems to be ques-

tionable whether the good status is attainable in any case within this short period of time. For example, owing to the long travel times of nitrates from non-point sources as illustrated in Figure 1, it is important to provide tools to initiate and prove a reversal of trend in the environmental impact. To do so, spatially and temporally differentiated measurements have to be initiated. Therefore the tools have to be spatially and temporally differentiated as well. Hence simulation systems with a high spatial and temporal resolution are of particular importance in planning and validating measures. Unfortunately they are not yet available to meet all WFD-specific requirements. In particular most simulation systems cannot resort to the large amount of up-to-date spatial and temporal data stored in a GIS.

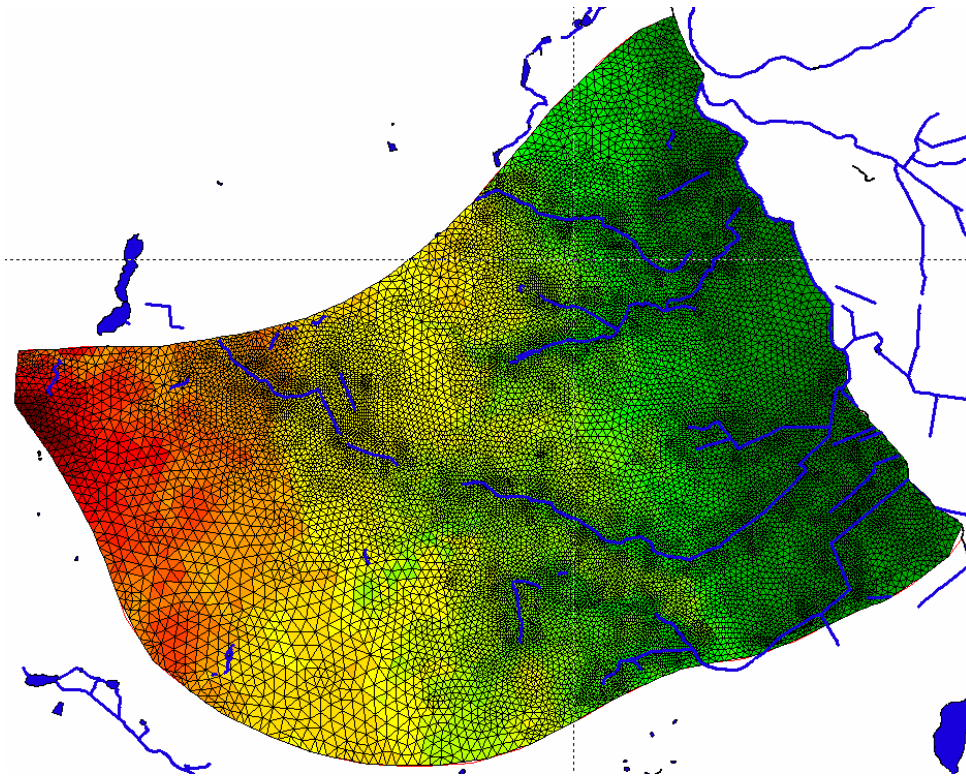


Figure 2: Finite Element Mesh of the ISSNEW pilot area in the federal state of Brandenburg, Germany.

To deal with this drawback, but also to benefit from the accurate and well-proved existing simulation systems, ISSNEW combines the capability of a GIS with the accuracy of simulation systems using intelligent bidirectional interfaces. To show the feasibility of this approach, ISSNEW will be implemented to evaluate the non-point nutrient entries in a pilot area of about 100 km² in the federal state of Brandenburg, Germany (Figure 2). The groundwater body at risk will be used to deduce the current situation from data of the past and also to forecast the effects of possible measures. The primary objective of the pilot study is to gain experience and to survey the feasibility of the ISSNEW approach in practice.

As mentioned above, several stand-alone applications are used to realize the project. The underlying ISSNEW Information System is based on the ESRI ArcGIS8 family. The data management is implemented by an ArcSDE instance with a WFD-specific database model to store surface- and groundwater-relevant information and management data, but also meta data and information required by the simulation systems, e.g., soil stratum and cultivation data. To facilitate data acquisition and maintenance, the ArcMap user interface is enhanced by a series of WFD-specific internal and external tools. To estimate the water balance, the crop growth and the nutrient turnover in the root zone SOCRATES (Wieland et al. 2002) is used. SOC-

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RATES is a one-dimensional process-orientated model. For the description of water and nitrate flow in the unsaturated zone – between root zone and phreatic surface – the UZ Module (Waldow 2003) is used. Finally the simulation of flow and transport processes in the saturated zone is realized by the deterministic-numeric simulation system FEFLOW (Diersch 2002). Optionally MODEST (Dannowski et al. 2002) can provide a simplified calculation of nitrate transport and discharge in the ground.

With this collection in mind it appears that not only the simulation systems needs to have access to the data stored in the information system, but also the simulation systems have to be coordinated. Therefore the intelligent ISSNEW user interface is developed. The interface design is subject of this work.

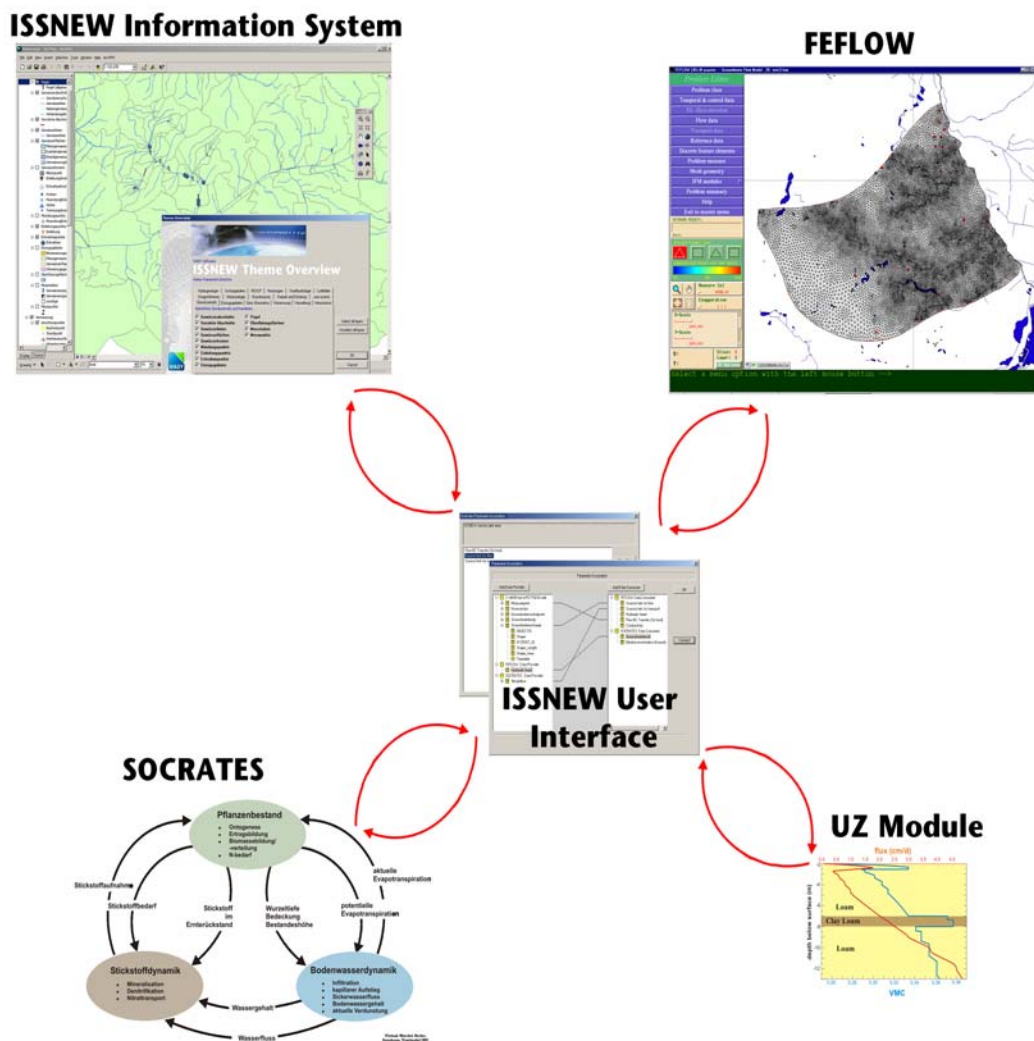


Figure 3: Overview of the ISSNEW tool composition, with the user interface as central controlling unit.

The ISSNEW user interface

So far simulation systems often use data stored in files for parameterization and to exchange information. However, file-based data handling is inefficient and in general requires user interaction. File-based data often leads to inconsistent models due to different versions of the

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basic data. Frequently extended effort is required to keep models up-to-date. Hence the consequence is that model parameterization should become a self-acting process executing predefined rules. Consequently this also means that different simulation systems have to use the same (application-independent) data pool. This suggests storing and maintaining all required data in a GIS, because the majority of the data are of a spatial type. Unfortunately simulation systems are often stand-alone applications, which are not modifiable due to the lack of source code or economical considerations. So an implementation of database access within the application often is not possible. On the other hand, many modern commercial systems provide a programming interface allowing to overcome file-based data transfer. Considering the ambition of ISSNEW – thus not only data exchange but also cooperative simulation – the participating simulation systems have to be controlled externally. As well they have to exchange data among each other. This suggests an abstract design of data exchange and simulation control.

The ISSNEW user interface is implemented using the Microsoft Component Object Model (COM) to provide such an abstract design. But unlike the classical understanding of the interface term in COM, it does not only consist in a definition of properties and methods. Rather - beside the definition of COM interfaces to connect the information system with the simulation systems - it provides a graphical interface to define the data- and workflow. It also has the capability to execute these definitions during model initialization and simulation. It features the persistent storage of such a scenario draft and the possibility to duplicate and modify scenarios, which are important features to enable efficient measure planning.

To provide a flexible way to connect different simulation systems among each other and also to the GIS database, the ISSNEW user interface defines a set of COM interfaces. These interfaces have to be implemented by the simulation systems or - if needed - by additional external components according to the requirements of the simulation system.

Presently the following COM interfaces are to be implemented:

- **data consumer** if the component requires data from other components,
- **data provider** for all components, which maintain or calculate data,
- **simulation participator** if the component provides any calculation and
- a set of **abstract data types** for data exchange.

The access to the GIS is realized by a component implemented using the ESRI ArcObject library. The GIS component provides data stored in the database and enables the ISSNEW composition to return simulation results to the GIS. Beside the data management the GIS does not participate in the simulation process; therefore it only implements the consumer and the provider interface. In general the simulation components will make use of all of these interfaces. An important issue of the design is that using the COM interfaces is solely based on a description of the own model. There is no need of any knowledge of foreign models or data structures.

Therefore the so-called mapping of information and workflow of the individual models has to be defined by the user. This requires a central instance realized by the ISSNEW user interface. So the different components are linked to the ISSNEW user interface, not against each other. This enables the ISSNEW user interface to control the path of data and the simulation workflow. The conception of the ISSNEW composite is illustrated in Figure 3.

To enable convenient user mapping, the ISSNEW user interface provides a graphical user interface (GUI), which offers dialogs for scenario management, information mapping and workflow control. A preliminary dialog design to link data between different components is shown in Figure 4. There the user can link data source and destination simply by pressing a button. In most cases a simple connection will not be sufficient, of course. Thus each link has a set of properties, which can be edited to define for example spatial or temporal selection, unit conversion and regionalization rules. Similar GUIs are under development to specify the simulation workflow. After defining the workflow and mapping all the data, the predefined

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scenario can be used to update the simulation systems whenever data is modified or new data is added. Simulations can be repeated ensuring that the same environment is used. In conjunction with the ability to store the defined scenario persistently in a repository inside the database, it is possible to reproduce and comprehend the origin of previously generated results; therefore it provides a documentation of decisions in measure planning.

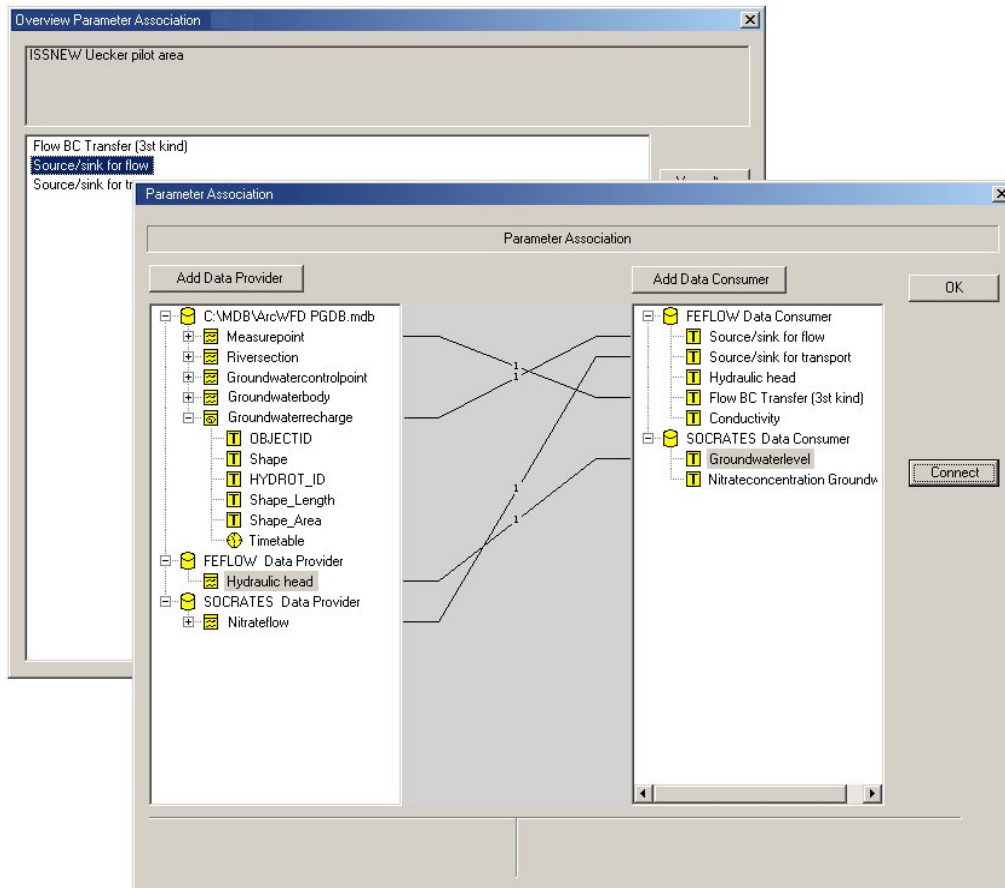


Figure 4: Illustration of the preliminary dialog to link source data with target parameters.

Conclusions

ISSNEW follows up an ambitious objective: to combine different standalone simulation systems to a powerful simulation composite, including a GIS for data management and storage. With respect to the short time frame of the WFD there is little scope to replace the current standalone applications by cooperative solutions. Hence an intelligent interface to manage such a coupling seems to be a promising approach. It will be used to evaluate non-point nutrient entries during this project. The current status of development shows that this is a practicable way to combine simulation systems and provide the user with a GUI for system handling. An important issue during implementation is to minimize required expert know-how for usage, to maximize automation and therefore to make manifold scenario computations possible. There are some open questions, of course, for example, performance of the simulation, efficient data exchange and the feasibility of the results. If the project succeeds in the quantification of non-point nutrient entries, it provides a framework to establish simulation composites in a wide area of environmental planning and beyond this.

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