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Integration of MONERIS and GREAT-ER in the decision support system for the German Elbe river basin

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Abstract

The Elbe-DSS is a computer based system for integrated river basin management of the German part of River Elbe basin. Simulation models are used to assess the efficiency of measures such as reforestation, changes of agricultural practices or the efficiency of wastewater treatment plants for achieving management targets. MONERIS and GREAT-ER are integrated into the Elbe-DSS to assess nutrient and pollutant loads. MONERIS calculates nutrient inputs from diffuse and point sources on a sub-catchment scale of about 1000 km^2. GREAT-ER is a tool for exposure assessment of point source emissions and considers fate in sewage treatment plants as well as degradation and transport in rivers. Both models make long-term predictions, but their spatial scales of operations differ. GREAT-ER divides the whole river network into small segments that are linked through a routing algorithm. The segments are coupled to MONERIS using accumulated flow length distribution. Linking the two models allows to distribute diffuse nutrient emissions calculated from MONERIS and point source emissions from GREAT-ER to the river network, where further elimination and transport processes are calculated. We exemplify the DSS in a study assessing the effects of different reforestation and erosion control measures on phosphate loads and concentrations in the river network.

Keywords: River basin management; Water quality; Integrated modelling; Decision support system

Software availability

Name of Software: Elbe-DSS
Developer: German Federal Institute of Hydrology (BfG), Project Group ELBE-ECOLOGY
Contact address: Dr. Sebastian Kofalk, German Federal Institute of Hydrology (BfG), Scharrenstr. 2-3, 10178 Berlin, Germany
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Email: kofalk@bafg.de
Year first available: 2005
Hardware required: PC (2000 MHz or more, 1024 MB of RAM, Windows NT/2000/XP)
Software required: Excel 97 or higher
Program languages: C++, Python, Fortran77
Program size: 500 MB including data
Availability: CD from developer
Cost: free of charge

1. Introduction

Integrated river basin management involves all management objectives related to the use, pollution mitigation and rehabilitation, protection and rehabilitation of water bodies as well as many other impacts on water quantity and quality in a river basin. An integrated approach implies that relations

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between the abiotic and the biotic part of the various water systems, between ecological and economic factors and between various stakeholder interests are considered in decision-making processes. The European Water Framework Directive (EU, 2000) consequently calls for a multidisciplinary approach of river basin management. A decision support system (DSS) for integrated river basin management of the German part of the Elbe river basin (Elbe-DSS) has been developed, which includes water quantity, chemical quality and ecological state of surface waters. System analysis of water quality management and design of the Elbe-DSS are presented in Matthies et al. (in press). Management objectives, external scenarios, and measures were derived from repeated consultations of stakeholders and potential end-users. System diagrams were developed for the catchment and river network and appropriate models and databases were selected. Concerning water quality management issues, MONERIS (Behrendt et al., 1999) was chosen for the catchment module and GREAT-ER (ECETOC, 1999a; Matthies et al., 2001) for the river network. In this paper, we describe the coupling of both models and their integration into the Elbe-DSS. Finally, the effects of the measures reforestation and erosion control on the reduction of phosphorus load and concentration in river water are demonstrated.

2. Software concept

The Elbe-DSS is implemented using the DSS-generator Geonamica® developed by RIKS (Hahn and Engelen, 2000), which is also used in other DSS projects (Oxley et al., 2004). Model runs are performed inside the Geonamica® framework that also ensures the correct scheduling of the different processes. The Elbe-DSS contains a GIS-based user interface, which allows flexible easy-to-use access to pre- and user-defined scenarios. Furthermore, a database management system (DBMS) and a knowledge-based toolbox are integrated under the graphical user interface. Evaluation tools have been provided for various kinds of decision-making, e.g. risk-based for hazardous pollutant concentrations, monetary-based for engineering measures or ecological services for floodplain restoration.

3. Integrating GREAT-ER and MONERIS

3.1. Selected models

The MONERIS model (Behrendt et al., 1999) calculates nutrient inputs of phosphorus and nitrogen into river basins. It is parameterised for 132 sub-catchments in the German Elbe river basin and allows the average long-term simulation of P- and N-loads from point and non-point sources. MONERIS calculates diffuse inputs caused by erosion, surface runoff, groundwater flow, tile drainage, atmospheric deposition and impervious urban areas for each of the sub-catchments. Inputs from point sources are calculated for effluents from wastewater treatment plants (WWTP). All discharges from point and non-point sources are summarized at the level of sub-catchments and passed down from upstream to downstream catchments. Along each of these pathways from sources of emissions to the outlet of the river basin, processes of transport, transformation, retention, and loss are taken into account. A detailed description of the internal model structure of MONERIS and the used equations is given in Behrendt et al. (1999, 2003).

GREAT-ER is an aquatic fate and exposure assessment model that calculates concentrations of hazardous substances released by point sources, e.g. sewage treatment plants (Matthies et al., 2001; ECETOC, 1999a). The entire digital river network (Federal Environmental Agency, 2004) is divided into reaches of about 2 km length, which result in a number of approximately 33,500 reaches in the German part of the Elbe River (without tide influenced coastal sub-catchments). GREAT-ER takes into account emissions from households and industrial inputs, degradation in sewer system and wastewater treatment plants depending on treatment efficiency. GREAT-ER is able to deal with uncertainty by running Monte–Carlo simulations, using an approach similar to the CatchMODS system of Newham et al. (2004). Further details are given in ECETOC (1999b). MONERIS is a deterministic model without the possibility of Monte–Carlo simulations.

3.2. Coupling of MONERIS and GREAT-ER

MONERIS and GREAT-ER both calculate annual conditions averaged over long-term periods without explicitly considering process dynamics. However, whereas MONERIS calculates discharges and diffuse inputs at a sub-catchment scale of about 1000 km^2, GREAT-ER operates at a scale of river reaches around 2 km in length. Thus, coupling of both models is mainly a spatial problem, i.e. ensuring compatibility of the different spatial resolutions.

Linking the models requires the definition of an interface. Some model components such as fate and transport processes of nutrients from point sources are parts of both models. MONERIS only provides overall aggregated emissions per sub-catchment, but GREAT-ER incorporates the geographical location of the treatment plants and their different treatment technologies. Point source discharge in the Elbe-DSS is modelled by GREAT-ER because of the disaggregated single treatment plant approach. Other details of municipal wastewater treatment like sewer system overflow are not considered in GREAT-ER and are therefore calculated in MONERIS. Hence, both models could not be used as entire packages and it was necessary to separate components of both models. Fig. 1 shows the information and data flow between the various model components. MONERIS delivers diffuse discharge for processing in GREAT-ER. Thus, nutrient loads from point sources (GREAT-ER) are combined with those from diffuse non-point sources (MONERIS). It is ensured that measures and scenarios affect both models in a consistent way, e.g. changed demographic patterns will influence the number of inhabitants connected to the sewage treatment plants (GREAT-ER) as well as the number of inhabitants that are not connected to a sewage treatment plant (MONERIS).

The discharge of diffuse inputs into the river system in MONERIS is realized by linking sub-catchments to