VICAIRE - MODULE 2

Qualitative Hydrology - Chapter 9

Summary: Water Quality Modeling

The natural systems are very complicated and high-organized systems. Modeling is a continuous process of developing models in times, which more and more adequate to describe the real process. Water quality models try to simulate changes in the concentration of pollutants as they move through the environment in different water bodies, as the fate of pollutants is the resultant of interactions between mass transfer and kinetic processes. A pollutant concentration entering the environment may increase or decrease due to a wide variety of mechanisms. All these changes are the subject of water quality modeling.

The water quality models represent a system of equations, relationships and observed data, created for description of the natural system, for demonstration and checking its behavior under different conditions in time and in suitable type with significant economy of money and time.

The focus here is the purpose, types, structure and application of the water quality models.

The developing of water quality modeling is implemented as a continuous process beginning with the presentation of the natural system as well as the purpose of modeling.

The key elements for creation the suitable water quality models are related with the good knowledge about a change in state of a system, presented with the difference in properties between the final and the beginning state. It is not possible to assess water quality without evaluation of the water quantity. That is why the water quality modeling includes as a main part the water quantity modeling (determination of flow characteristic), which gives the answer how water movement affects the concentration of the dissolved and suspended constrains.

The process of model building is an iterative process, which starts with expression of a working hypothesis, typically based on a priori knowledge about the system in the form of mathematical model and involves: formulation of objectives; review of theoretical background; formulation of the model; creation of a model structure; formulation of equations; formulation of methods of solution; selection of a computer code; calibration of the model; validation of the model; statistical assessment of paired observations and simulations; sensitivity analysis, and visualization of results in graphs, tables and ArcView shapes.

Basic equations for water quality modeling, which are the modeling fundamental are: conservation equations, which describe the conservation of momentum, water mass, heat energy, and constituent mass and equation for continuity of water.

The used solution techniques for solving the basic equations are analytical solution and numerical solution in dependence of the type of the system equations.

All simulations are subject to uncertainty having in mind that the hydraulic and transport parameters and boundary conditions are never known in sufficient details as well as the existing distributions of the pollutants. Uncertainty in the results may be classified as associated with model input parameters and with numerical and conceptual difficulties in modeling pollutant transport.

The available water quality models are many different types in dependence of the level of input and output information, the complexity of the modeling events, the modeling water body, used mathematical methods, the type of the basic equations, the aim of the modeling, the structure of the modeling system, the scale of interest and others. Basically they are divided into simulation and optimization models.

The simulation models describe all models, represented water quality changes in some mathematical form in which the processes are deterministically represented and also statistical models while the optimization models are a group of mathematical techniques used to obtain the least costly solution to some allocation situation.

The simulation models by the type of model are divided into mechanistic, empirical, deterministic and stochastic models. The common tendency is the models to be more fundamental and less empirical. From the practical view the water quality management models will have empirical character in future.

Types of water quality models in dependence of the simulated water body are: models of water quality in rivers; models of water quality in estuaries; models of water quality in reservoirs and lakes; models of water quality in ground waters; models of water quality in run off.

Types of water quality models by function of pollutants: for estimation of non-point source pollution of stream flow from watershed and for estimation of point source (in stream) pollution. Usually these two models work together, included in one common decision making system for evaluation of the water quality in every reach of the river, taking into account the self-purification capability of the stream flow and all physical, chemical and biological processes simulations.

The monitoring aquatic data are divided into three types: continuous records; discrete records from samples taken at particular points in time and cumulative records. All these data needs from the more detailed analysis related with the assessment of common trend of changing and the notation of the measurements, declined from the trend. The monitoring aquatic data are very important for calibration and validation of the water quality models.

For better understanding, here, are presented some characteristics of a special water quality assessment system REKA (River Environmental Knowledge and Assessment), developed for the Yantra river basin in Bulgaria to evaluate non-point and point sources of pollution in a media of GIS. REKA system has two sub-components: BISTRA (Basin Impacts of Simulated Transport from Rural Areas) and VODA (Validation and Optimization for Decision Analysis). The system goal is to create an approach to simulate and to assess the water quality in various river reaches in dependence of future climate variability and socio-economic changes.

Application of REKA requires the availability of a comprehensive, well-structured database. All these spatial data are presented as ArcView map layers and attribute tables attached to the layers. Some of the required input layers are presented for Yantra river basin. BISTRA assesses stream flow, nutrients and sediments for every outlet of the subbasins. BISTRA output results are: monthly precipitation, evapotranspiration, groundwater, runoff, stream flow, erosion, sediment, and dissolved and total nitrogen and phosphorus loads. They are entered into Excel file, created as an input file for VODA in-stream model in proper order. REKA delivers loadings and water volume data to VODA by stream reach. VODA then computes flows and pollutant concentration and loads by reaches. VODA can be used to generate a scenario based on current conditions or to simulate the water quality impacts of proposed treatment facilities or discharge regulations. VODA also provides for input of alternative weather conditions, based on the validation period or a typical wet, average, or dry year. It is also possible to input temperature and precipitation change scenarios derived from global climate change models. Typically, simulations will be framed in terms of low-flow months during relatively dry years. The numerical results of VODA's simulation and optimization are then passed back to ArcView for visualization, viewed as Excel charts and tables or as GIS-layers - ArcView shapes.

Briefly, it has to be mentioned that the water quality models have shown that they are the most convenient and powerful operational tools that allow to precise the water quality management policies. Nevertheless, they are always necessary to perform many various simulations of different pollutants for a given basin, to create many different scenario for every sensitive river reach and to present the emission reduction sensitive area, which can vary with the periods of investigation and also with the meteorological weather conditions.