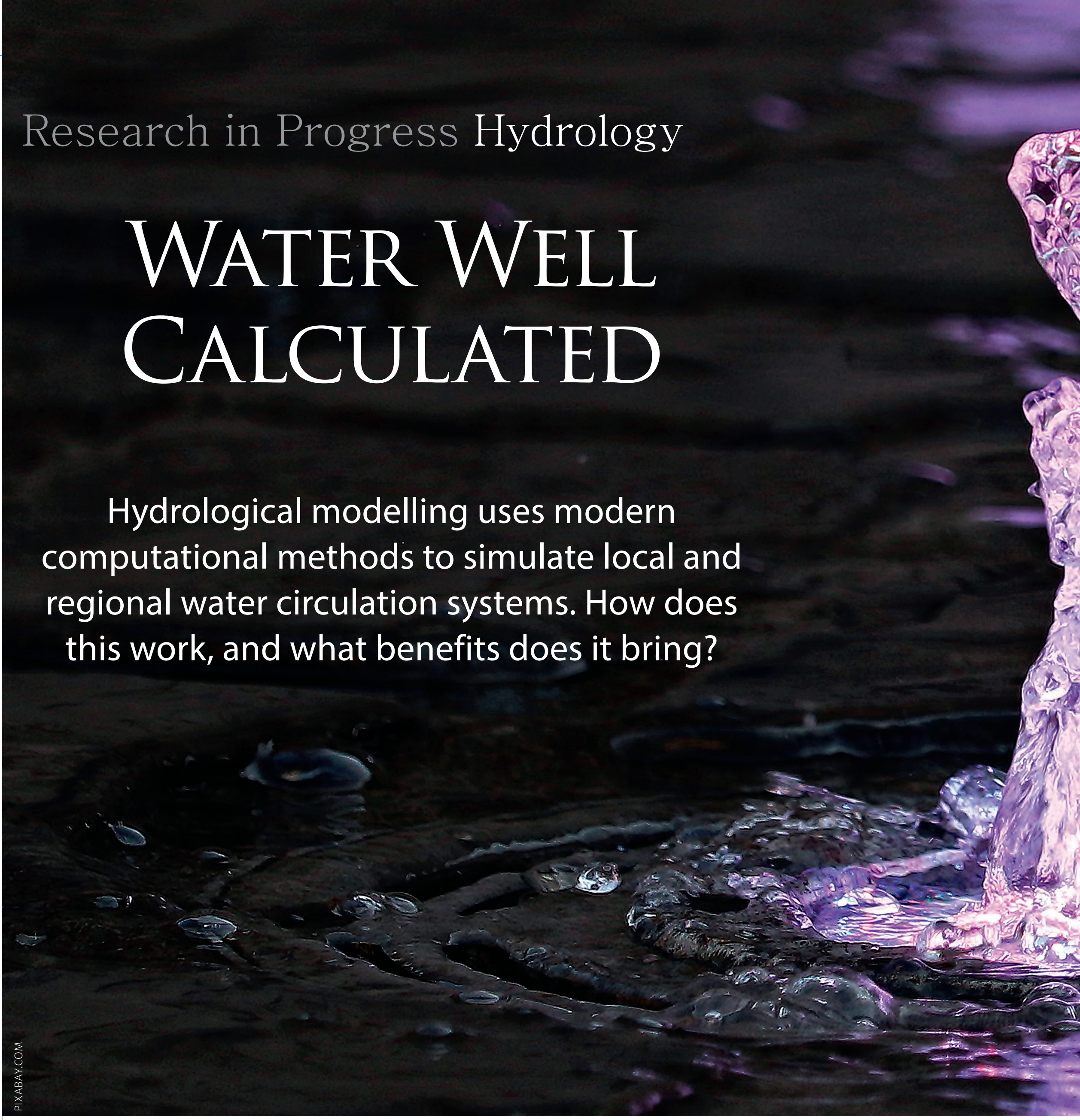

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Water Well Calculated

Hydrological modelling uses modern computational methods to simulate local and regional water circulation systems. How does this work, and what benefits does it bring?

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Humans have always been interested in the natural world around them, striving to understand the phenomena and processes occurring within in it. Scientists, therefore, attempt to provide a description of the relations between various aspects of the environment. Because such relations are often very complex, the explanation provided by scientists is necessarily a simplification. This simplified version of reality is called a *model*, and the approximate replication of phenomena and processes using a model is called *simulation* or *modeling*.

Models and simulations are widely used in many fields of science, including hydrological studies of both surface and ground waters. The models may concern a single process, such as precipitation infiltration, in other words rainwater seeping into the ground, or a group of processes, such as evaporation, infiltration, flow, and changes in water chemistry. It all depends on the purpose of modeling. It may be to examine the conditions of the water cycle, and thus determine the area of supply, flow and drainage (outflow) of water, including determining the relationship between ground and surface waters. It may be to identify flood-risk zones, identify and protect water resources, or assess the impact of certain human activities on the soil and water environment. In addition to the quantitative aspect, modeling can be used to determine changes in the quality of surface and/or groundwater, such as assessing the direction and speed of migration, concentrations of possible pollution, the extent of the impact of a potential pollution hot spot, as well as assessing the water's susceptibility to contamination.

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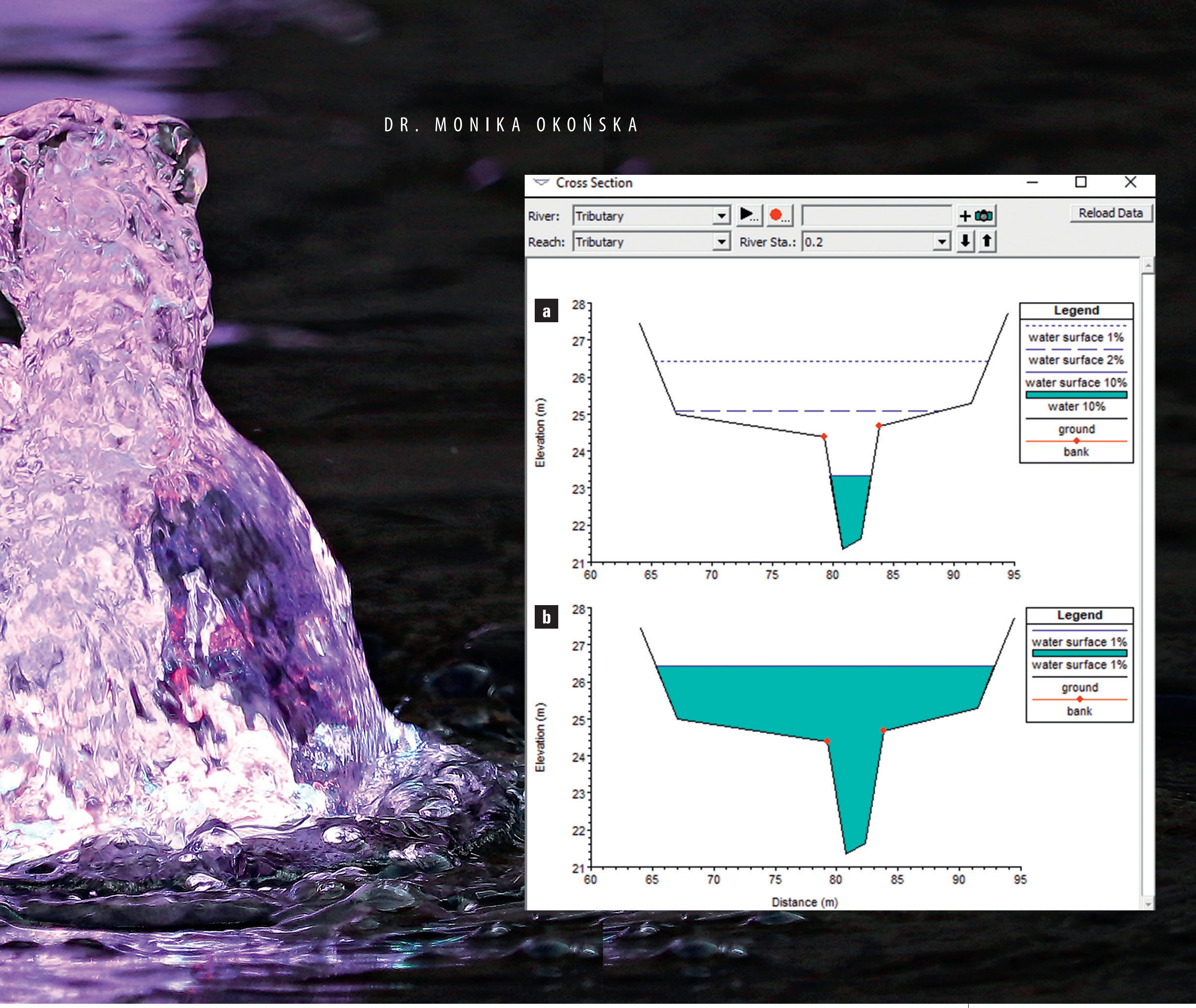
In the first stage, a conceptual model is created – an image of the real hydrological system, taking into ac-



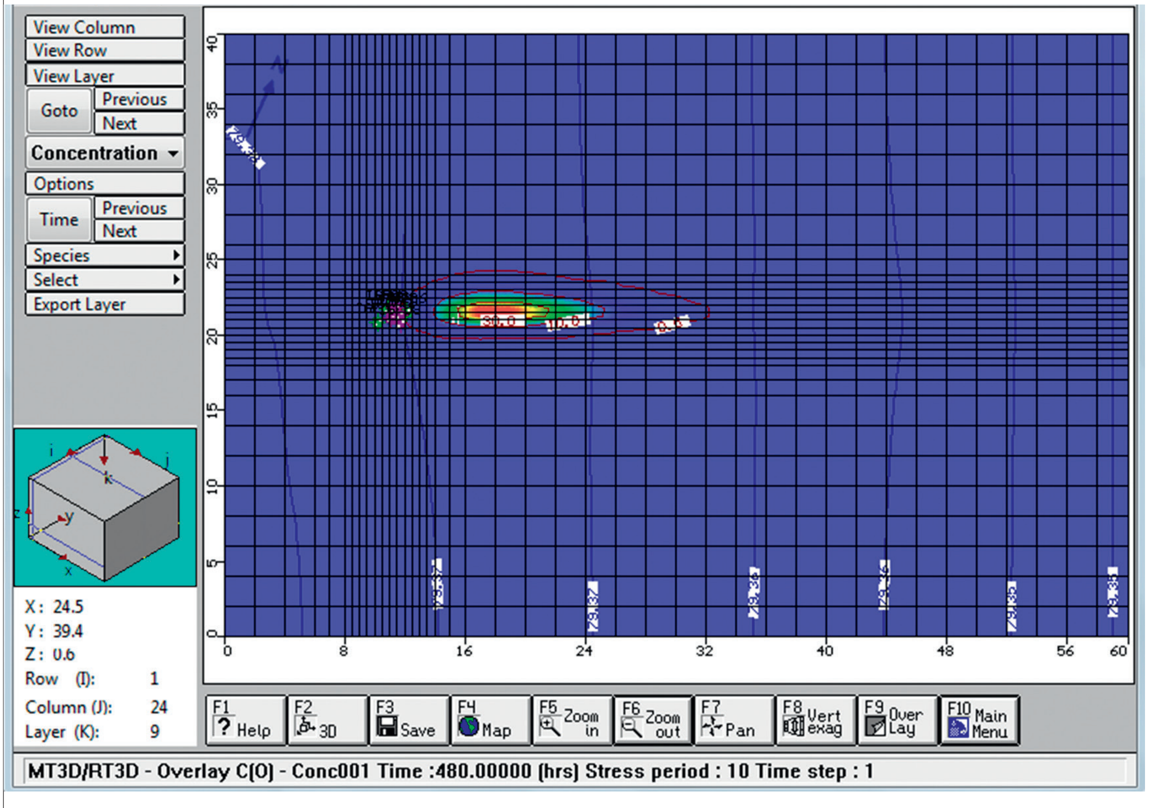
Cross section of a river valley – hydrological forecast for 10% flow (a) and 1% flow (b).

count its structure and the key processes occurring within it. To do this, scientists use available archival data and their own hydrological observations and measurements. Next, the model boundaries are defined. Once we have the concept, the next step is to describe the phenomena and processes occurring within the modeled system using mathematical equations, hence creating a mathematical model. There are two ways to solve such mathematical equations, depending on the complexity of hydrological conditions and the size of the model. An analytical method is often used for one-dimensional models and for selected points of the studied area. The numerical method is used to obtain results for the entire research area and for 3D calculations. Software developed over the past two decades has enabled computational algorithms to come into very broad use in hydrological research.

One of the key stages of modeling is the transition from continuous reality to a model consisting of blocks or computational elements. Each block is assigned average values. The separating out of individual model layers creates clear boundaries, while in the natural environment changes in properties or conditions vary smoothly. The model has to have a finite number of calculation blocks; the more there are, the longer it takes to perform calculations. The boundaries, however, should not distort calculations of pressure distributions or pollutant concentrations.

Mathematical equations describing water flow or migration of pollutants are always solved for the assumed conditions occurring at the beginning of the modeled timeframe, such as in the case of hydrodynamic models for the given values of the initial position of the water table in the research area. Appropriate conditions are also assumed at the edges of the spatially finite model – the model boundary does not mean a tight barrier preventing water inflow or outflow. It is extremely important to incorporate the right conditions, as this determines the credibility of the results obtained. For different initial and boundary conditions, the same equations will have different results.

In order for the model to provide a good representation of an aquifer, the results generated by the model should be compared to actual values measured during



Predicted migration of a spot of pollution within an aquifer.

field tests, such as water levels or pollutant concentrations. This is called *model calibration*. It can be done by trial and error or by optimization methods in which computer programs automatically try to find the best match between the measurements and the values calculated by the model. Sometimes, for the calibration to be successful, it is necessary to conduct additional field and/or laboratory tests, change the boundary conditions or model parameters, so as to minimize the discrepancy between the results of calculations and field observations. After water flow and pollutant transport simulations are carried out, the model's reliability is then evaluated. This involves comparing the results obtained with the current knowledge of the studied phenomena, empirical data, or approximate analytical solutions. Once it is determined that the model is reliable, predictions can then be made related to the hydrological system in question.

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Observing the migration of pollution through a river, soil or aquifer involves recording at a given measuring point the changes in the concentration of this pollution over time, referred to as the *breakthrough curve*. Migrating contaminants may undergo diffusion, hydrodynamic dispersion, sorption and/or decay.

Modeling can be used to identify the processes and determine the migration parameters of selected pollutants. This is done both in the lab and through field studies, during which pollution breakthrough curves are obtained. The curves are then interpreted through numerical modeling, providing information on the processes and parameters of pollutant migration. These results can be used to simulate pollution migration in aquifers, including hydrogeological forecast models.

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Models constructed for river catchments, hydrogeological structures, and protected areas help identify local and regional water circulation systems. The measurements obtained from identification models may form the basis for prognostic research on the quantitative and qualitative changes of water resources in both natural and forced conditions, such as using groundwater intakes. Numerical hydrological modeling is a modern and rapidly developing tool that allows scientists to recreate a number of hydrodynamic and hydrogeochemical processes occurring in the natural environment. Modeling results can provide useful input to making important environmental decisions. However, it should be noted that models are only projections of reality and the key issue here is their credibility. Good hydrological data are very important in modelling. A model is only as good as the data.

Monika Okońska

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