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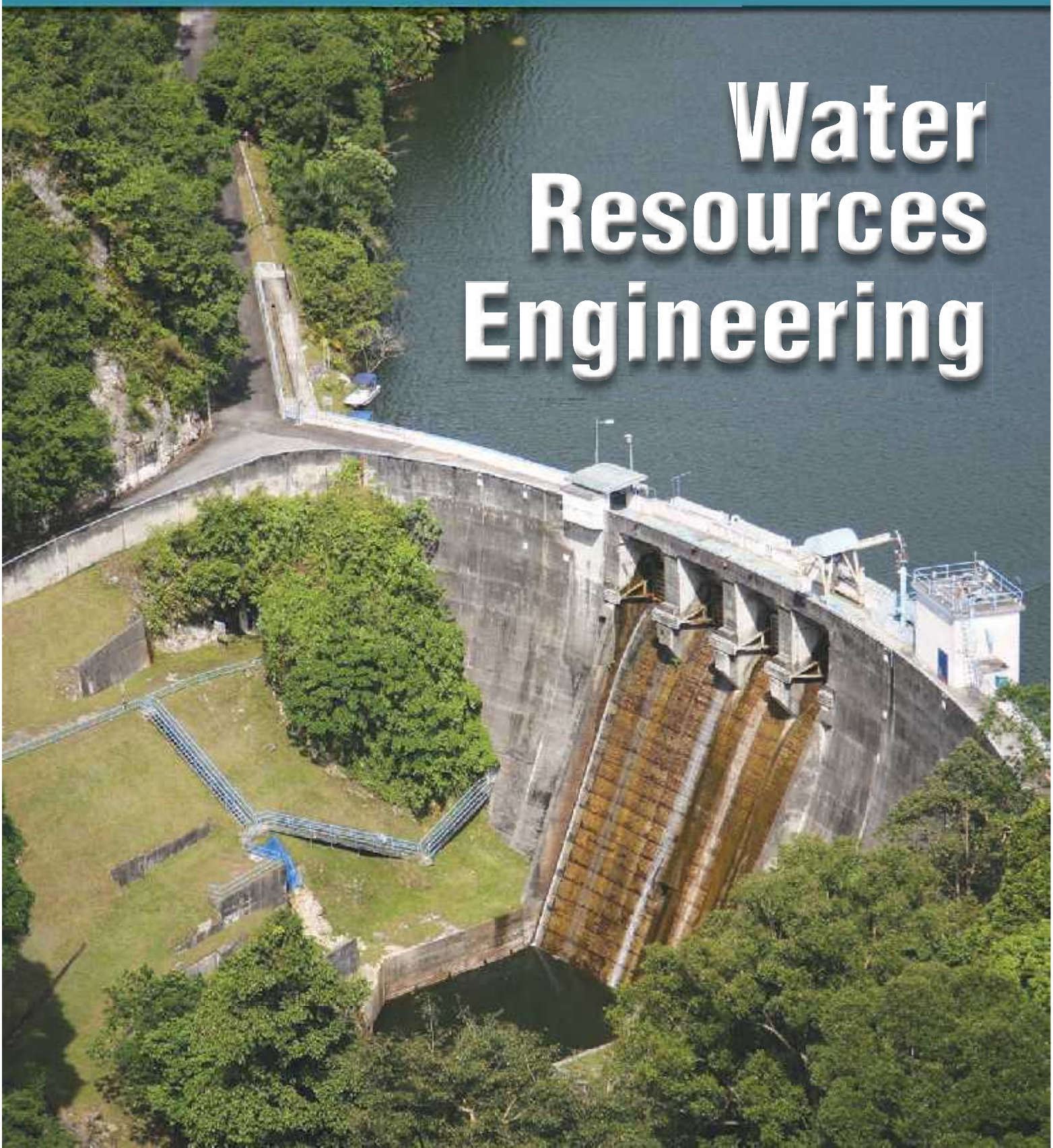

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November 2012
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Water Resources Engineering: The Past and the Future

by ***Ir. Zainal Abidin bin Othman***
Chairman of Water Resources Technical Division
Session 2011/2012

WATER resources engineering is the profession that is responsible for the planning, development and management of water resources. Fundamentally, it is about the collection and management of water as a natural resource, and in the latest turn of the century it also involves efforts to ensure the sustainability of the resource. As a discipline, it combines hydrology, environmental science, meteorology, geology, conservation and resource management. It is also associated with the prediction and management of both the quality and quantity of water, on the surface as well as underground.

Traditionally, engineers have held and enjoyed considerable authority and public confidence in engineering planning, development and management of water resources projects. But as we move into the 21st century, the possibility to engineer sustainability of the water resources available to meet the demand of the growing population has become an issue of concern.

This has led to the need of finding alternatives and considering the measures to be taken now and in the future to ensure that the basic needs for water, sanitation, nutrition, health, safety and employment for the public are fulfilled. The natural water resources will be limited, and effective management of it becomes even more critically important and increasingly difficult as well.

There is a need then to approach the planning, development and management of water resources in a holistic manner. This will require a major paradigm shift from control of nature to participation with nature, that embraces the principles of sustainable development, renewable resources management, and appropriate technology. And this approach is in line with the Integrated Water Resources Management (IWRM) as advocated in the National Water Resources Study (NWRS).

Various steps have been taken to provide the foundation for sustainable water resources management in the country, including the review of the National Water Resources Study (2000-2050), and the formulation of a National Water Resource Policy and the National Water Resources Law.

Apart from drafting the National Policy and Law on water resources, the review also formulates a Decision Support System (DSS) Framework, which includes a water resource database with the capacity of producing regular updates on water availability and demand, existing and future water catchment areas, water resources development programmes and other related information relevant to water resources planning, development and management.

In addition to the framework for policy and the relevant law, having a unified leadership sharing the same sentiments is also important to ensure successful implementation.

For any sustainable decisions, communication between professionals in water resource engineering and external stakeholders, namely the political and business sectors and public at large, must be dramatically improved. These professionals need to get their messages across to the principal decision makers and ensure that they have a full understanding before making, at times, irreversible commitments.

In this issue of *JURUTERA,* Y.Bhg. Dato' Ir. Syed Muhammad Shahabudin, who has had 49 years of experience in the water industry, provides his views on the Draft Water Resources Policy, the current scenario of water resources development and management, and water demand management (WDM) initiatives. ■

Introduction to Water Quality Modelling



by Mr. Renjith Vishnuradhan, Ir. Assoc. Prof. Dr Zaki Zainudin and Prof. P. Vethamony

IN recent years, water pollution control and water quality management strategies are gaining prominence in developed as well as developing countries in the wake of global environmental scenarios such as resource depletion, climate shifts, population pressure and, last but not least, increased public awareness. In spite of all the efforts taken by the research community and governmental agencies, water quality is deteriorating in many areas around the world.

Access to safe water is a basic human right. According to UNICEF, water related diseases caused by insufficient safe water supplies coupled with poor sanitation and hygiene cause 3.4 million deaths a year, mostly among children [1]. From the development's perspective, water plays one of the significant roles. Thus, more stringent regulations are mandatory for maintaining the water quality for sustainable utilisation.

Water quality models have made the job of policy makers and researchers much more reliable and sustainable in recent decades. Now, it is possible to predict the condition of water quality based on changes in land use, surge of population, effluent discharge and the global climate situation. Often water quality models can fill data gaps which are a major constraint in water quality assessment and management. It serves the purpose of identifying the pollution sources and helps to decipher various complex biogeochemical processes in the water bodies simultaneously, which would otherwise be difficult to assess with field monitoring alone. It is possible to predict future events with great accuracy. This makes sense in the case of water quality models, which are predictive tools for representing complex physical, chemical and biological processes. Generally water quality models can be of two categories; conceptual and mathematical. Mathematical models are often reliable for simulating the complex processes which determine the ultimate fate of the water bodies, and are also cost effective.

Determining the best model to be used is one of the prominent issues in water quality modeling. This depends on the problem to be addressed and the type of water body in question. Nowadays, water quality models are utilised for diverse types of fresh and salt water bodies such as rivers, lakes, estuaries, creeks, and bays.

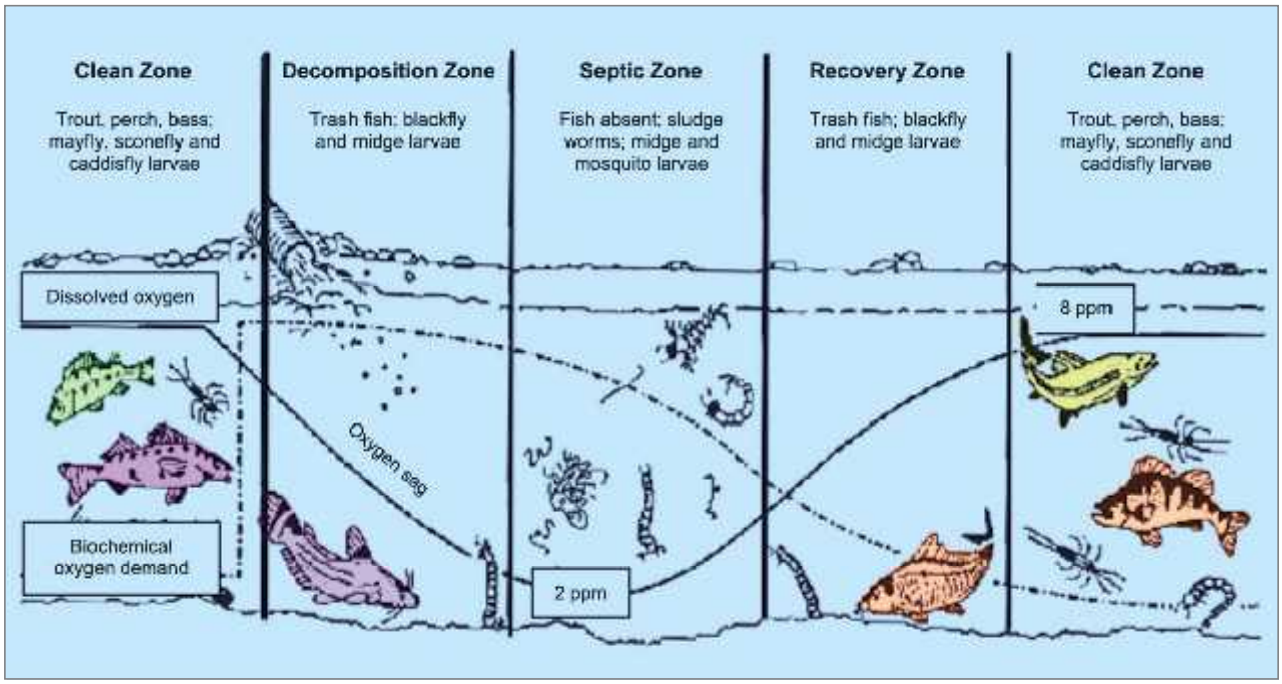

Figure 1: Basic concept of WAC and dissolved oxygen sag curve [5]

Finally, the reliability will be affected by the quality and quantity of data which are used for the model predictions. Models can be one, two or three-dimensional. Based on the requirements, sometimes, simple one-dimensional model can be more handy and reliable than a complex three-dimensional one. The complex models often require the necessary expertise and a good number of user groups for successful implementation.

One of the preliminary processes in water quality modeling is the prediction of transport and dispersion processes using the respective ambient data. Prior to this, the water body of interest is divided into grids, elements, or segments. The grid size and the time steps should comply with the stability of the mathematical solutions. The predicted hydrodynamic conditions are mostly used as input for the water quality model component. The transport properties of water bodies are devised by numerical solutions of differential equations of motion and continuity. Generally, present generation water quality models have the following components: movement of water bodies, dispersion, dilution of dissolved substances and its first order decay, water quality process and sediment transport [2].

All these components are inter-dependent, and are usually represented by time varying partial differential equations in one, two or three-dimensional spaces. In addition, initial and boundary conditions should be specified in order to solve these equations for respective water quality predictions. The model has to be calibrated against field data before it is used for the task in hand. Once the model is calibrated for a particular region and task, the model results can be verified with measurements. If a good match between model and field data is found, the model can be used for simulating water quality parameters for a prolonged duration. Large number of constants and coefficients are needed for calibrating a water quality model, but many of them are very difficult to measure in the field. In such a situation, users can rely on available data or refer to a standard manual such as the one by US EPA [3].

At present, regulations for effluent control are concentration-based and do not have specified stringent volumetric discharge limits. Consequently, the Total Maximum Daily Load (TMDL) approach is not fully integrated into the current regulations. TMDL approach is a real challenge in developing countries, where the economic development induced population surge and industrial pressure are critical factors. Water quality models can determine the maximum TMDL that can be released from a proposed development without exceeding the Waste Assimilative Capacity (WAC) of water bodies. WAC is nothing but the ability of water bodies to withstand a certain amount of pollutant without impairing the ambient water quality condition [4]. The Dissolved Oxygen (DO) sag curve shown in Figure 1 forms the basis of many water quality models and is characterised by the Streeter Phelps formulation. The formulation describes the response of ambient DO levels towards organic (BOD) contribution.

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The present day opportunities in utilising water quality models to tackle various environmental problems are diverse. They are popular tools in EIA (Environmental Impact Assessment) procedures related to the development of specific industries, and in river or coastal waters rehabilitation programmes. Two of the most popular models among the modelling community are QUAL 2K [6] and Water Quality Analysis Simulation Program (WASP 7) [7]. Both these models are supported by US Environmental Protection Agency (US EPA) and work in the Microsoft Windows environment. Data requirements for running the models include ambient water quality, water body hydrogeometry, pollution sources, point and non-point sources, long-term water quality and discharge data, sediment oxygen demand, and topographic maps or GIS support. In addition to these datasets, bathymetry, current, wind and tide data are needed for marine applications.

QUAL2K (or Q2K) was originally developed by Prof. Steven Chapra and his colleagues at Tufts University; it is a one dimensional river and stream water quality model that was intended to represent a modernised version of the QUAL2E (or Q2E) model. This model assumes that the riverine channel is well-mixed vertically and laterally. All the water quality variables are simulated on a diurnal time scale. In QUAL2K, the total number of headwaters (i.e. tributaries) must be identified prior to developing the model, as well as the total length (in km) of each headwater reach. Microsoft Excel is used as the graphical user interface for this model.

WASP helps users in interpreting and predicting water quality responses to natural phenomena and man-made pollution for various pollution management decisions for fresh water and marine environments. This is a dynamic compartment-modelling programme for aquatic systems, including both the water column and the underlying benthos, and the model can be one, two or three dimensional, depending on the complexity of intended use. The time varying processes of advection, dispersion, point and diffuse mass loading and boundary exchange are represented in the model.

QUAL2K and WASP are frequently used in both developed and developing countries as a sustainable decision-making tool. The Department of Environment (DOE) and the Department of Irrigation and Drainage (DID) has adopted river models more intensively in their respective river basin management programmes, including the *Program Pencegahan Pencemaran dan Peningkatan Kualiti Air Sungai (DOE)* and the Integrated River Basin Management (IRBM) programme (DID).

One of the earliest river rehabilitation studies conducted by DOE was for the Tebrau and Segget river basins in Johor. Various modelling scenarios were simulated to achieve a Class III denotation of the National Water Quality Standards (NWQS) using the QUAL2E model. Subsequent studies followed for other basins throughout the country, namely the Sg. Langat, Sg. Linggi, Sg. Sepetang, Sg. Rajang, Sg. Merbok and Sg. Kuantan basins, where models such as QUAL2E, QUAL2K or WASP were utilised to assist the development of proposed mitigation measures.

As mentioned previously, current regulatory effluent control measures are concentration-based and do not prescribe volumetric discharge limits, EIA studies are alternate venues, where TMDL can be enforced under the designated approval conditions. Water quality modelling in Malaysia has clearly gained wide acceptance throughout the years and looks to flourish further as a critical management tool in river basin management.

In India, WASP is a suitable model to estimate the WAC of coastal waters along the west coast. The study areas include most populous urban and industrial areas. Recently, a WASP modelling network for the coastal waters off Mumbai, one of the major global coastal megacities, has been developed. Hydrodynamic input from MIKE was used in the water quality model to simulate DO and BOD changes as a consequence of sewage effluent input.

(Continued on page 16)

Water quality modelling is a useful tool to effectively tackle water quality problems. Facts presented in this article only touch on the most fundamental aspects of water quality modelling. A deep understanding of water quality processes, interactions, as well as field knowledge and experience are prerequisites towards the development of a representative model. Better results will always emerge from a better understanding of the subject. ■

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