GROUND WATER FLOW MODELING USING FUZZY LOGIC

[1]G. R. UMAMAHESWARI, [2]Dr.D. KALAMANI
[1] Department of Mathematics, Erode Sengunthar Engineering College, Thudupathi
Erode – 638 057, Tamilnadu.
[2]Department of Mathematics, Kongu Engineering College, Perundurai
Erode – 638 052, Tamilnadu, India
E-mail: [1] grumamaheswari@gmail.com, [2] kalamanikec@gmail.com

ABSTRACT:

Water is a renewable resource out of total precipitation only 11% of surplus is used for domestic, irrigation and industrial processes. From ancient time to present day society has always experience the shortage of water. It is important to analysis the present condition of the existing groundwater level and future prediction with controlled exploitation leads to solve this distress in future. The present study carried out to predict the groundwater level fluctuation in Amaravathi river basin.

Keywords: Groundwater Modeling, Prediction, Water Level Fluctuation, Amaravathi River Basin.

1. INTRODUCTION

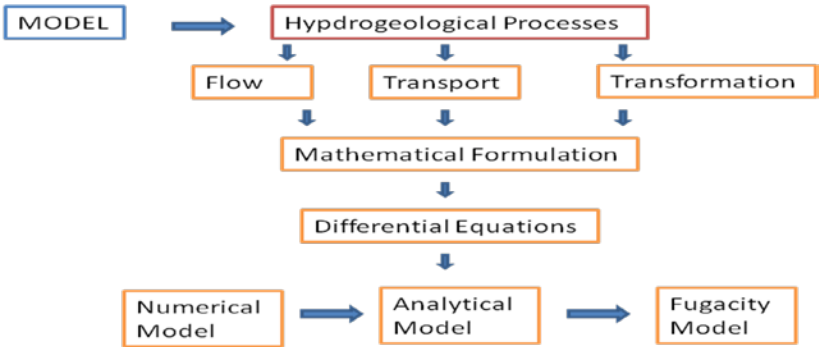
About one third of one percent of the earth's water is accounted for groundwater. The use of groundwater models is prevalent in the field of environmental science. Models have been applied to investigate a wide variety of hydrogeologic conditions. Groundwater models describe the groundwater flow and transport processes using mathematical equations based on certain simplifying assumptions. These assumptions typically involve the direction of flow, geometry of the aquifer, the heterogeneity or anisotropy of sediments or bedrock within the aquifer. Because of the simplifying assumptions embedded in the mathematical equations and the many uncertainties in the values of data required by the model, a model must be viewed as an approximation and not an exact duplication of field conditions.

2. MODEL DEVELOPMENT

A groundwater model application consists of two distinct processes,

First process: Model development

Second process: Application of that product for a specific purpose



2.1 Model Objectives

Model objectives should be defined which explain the purpose of using a groundwater model. The modeling objectives will profoundly impact the modeling effort required.

2.2 Hydrogeological Characterization

Proper characterization of the hydrogeological conditions at a site is necessary in order to understand the importance of relevant flow or solute transport processes. Without proper site characterization, it is not possible to select an appropriate model or develop a reliably calibrated model.

2.3 Model Conceptualization

Model conceptualization is the process in which data describing field conditions are assembled in a systematic way to describe groundwater flow and contaminant transport processes at a site. The selected model should be capable of simulating conditions encountered at a site. For example, analytical models can be used where field data show that groundwater flow or transport processes are relatively simple. Similarly, one-dimensional/ two-dimensional/ three-dimensional groundwater flow and transport models should be selected based upon the hydrogeological characterization and model conceptualization.

2.4 Model Design (Input Parameters)

Model design includes all parameters that are used to develop a calibrated model. The input parameters include model grid size and spacing, layer elevations, boundary conditions, hydraulic conductivity/transmissivity, recharge, any additional model input, transient or steady state modelling, dispersion coefficients, degradation rate coefficients etc.

2.5 Model Calibration

Model calibration consists of changing values of model input parameters in an attempt to match field conditions within some acceptable criteria. Model calibration requires that field conditions at a site be properly characterized. Lack of proper site characterization may result in a model calibrated to a set of conditions that are not representative of actual field conditions.

2.6 Sensitivity Analysis

A sensitivity analysis is the process of varying model input parameters over a reasonable range (range of uncertainty in value of model parameter) and observing the relative change in model response. Typically, the observed change in hydraulic head, flow rate or contaminant transport are noted. Data for which the model is relatively sensitive would require future characterization, as opposed to data for which the model is relatively insensitive.

2.7 Model Verification

A calibrated model uses selected values of hydrogeologic parameters, sources and sinks and boundary conditions to match historical field conditions. The process of model verification may result in further calibration or refinement of the model. After the model has successfully reproduced measured changes in field conditions, it is ready for predictive simulations.

2.8 Predictive Simulations

A model may be used to predict some future groundwater flow or contaminant transport condition. The model may also be used to evaluate different remediation alternatives. However, errors and uncertainties in a groundwater flow analysis and solute transport analysis make any model prediction no better than an approximation. For this reason, all model predictions should be expressed as a range of possible outcomes that reflect the assumptions involved and uncertainty in model input data and parameter values.

3. MODELLING OF GROUNDWATER FLOW AND MASS TRANSPORT

Groundwater modeling begins with a conceptual understanding of the physical problem. The next step in modeling is translating the physical system into mathematical terms. In general, the results are the familiar groundwater flow equation and transport equations. The governing flow equation for three-dimensional saturated flow in saturated porous media is:

$$\frac{\partial}{\partial x}(K_{xx}\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_{yy}\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_{zz}\frac{\partial h}{\partial z})-Q=S_s\frac{\partial h}{\partial t}$$

Where,

Kxx, Kyy, Kzz = hydraulic conductivity along the x,y,z axes which are assumed to be parallel to the major axes of hydraulic conductivity;

h = piezometric head;

Q = volumetric flux per unit volume representing source/sink terms;

Ss = specific storage coefficient defined as the volume of water released from storage per unit change in head per unit volume of porous material.

An understanding of this equation and associated boundary and initial conditions is necessary before a modeling problem can be formulated. Basic processes, that are considered, include groundwater flow, solute transport and heat transport. Most groundwater modeling studies are conducted using either deterministic models, based on precise description of cause-and-effect or input-response relationships or stochastic models reflecting the probabilistic nature of a groundwater system.

The governing equations for groundwater systems are usually solved either analytically or numerically. Analytical models contain analytical solution of the field equations, continuously in space and time. In numerical models, a discrete solution is obtained in both the space and time domains by using numerical approximations of the governing partial differential equation. Various numerical solution techniques are used in groundwater models. Among the most used approaches in groundwater modeling, three techniques can be distinguished: Finite Difference Method, Finite Element Method, and Analytical Element Method. All techniques have their own advantages and disadvantages with respect to availability, costs, user friendliness, applicability, and required knowledge of the user

4. FUZZY LOGIC

The Fuzzy rule-based approach introduced by Zadeh (1965) [10] is being widely applied in various fields of science and technology. It is a qualitative modeling scheme in which the system behavior is described using a natural language. The transparency in formulation of fuzzy rules offers explicit qualitative and quantitative insights into the physical behavior of the system.

The application of fuzzy logic as a modeling tool in the field of water resources is a relatively new concept although some studies have been carried out to some extent in the last decade and these have generated much enthusiasm. Bardossy & Duckstein (1992) applied a fuzzy rule-based modelling approach to a karstic aquifer management problem. Bardossy & Disse (1993) used fuzzy rules for simulating infiltration. Fontane et al. (1997) and Panigrahi & Mujumdar (2000) applied fuzzy logic for reservoir operation and management problems.

5. APPLICATION OF FUZZY LOGIC

Fuzzy set theory, which has been proposed in 1965 by Lofti A. Zadeh (1965), is a generalization of classical theory. Fuzzy logic representations found on Fuzzy set theory try to capture the way humans represent and reason with real world knowledge in the face of uncertainty. Uncertainty could arise due to do generality, vagueness, Ambiguity, chance or incomplete knowledge.

A Fuzzy set can be defined mathematically by assigning to each possible individual in the universe of discourse, a value representing its grade of membership in the fuzzy set. This grade corresponds to the degree to which that individual is similar or compatible with the concept represented by the Fuzzy set. In other words, fuzzy sets support a flexible sense of membership of elements to a set.

The range of the model input values, which are judged necessary for the description of the situation, can be portioned into fuzzy sets. The process of formulating the mapping from a given input to an output using fuzzy logic is called the fuzzy inference. The basic structure of any fuzzy inference system is a model that maps characteristics of input data to input membership functions, input membership functions to rules, rules to a set of output characteristics, output characteristics to output membership functions, and output membership function to a single valued output or a decision associated with the output. In rule based fuzzy systems, the relationship between variables are represented by means of fuzzy if-then rules e.g. “if antecedent proposition then consequent proposition”.

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