Chapter 1

INTRODUCTION

1.1. The Groundwater Systems

Social and economic development throught much of the world is characterized by a sharp increase in groundwater exploitation. This is due in part the fact that the available surface water is often fully developed and committed. The problem of determining the limits of groundwater exploitation is made more complex by the increasing rate of groundwater development. The rational limit of groundwater exploitation is that quantity which may be withdrawn from formation with a prescribed development during a definite planned period taking into account : (1) Protection from depletion, (2) Protection from pollution, (3) Negative ecological effects, (4) Economic efficiency of exploitation.

The geologic formations that are capable of storing and transmitting the subsurface water are known as aquifers when the groundwater can be removed economically and used as a source of water supply.

The aquifers are classified into three types [22]:

(i) Unconfined aquifer: is one in which a water table serves as the upper surface of the zone of saturation.

(ii) Confined aquifer: is one in which the groundwater is condfined under pressure greater than the atmospheric by overlying, relatively impermeable strata.

(iii) Semiconfined or leaky aquifer: has partially permeable confining layer or aquitard that is capable of leakage and storage.

The aquifers are also referred to as groundwater reservoirs or ground–water systems.

Groundwater systems are traditionally developed as sources of domestic, industrial, or agricultural water supply. The generally good quality of the water and its accessibility in many regions of the world have been important factors in stimulating the development of this relatively low-cost, reliable water resource. Groundwater systems can also provide temporary or long-term storge and treatment of wastewater.

The groundwater system is defined by [22]:

(a) The set of controlled and partially inputs to the system. For example, subsurface inflows, natural recharge and replenishment from irrigation return flows and streams are major inputs to the aquifer system.

(b) The system outputs, which include subsurface outflows, discharges to surface water and evapotranspiration losses.

(c) The parameters of the groundwater system. The parameters define the flow, quality, and thermal properties of the aquifer, such as, the storativity, the transmissivities, and dispersion parameters.

(d) The control or decision variables. These decisions detail the pumping and injection of the groundwater system.

(e) The state variables that characterize the condition of the system, such as, the hydraulic head and the concentrations of all constituents in the groundwater system.

Groundwater systems can be classified by considering the properties of the parameters, state, and decision variables. Typically, groundwater systems are distributed parameter systems. That is, the parameters vary spatially in the basin. Hydraulic parameters that vary spatially are also said to be nonhomogeneous. In contrast, an aquifer where the parameters do not vary spatially (but may vary temporally) is a lumped parameter system, or said to be homogeneous. The groundwater system is said to be anisotropic if the hydraulic conductivity varies from one location to another.

The management of groundwater systems is broadly concerned with the evaluation of the environmental, hydrological, and economical impacts and trade-offs associated with the development and allocation of groundwater supply and quality to competing water uses or demands. The management and planning problems are physical, chemical, and hydraulical transport processes occurring within the groundwater basin.

In the analysis of groundwater systems there are three classes of management problems : the inverse problem, the predicion problem, and the optimization problem. The inverse problem is concerned with the estimation of the system parameters and possibly, unknown boundary and initial conditions from field observations of the state varialbles of the system. Assuming that all inputs and outputs are known with some degree of reliability, the inverse problem is the identification of the unknown parameters embedded in the partial differential equations that characterize the flow or mass transport occurring in the groundwater system. The prediction problem assumes, however, that all the system parameters and inputs are known throughout the aquifer system. The prediction of the response or dynamic behavior of the system is obtained from the analytical or numerical solution of the partial differential equations characterizing the groundwater system. The optimization problem is concerned with the optimal planning, designing, and operational policies for the grounwater system [22].

1.2. The Model Building Process [22]

Simulation and optimization models of groundwater hydraulics or quality are mathematical representations of the groundwater system. The model building process consists of several interrelated stages.

In the first stage of the modeling process, pumping data, groundwater contour maps, water levels, precipitation, stream flow, and recharge information are compiled and statistically analyzed to determine the aquifer parameters, recharge conditions, initial and boundary conditions, and current groundwater extraction patterns.

The model choice problem, the second stage of the process, is characterized by a hierarchy of mathematical models. From a planning perspective, however, mathematical models of the groundwater flow or mass transport will consist of :

(1) Algebraic, differential, or integral equations that characterize the flow or transport processes. These equations relate the state variables of the system, the policy or decision variables that provide control over the state variables, the parameters that define the flow, quality and properties of the system.

(2) Boundary conditions that define the inputs to the system such as recharge and outputs such as discharges to surface water.

(3) Initial conditions that portray the state of the system prior to development or operation of the aquifer system.

The third stage of the model building process is the validation of the mathematical model. By using the parameters and boundary conditions determined from the calibration of the model, the validation process predicts groundwater levels of water quality concentrations.

Following these stages, the mathematical model can be used for the prediction (simulation) and/or optimization of the groundwater resources of the aquifer system. In a simulation approach, a set of planning, designing, or operational policies can be analyzed by examining the simulated response of the aquifer system to the proposed management alternatives. In contrast, optimization models identify the optimal planning, design, or operational policies within the context of the system's quantifiable objectives and hydrologic, economic, and environmental constraints.

1.3. The Groundwater In Egypt [35]

The groundwater in Egypt can play an important role especially during drought periods. The groundwater development is necessary to meet the increasing water demands which Egypt needs for irrigation, industry and domestic purposes. It is controlled mainly by economic and quality considerations.

Geographically Egypt is divided into five regions. The Nile Delta formation, the Nile Valley aquifer, the Western Desert, and the Eastern Desert and Sinai Penin-sula aquifers. Figure 1.1 shows the main aquifers in Egypt.