

## V.2 NILE DELTA GROUNDWATER STUDY

## Progress Report

June 1, 1977 - August 31, 1977

Project Objectives.

1. Develop a numerical model for the prediction of seawater intrusion and piezometric head in coastal aquifers involving irregular coastline.
2. Apply an existing aquifer model AQUIFEM and, later, the seawater intrusion to the Nile Delta aquifer to evaluate aquifer water supply capacity (safe yield), aquifer cyclic storage capability, and irrigation and drainage effects.
3. Study the details of seawater intrusion in the Delta aquifer in order to formulate boundary conditions for the model and to evaluate model results.
4. Evaluate the need for more sophisticated model studies in the future, due to the complexity of the seawater intrusion problem.
5. Transfer modern groundwater modeling techniques to Ministry of Irrigation staff and Cairo University faculty.
6. Study the conjunctive use of surface water and groundwater in the Nile Basin.

The first year of the study will concentrate on AQUIFEM application, model development, data preparation, and a detailed analysis of the seawater intrusion process. The application of the seawater intrusion model to the Delta aquifer is scheduled for the second year of the project, to be proposed at a later time.

Progress During Report Period: 1 June - 31 August, 1977.

At the beginning of the report period, Professor John Wilson and Mr. Kenneth Strzepek visited Cairo for three weeks. A great deal was accomplished during the short stay in Egypt. Two formal seminars were given to an audience of Ministry of Irrigation and Cairo University staffs. The seminars were entitled, "Simulation Modelling an Analytical Technique" and "Guidelines for Simulation Analysis." Additional informal seminars were held on the topic of seawater intrusion in coastal aquifers and in the Delta aquifer in particular. A meeting was held with His Excellency Abul El 'ta, Minister of Irrigation. He was pleased that our project was being undertaken and gave his support by stating that all the data that we needed would be provided.

A series of meetings were held with Dr. Kamal Hefny and his staff at the Groundwater Research Institute, to discuss existing data for the Delta aquifer and the program of analysis planned for the coming six months. A report containing compiled data was presented by Dr. Hefny's staff. Primary attention will be given to collecting additional information on the hydraulic conductivity of the aquifer and the clay cap. Because AQUIFEM (Aquifer Finite Element Model) is probably too large for long-term use on the University Computer, a finite difference model, called NILAQC, will be developed to replace it for the preliminary analyses.

Professor Sherif M. Makian Ebeid, of the Electrical Engineering Department, Cairo University, joined the project during our visit. He helped implement AQUIFEM on the University computer, and during August updated it with the latest code. He is an excellent addition to the staff because of his familiarity with computer models and with the Delta hydrology.

Professor Abdelwahab Amer of the University devoted his full time to the project during our visit. A training program for university students in groundwater modeling is under his direction with the help of Dr. Makian.

Professor Amer travelled to M.I.T. at the beginning of August. While here, he helped develop a finite element grid for the entire Delta aquifer and saw it implemented for the central portion of the Delta. Since then the model has been used to revise estimates of vertical recharge and discharge due to leakage through the clay cap. Professor Amer also studied basic elements of numerical models and collected literature on seawater intrusion to be used in the training program.

Professor Ebeid has applied NILAQC to the Delta aquifer to evaluate parameters and boundary conditions. The approach has been to first calibrate the model using the relatively steady state piezometric heads of current conditions, then to calibrate for transient conditions using observed heads for years prior to the High Dam. This technique should provide an indication of seawater interface movement. Then the model will be available for preliminary evaluation of steady state safe yield.

Several new analytical seawater intrusion models have been developed to account for the conditions observed in the data obtained during the June visit. These models are oriented toward providing mix regions of recharge/discharge through the clay cap, depending on the distance from the coastline.

Part of the Delta aquifer study is oriented toward a preliminary application of MITSIM, the river basin simulation model and the evaluation of future opportunities for systems analysis. A series of meetings were held with Sarwat Fahmy of the Ministry of Irrigation who is the Egyptian director of the Office of the Water Master Plan. We were given the utmost cooperation and all the data we requested that was available was supplied promptly. Additionally, a great deal of time was spent working with Dr. Elassiouti, Head of the Irrigation and Hydraulics Division of the Faculty of Engineering, Cairo University to introduce the concepts of system analysis. A training program in "System Analysis in Water Resources Planning" was begun for the Cairo University staff expected to participate in the official project. Many contacts were made that will be useful in the future as this project becomes full scale. Among them was a visit to the Hydraulics Research Center at the Deltaic Barrage.

After arrival back in the United States the existing MITSIM was modified to meet the needs of the Nile Basin. The data obtained in Egypt was analyzed and a simulation analysis was performed to analyze the operation of High Dam and the Toska Spillway. These preliminary results will be sent to the Ministry staff for comments and suggestions. Also theoretical work is being conducted to establish statistical confidence in the results obtained from the simulation analysis.

#### Future Activities, Travel and Seminars for Next Period.

The goals for the fall period of the project are:

1. Complete preliminary NILAQ and AQUIFEM calibrations and safe yield analyses of the Delta aquifer.
2. Compile and organize the steady state analytical seawater intrusion studies with applications.
3. To complete the transient analytical models of seawater intrusion.
4. To make the final choice of approach for the numerical seawater intrusion model.
5. To continue data collection and preparation efforts for Nile Delta.
6. To continue background studies for the use of simulation and other systems analysis techniques in the Nile River Basin and complete the preliminary evaluation of the High Dam and Toska Spillway.

7. Additional training of staff by Professors Amer and Ebeid of staff in the use of groundwater models and in groundwater hydrology.

In late December Professor Wilson and Professor David Marks will visit Cairo to:

1. Give formal seminars of groundwater modeling and seawater intrusion in aquifers.
2. Continue liaison regarding data for Nile Delta and River Basin Simulation Models: data, results, coordination.
3. Explore grounds for water resources systems analysis project connected to the Water Master Plan.

This trip will be preceded by Dr. Hefny's visit to M.I.T., in late October. Dr. Hefny will spend one week at M.I.T. and a second week with the Water Resources Department of the State of California studying their seawater intrusion control barrier plans and groundwater management.

#### Difficulties Encountered

It has been discovered that the Cairo University Computer System will be inadequate to meet the needs of running MITSIM. MITSIM requires approximately 400 K words of storage and the Cairo University facility has approximately 250 K. A program overlay is possible; however, overlays have never been performed at Cairo University before. The seawater intrusion model to be built will also require relatively large core, unless it is designed from the outset to be disc-oriented. AQUIFEM fits on the computer, but is not an efficient program for the ILC logic. Some alternative arrangements should be made that will meet our needs as well as be acceptable to Cairo University.

Another problem is that in the Division of Irrigation and Hydraulics no one has a knowledge of numerical modeling and system analysis techniques. A large part of our effort must be to educate the staff in these modern techniques. This, however, does take a great deal of their time, slowing the analysis process.

There is inadequate data describing the location of the seawater wedge. Deep cores were drilled many years and then abandoned, for a one time measurement. Several deep wells are currently being drilled in the Eastern Delta. However, there are numerous measurements in shallow wells which accurately locate the intersection of the interface with the clay cap. This lack of information of the interface may greatly increase the uncertainty of development alternatives and slow down the analysis phase of the project.

A.I.D. Investment Opportunities.

There are significant investment opportunities in the deep exploration of the Delta aquifer. The purpose would be to better define the spatial and temporal characteristics of the seawater interface and its zone of transition, and to locate the basement or bottom of the aquifer. Secondary benefits would be derived in the form of estimates of vertical hydraulic gradients and vertical variation of hydraulic conductivity. A series of longitudinal and lateral boring would be required.

Supplemental Progress Report - August 30, 1977.Summary for River Basin Simulation Study.

1. The Ministry of Irrigation is currently addressing the problem of developing an overall systems plan of Egyptian Water Resources. This plan is being carried out by the Office of the Water Master Plan and the UNDP. It is to include Egyptian as well as expatriate staff. They wish to employ modern water resources system analysis techniques, but at present have no ability to do so. The first phase of the project is devoted to data collection. The present data set is rather limited or found in another Ministry.
2. The current project is very well suited to fit into the Ministry's planning process. The need for analytical techniques can be provided by the project especially with M.I.T.'s experiences in international River Basin Planning. The project can also help with more efficient data collection by providing a focus for the data collection. By introducing these techniques there will be a need to train Ministry personnel in these techniques.
3. The future direction is seen in reviewing the requirements of the planning process and designing methodologies and implementation of planning tools to design a Master Plan for Water in Egypt. These topics will be discussed during Professors Marks' and Wilson's December trip.

Summary for Nile Delta Study

1. The Ministry of Irrigation currently has limited capability for employing modern techniques of groundwater analysis, particularly numerical models. Until recently all modeling was done by expatriate staff on U.N. projects. Now, Dr. Ebeid of the University has become involved in modeling, including one other project prior to this. However, he is a consultant

to the Ministry rather than a staff member. The data base collected by the Ministry is not oriented toward those items of most interest in resource evaluation. This is typical where the data has not been drawn together in a systematic analysis of the resource. There are also gaps in the data, attributable to lack of funds rather than approach. The sparse information available for the deep portion of the Delta aquifer is an example.

2. The current project can strengthen the Ministry by improving analytical capabilities, and through these capabilities demonstrating the importance of various types of data.
3. Near term future research in this project will primarily be directed toward the development of a numerical model of seawater intrusion in the Nile Delta. Additional topics being considered include an evaluation of the New Valley Development, the use of systems techniques to improve data collection and analysis, and a detailed level study of river aquifer interaction in Upper Egypt. It would be particularly valuable to the Ministry to enhance the data collection program. It is anticipated that the seawater intrusion study will take an additional two years from the date of this report. Additional studies will be for at least a two-year period.