

**Review of Planning Distribution Model (PDM) Status
and Application Possibilities for the Egyptian Irrigation System**

Planning Studies and Models Component
Irrigation Management System Project

by

R.W. Hill, R.C. Peralta, and G.P. Merkle
Biological and Irrigation Engineering Department
Utah State University

Imbaba - Cairo, Egypt
September 1993

EXECUTIVE SUMMARY

The comprehensive water management Planning Distribution Model, or *PDM*, was developed by the Biological and Irrigation Engineering Department, Utah State University (USU), under contract with the United States Bureau of Reclamation (USBR). Most of the work was carried out in the Planning Sector, Ministry of Public Works and Water Resources (MPWWR), in Cairo, under the Planning Studies and Models Component of the USAID funded Irrigation Management Systems Project.

The initial coding and debugging of the current *PDM* began in January of 1993 and was completed in July of 1993. A TDY team review of model features and functions was scheduled for August 23 to September 11, 1993 to include the Planning Studies and Models (PSM) project review workshop in Port Said (August 26-29, 1993). In addition to the presentations and informal exchange at the workshop, discussions were held with MPWWR personnel at Sharkia. However, some anticipated interviews with senior staff were not possible due to their attendance at the ICID meetings in Europe.

The specific objectives of the TDY were :

- To identify and describe potential *PDM* uses and to suggest guidelines (framework) for further application of the *PDM* water management model in Nile River irrigation-related studies and operations.
- To perform a critical review of the *PDM* user's guide and core calculation procedures prior to further evaluation by USU and the USBR.

Potential *PDM* Uses and Applications

The *PDM* was developed for performing simulations of water distribution, crop water requirements, and crop yield response for irrigation and other uses in branching canal and drainage networks. The myriad of potential *PDM* uses in Egypt's irrigation systems include: directorate-level operational planning, analysis of national water management policy, long-term planning, infrastructure development, design analysis, identification of research needs, and training of decision-makers, water managers and others.

Potential applications of the *PDM* rely on its abilities to predict the temporal and spatial distributions of:

- i. volumetric crop water requirements;
- ii. water needed to satisfy other needs;
- iii. additional drainage or groundwater needed to supplement existing supplies;
- iv. salinity concentrations in crop root zones and in drains; and
- v. relative crop yield response to soil salinity, soil water deficit and waterlogging as related to irrigation system management.

- Successful realization of the *PDM*'s potential benefits in the long term (sustainability) will require adequately trained personnel, suitable facilities and equipment, well coordinated data collection programs and a high degree of cooperation and information sharing within MPWWR and with other agencies such as the Ministry of Agriculture. MPWWR is to be commended for the already evident commitment to sustainability. It is critical that a continued strengthening of this commitment be realized as the *PDM* application process moves forward. This may especially be true within the Irrigation Department of the Ministry.

The *PDM* provides a methodology for integration of various IMS project components such as MSM, IIP, S&M when applied in the directorates, and perhaps for MFS at the national level. The following steps are proposed for the incremental application of the *PDM* in Egypt:

1. Apply the *PDM* in a pilot area (Bahr Meshtoul) to validate the physical reasonableness and computational correctness of the *PDM* and to provide real-life hands-on experience for selected PSM staff;
2. Apply the *PDM* as a methodology to a Directorate (Sharkia) to integrate other IMS components, to test the realities of sustainability and transferability to the directorate and Irrigation Department levels and to exercise a greater range of the *PDM* capabilities in a more comprehensive way than possible in the relatively small pilot area;
3. Evaluate the application experience in 1 and 2 to assess the adequacy of: data utilization, cooperation, facilities and training level of technical staff, and to formulate recommended adjustments and future application directions; and,
4. Proceed with application by directorates throughout Egypt (or subsets of) and/or implement at the national level in cooperation with MPWWR's Irrigation Department in Cairo for planning development and operational studies, depending on the conclusions from the evaluation (step 3).

Assuming that the evaluation (in step 3 above) leads to the decision to proceed with further application at the directorate level, twelve (12) site selection (readiness) factors were proposed for use in priority ranking of the order of implementation. USU will be involved in the initial application to the Bahr Meshtoul pilot area, and to a lesser extent to the entire Sharkia Directorate. By the end of the PSM project it is expected that the MPWWR will have gained sufficient expertise in applying the model that further use and replication within Egypt will be achievable without outside consultants. An incrementally reduced involvement by USU, USBR and USAID will help provide for local sustainability of the modeling effort and its practical application.

- The incremental *PDM* application process, as presently envisioned, is sound and should continue to be pursued.

PDM User Manual and Calculations Procedures Review

The PSM project review workshop in Port Said (August 27-28, 1993) provided the TDY team with a good introduction and overview of the *PDM* and its relationship with other PSM components. Subsequently, the team reviewed the *PDM* user's guide and calculation procedures. Editorial changes, terminology definition adjustments and a few points of clarification were suggested. Extensive discussions and specific recommendations involving model philosophy and calculation details focused primarily on crop yield relationships, soil water budgets and ET.

Related Activities and Field Observations

The team reviewed reports on a variety of topics such as crop water use, drainage reuse and groundwater to gain insights into system hydrology. The potential effects of continuing increases in irrigation water demands from surface and groundwater were considered. Available information on crop ET appears to be sufficient for initial application of the model. An opportunity exists for further study of the ramifications of increasing demands on water allocations.

Two days were spent in the field: one in the Bahr Meshtoul and Sharkia areas and the other in the eastern delta horizontal expansion areas served by the Ismailya canal. Interviews were held with Eng. Maher El-Khodari General Manager of Irrigation in the Sharkia Directorate and with the directors of Sharkia horizontal expansion and drainage programs.

Acknowledgements

The work described herein was part of a contract between the United States Bureau of Reclamation (USBR) and the Biological and Irrigation Engineering Department, Utah State University (USU). Most of the work was carried out in the Planning Sector, Ministry of Public Works and Water Resources (MPWWR), in Cairo, under the Planning Studies and Models Component of the Irrigation Management Systems Project. The funding support of USAID is acknowledged. The team is grateful to MPWWR staff (Dr. Bayoumi, Eng. Mohsen and others) for sharing their time and suggestions, arranging travel and providing transportation and availability of other facilities.

The Team attended the Planning Studies and Models (PSM) project review workshop in Port Said (August 26-29, 1993). This provided a welcome opportunity for the Team to get acquainted with personnel as well as with the IMS components.

The careful review of the report drafts by Russ Backus (USAID) was appreciated as were the helpful suggestions of Joe Wensman (USBR). Especially appreciated was the assistance in numerous ways and many other courtesies given to the Team by Leo Busch (USBR Team Leader).

Table of Contents

Executive Summary	ii
Acknowledgements	v
I. Introduction	1
A. Background	1
B. Objectives	1
C. Overview of the PDM	1
II. Potential Uses of the PDM in Egypt	3
A. Development Studies	3
1. Policy	3
2. Strategy	5
3. Long-Term Planning	7
4. Hydraulic Infrastructure	9
5. Operations	9
B. Short-Term Operational Planning	10
1. Evaluation of Water Delivery Equity	10
2. Projection of Near Future (7 to 30 days) Water Deliveries within a Directorate	11
3. Determination of Water Depths at Calibrated Measurement Nodes	11
4. Response to Localized Salinity Problems	11
5. Aswan releases	11
6. Operational Allocation of Water Among Directorates	11
C. Use of PDM to Define Research and Evaluation Opportunities	11
1. Salinity	11
2. Water Distribution	12
3. Crop Water Requirements	12
4. Drainage	12
5. Information Needs of Users	12
6. Conjunctive Water Management	13
7. Maintenance	13
8. Droughts	13

III. Framework to Guide Model Application	13
A. Recommendations and Benefits	14
B. Recommendations of Previous Analysts	16
C. Considerations in Selecting Study Area for Step 1	16
D. Considerations in Determining Further PDM Application (step 2)	19
E. Scope of Model Application	20
F. Procedures for Applying the Model	20
G. Final Evaluation of Model Application	21
H. Implementation Constraints	22
1. Field Data	22
2. Personnel Training	22
3. Time	22
4. Communications	23
5. Dependencies on other Projects	23
IV. PDM User Manual and Calculations Procedures Review	23
V. Related Activities and Field Observations	24
BIBLIOGRAPHY	26
ANNEX A. Scope of Work	29
ANNEX B. Chronological activities summary of USU/USBR Egypt TDY 24 August - 16 September 1993	31
ANNEX C. Required data for application of the PDM as described in: a) the document " Scheduling of Planning Distribution Model (PDM) Planning Studies and Models (PSM) Project (circa May 1993); and b) the memo "Cropping pattern and weather data requirements for the PDM (Aug 3, 1993)	35
ANNEX D. Newspaper article: Sharkia Village Lacking Irrigation Water	42
ANNEX E. Groundwater considerations for achieving optimal sustainable groundwater and conjunctive water management	43
A. Background	43
B. Recommended minimum future actions	45
C. Potential future applications of S/O modelling	46

I. Introduction

A. Background

The Planning Distribution Model, or *PDM*, was developed by the Department of Biological and Irrigation Engineering, Utah State University (USU), under contract with the United States Bureau of Reclamation (USBR), Department of the Interior. Most of the work was carried out in the Planning Sector, Ministry of Public Works and Water Resources (MPWWR) of the Arab Republic of Egypt, in Cairo, under the Planning Studies and Models Component of the Irrigation Management Systems Project. The United States Agency for International Development provided all of the funding under Grant No. 263-0132.

Related models have been developed and tested at USU and at the MPWWR over the past decade, but the initial coding and debugging of the current *PDM* was completed in July of 1993. As the capabilities of the model are more thoroughly understood, its scope of potential uses can be delineated. A review of model features and functions is also timely prior to its implementation within selected irrigated areas of Egypt. Thus, a TDY team visit to Egypt was scheduled to coincide with the PSM project review workshop in Port Said (August 26-29, 1993). The workshop provided an introduction of the team to the PSM modeling program as well as to the Irrigation Management Systems project in general. Especially appreciated was the opportunity to get acquainted with MPWWR, USAID and other project personnel. Documents relating to the TDY scope of work are found in Annex A. Annex B contains the Chronological Activities Summary.

B. Objectives

The specific objectives of the TDY were :

- To identify and describe potential *PDM* uses and to suggest guidelines (framework) for further application of the *PDM* water management model for MPWWR and others in Nile River irrigation related studies and operations.
- To perform a critical review of the *PDM* user's guide and core calculation procedures of the model prior to further evaluation by USU and the USBR.

C. Overview of the *PDM*

The *PDM* was developed for performing simulations of water distribution, crop water requirements, and crop yield response for irrigation and other uses in branching canal and drainage networks. The model is intended primarily for use in planning and training activities, but it can also be applied to design and analyze studies of agricultural irrigation systems.

The *PDM* design addresses many important issues for high-level water resources planning, with particular emphasis on the irrigation needs of agricultural users. In terms of constraints to planning and operation, the model can help overcome deficiencies in the techniques for making decisions at the national and regional levels, and can indirectly assist planners in alleviating problems of water allocation during shortages, accumulation of salts in the agricultural soils, conjunctive management of water resources, and other planning and operating limitations.

The capabilities offered by the model include generation of irrigation water requirements, and crop yield response due to water shortage, water-logging and excessive salinity. This entails a multi-perspective approach to the modeling capability. Simulation features must permit the investigation of relevant planning issues from both the demand and supply sides of the problem. Thus, in general, the objective of the *PDM* is to serve as a comprehensive simulation tool for water resources planners, and to a lesser extent for system operation.

The model is highly interactive and includes integrated data editing capabilities, with numerous options for system layout and configuration, simulation processes, and output of results. Internal data cross-checking and input range restrictions on individual parameters help prevent infeasible configurations and operating conditions. Canal networks for supply and drainage systems are built interactively by inserting and arranging *nodes* graphically in a system layout window on-screen, where nodes represent locations of command areas, municipalities, channel bifurcations and other physical features.

In simulations the *PDM* can generate system flow requirements based on calculated crop water needs, input hydrographs for M&I nodes, and conveyance losses. Daily water balance calculations are performed for command area soil water and for canal reach storage in the supply and drainage systems. Options allow water to be taken from a combination of the supply system, drainage systems, and groundwater resources (through both pumping and capillary rise). Various features can be enabled and disabled from one simulation to another to quickly examine the effects of different conditions on overall water management.

The model can estimate relative crop yield reduction due to root zone water deficit, soil water salinity, and water logging. Daily weather data can be generated by the model based on inputted long-term monthly means and standard deviations. The generated values can also be skewed toward wet or dry years.

Results from the model can be shown in a variety of formats as tables, pie graphs, bar charts, and curves. Graphical displays have many options such as font size, colors, pen widths and 2-D or 3-D bars and pies. Multiple windows of the same or different types can be shown on the screen. Reports can be created and written to disk files in text format.

II. Potential Uses of the PDM in Egypt

Because of its design and attributes, the *PDM* is potentially very useful on a much broader scale than initially envisioned. Originally planned as a directorate-level planning and operational tool, the *PDM* can also help address issues of national policy, long-term planning, infrastructure development, and research planning. In addition, it can be used for decision-maker (DM), water manager and user training related to the other issues.

Potential applications of the *PDM* rely on its abilities to predict the temporal and spatial distributions of:

- i. crop water requirements;
- ii. water needed to satisfy other needs;
- iii. additional drainage or groundwater needed to supplement existing supplies;
- iv. salinity concentrations in crop root zones and in drains; and
- v. relative crop yield response to soil salinity, soil water deficit and waterlogging resulting from system management.

To fully realize the benefits that the *PDM* offers, the required field data (Annex C) must be validated for the studied areas. In listing potential *PDM* applications below, it is assumed that the necessary data have been acquired and validated.

A. Development Studies

1. Policy

Decisions concerning how to implement national policies are frequently far-reaching and economically significant. It is useful to be able to predict the effects of policy implementation decisions before those decisions are finalized. In that way poor decisions can be avoided. This section discusses how the *PDM* can be used to evaluate potential actions that address specified national goals and policies.

a. Assuring National Food Security

Assuring self sufficiency in food production is an important national policy. As populations increase, Egypt needs to maintain and increase agricultural production. This can be accomplished by:

- increasing the land area dedicated to agriculture (horizontal expansion);
- changing cropping patterns (conversion from one crop to another); and
- improving soil and water management efficiency (reducing water lost to the Mediterranean; reducing salinization; increasing crop yield per unit of water, land, or money).

By helping predict items i-v above, the *PDM* permits evaluating, a priori, the effects of changing cropping areas, patterns or soil and water management. In

consort with other studies, the *PDM* can be used to estimate Aswan Dam releases needed to achieve specific food production goals. Alternatively, the *PDM* can help estimate the food production that will result from a particular combination of Aswan release strategy and downstream land and water management.

b. Promoting Public Health and Welfare

Promoting the health and welfare of the general populace involves issues discussed in other sub-sections--including food production, economic growth, privatization, and others. It also includes consideration of equity in providing water. Use of the *PDM* can help determine how best to provide water to portions of the Delta that currently might not be receiving their appropriate historically allocated share (Annex D, Egyptian Gazette, Apr 1993). The *PDM* can help ensure that flows in canals are adequate to reduce health hazards, such as those resulting from schistosomiasis or waste disposal.

Maintaining appropriate flow rates is especially important since the canals currently serve many functions. They are commonly used for domestic consumption (drinking and cooking), washing (clothes), bathing, recreation (swimming), livestock washing and watering, irrigation, wildlife habitat (fish and waterfowl), fishing, waste disposal (solid and liquid waste), and some small-scale industrial water supply. Ensuring adequate dilution helps reduce the health impacts of these multiple uses.

c. Encouraging Economic Growth

Agricultural or industrial expansion frequently requires assuring an increased water supply. The *PDM* can help estimate surplus surface or drainage waters that might be available for such expansion. Knowledge of the spatial and temporal distribution of available waters can help planners know what sort of industrial-use expansions are feasible. Inversely, the *PDM* can be used to adjust allocations to existing users to permit allocation to specific potential users.

In addition, the *PDM* can be used to evaluate the effect of changes in the policies that control or encourage alternative cropping systems.

d. Providing Environmental Protection

Preventing unacceptable harm to the environment is important for sustaining long-term production and wildlife resources. The *PDM* can help in the development of water use strategies that prevent unacceptable salt concentrations in the root zones or drainage waters. The *PDM* can help assure that system outflows are adequate for wildlife habitat, and riverine or coastal fisheries. Flows calculated by the *PDM* can be used in other models to evaluate concentrations of contaminants (in addition to salinity) that will result from specified loadings (Ejaz and Peralta, 1993).

e. Encouraging Privatization

Increasing private ownership of the means of production can require the availability of specified water supplies. The *PDM* can help evaluate the:

- availability of water for any new proposed use;
- effect of changes in cropping areas that might result as land ownership changes. For example, the effect of mesqa ownership or management changes on flows, salinities and relative crop yields can be assessed;
- effect of changes among industrial water users and needs; and
- effect of changes in water allocation policy and water rights or laws.

f. Providing Navigable Waterways

River traffic is important for tourism and transport of foodstuffs and commodities on the Nile River. River stages should be sufficient for minimal navigation requirements. The effect of assumed minimal stage requirements can be evaluated using the *PDM*. These effects include changes in flows, salinities and relative crop yields.

Dredging or river modification can affect the stage-discharge relations of control locations. River modification can reduce the river flowrates (and the stage) needed to maintain specified drafts. The *PDM* can be used to evaluate the effect of changes in required flowrates on downstream water distribution, salinities and relative crop yield.

2. Strategy

Planners frequently attempt to develop management strategies which address specific problems. Listed below are three opportunities to which the *PDM* can be readily applied.

a. Drought Contingencies

In a time of extended drought, water supplies in Lake Nasser might become inadequate to satisfy normal water needs. *PDM* can be used to plan the releases that will be sufficient to satisfy, for example, only 60 percent of normal irrigation water needs and 100 percent of M&I needs. (In essence irrigation usually is the lower bound on Aswan releases.) Once this potential release schedule is determined, the *PDM* can be used to identify the temporal and spatial distributions of delivery shortfalls. If other water supplies are unavailable, water users can adjust cropping patterns (planting less rice, for example) to require less water.

Rather than reducing production, it might be preferable to compensate for any surface water shortfall via alternative supplies--by increasing use of drainage or

groundwater. The *PDM* can identify the spatial and temporal distribution of these sources needed to overcome the surface water shortfall.

For either situation, the *PDM* can be used iteratively to attempt to maximize delivered water or relative crop yield. In such simulations, the modeler might change cropping patterns, priority of water use, or groundwater or drainage water pumping capacity.

b. Minimizing Flow to the Mediterranean Sea

Water managers might feel that minimizing the flow of surface water or groundwater to the sea is desirable. Except for the contribution of such water to salt removal, brackish water wildlife habitat and fisheries, such flows can be considered wasted. The *PDM* can be used to evaluate the effect on these flows of alternative cropping patterns, prioritizations of use of water sources, and distribution networks.

It should be noted that Manzala Lake, which benefits from downstream flows (Egyptian Gazette, Sept 5, 1993) is considered a valuable fishery. The recently approved plan to improve the harbor and lake fish production (for export) includes water quality improvement.

c. Safe Sustained Groundwater and Conjunctive Water Use

The *PDM* can be used to estimate the groundwater pumping needed to satisfy any water needs unmet from surface water or drainage reuse. In that process, the *PDM* can include an externally determined upper limit on how much groundwater can be pumped in each command area. The harmful consequences of assuming too large of values as upper bounds of pumping can be significant.

Increasing use of groundwater in the future during either normal or drought conditions can lead to difficulties. Simply assuring that total groundwater extraction does not exceed a pre-specified total delta-wide sustained yield value is not enough for safety.

If the spatial or temporal distribution of groundwater pumping is inappropriate, undesirable localized decreases in head, changes in surface water-groundwater interflow or salt water intrusion can result. All of these problems can be prevented if the individual distributed groundwater extraction rates do not exceed those of an acceptable spatially distributed sustained groundwater yield pumping strategy.

Such a sustained yield pumping strategy can be computed using spatially distributed numerical models either in steady-state or transient mode. Thus, at a minimum, the *PDM* should be used in consort with a groundwater flow simulation model. A spatially distributed safe sustained groundwater yield pumping strategy

determined by the groundwater model will provide the upper limits on groundwater extraction rates for each command area within the *PDM*.

Even better, optimal sustained yield strategies can be developed using a sufficiently detailed simulation/optimization model. Such a model can directly compute the steady or transient strategy that maximizes delivery of surface and/or groundwater use, while satisfying pre-specified bounds and constraints on: hydraulic gradients, water table heads, surface water flow rates, and all decision variables (See Annex E). Use of such an S/O model avoids the exhaustive repetition of runs necessary if only a normal groundwater simulation model were used. It also guarantees that the best pumping strategy (for example a maximum possible safe sustainable pumping strategy) is developed for the study area and management goals. No simulation model alone can do that.

3. Long-Term Planning

a. Delivery Requirements for New Lands

Horizontal expansion planning in the desert areas adjacent to the Nile Delta involves water transfers from the Nile for irrigation and M&I uses. This brings up the issues of water availability for an increased area, effects on existing lands, water quality of return flows, permissible cropping patterns and irrigation methods, and the role and extent of possible conjunctive use of groundwater. The *PDM* could be used to study the effects of increased water requirements for horizontal expansion, with adjustments in specific input parameters reflecting the irrigation method (efficiency of on-farm water use), and return water quality (salinity levels). Canal capacities could be checked for increased demands in selected reaches, and groundwater pumping could be examined as a potential source of supplementary water.

b. Supply System Source Releases

PDM assumes a single node is the upstream source of water for the supply system. This node could be Lake Nasser, if the river system is modelled. Alternatively, that node could be some major diversion point, if only a portion of the entire Egyptian irrigation system were being modeled. The *PDM* can generate daily system demands, adjusted for lag time, and the resulting hydrograph for a particular planning scenario could be used as input to a reservoir model for more detailed studies on water availability, and on the feasibility of meeting the demands. For simulated systems beginning at a diversion point, rather than at a reservoir, the generated demand hydrograph could be inputted into a canal hydraulic model to determine the operational feasibility of satisfying the demands as far as volume and timing are concerned.

c. Changes in Pumping Technology

In the Nile Delta there has been a trend away from animal-driven saquias (water wheels) toward motorized pumps for supplying irrigation water to mesqas. One of the consequences of this trend is to increase flow rates to mesqas, allowing larger field sizes and permitting more intensive cropping of rice. The *PDM* could be applied to the study of this effect by changing the total pumping capacity of a command area from the supply and drainage systems, and by changing the resulting shifts in actual and projected cropping patterns. For example, the *PDM* could demonstrate the effect of shifting from animal fodder production to food for human consumption.

Other possible results from a study of this trend could be that some of the channel capacities become restrictive, whereas they were previously adequate.

d. Changes in On-Farm Irrigation Methods

Changes in on-farm irrigation methods could be studied to reduce or eliminate surface runoff by adopting basin irrigation to a greater extent in the existing lands, or to use pressurized systems where water availability may be more restricted. The *PDM* would take into account the type of irrigation system through changes in the specified surface runoff percentage, which would also affect the amount of water entering the drains as return flow. The consequences of this could be manifested on a macro scale more than within a given command area, and the simulation results would show this effect through water availability and salinity, and ultimately through estimated relative crop yield.

e. Reuse of M&I Effluent

The *PDM* does not deal with the chemical processes or environmental issues associated with the reuse of effluent, but it can be applied in an oblique way by simply considering the introduction or removal of such sources to the irrigation and drainage systems. For example, a decision to discontinue the mixing of effluent with fresh water (possibly because of health concerns) could be *hydrologically* evaluated through *PDM* simulations.

f. Navigation in Rivers and Canals

Flow requirements for navigation are taken into consideration in the *PDM* by specifying a minimum monthly flow rate for each canal reach. When possible, the model maintains this minimum flow even when it exceeds the total downstream water requirements. Possible changes in navigation needs on a seasonal basis, and their effect on overall water management, could be studied simply by changing these input values and making different simulation runs.

The *PDM* could also be used to study changes in minimum draft requirements by boats, making use of the entered open-channel stage-discharge relationships at measurement nodes. Thus, simulations could be made in which the required

flows are determined at measurement nodes such that the minimum draft is maintained, and the effect on overall water management could similarly be assessed. Volumetric reach capacities could also be varied in simulations to accommodate differences in navigation requirements, and this would indirectly affect water availability to Command Area and M&I nodes in the model.

4. Hydraulic Infrastructure

a. Supply and Drainage Systems

The *PDM* could be used to study possible additions or modifications to the supply and drainage system channels, and to their flow control structures. Such changes would affect simulation results in that capacities of the reaches and/or structures would be altered. The addition or removal of reaches or structures would change the system layout, and would potentially affect water distribution and water availability to at least some of the Command Area and M&I nodes. These effects could be noted in the *PDM* simulation results, and appropriate conclusions could be made.

b. Groundwater Pumping

Groundwater pumping in command areas is restricted in the *PDM* by a user-specified maximum total flow rate for each Command Area node. Thus, one could examine the effects of more groundwater wells and possibly greater pumping capacity on existing wells. The effect of more or less groundwater use on overall salt balances could also be studied through application of the model.

Furthermore, the hierarchy of conjunctive groundwater use (as opposed to the use of supply water, and the reuse of drainage water) can be altered in the model, groundwater pumping can be specified through hydrographs, and groundwater use can be completely disallowed, all through simulation options.

A groundwater simulation model could be applied with the *PDM* to study the effects of groundwater pumping in more detail. This could involve investigations into sustainable aquifer yield, possible artificial recharge, and salt water intrusion.

As in section II.A.2.c., a groundwater simulation model can be utilized to provide guidance on acceptable groundwater pumping rates. A simulation/optimization conjunctive use model can be used to provide optimal guidance on pumping rates.

5. Operations

In the context of development studies, operations refers to predetermining likely monthly patterns of water management conditions over an annual time frame. For example at the directorate level this may influence annual decisions of monthly water duty limits to

districts in response to imposed constraints from higher authorities. The following four examples illustrate this concept.

a. Seasonal Canal Supply Hydrographs

The *PDM* could generate demand hydrographs on a monthly (or shorter time step, say, 10 days) for all the districts within a directorate. This could be done for existing or anticipated cropping patterns for average weather conditions, etc. The hydrographs could then be used with a canal model to estimate relative changes in gate operation rules or set points. The implications in canal management changes in irrigation scheduling practices, i.e. from rotation to continuous flow at the laterals or mesqa level, could be studied by ministry and directorate personnel. Conversely, the consequences of imposed supply hydrographs on canal operation, water delivery schedules and crop response could be examined.

b. Salinity Management

The model can be used to identify areas where crop yields could be unacceptably reduced by use of high salinity drain water resulting from traditional water delivery practices. Managers could then develop and test alternative water allocation plans for supplying more freshwater to the area.

c. Groundwater Pumping Requirements

With continued development of the horizontal expansion areas, increasing amounts of water will be redirected to meet these needs. The *PDM* could be used to indicate the magnitude and general location where groundwater pumping would be most desirable to reduce adverse effects. This in turn could be used to direct government incentive programs for farmers (perhaps at the mesqa level?) to develop the ground water. This should be performed in the manner described in Section II.A.2.c.

d. Treated M&I Effluent Usage Timing

Continued increases in irrigated area and/or droughts could stretch the river and drain water supply to undesirable limits with resultant salinity increases and crop yield declines. Apparently, there is M&I effluent water which is not now used for irrigation. Consideration of quality aspects of this water may suggest that it should be used only when sufficient dilution could be achieved, which could be identified with the *PDM*.

B. Short-Term Operational Planning

1. Evaluation of Water Delivery Equity

Perform mid-season (and post-season) analysis of actual versus estimated water deliveries and water budget to allow mitigation adjustments to be made in the near future

2. Projection of Near Future (7 to 30 days) Water Deliveries within a Directorate

The comments of section II.A.5.a. apply here as well.

3. Determination of Water Depths at Calibrated Measurement Nodes

The unsteady canal model could be used to determine day to day canal gate openings, etc., for hydraulically delivering the water.

4. Response to Localized Salinity Problems

The comments of section II.A.5.b. apply here also.

5. Aswan releases

Determining downstream water needs permits determining Aswan releases. The release from Aswan should be sufficient to satisfy downstream water needs, or some pre-specified portion thereof.

6. Operational Allocation of Water Among Directorates

This is an intermediate operational use between guiding Aswan releases and allocation to districts. By determining water demands for each directorate, allocation between directorates is possible.

C. Use of *PDM* to Define Research and Evaluation Opportunities

A comprehensive simulation model such as the *PDM* lends itself well to research needs identification studies. For example, the model could be repetitively run while varying selected parameters across their respective practical ranges in a sensitivity analysis. Those parameters which the model output is most sensitive to are the ones which probably should be studied or researched in the field. Technical parameters which can be examined in this manner include: irrigation efficiency (on-farm, mesqa or larger areas), canal seepage losses, soil salinity, drainage water salinity, proportion of water supply taken from drains and/or ground water, depth to water table (drain design/performance), hydrologic interaction between districts and directorates, crop water use (crop coefficients, ETo calculation method and adequacy of weather data) and a large variety of cropping pattern related scenarios.

The brief examples listed below are suggestive of some of the possibilities.

1. Salinity

Identify possible areas of yield threatening high groundwater levels or soil salinity levels.

2. Water Distribution

a. Identify possible inequities of water supply among nodes (comparing historical supply to estimated demand). This helps MPWWR to know how best to achieve uniformity of distribution between command areas.

b. Determine seasonal demand hydrographs and required changes for varying cropping patterns and weather. (Once the demands are specified, the hydraulic models could be used for implementation of desired water distribution scheduling. Similarly, *COMMOD* could be used to examine field and mesqa level irrigation scheduling and efficiency scenarios).

3. Crop Water Requirements

The adequacy or reasonableness of available crop coefficients and Eto computation methods and how sensitive the model results are to these values may indicate needed additional field studies or model coefficient adjustments.

4. Drainage

a. Determine adequacy of drainage channel capacities.

b. Determine possible limits on drainage reuse.

5. Information Needs of Users

Users range from Ministry (MPWWR, Agriculture, etc.) administrators and planners (directorates and above) to perhaps farmers and students. The *PDM* model could provide background water budget information for multi country negotiations on the Nile. For example, the *PDM* estimates water needs and crop yields for assumed situations. This permits Egypt to anticipate the effect of any water supply shortfall on national production and returns. This quantification is important if Egypt is negotiating for water with other users of the Nile headwaters.

On the more local level, through engineering studies of crop patterns and resultant water demands the limits for allowable rice area could be determined. Times of anticipated water shortages could be identified, thus allowing warning notices to be posted as farmer advisories (at the mesqas). This can enhance Dept. of Agriculture efforts.

6. Conjunctive Water Management

As mentioned previously, the *PDM* can be used to identify the spatial and temporal distributions of surface water, groundwater and drainage water reuse needed to satisfy

water needs for assumed cropping patterns and priorities. Also assumed are coefficients implicitly or explicitly describing movement of water from irrigated fields to the drains. The assumption is made that groundwater pumping does not affect groundwater levels--because they are controlled primarily by subsurface drains.

The validity of these assumptions needs verification. The sensitivity of computed water allocation strategies to the assumptions needs to be determined. The necessary field research will greatly and systematically expand the manager's knowledge of the water system's response to stimuli.

Related to *PDM* use is utilization of a simulation/optimization (S/O) model, such as the Utah State Response Matrix Model, *US/REMAX* (Peralta and Aly, 1993). *US/REMAX* directly computes optimal conjunctive water management strategies. In that process it simulates 3-dimensional groundwater flow and surface water-groundwater interflow in detail.

Merging some of the capabilities of *US/REMAX* with the *PDM* is a valid applied research goal. With the product, one could assure that computed seasonal or short-term allocation strategies are in harmony with long-term safe sustained yield goals.

7. Maintenance

Could be used to indicate canal cleaning needs when actual flow capacity is less than required to meet estimated demands in specific reaches.

8. Droughts

The following could be considered in developing drought contingency response plans:

- a. Cropping pattern changes
- b. Reservoir management interaction with increased use of drainage water and/or potential groundwater use.
- c. The possible effects of mandated reduced groundwater pumping and possible impacts on water available for power generation or other uses could be investigated for the case of extended drought.

III. Framework to Guide Model Application

Which of the many potential uses of the *PDM* are most appropriate for Egypt at this time? As an extreme, answering that question can involve considering both the costs and benefits of application. However, this quantification is difficult or impossible, especially since the *PDM* has not yet been applied rigorously in the field. A practical less quantitative alternative is to use judgement, guided by experience.

To provide focus in this section, we begin by stating the recommendations for *PDM* application, and expected benefits of the recommended approach. Subsequent subsections support or clarify the recommendations. They contain:

- a review of software development and application recommendations made by previous teams;
- a discussion of the criteria used to select the study area to be addressed after Bahr Meshtoul;
- a review of how to evaluate the success of *PDM* application to a directorate, and determine whether application should be extended to a greater area;
- model scope, application procedures, organizational responsibilities, and implementation constraints.

A. Recommendations and Benefits

The recommendations are:

1. MPWWR personnel apply the *PDM* to the Sharkia Directorate after it has been applied to Bahr Meshtoul pilot area. Sharkia is assumed to be the most appropriate representative area for the step to the directorate level. Note that in Bahr Meshtoul, *PDM* command area (CA) nodes are mesqas. In Sharkia, CA nodes would be larger areas (perhaps districts) to correspond with MSM sites. *PDM* should be enhanced as necessary for this 'beta-test' application.
2. Evaluate the results of step 1 and determine whether or how best to continue *PDM* application. This evaluation involves considering ease of data collection, model use and desirable model enhancements. It includes estimation of MPWWR ability to utilize results for managing the entire Nile System (a step 3 desktop activity for the MPWWR 18th floor). It also includes determination of directorate ability to apply the *PDM* directorate by directorate. Unless there are significant mitigating circumstances, if the step 1 directorate does not use the *PDM* results, the *PDM* should probably not be applied to other directorates in step 4.
3. Depending on the evaluation in step 2, apply the *PDM* to the Nile System (downstream of the High Aswan Dam) or some portion thereof, after it has been applied to the Sharkia Directorate. Failure of the directorate of step 1 to apply *PDM* results in management does not necessarily mean that the *PDM* should not be applied to part of or to the entire Nile System. Management responsibilities of the MPWWR at Imbaba differ from those of an individual directorate. Also, since the nodes differ, the degree of control of flows to nodes differs. The *PDM* could be a highly successful tool for management of the entire Nile System and yet be only marginally successful for directorate level management use.

The level of detail considered in this application (level of canal addressed) will depend on the results of the experience in step 1. *PDM* nodes could range from groups of directorates to districts or groups of districts. Again, *PDM* enhancement may be indicated.

4. If previous experience warrants, apply *PDM* to other directorates which satisfy criteria indicative of their likelihood of success. Use the recommended evaluation process (described later) to prioritize those directorates for *PDM* application.

This stepwise approach provides:

- Minimal risk. While demonstrating application to a representative directorate (Sharkia), MPWWR personnel will determine how difficult it is to acquire data and to utilize the *PDM*. It is better to experience this in one directorate than for the entire detailed distribution system. It is necessary to apply the *PDM* to a sufficiently complex system as early as possible to judge ease of use, sustainability, and desirable modifications. Evaluation after application to Sharkia insures that the *PDM* will not be applied to the entire downstream system unless justified.

- Maximal opportunity to achieve success in applying the *PDM* to a representative area. The Sharkia Directorate is an appropriate area because its features test all major capabilities of the *PDM*. It is an ideal location for application because it includes other major programs of the IMS. (These are: Irrigation Improvement Program, IIP; Main Systems Management, MSM; and Surveying and Mapping, S&M.) This insures greater data availability and agency involvement.

- Maximal opportunity to achieve success in applying the *PDM* to the entire Nile system. The previous application to Sharkia will have demonstrated the ease or difficulty of data collection and validation. This will help the MPWWR to know what level of canal should be included in the Nile System application.

- Maximal development of agency memory and personnel training. The same *PDM* model is used for both directorate and Nile System planning. The same MPWWR (Imbaba) personnel that are trained in *PDM* use on Bahr Meshtoul are trainers of the personnel addressing Sharkia. These same experienced trainers would then be available to address the entire Nile system (below Aswan) or portion thereof. They would also be able to train the personnel of other directorates.

In addition to the previously mentioned benefits, the above approach is selected because:

- it satisfies the major criteria or recommendations of previous software system evaluators (see Recommendations of Previous Analysts below);
- it uses the most qualified directorate as the first significant field application (see Considerations in Selecting Study Area for Step 1, below);
- it provides for sustainability of the expertise developed in using the *PDM*;
- it provides for systematic evaluation and enhancement of the application process and the *PDM*; and
- it provides long-term expansion in *PDM* use and the utility of its results.

B. Recommendations of Previous Analysts

Cited here are the views of those who have previously analyzed the modelling needs and goals of the MPWWR and the IMS project. These citations support *PDM* development and application and our recommendations.

The ISPAN Technical Support Center (1990) recommended that PSM efforts should meet water planning needs at the directorate level. It recommended that "A new operations distribution model should be developed that will focus on directorate-level water management and serve national planning needs as well."

A Special Assessment Team Report stated that "...purpose of the PSM component is to complete the development of water resources planning computer models and provide an environment in which these models can be used as primary decision-making tools" (Green et al, 1990). They suggested that:

- selected models should be applied to a small area initially, which should indicate their applicability for subsequent application to larger areas;
- a *PDM* should be used for monthly, weekly, and daily allocation of flow distribution downstream of the Aswan;
- the *PDM* initially be applied to the main stem of the Nile, including barrages and diversion dams and first and second order canals; and
- groundwater use should be considered in applying the *PDM*.

Alison and Levine (1993) indicate that great effort should be made to integrate data use and encourage collaboration between the PSM, IIP, MSM and SM components of the IMS project.

C. Considerations in Selecting Study Area for Step 1

The most extensive long-term application of the *PDM* will involve its eventual application to all irrigated land below the High Aswan Dam. The *PDM* is currently being applied to the Bahr Meshtoul as a pilot area. In this activity personnel are being trained, data collected, and the application process is being tested. The next step (Step 1) is to expand the *PDM* application to the directorate level (or nearly so). This is necessary to test more features than exist within the Bahr Meshtoul area.

Which study area should the *PDM* be applied to after the Bahr Meshtoul? In general, priority for applying the *PDM* should be based on the likelihood of successful application. An exception to this rule can occur if some area has a critical problem that urgently needs to be addressed (drastically declining crop yield or economic returns; extremely inequitable water distribution; increasing social unrest; severe salinization, water quantity, quality, health or environmental problems).

The team identified several factors which are indicative of the probability of successful *PDM* application. These factors can be used to prioritize or rank sites for *PDM* application and are listed below. They can also be used to aid prioritizing the study areas that should be addressed in step 4. During that prioritization, appropriate

consideration should be given to the seriousness of problems that can be addressed with the *PDM* .

1. Representative of the Delta (Representative)

Does the area contain a range and diversity of physical circumstances which reflect those in the Nile delta "old lands"?

2. Physical proximity to MPWWR Cairo office (Proximity)

Is the area close enough to minimize travel time for more convenient interaction with PSM staff?

3. Communication possibilities with management (Communication)

To what degree are directorate personnel interested in collaboration and willing to meet PSM staff at least "half-way"?

4. Size (Size)

The selected area should be large enough to exercise the *PDM* options yet the field data collection should still be tractable. This is particularly important in the pilot study.

5. Possible interaction with horizontal expansion (Expansion)

6. Extent of calibrated measuring weirs (Measurement)

7. Extent of telemetric MSM sites (Telemetry)

8. Availability of recent land use/cropping pattern maps (Maps)

9. Location of a weather station within the area (Weather)

10. Water supply from drains and ground water (Mixed Supply)

Does the area have an existing or a potential for conjunctive use?

11. Availability of computer facilities and trained staff (Tech Staff)

12. Previous field research studies (Previous Study)

Have more comprehensive field studies been conducted within the area and is the data available?

Table 1 illustrates how the selection factors and weights (weak= 1, strong=9) can be used to compare *PDM* application to the Bahr Meshtoul, Sharkia Directorate and Serry Canal Region. The higher the resulting score, the greater the expected benefits and likelihood of success--consequently the higher priority for *PDM* application.

Table 1. Proposed Site Selection Matrix Comparing Three Different Sites.

	Potential Application Sites		
	Bahr Meshtoul	Sharkia Directorate	Serry Canal
1. Representative	7	9	5
2. Proximity	9	9	2
3. Communication	8	8	5
4. Size	9*	9	7
5. Expansion	1	9	1
6. Measurement	7	6	4
7. Telemetry	6	5	8
8. Maps	9	7	3
9. Weather	8	9	?
10. Mixed Supply	7	9	2
11. Tech Staff	8	5	5
12. Previous Study	8	8	8
Totals:	87	93	50?

Note: An asterisk (*) indicates adjustment for pilot area consideration, and a question mark (?) denotes insufficient information.

The Sharkia Directorate is recommended for Step 1 as a result of this representative application, and the following:

1. The *PDM* application will tie into the existing and proposed MSM telemetry measurement sites in Sharkia, using that data as input to the *PDM*. This also serves to help integrate the PSM and MSM project components.
2. The *PDM* will be demonstrated on a larger area that better highlights the features and capabilities of the model, and for which the model was designed. This larger area should preferably include the Bahr Meshtoul pilot area, from which valuable experience will have been learned under the Task 9 activities.
3. Application to a more complex study area enhances development of the MPWWR's capability to collect the necessary field data on a larger area, and to incrementally transfer application of the model to the ministry before project completion, thus enhancing the prospects for post-IMS sustainability.
4. When Bahr Meshtoul was being selected as the pilot area Sharkia Directorate officials were given a sales pitch on the utility of the *PDM*. Their support for the pilot area testing was probably gained via the implication that the *PDM* would subsequently be applied to the Sharkia Directorate, which contains the Bahr Meshtoul. A sense of integrity indicates that Sharkia be the test directorate, unless some other directorate would pose a significantly better application.

D. Considerations in Determining Further *PDM* Application (step 2)

This step includes determining whether MPWWR (Imbaba) should apply *PDM* to the entire Nile System (a step 3 activity) or some portion of it greater than a directorate in size. To some extent this decision requires evaluating how well the Sharkia Directorate has utilized the results of *PDM* application.

If the directorate is successful in assembling data, achieving reasonable results from the *PDM*, and implementing those results in management, there is good likelihood that MPWWR (Imbaba) will be able to apply *PDM* successfully to the Nile System. If the directorate is not successful to some degree, the reasons for those failures should be considered carefully. It might be that difficulties of directorate-level implementation are insignificant in Nile System management, or that appropriate procedural adjustments can be made by MPWWR (Imbaba).

Success in *PDM* implementation cannot be determined on the basis of a numerical score--with some value differentiating between success and failure. Success should be determined based on how well the *PDM* helps water management. The *PDM* should be considered successful if it is used, among other applications, to:

- Determine water needs and allocate water accordingly; or
- Examine the water management impact of real water allocation activities, for example, horizontal expansion, and make decisions accordingly.

The evaluation should include determination of:

- The impact of specific deficiencies in available water management data

- Transferability of the gained training and experience to other areas and personnel
- Institutional and human resources constraints that affect collection of data needed by *PDM* or affect use of *PDM* products

E. Scope of Model Application

The *PDM* is targeted for users with at least some knowledge of microcomputer usage, and with at least minimal understanding of the issues involved in water management planning and operation. It is also preferable that a user of the model have some background in methods for estimating crop water requirements, crop yield response, and other physical processes related to agricultural irrigation systems. The more the model user understands the capabilities and underlying technical features of the *PDM*, the more valid its application will be.

The *PDM* does not directly address groundwater modeling, open-channel hydraulics, economics, water law, or sociological subject areas. Water quality analysis is limited to salinity in the form of total dissolved salts, and specific toxicities to plants are not considered.

The model can be applied to a single command area, or to up to approximately 1000 command areas, of user-defined size and extent. Thus, the *PDM* can be applied to an entire river system if desired. The utility of the model is most apparent when at least several command areas are considered in a simulation.

F. Procedures for Applying the Model

Initially necessary field data will be collected and the *PDM* applied to a portion of the Egyptian irrigation system as a planning, training, analysis and operational tool. This tool can provide an additional source of planning and operational information from which water management decisions can be based. The additional information will be contingent on the acquisition and entry of field data (see Annex C), and will be presented from a "macro" or systems perspective. Such a perspective is difficult to attain without the use of a model because of the complex interactions that can exist in a typical irrigated area in Egypt.

The application of the *PDM* in Egypt is proposed to be incremental in that it would first be calibrated and used on a relatively small irrigated area, such as Bahr Meshtoul in the Sharkia Directorate. Then it will be applied to a larger area corresponding to a complete or partial irrigation Directorate. Finally, the model will be transferred either to the entire Egyptian irrigation system downstream of Aswan, some portion thereof, or to other Directorates. USU will be involved in the initial application to the Bahr Meshtoul pilot area, and to a lesser extent to the entire Sharkia Directorate. By the end

of the PSM project it is expected that the MPWWR will have gained sufficient expertise in applying the model that further use and replication within Egypt will be achievable without outside consultants. An incrementally reduced involvement by USU, USBR and USAID will help provide for local sustainability of the modeling effort and its practical application.

The *PDM* should be used in manager training to:

- Increase understanding of how the irrigation system really works
- Generate potential operational scenarios in a planning context to illustrate the capabilities and features of the *PDM*, and to help MPWWR personnel understand how it can be practically applied to real water allocation opportunities.

Following and during training, *PDM* results should guide water allocations and decision-making. In addition to testing alternative scenarios and determining allocations, the sensitivity of *PDM* results to assumed parameters should be evaluated.

G. Final Evaluation of Model Application

To realize the potential benefits of the *PDM* will require cooperation with other IMS components to provide reliable data. The initial objectives of the IMS were to have the MSM, IIP and S&M Projects provide the PSM Project with data to accomplish the efficient management of the Nile River water resources. The use of this data will enable the successful demonstration of the *PDM* within the Sharkia Directorate in cooperation with other Ministry operational and planning entities.

The *PDM* use would then be introduced to other Ministry operational and planning entities to effectively implement their stated mission objectives. This in turn would insure the sustainability of the *PDM* within these entities, which have a higher priority and reliability of funding within the Ministry, i.e. Department of Irrigation and Horizontal Expansion Sector. The PSM Project has initiated these IMS integration efforts with other IMS Components and Ministry Sectors.

The final test of whether or not the exercise of designing and developing a water management planning model was worth it may depend upon the extent of its continuing use by agency staff. The *PDM* output is designed to be useful to MPWWR staff not only for planning studies but also for operations, as discussed earlier. However, the output will be useful only if it is trusted. This trust is developed as users become familiar with the model operation and gain confidence in the reliability of model estimated water management parameters. The *PDM* will be submitted to "tests of reasonableness" towards developing confidence in its output. Tests of reasonableness of model outputs include comparison of calculated water demands, water budgets and crop yields with observed values for correspondence to seasonal variations in weather and cropping patterns.

Based on several statements made at the PSM review workshop, one of the most valuable outcomes of the *PDM* application could be the better definition of irrigation water demands from the command level on up the Nile river system.

The *PDM* with its user-friendly features bypasses many common excuses for non-use.

H. Implementation Constraints

The currently identifiable constraints to application of the *PDM* in Egypt are related to availability of field data, technical training, time limitations, communications, and coordination assumptions with other IMS project components. Each of these are discussed in the items below.

1. Field Data

There is currently a serious need for additional and up-to-date field data for strengthening water management decisions within Egypt, and for successful application of the *PDM*. The MPWWR has taken on the responsibility for collecting the necessary data items to be used in the *PDM* (and the ICMs), calibrating in the field where appropriate, and analyzing and inputting the data to the model. These activities will be conducted with technical advice from the USBR and USU through mid-September of 1995, and after that it will be entirely up to the MPWWR.

2. Personnel Training

At this time there is still an important need to train MPWWR engineers on the practical uses of the *PDM* in Egypt, and on the underlying technical processes contained in the model. This will be dealt with in conjunction with Tasks 3, 9, and 10 of the USBR-USU contract, primarily by Dr. Merkley in Cairo. However, it must be emphasized that continued training must occur within the MPWWR (and by the MPWWR) to provide for sustainability, because it is apparent that there is often a high turnover rate with the MPWWR junior engineers. Thus, the initial *PDM* training by Dr. Merkley would also serve to train those who would subsequently train other ministry engineers.

3. Time

Time is always a constraint, and particularly so in this project. It is necessary for data collection and analysis to proceed in a fairly consistent manner throughout the remaining two years of the project, with concurrent application, testing and enhancement/debugging of the *PDM*. Delays in these activities will reduce the extent to which the *PDM* can be successfully applied before the end of the project, and will reduce the chances for sustainability of *PDM* application after September of 1995. It can be argued that the current objectives for applying the model in Egypt are fairly ambitious, and they leave little room for missed opportunities in data collection, model application, training of model users, and model evaluation.

4. Communications

One of the difficulties in application of the *PDM* is related to communications in general, between Cairo offices and the Directorates, and between various different governmental agencies and ministries within Cairo. Some of the communication constraints are due to misunderstandings, the need for negotiations, and different perspectives and priorities. Data collection and model application could be made more expedient if some of these kinds of constraints could be diminished, but this is outside of the scope of USBR and USU involvement.

5. Dependencies on other Projects

The application of the *PDM* in Egypt will definitely involve assumptions about anticipated implementation schedules of other project components within IMS, including (1) the production of maps, thematic cropping pattern overlays, and ortho-photos from the Surveying and Mapping (SM) component; (2) installation of additional telemetry sites in the Sharkia Directorate by the Main System Management (MSM) component; and (3) adoption for use in Irrigation Improvement Project (IIP) pilot areas.

IV. PDM User Manual and Calculations Procedures Review

The PSM project review workshop in Port Said (August 27-28, 1993) provided the TDY team with a good introduction and overview of the *PDM* and its relationship with other PSM components. Subsequently, the team reviewed the *PDM* user's guide and calculation procedures. Editorial changes, terminology definition adjustments and a few points of clarification were suggested. Extensive discussions and specific recommendations involving model philosophy and calculation details focused primarily on the following:

- i. Crop yield response to soil salinity (ECe) and the use of a layered root zone in the soil salt balance calculation;
- ii. Water table uptake and water-logging interaction in connection with deep percolation and drainage;
- ii. Yield response to soil water deficits and variation with growth stage;
- iv. Seasonal water budget accounting for water balance reports;
- v. Computational procedures for the potential evapotranspiration, ET_p, equations included in the model; and
- vi. Significance and effect of groundwater hydrology and availability on long term management.

Items i, ii and v above were examined in detail, particularly the ET_p computation. The specific equations were verified with independent manual calculations and with weather

data from the Meshtoul pilot area site (Sep 1988). A probable data reporting error was discovered in the wind travel values. The recorded wind (km/day) appears to be about 1/10 of expected or typical field values. The reported values are less than the lower measurement threshold for anemometers currently in use.

V. Related Activities and Field Observations

The team reviewed reports on a variety of topics such as crop water use, drainage reuse and groundwater to gain insights into system hydrology. The potential effects of continuing increases in irrigation water demands from surface and groundwater were considered. Available information on crop ET appears to be sufficient for initial application of the model. An opportunity exists for further study of the ramifications of increasing demands on water allocations.

Two days were spent in the field: one in the Bahr Meshtoul and Sharkia areas and the other in the eastern delta horizontal expansion areas served by the Ismailiya canal. Interviews were held with Eng. Maher El-Khodari General Manager of Irrigation in the Sharkia Directorate and with the directors of Sharkia horizontal expansion and drainage programs. Directorate staff demonstrated the retrieval of canal stage measurements with the MSM telemetry equipment.

The team learned that the installation of new field drains (with the same design as previously used) is completed for about two-thirds of the Sharkia area. The Sharkia manager shared the rice area limits as given by the ministry. He indicated that a main concern was farmers planting rice in illegal areas.

The crops in the Bahr Mashtoul area generally look good. Only a few fields showed non-uniform growth or signs of fertility deficiency. Rice was present in large extent with a lesser proportion of cotton and maize and some vegetables. The motorized pumps were abundantly in use, whereas only four of the several saquias that we saw were actually in use. The location of the weather station in Bahr Meshtoul was representative of the crop areas and seemed to be secure. However, its condition indicated a need for maintenance and calibration checks (the anemometer was missing, grass was taller than the evaporation pan and the hygrothermograph temperature was 13 deg C higher than the glass thermometers).

The horizontal expansion director for Sharkia Directorate indicated that wheat, maize, orchards and vegetables were the anticipated crops for the new lands. Sprinkler (not center pivots) and drip irrigation methods will be used. The extent of planned horizontal expansion with and without the northern Sinai was also discussed. Apparently, 532,000 feddans (1 feddan = 4200.83 m²) will be in the delta with about 315,000 feddans more in the Sinai. The water duty is to be 24 m³/feddan/day year-round. This contrasts with the old lands duty which varies from 30-50 m³/fed/day at the mesqa (rice is 70). To the east of Zagazig the complexity of the irrigation system was evident by the observed commingling of drain water, including M&I effluent, with canal water. West of Ismailiya the team inspected a drip system in an orchard and saw several operating center pivots.

Some maintenance opportunities were apparent to correct clogging, leaks and other causes of non-uniform water application.

BIBLIOGRAPHY

Alison, K., and Levine, T. 1993. IMS Project review and planning workshop. ISPAN Report No. 54. Presented on 1-4 Apr 1993 in Port Said, Egypt.

Drainage Research Institute. 1993. Drainage water. Ministry of Public Works and Water Resources, Water Research Center, Planning Sector, Water Security Project, Cairo, Egypt. Vol. 1, Assessment of Drainage Water Quality and Allowable Reuse Limits, 139 p.; Vol. 2, Drainage Water Status in Nile Delta, appx 100 p.; Vol. 3, Drainage Water Reuse Projects, 45 p.; Vol. 4, The Simulation Model Siware, 48 p.

Drainage Research Institute. 1987. Pilot areas and drainage technology project, Meshtoul pilot area, Year book 1984/1985, collected data-tables. Ministry of Irrigation, Water Research Centre, Cairo, Egypt.

Drainage Research Institute. 1989. Pilot areas and drainage technology project, Mashtoul pilot area, Year book 1987/1988, collected data-tables. Ministry of Public Works and Water Resources, Water Research Centre, Cairo, Egypt.

Drainage Research Institute and Winand Staring Centre. Undated. Report of the Reuse of Drainage Water Project. Drainage Research Institute, Cairo, Egypt, and Winand Staring Centre, Institute for Integrated Land, Soil and Water Research, Wageningen, The Netherlands. 8 p.

Egyptian Gazette. 1993a. Ordeal of small village in Sharkia. In, The Egyptian Gazette, April 13, 1993. 1 p.

Egyptian Gazette. 1993b. Manzala Lake. In, Local Glimpses, The Egyptian Gazette, September 5, 1993. p. 1.

Ejaz, S. M. and Peralta, R. C. 1993. Optimizing point and nonpoints loadings to a stream. In Proceedings, ASCE National Irrigation and Drainage Division Conference Proceedings, July 21-23, Park City, Utah. 8 p.

Green, G., Kirshen, P. and Zimbelman, D. Dec 1990. Special Assessment Team Report for the Planning Studies and Models Component of the Irrigation Management System Project for the Nile River. Cairo, Egypt.

ISPAN Technical Support Center. Sep 1990. Irrigation Support Project for Asia and Near East Report No. 35, Irrigation Management Systems Project, Arlington, Virginia.

Khalek, M. A. A. and Roest, C. W. J. undated. Comparison of simulation results with measurements. Report of the Reuse of Drainage Water Project. Drainage Research Institute, Cairo, Egypt, and Winand Staring Centre, Institute for Integrated Land, Soil and Water Research, Wageningen, The Netherlands. 21 p.

Maaskant, M., Abbas, M. S. and Kandil, N. F. 1985. Estimation of available drainage water for the El Umum reuse project. Report 7, Drainage Research Institute, Giza, Egypt; and Institute for Land and Water Management Research, Wageningen, The Netherlands. 31 p.

Merkley, G. P. 1993a. Planning distribution model. Ministry of Public Works and Water Resources, Planning Sector, Planning Studies and Models Project, Cairo, Egypt. 65 p.

Merkley, G. P. 1993b. Proposed development of a planning distribution model. Ministry of Public Works and Water Resources, Planning Sector, Planning Studies and Models Project, Cairo, Egypt. 82 p.

Merkley, G. P. and Walker, W. R. 1993. Recommendations for the use of selected irrigation command models. Ministry of Public Works and Water Resources, Planning Sector, Planning Studies and Models Project, Cairo, Egypt. 154 p.

Ministry of Irrigation. 1981a. Water Demands. In, Master Plan for Water Resources Development and use. Technical Report 2, UNDP-EGY/73/024, Cairo, Egypt. 150 p.

Ministry of Irrigation. 1981b. Water Quality. In, Master Plan for Water Resources Development and use. Technical Report 7, UNDP-EGY/73/024, Cairo, Egypt. 62 p.

Neale, C. M. U., Ramsey, R. D., Farag, F. A. and Ahmed, R. H. 1993. Software development for irrigation distribution systems in Egypt, Task 1 Report, First Draft. Ministry of Public Works and Water Resources, Planning Sector, Cairo, Egypt. Appx. 70 p.

Peralta, R. C. and Aly, A. H. 1993. Utah State model for optimizing management of stream/aquifer systems using the response matrix method (*US/REMAX*) user's manual, version 2.0. Software Engineering Div., Biological and Irrigation Engineering Dept., Utah State Univ., Logan, Utah, 84326 USA. 238 p.

Research Institute for Groundwater. 1992a-h. Groundwater resources and projection of groundwater development. Research Institute for Groundwater, Water Research Center, Ministry of Public Works and Water Resources, Water Security Project, Cairo, Egypt.

1992a Executive Summary, 8 p.;

1992b Main Report, 93 p.;

1992c Annex I, Groundwater Development, 37 p.;

1992d Annex II, Aquifer Boundaries, 55 p.;

1992e Annex III, Losses from Irrigation, 29 p.;

1992f Annex IV, Groundwater Development Strategies, 61 p.;

1992g Annex V, Groundwater Potential in Other Aquifers, 31 p.;

1992h Annex VI, Groundwater Quality, 36 p.

World Bank. 21 Sep 1992. Arab Republic of Egypt: an agricultural strategy for the 1990s. Report No. 11083-EGT, Agriculture Operations Division, Country Department II, Middle East and North Africa Region. 125 p.

ANNEX A. Scope of Work

The TDY Team was provided with three documents (or portions thereof) which related to the sow. The TDY objectives represent the sow as adjusted in Cairo. Extracts from these documents follow.

Document 1 (circa mid August FAX from USU Egypt Team Leader):

Terms of Reference (summary):

1. Assist Merkley in a technical evaluation of the PDM, including crop consumptive use calculations, crop yield response, soil water balance and salinity modeling in the crop root zone, and upflux from a shallow water table. It is expected that suggestions for improvements will come from this evaluation.
2. Meet with various Egyptian and ex-patriot personnel on data collection, data availability, and data quality for the PDM. This would include interviews with MPWWR officials, WRC engineers, and contractors on other IMS components (i.e. MSM, IIP, SM, MFS).

Document 2 (Aug 19 ? USBR FAX)

3. Preparing an analytical framework to guide implementation of the activity and the development of conclusions regarding application of PDM in Egypt. This framework will describe the process by which the model's potential will be explored (a) as a tool for day to day operational planning by field staff at the district or directorate level, (b) for use in system analysis, strategic research, and policy development, and (c) for annual and long-term planning at the central level. The framework will also guide the assessment of the model's value regarding the management of technical parameters of the irrigation system, including salinity and other water quality parameters, water distribution, drainage, information needs of users, conjunctive use, maintenance, and droughts.

Document 3 (Provided in Cairo by USAID, item 4 was omitted, it was part of Task 2)

1. Identify potential uses of the model in Egypt within such general areas as:
 - Undertaking studies useful to the development of policy, strategy, long-term plans, infrastructure, and operations for various levels within the MPWWR.
 - Undertaking shorter-term operational planning at various levels of the system, from small command areas to the Nile system.
 - Management of technical parameters of the irrigation system, including salinity and other water quality parameters, water distribution, drainage, information needs of users, conjunctive use, maintenance, and droughts.
2. Prepare an analytical framework to guide (a) the assignment of priority to potential uses of the model; (b) selection of one or two such areas for practical application; (c) design and implementation of the practical application(s), and (d) the evaluation of results of its application. This framework will address the model's value in overcoming priority constraints to Egypt's irrigation sub-sector development; capabilities of the model; issues related to the long-term introduction of model use; and the capability of organizations that would implement practical application of the model (e.g., the DSU and field directorates), and needs for their development.
3. Select one or two potential uses that would be most appropriate in view of the framework noted in (2) above, and describe corresponding practical application(s) of PDM.
4. Prepare a description of the institutional setting in which the model will be applied; e.g., current planning and operational procedures, organizational responsibility, and relevant priorities.
5. Update plans for the PDM verification/validation in the Bahr Mashtoul command area on the basis of findings from the work discussed above.
6. ~~Prepare detailed plans for~~ ^{Discuss how} ~~undertaking, evaluating, and reporting on the practical application.~~ ^{how to}
7. Delineate responsibilities for USBR, USU, the DSU, and other involved organizations/individuals for implementing the practical application(s). These responsibilities should include necessary training and oversight of staff in the DSU and other Egyptian organizations.

**ANNEX B. Chronological activities summary of USU/USBR Egypt TDY
24 August - 16 September 1993**

Date	Location	Activity Description
24 Aug	Cairo	RWH and RCP arrive Cairo late pm met by Gary Merkley (USU) and Leo Busch (USBR) - join Wynn Walker (who arrived Aug 22)
25 Aug	Cairo	Meet Joe Wensman (USBR/Denver), Russ Backus (USAID) and Aris Georgakakus (IPA from Georgia Tech). Meet with Dr. Bayoumi (PSM-MPWWR) at Ministry office in Imbaba also meet Mihail Andgelic (MFS,FAO). Wynn gave the TDY team an overview of the IMS project with focus on the PDM continuing into the pm
26 Aug	Cairo - Port Said	At Imbaba review Task III scope of work as well as other reports. Meet with Eng. Gamil and Dr. Bayoumi. Eng. Gamil stressed the importance of getting PDM to the end user, the value of the output to MPWWR and mentioned the USAID emphasis on sustainability, coordination and cost recovery. Travel to Port Said in the pm
27 Aug- 28 Aug	Port Said	Attend the PSM Project review workshop which included presentations on the various models and linkage with other components of the IMS project etc. USU team continues discussions of PDM.
29 Aug	Port Said - Cairo	Travel to Cairo. Observe intense small plot vegetable cultivation near Port Said - also reclamation lands to west of road. USU team continues discussions, plan out next few days itinerary.
30 Aug	Cairo	Wynn departs Cairo. Remaining USU team (TDY's RWH and RCP with Egypt team member Gary Merkley) begins review discussions of PDM user manual and calculation procedures. Begin assembling documents concerning: ET, drainage, groundwater, Egypt Water Plan.
31 Aug	Cairo	Meet at Imbaba with Leo and Joe. Review itinerary and some documents. Meet with Dr. Bayoumi discuss schedule

(planned field trips). Continue PDM review. review documents and PDM manual.

- 1 Sep Cairo Meet at USAID office with Russ Backus, David Smith and Mr. Shawky - USAID, Carroll Hackburt (IIP) and Leo and Joe -(USBR). Discuss PSM activities ie. ICM's and PDM use. Receive USAID suggestions for TDY scope of work. Begin identifying categories of potential PDM uses. With Leo and Joe develop an initial outline for the TDY report. Review documents and PDM manual.
- 2 Sep Shar- USU team meets Eng. Mohsen at Imbaba and travels to
kia Sharkia Directorate. Meet with Eng. Maher (general manager irrigation), discuss progress of new field drain installation and rice area limits and rotation schedules. Visit the Bahr Mestoul command area, look at supply canal inlet telemetric site and travel down the canal. Observe saquias (only 4 being used) and the many mechanical pumps in use. Stop at weather station - it is well situated but in need of some maintenance (no anemometer). The crops looked good - a lot of rice, some cotton and maize and a few vegetables. Return to Cairo.
- 3 Sep Cairo Rest. Go to Maadi area, then visit the Pyramids at Giza with Aris under Gary's guidesmanship. Review documents.
- 4 Sep Shar- Meet Eng. Mohsen at Imbaba then to Zagazig (Sharkia
kia Directorate offices). Talk with Eng. Abdel Hauq (Sharkia and Horizontal Expansion Director). Discuss extent of planned along new lands, crops and irrigation methods (sprinklers - no the center pivots! - and drip) and water duty as compared to old Ismai- lands. Meet with Eng. Abdel Fattah Ali (Sharkia Drainage
lya Director). Discuss design of new field drains (same as old).
canal Travel to east along a canal, observe drain (M&I effluent) being pumped into canal. Follow Ismailya canal towards horizontal expansion area (new lands). Observe drip irrigated citrus orchard and several center pivots - some were in use. Follow newer canal back to the west. Return to Cairo.
- 5 Sep Cairo USU team works on report draft writing. Also continue review of PDM in late pm. Review documents.
- 6 Sep Cairo With Leo at Imbaba. Team continues report writing and discussions. Assemble draft for USAID initial review- give to Russ Backus. RWH and RCP meet Terry Howell and

Arlin _____ from USDA (Texas). They are in Egypt to install 2 lysimeters and an electronic weather station (CSI-CR12) at Ismailya (OCID funding). Terry suggested that Joe Richie may have previous lysimeter data from Egypt. Continue PDM review in pm.

- 7 Sep Cairo USU team and Leo meet in am at USAID with Russ and receive and discuss his comments on the report draft. Continue writing and rewriting of the report draft, etc.
- 8 Sep Cairo Continue report rewriting (part III) and add Executive Summary and summary field observations and model review. With Gary and Leo in pm at Imbaba put together next draft for USAID's review. Begin writing chronological activities summary. Review documents.
- 9 Sep Cairo At Imbaba, make final adjustments in Executive summary in preparation for the exit meeting with Dr. Bayoumi and USAID while Gary demonstrates the PDM to IIP, USAID and Ministry personnel. Present summary observations and findings and discuss ground water concerns in exit meeting, attended by: Dr. Bayoumi, Eng. Mohsen, Clem Weber, Russ Backus, Leo Busch and the USU team. The team continues report editing, additions and modifications in the pm.
- 10 Sep Cairo Rest. Travel to the Maadi area. Visit petrified forest to east of Cairo. In pm RCP prepares for the ground water meetings and RWH prepares for travel to Upper Egypt.
- 11 Sep Cairo RCP meets with Dr Bayoumi concerning groundwater concerns and presents seminar. Review documents. RCP and Leo make closure arrangements. RWH travels to Luxor to Luxor meet Mr. Mamdouh Massoud of Assiut Univ. and continues Sohag to Sohag with him. RCP prepares for departure.
- 12 Sep Cairo RCP departs Cairo.
Sohag RWH in Upper Egypt. Reviews field studies etc.
- 13 Sep Sohag RWH returns to Cairo.
- 14 Sep Cairo Continue in-depth PDM review. Meet with Leo and MSM (Andy Tczap and Mike Leuck) to determine if/how weather sensors could be piggybacked onto the DCP for telemetry into MSM system, for deployment in Meshtoul.

- 15 Sep Cairo Continue with PDM review. Make report changes, review and print (Draft 4). Meet with Leo and Gary to sum up TDY and needed follow-up (weather sensors, possible return trip for RWH in early Jan. 94). Discussions about water measurement concerns (ie. how do gate openings get factored into the telemetry data ?). RWH prepares for departure.
- 16 Sep Cairo RWH departs Cairo.

ANNEX C. Required data for application of the PDM as described in:
**a) the document " Scheduling of Planning Distribution Model (PDM)
Planning Studies and Models (PSM) Project (circa May 1993); and**
**b) the memo "Cropping pattern and weather data requirements for the
PDM (Aug 3, 1993)**

**Scheduling of Planning Distribution Model (PDM)
Planning Studies and Models (PSM) Project**

Application of the PDM within the Sharkia Directorate

<u>Elements</u>	<u>Description/Responsibility</u>
<i>A. Expand GIS</i>	
	Tasks are to be accomplished by S&M and the PSM staff in consultation with USU and USBR, with priorities established. Given priorities of Districts will be established starting at the southern portion of the Sharkia Directorate adjunct Bahr Mashtool.
1. Topographic Maps	Obtain 3 copies of existing 1:25,000 maps from Egyptian Survey Authority of entire Sharkia Directorate
2. Orthophotos	Request proposed delivery priority of new 1:10,000 B&W orthophotos by S&M of Districts in the Sharkia Directorate as provided in Table 1, attached.
3. Topographic Maps	Request proposed delivery priority by S&M of new 1:50,000 maps as provided in Table 2, attached.
4. Develop Database	The Decision Support Unit (DSU) will expand the GIS as orthophotos are made available and field verified by the DSU and Sharkia personnel.
<i>B. Hydrologic Data</i>	
	Tasks will be accomplished using existing and future MSM telemetric database plus additional data acquisition as noted below.
1. Connect Networks	Provide access between PSM and MSM computer networks for exiting hydrological data acquisition.
2. Bahr Mashtoul	DSU/Sharkia Hydrography Team maintain stage-discharge relationships for existing stations.
3. Sharkia Directorate	DSU/Sharkia Hydrography Team provide stage discharge relationships according to priority given in Table 3, attached.

C. Climatological Data

1. Historical Database Acquisition will be accomplished by contracting with local consultant and DSU in consultation with USU, and the DSU will develop and maintain PDM data files.
2. Near Real-Time Database DSU will establish a linkage with area climatological stations for acquisition of daily climatological data and maintenance of the PDM database.
3. Actual Crop ET Data DSU will obtain available 10-day-interval crop evapotranspiration (ET) data for Egypt from existing MPWWR records.

D. Seasonal Crop Patterns

1. Field Survey Data DSU will obtain seasonal cropping information from the Sharkia Directorate and maintain the PDM database. Statistical sampling will be attempted with the assistance of the Agricultural Credit and Economics (ACE) Office of USAID.
2. Remote-Sensing Data DSU will obtain seasonal cropping information from the S&M project and maintain the PDM database.

E. Groundwater Database

- Acquisition of shallow groundwater (GW) levels, historical pumping, and near realtime database.
1. Historical GW Pumpage A local consultant will be contracted to provide acquisition of historical pumpage database for PDM.
 2. Current Pumpage DSU will provide linkage with the GW Research Institute and the Sharkia Directorate office in acquiring actual field tube well location and pumpage records.
 3. Shallow GW Monitoring DSU will provide linkage with the Drainage Research Institute (DRI) for historical levels and establish a program for near realtime data acquisition.

F. Soil Moisture Monitoring

DSU will attempt to monitor soil moisture levels under various crops within the Bahr Mashtoul Pilot

Area by possible acquisition of a soil moisture monitor.

G. Crop Production Value

The value of production will be determined through the efforts of the ACE Office of USAID, working with the Ministry of Agriculture and Survey and Mapping Component of IMS.

H. Operational Scenarios

USU will use the PDM to evaluate several scenarios of operation for the Bahr Mashtoul canal command area. Suggestions for analysis will be sought from the Planning Sector, the Sharkia Directorate, U.S. Bureau of Reclamation and USAID.

I. Other Parameters

Depending on the nature of the recommended operational scenario, other parameters may be monitored by DSU to assess the level of achievement of objectives. For example, if recommendations relate to improvements in water quality, electrical conductivity (EC), sodium adsorption ratio (SAR), boron, nitrate/nitrite (as N), and other possible chemical constituents may be monitored in irrigation water, groundwater, and surface drainage from the area.

J. Task 3 USU PDM Report

USU will prepare a report with results of the study, recommendations for data collection procedures to improve model reliability, recommended irrigation operation procedures, suggestions to the Ministry on how the model could be incorporated into the planning process, and a plan for further MPWWR studies and actions to enhance the promotion of the model among users in the Planning Sector and in the irrigation directorates.



MEMORANDUM

Date: August 3, 1993

To: Leo A. Busch, USBR COTR

From: Gary P. Merkley, USU Team Leader

Subj: Cropping pattern and weather data requirements for the PDM

To help focus field data collection activities, and to minimize confusion, I have prepared an updated list of PDM crop and weather data requirements. I understand that the MPWWR is in the process of collecting data from local sources and from the field, and some guidance and clarification of model requirements would be useful at this time.

I would like to suggest that those involved with data collection and analysis refer to the PDM and its User's Guide to familiarize themselves with its features, and data needs, formats, and units. I think it will be interesting and useful to enter data into files through the PDM interface as the values are obtained, incrementally building the system configuration and crop and weather data bases.

Crop Characteristics

Crop characteristics data includes crop coefficients, root depths and duration of each crop and each growth stage. The PDM has five growth stages for non-perennials: Establishment, Vegetative, Flowering, Yield Formation, and Ripening. Perennials, such as tree crops, are assumed to have a single "growth stage".

These are the required crop characteristics:

1. Crop names
2. Crop coefficients for each growth stage
3. Crop root depths for each growth stage (mm)
4. Duration of each growth stage (days)
5. Tolerance to salinity
6. Tolerance to water deficit
7. Affected by water-logging?
8. Perennial or seasonal?

The values for salinity and water deficit tolerance are described in the PDM User's Guide. Those crop values that are not immediately available may be taken from a source such as the FAO, then updated and refined when possible.

Another set of crop characteristic data is the actual crop ET_m (maximum consumptive use, in mm) for each crop type on 10-day intervals. These data should be cumulative for every 10-day interval, and the date of the first interval can be specified in the PDM.

Cropping Patterns

Cropping patterns involve information about crop types, planted areas, and planting dates - all with some sort of geographical reference. That is, we need to know what areas (feddans) are/were planted in which crops in each command areas. The command areas are defined as we wish, but we had discussed the idea of perhaps creating three separate layouts in the PDM for Sharkia: one with a few very large command areas, another with "medium-sized" command areas, and a third with smaller command areas. The smallest that we will want to go is something on the order of the area served by Bahr el Hagar in Bahr Meshtoul, but we can go smaller if we have the data, and if it seems useful or interesting.

Cropping pattern data also involves crop planting staggers. This means that we would like to have some idea about how the planting of each crop in each command area is distributed with time. Is it all planted at once, or are there "staggers" with some planted first, and the rest at a later date?

Here is a procedure that could be followed:

1. Define the command areas on maps.
2. Determine the net cropped areas of each in feddans.
3. Obtain lists of crop types, areas and planting dates for each command area.
4. Separate the planting dates for each crop type into up to three crop staggers.
5. Calculate area percentages of each stagger and crop type in each command.

Weather Data

Daily weather data files are used as independent databases, as are crop characteristic data files. Each file contains up to one year of daily weather data (366 values) for each of five climatological regions. Weather data are used by the model to determine reference crop evapotranspiration, ET_p, and to quantify the gross amount of precipitation in command areas.

These are the eight daily weather values:

1. Minimum Temperature (°C)
2. Maximum Temperature (°C)
3. Average Temperature (°C)
4. Relative Humidity (%)

5. Wind Speed (m/s)
6. Rainfall (mm)
7. Pan Evaporation (mm)
8. Sunshine (hrs/day)

The three temperature values refer to air temperature, the relative humidity is the average daily value, wind speed is measured at a height of 2 m from the ground, and sunshine hours per day are limited by the maximum total number of hours of daylight.

The pan evaporation values can be from any pan classification (e.g. Class "A" Pan) provided that the coefficients concur with the data values. Rainfall refers to precipitation in general, not only rain.

We would like to have at least 20 years of daily weather data for each site, because long-term averages and standard deviations are needed for the weather generation routines in the PDM. Each site would potentially be considered as a climatological region in the model.

The long-term data values can be taken from several years of daily data. These long-term items are averages and standard deviations of:

1. Daily ETp, by month (mm)
2. Daily Air Temperature, by month (°C)
3. Total Monthly Precipitation (mm)
4. Total Monthly Days with Precipitation
5. Daily Pan Evaporation, by month (mm)
6. Daily Relative Humidity, by month (%)
7. Daily Wind Speed, by month (m/s)
8. Sunshine Hours per Day, by month

As for daily values, the wind speed is assumed to be measured at a height of 2 m from the ground surface.

Note that both crop characteristic and weather data can be read by the PDM as text files, and these formats are given in the User's Guide. However, cropping patterns can only be entered and edited from the PDM interface because there are stored in the system configuration file.

ANNEX D. Newspaper article: Sharkia village lacking irrigation water

The Egyptian Gazette TUESDAY, APRIL 13, 1993

Ordeal of small village in Sharkia

Farmers in a small village in Sharkia governorate said that scores of their relatives were arrested when they asked governorate officials to help them save their crops.

The saga of these farmers in Bahgat village began in 1987, when they discovered that the only canal that supplied their land with irrigating water had gone dry. Realising that this would destroy the village's main crops, wheat and maize, the farmers decided to notify the officials concerned regarding the impending catastrophe.

• Security

Unfortunately they were arrested at the governorate building and accused of destabilising the city's security and peace.

"Since that time our relatives have been kept under arrest; we also stopped our agriculture activities because there is not enough water to irrigate the crops," a farmer told the local weekly magazine, *Hurriyat*, last week.

"Ever year we have this problem; the larger part of the village's crops are destroyed and we lose our livelihood."

Underlining the deteriorating situation, the farmer said that their lands had not been irrigated for over 40 years. "We leave our homes to spend hours sitting by the canal waiting for the water to flow through it."

The farmers' resentment was exacerbated when they discovered that the wealthy villagers always manage to bribe guards to get water to their land. "There wealthy people pay magnanimously to the guard who controls the sluice gate that increases the water flow in the canal," said Haj Sherbini Mohammed.

"We are limited-income farmers and cannot afford the purchase of pesticides, although they are urgently required for the crops".

• Cold response

An elder colleague, Haj. Salah el-Azazi, who was standing nearby, added that they were regularly forced to

collect a considerable sum of money from among themselves before they could persuade this guard to allow water into the canal. "Although we complained many times to this guard's senior officials, we received a cold response. It appears as if they share the money received."

The tragedy is shared by many other village residents, especially those who earn their living through cooperating with the landowning farmers.

According to Haj. el-Azazi, these hired farmers had left the village to seek jobs in neighbouring villages.

■■■■
The village's dilemma worsened when mountains of rubbish and garbage began getting dumped into several parts of the canal. "Some villagers began throwing garbage in the canal and turned it into an abode of insects and flies," Haj. el-Azazi said. Accordingly the residents there complained of several illnesses including allergies.

• Writhing

The magazine's correspondent said that a casual visitor would be attracted to the sight of a farmer or a small child writhing while scratching his body hard. "Most of the people here draw blood to their bodies by their scratching; we do not receive the required health service; and if we complain, the officials accuse us of destabilising the city's peace," said Haj. el-Azazi, who appeared to be the village spokesman.

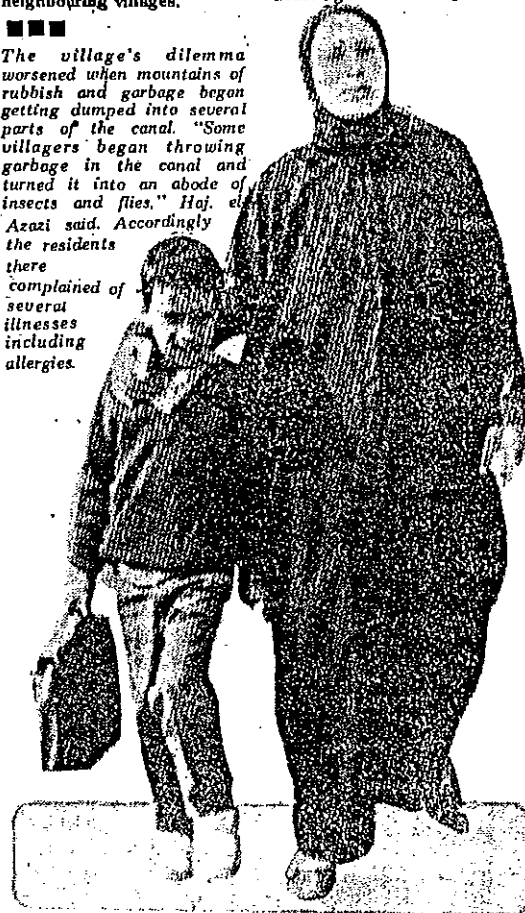
An ambitious sanitary drainage

recommended to save the villagers from the filth there, was shelved until further notice. "We learnt that the governorate officials were seeking funds from Cairo to finance the project; furthermore, these officials hinted at the possibility of helping us if we collected part of the money; but we are destitute," the spokesman said.

Regrettably, the residents whose health condition worsen have to travel either to Cairo or to Alexandria since there is no a health clinic in this village. "We are burdened by the costs of travel and the skyrocketing fees charged by Cairo's doctors; every time we appeal to the officials to set up a health clinic in the village they promise that the project will be implemented next year. For several years now we have been waiting for this "next year" which apparently will never come".

■■■■
The village's children are scarcely more fortunate. About 1,500 children are forced to cover a six-kilometre distance before they arrive at their schools in the neighbouring villages. "This terrible journey is made every morning by these small children, who have to shoulder all their books and food; and worse, some of these children sometimes have had accidents during this laborious journey," said Haj. el-Azazi.

Bahgat village, appeared to fall victim to election manoeuvres: during the country's election for P.A's membership, the residents received voluble promises from election rivals; they were promised a new school, a health clinic and a good sewerage system. But unfortunately these all were elections promises to gain support of these innocent village people. As soon as the winners were announced these politicians gulped down their promises. Furthermore, due to the fact that the People's Assembly is located in Cairo, these villagers no longer get to see their respected parliament members to remind them of their promises.



A woman had to accompany her child in his laborious journey to school.

ANNEX E. Groundwater considerations for achieving optimal sustainable groundwater and conjunctive water management

A. Background

- In some reaches of the Nile River and its branches flow is from the aquifer to the rivers. In other reaches, flow is from the surface water resources to the aquifer. The direction of the interflow can differ depending on location, and can change with time.
- Releases from the High Aswan Dam probably constitute the major source of groundwater (as well as surface water) in the Nile Valley and Delta. Even though groundwater flows to the Nile River in some areas, most of that water was probably initially in the river. Groundwater flows which might enter the Nile System Aquifer from other adjacent aquifers are as yet unquantified, but are probably comparatively small.
- Increasing water demands should probably be partially satisfied using groundwater. Planning for a sustained drought should utilize groundwater, to the extent possible.
- The spatial and temporal distribution of groundwater pumping should be managed somewhat carefully. Just because a total aquifer sustained groundwater yield has been identified, does not mean that quantity can be extracted from any location. Clearly, attempting to extract all the water from a single small portion of the aquifer would probably cause unacceptable drawdown. Similarly, not all spatially distributed pumping rates are desirable, even if their sum equals the total aquifer sustained groundwater yield. (A set of such pumping rates is termed a pumping strategy.)
- A sustainable pumping strategy that does not cause unacceptable consequences can be termed a 'safe sustained yield strategy'. There are an infinite number of such strategies for an aquifer system. These strategies can range in magnitude of total pumping--from very little pumping to some potentially high rate. The question is: which strategy is best?
- Steady-state simulation models are frequently used to develop acceptable sustained yield pumping strategies. Such models are used iteratively until the modeler feels that he has tested the best pumping strategy for his management goals and constraints. Constraints might be conditions that must be satisfied to assure strategy acceptability. They can refer to the range of acceptable system responses to the pumping strategy. For example, the water table elevation at a node near the coast might need to be at least 2 m above mean sea level to prevent unacceptable salt water intrusion. In that case, the modeler will evaluate the system response to each assumed pumping strategy to assure that the head is at least 2 m in that location.
- There are difficulties with using a simulation model to develop acceptable pumping strategies.

- The trial and error approach required with using a simulation model can be very tedious.
 - There is no guarantee that a strategy developed using this approach is actually the best one for the particular management problem and system--only that it is the best among those tested.
 - It becomes more difficult to attempt to develop optimal water management strategies as management goals and constraints become more complex--for example for goals of maximizing economic return or dynamic conjunctive use.
- Use of a simulation/optimization (S/O) model will directly yield the best solution for the management goals and constraints posed for a study area. This results because the S/O model includes both simulation capability and operations research optimization algorithms. *US/REMAX* is the recommended S/O model because of its capabilities, documentation, and ease of use. It can also readily perform multi-objective optimization.
 - *US/REMAX* (Utah State REsponse MAtrIX model) can develop optimal steady or transient groundwater or conjunctive use strategies for multilayer stream-aquifer systems. A very important feature in some areas is *US/REMAX*'s ability to dynamically model and optimize the effect of groundwater pumping on river stage and the effect of river water diversions on aquifer head. This is beyond the capability of most groundwater simulation models. The advanced version used in the Dept. of Biological and Irrigation Engineering of Utah State University also can use quadratic or nonlinear objective functions (such as those which are useful for economic optimization), and nonlinear constraints (including those useful for groundwater contamination management).
 - One cannot optimize management of a system unless one can acceptably simulate system response to management stimuli. Thus, one must always first calibrate/validate a simulation model to an area before one can apply an S/O model. The spatial and temporal discretizations in both simulation and S/O models should be the same.
 - *US/REMAX* is designed in a modular fashion. It currently accepts physical system parameter data in the format required by MODFLOW and STR. This assumes a rectangular grid which differs from the triangular mesh used in the Egyptian simulation reports that were reviewed. With an acceptable amount of effort, *US/REMAX* can be modified to accept data in a format required by some other simulation model.
 - MODFLOW is the most widely used groundwater flow simulation model in the US. STR is a stream routing package that can be used with MODFLOW. STR adds the ability to simulate the effect of groundwater pumping on river stage, and the effect of river water diversions on groundwater levels. *US/REMAX* uses these codes to develop influence coefficients. It uses those influence coefficients in its process of computes the optimal groundwater or conjunctive use strategies.
 - The decision as to whether *US/REMAX* should be modified to accept data from another model, or whether MODFLOW/STR (within *US/REMAX*) should be calibrated for the study area depends on several factors. These include: the capabilities of the other

model, confidence in the previous calibration, and management goals. *US/REMAX* will If the simulation features of MODFLOW/STR and other *US/REMAX* features beyond those of the alternative model are important, than probably a re-calibration using MODFLOW's rectangular grid is desirable. For example, will managers want to explicitly control groundwater contaminant transport within future optimal conjunctive use strategies (rather than simply controlling transport by controlling gradients)? If so, *US/REMAX's* ability to handle nonlinear constraints is desirable. (Use of this feature will require calibration of a solute transport simulation model.)

- The Groundwater Research Institute has calibrated finite element flow simulation models for at least two areas within the Nile system (Probably because of data unavailability, only steady-state calibrations were cited in the reviewed reports. More boldness is needed to apply such models to transient situations than normal--because specific yield is not calibrated.) Triangular elements were used. A two layer aquifer system was assumed for a study area in a portion of the Nile River Valley. The Eastern Nile Delta was possibly calibrated using a two-layer model also.

- The Groundwater Research Institute has performed steady-state and transient simulations for several areas. These might provide information which can be used as upper bounds on groundwater use within CSU's conjunctive use model or the *PDM*. In that process, it is appropriate to simultaneously consider the assumptions concerning time scale, physical processes, etc. used within the groundwater and other model.

B. Recommended minimum future actions

- Spatially distributed safe sustained yield pumping strategies should be obtained or developed for areas to which the conjunctive use model or the *PDM* are applied, if groundwater use is to be so significant that groundwater problems might result. The spatial distribution of sustainable pumping rates should be used as upper limits of acceptable groundwater use in those models which do not explicitly model groundwater flow.

- Acceptable safe sustained yield pumping strategies might have already been developed for the eastern delta or other areas where the conjunctive use model or the *PDM* will be applied. Modelling assumptions made while developing these strategies should be reviewed. (How many aquifer layers were simulated when the eastern delta was addressed? To what extent were surface water levels responsive to groundwater pumping, or were they assumed unaffected? Were volume balances simulated within the supply and drain canals? How significant are differences in time scales assumed for simulation in the groundwater models versus other models? Was the possibility of significant subsidence of the ground surface, after dewatering due to pumping, considered?)

C. Potential future applications of S/O modelling

- Optimal safe sustained yield pumping and conjunctive use strategies can be computed using an S/O model such as *US/REMAX*. Depending on user preference, these strategies can be volumetrically, hydrologically or economically optimal. They can include linear or nonlinear objectives and constraints and can address contaminant transport concerns explicitly, or implicitly through hydraulic gradient constraints. *US/REMAX* is easy to use, robust, powerful and well documented.
- A hybrid S/O model can be developed to aid the process of estimating parameters needed within the *PDM*. This would probably enhance the 'reasonableness' with which the *PDM* predicted system responses to allocations. This model would use optimization to help apply the *PDM* to a particular study area. This can greatly speed the process of validating the field data needed within the *PDM*. (Return flow coefficients are one example.) A 'hybrid' model would probably be used because it could express system response to stimuli using a combination of superposition (response matrix), regression or embedding approaches. In other words, it might combine features of *US/REMAX* and *US/EMBED*. (*US/EMBED* is a S/O model that explicitly includes all groundwater flow equations while developing steady or transient safe sustained yield pumping strategies.)
- An S/O model can be used to aid parameter estimation for calibrating groundwater simulation models. This would be used for areas for which sustained yield groundwater pumping strategies would need to be computed.

RC 175

New Policy: Excess-Page Fee for AGU Journals

To encourage concisely written articles for AGU journals and to thereby enhance scientific communication, AGU has established an excess-page fee for *JGR*, *Water Resources Research*, and *Radio Science*.

- For *Water Resources Research* there will continue to be no page charges for the first 8 journal pages for each regular manuscript or technical note. Page charges for pages 9 and 10 are \$150 each. Charges for page 11 and thereafter are \$250 per page (\$150 basic page charge + \$100 excess-page fee).
- For review articles page charges after page 8 will be \$150 per page.
- The new page charge policy is in effect for all papers received at the editor's office after March 28, 1992.



The following example shows how total charges are computed:

Length of published paper	13 journal pages	
Number of pages typeset free of charge	- 8	
Number of pages subject to charges	<u>5 journal pages</u>	(See below for applicable charges)

14
- 8
6

Charges for pages 9 and 10	2 × \$150 = \$ 300
Charges for pages 11, 12, and 13	3 × \$250* = \$ 750
Total charges	= \$1050

2x150 = 300
3x250 = 750
total = 1050

(*\$150 basic page charge + \$100 excess-page fee = \$250)

See guidelines for estimating the length of your paper and tips on writing concisely.

For more information on the excess-page fee policy,
call AGU Author Information at 202-939-3200.

ESTIMATION GUIDELINES

Use the following simple formula IF the combined total of double-spaced manuscript pages, the number of figures, and the number of table pages equals 40 or less AND IF there are no more than 6 figures in the manuscript. For longer papers or papers with more than 6 figures, we recommend the more detailed estimation method. This formula is based on a **double-spaced manuscript with one-inch margins (top, bottom, left, and right) prepared in *12-point type:**

$$\begin{array}{r}
 \text{Number of manuscript pages} \quad \underline{\hspace{2cm}} \\
 + \quad \text{Number of figures} \quad \underline{\hspace{2cm}} \\
 + \quad \text{Number of table pages} \quad \underline{\hspace{2cm}} \\
 \hline
 \underline{\hspace{2cm}} \text{ Total} \div 4.5 + 2 = \underline{\hspace{2cm}} \text{ journal pages}
 \end{array}$$

NOTE: Use "4" instead of "4.5" as the conversion factor if the manuscript is in 11-point type, and "3.5" if the manuscript is in 10-point type.

DETAILED METHOD: Follow the guidelines for each of the seven elements below and enter the equivalent number of journal lines in the corresponding slot on the facing page:

1. **Title, authors' names, affiliations, copyright line, acknowledgments, addresses, and dates (manuscript received and accepted).** Allow 50 journal lines for these elements if there are no more than three **different affiliations**. Add 10 journal lines for every **different affiliation** beyond the third.
2. **Displayed Headings.** Allow 3 journal lines for each heading up to 40 characters long and 4 journal lines each for longer ones.
3. **Displayed Equations.** Allow 3 journal lines for every **simple** displayed equation that will fit on one journal line (<40 characters including the equation number). Allow 5 journal lines for every line in a complex built-up equation. See following examples:

Complex Displayed Equations

$$\frac{T_1}{2} = 2 \int_{0_1}^{\infty} dv_x - \frac{mv_x^2}{2 f_x(v_x)}$$

$$T_1 = T_0 \left[+ \frac{2r^3}{(1+r^2)^2} \right]$$

Simple Displayed Equations

$$v = v_1$$

$$B(r) = B_0 \exp(-r^2/l^2)$$

4. **Figures and Figure Captions.** Estimate the portion of a journal page each figure and its caption will occupy and select the most appropriate entry from below:

<u>Estimated final journal size</u> for a figure	<u>Equivalent number of</u> journal lines
1/4	30
1/2	60
3/4	90
1	120

5. **References.** Allow 3 journal lines per reference.
6. **Tables.** For a single-column table* count all lines in the title, column heads, body, footnotes, and rules or horizontal lines (2 journal lines for each rule). Add 4 journal lines per single-column table for layout requirements. For a double-column table* use the same method but **multiply the sum by 2** and add 8 lines for layout requirements.
- * To decide whether a table will fit within one journal column, count the characters (including letters, numerals, and spaces both between words and between columns) in the longest line in the table. It will be a single-column table if the count is no more than 50 and a double-column table if over.
7. **Text (including Abstract).** First find the average number of characters per line for your manuscript by counting a few full lines of text including letters, numbers, punctuation, and spaces. Then substitute the appropriate numbers for your manuscript into the following formula for the equivalent in journal lines. (*Do not recount any elements already counted above.*)

$$\frac{\text{Average number of characters per manuscript line}}{58^*} \times \text{Number of manuscript lines}$$

*Average number of characters per journal line

Fill in the equivalent number of journal lines for each of the seven elements as estimated with the guidelines given in the preceding section:

Elements	Number of Journal Lines
1. Title, Authors' Names, etc.	<u>50</u>
2. Displayed Headings	<u>129</u>
3. Displayed Equations	<u>86</u>
4. Figures and Figure Captions	<u>510</u>
5. References	<u>56</u>
6. Tables	<u>106</u>
7. Text	<u>823</u>
Total	<u>1760</u> ÷ 126 = <u>13.9</u> journal pages

*basically
14 pages*

 See reverse for tips on writing concisely.

Suggestions for Preparing Concise Papers

1. Eliminate unnecessary duplication of information. For example, details in figure captions should not be repeated word for word in text. Avoid wordiness, tautologies, and the passive voice. See *Strunk and White* (1979) and *Day* (1988, pp. 186-189) for useful hints.
2. Consider whether information can be presented more effectively and economically as text or as figures or tables (see *Day*, 1988, chapters 13 and 14).
3. Avoid excessive citation; give examples rather than an exhaustive list, or refer to a review paper for additional references.
4. Consider using AGU's microform option for extensive tabular material, lengthy mathematical derivations, and supporting data (including line figures but not photographs) that are likely to be of interest to only a small segment of the potential readership. Such material is incorporated in the microform editions of the journals and is part of the archived literature.
5. Draft figures economically (see *Day*, 1988, chapter 14; *AIP*, 1990, pp. 26-30). If possible, combine related figures. Ensure that lettering, symbols, and shading will withstand appropriate reduction (relatively simple figures should fit in a single column). Delete "titles" in large lettering (frequently used in viewgraph versions of the figure). Determine whether explanatory material is best presented as a legend within the figure or as part of the caption.

American Institute of Physics, *AIP Style Manual*, 4th edition, New York, 1990.

Day, R. A., *How to Write and Publish a Scientific Paper*, 3rd edition, Oryx, Phoenix, Ariz., 1988.

Strunk, W., Jr., and E. B. White, *The Elements of Style*, 3rd edition, Macmillan, New York, 1979.