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STRATEGIES FOR IRRIGATION DEVELOPMENT

IN EGYPT

by

Ministry of Irrigation
Government of Egypt

and

United States Agency
for
International Development

Water Management Synthesis II Project
Agricultural and Irrigation Engineering
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PREFACE

This study was conducted as part of the Water Management Synthesis II Project, a program funded and assisted by the United States Agency for International Development through the Consortium for International Development. Utah State University, Colorado State University and Cornell University serve as co-lead universities for the Project.

The key objective is to provide services in irrigated regions of the world for improving water management practices in the design and operation of existing and future irrigation projects and give guidance for USAID for selecting and implementing development options and investment strategies.

For more information about the Project and any of its services, contact the Water Management Synthesis II Project.

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FOREWORD

This report was prepared by a joint Egyptian and U.S. Team consisting of:

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GENERAL INFORMATION

Weights and Measures

1 feddan (fed)	=	0.42 ha = 1.04 acres
1 hectare (ha)	=	2.38 feddan (fed)
1 cubic meter (m^3)	=	35.21 cubic feet (cu ft)

Definitions

Marwa: Farm ditch.

Mesqa: Farm header ditch connecting MOI distributary and farmers' head ditches, serving 25 to 300 feddans.

Saqia: Water wheel worked by animal power and used to lift water from mesqas to fields.

Tambour: Manually-operated Archimedes screw-type pump.

Old Lands: Traditional agricultural lands in the Nile Valley and Delta.

Old New Lands: New lands development for irrigation in Nile Valley up to the present.

New Lands: Land identified for future irrigation development.

Abbreviations

ADB African Development Bank

AID U.S. Agency for International Development

ARC Agricultural Research Centre, Ministry of Agriculture

CID Consortium for International Development

EMCIP Egyptian Major Cereals Improvement Project

EPADP Egyptian Public Authority for Drainage Projects

ERRAT Egyptian Rice Research and Training Project

ET	Evapotranspiration
EWUP	Egyptian Water Use and Management Project
FC	Foreign Currency Cost
GARPAD	General Authority for Rehabilitation Projects and Agricultural Development MLR
GDP	Gross Domestic Product
GOE	Government of Egypt, Arab Republic
GRI	Groundwater Research Institute, Ministry of Irrigation
HAD	High Aswan Dam
IAS	Irrigation Advisory Service
IBRD	International Bank for Reconstruction and Development
IDA	International Development Association
IRR	Internal Rate of Return
LC	Local Currency Cost
LE	Egyptian Pounds
MLR	Ministry of Development and State Ministry for Housing and Reclamation
MOA	Ministry of Agriculture
MOI	Ministry of Irrigation
NARP	National Agricultural Research Project
NIIP	National Irrigation Improvement Program
O&M	Operation and Maintenance
OR	Operations Research
PPD	Project Preparation Department, Planning Sector, MOI
R&E	Research and Extension
RIIP	Regional Irrigation Improvement Project
SR	Structure Replacement
UNDP	United National Development Program

USAID	U.S. Agency for International Development Mission for Egypt
USDA	United States Department of Agriculture
WB	World Bank
WMP	Master Plan for Water Resources Development and Use
WPG	Water Plan Group, MOI
WRC	Water Research Center

Fiscal Year and Five-Year Plan Periods

GOE Fiscal Year:	July 1 to June 30
Current Five-Year Plan Period:	1982/83-1986/87
Next Five-Year Plan Period:	1987/88-1991/92

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CHAPTER I

EXECUTIVE SUMMARY

The Setting

The Land Base

Historically, Egypt's rich agricultural land resource, with the exception of a few scattered oases in the desert, has consisted of the 1200 km strip in the Nile River Valley between Aswan and Cairo and the Nile Delta between Cairo and the Mediterranean. About 60 percent of these lands, which total six million feddans, lie in the Delta. Historically, these limited lands have produced exportable surpluses, but in recent years increasing population has outrun production so that currently Egypt must import about 50 percent of its food requirements.

Egypt's response to its food gap problem has been two-fold: increasing productivity on the historical Nile Valley and Delta lands -- termed vertical development; and expanding its agricultural land base by bringing irrigation to, or reclaiming, alluvial areas at the Delta and Valley margins and to desert lands outside of the Valley and Delta -- called horizontal development. The historical Nile lands are called "old" lands; the others are "new" lands. Those being planned are simply called "new" lands. New lands already developed are "old-new" lands. Old new lands and new lands are generally of substantially inferior quality compared to old lands. The land base problem is aggravated by the recent acceleration of old land removed from agricultural production primarily by urbanization and industrialization.

Water Supply and Irrigation

Egypt's agricultural resources are no less bounded by water supply than they are by good lands. More than 95 percent of this supply comes from the Nile. Agriculture is essentially dependent upon irrigation, and consumes the bulk of the available water supplies. Egypt has no effective rainfall except in a narrow band along the northern coastal areas where an insignificant rainfed agriculture is practiced. The groundwater reservoirs underlying the Nile Valley and the Delta are also entirely dependent on deep percolation of irrigation water diverted from the Nile. They do not constitute an additional source of supply. Some limited renewable land and non-renewable groundwater resources occur in the Nubian sandstones of the West Desert and in Sinai.

The extent of new land development is limited, therefore, by water made available through more efficient use of the Nile supply. Creation of Lake Nasser by construction of High Aswan Dam (HAD) has made possible conservation of water formerly lost by floods. Attention has accordingly turned to increased efficiency of use, primarily for irrigation, but also for industrial, municipal, navigation and hydropower. There are also large evapotranspiration (ET) losses by swamps located in the upper reaches of the White Nile. Channelization of the river flow through these reaches could add substantially to supplies. One such project, Jonglei I in Southern Sudan, has been started, but has been suspended because of current security difficulties.

Egypt's basic entitlement at Aswan is 55.5 billion m^3/yr. Jonglei I could raise this to about 57.5 billion m^3/yr and eventually the White Nile conservation projects could increase this share to about 65[1] billion m^3/yr, but most probably not in this century. Considering other uses and adding the Jonglei I supply, an estimated 52 billion m^3/yr would be available for irrigation, and nonconsumable uses such as hydropower generation and navigation. This results in 40 billion m^3/yr for consumption in agriculture, the remainder would be released to the sea and northern lakes in the form of direct spills or drainage water, maintaining reasonable salt balance in the soil. Current consumptive use estimates are in the range of 30 billion m^3/yr, leaving some ten billion m^3/yr to take care of increased cropping intensity (from 185 percent to 200 percent) on old lands and to irrigate new lands (41). Estimates by the Water Master Plan are that this would provide water for 1.7 million feddans of new land development, but this figure is very sensitive to assumptions about present and future values of water use efficiency and consumptive use rates per feddan.

Ministerial Responsibility

Provision of irrigation and drainage infrastructure and operation and maintenance of the irrigation system to the point of delivery to mesqas is the responsibility of the Ministry of Irrigation (MOI). Agricultural support services, inputs, extension and research at farm level are assigned to the Ministry of Agriculture (MOA). The water users are responsible for the distribution of water from mesqas to fields and for mesqa operation and maintenance, but no Government agency has a clear mandate to provide technical assistance and support for carrying out this function. Across-the-board development of new lands is assigned to the Ministry of Development and Land Reclamation (commonly shortened to Ministry of Land Reclamation [MLR]) except that the required physical irrigation infrastructure is constructed, operated and maintained by MOI.

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[1]74 billion m^3 when the conventional method of computation in Egypt is used. That method accounts for water reuse, groundwater pumpage within the Nile basin, improved management of water, and reduced losses. However, the end computation on the total area that can be irrigated remains the same.

Budgeting Investments and Recurring Costs

Planning Horizon

The planning horizon for this study extends roughly over the next fifteen years, with a focus on the shorter term six year horizon. This study is concerned primarily with programs falling under the purview of the Ministry of Irrigation, but references are made to the complementary and supporting programs of other Ministries, particularly Agriculture and Land Reclamation.

Investments

Separate appropriations are made for salaries (Chapter I), recurring costs (Chapter II), and investment funds (Chapter III). Only investment funds are included in the Five-Year Plans; however, many strategy considerations will involve activities paid for by recurring costs. The following table provides the actual MOI expenditures from 1975 through 1985 and estimated expenditures for 1986-87:

Year	Chapter I funds L.E.	Chapter II funds L.E.	Chapter III funds L.E.	Total L.E.
75/76	16,288,087	14,615,637	38,000,000	68,903,724
76/77	19,346,550	15,188,340	46,500,000	81,034,890
77/78	23,543,947	19,038,689	90,053,500	132,636,136
78/79	27,219,144	26,043,261	175,160,000	228,422,405
79/80	29,436,448	30,880,057	239,649,000	299,965,505
80/81	31,323,927	32,031,469	260,605,000	323,960,396
81/82	42,747,144	35,587,391	234,524,500	312,859,035
82/83	53,527,971	44,480,871	221,883,000	319,891,842
83/84	57,944,749	52,439,495	182,573,000	292,957,244
84/85	69,289,025	58,507,497	252,300,000	380,096,522
85/86	73,776,604	62,679,111	290,700,000	427,155,715
86/87	85,325,971	86,343,951	329,049,000	500,718,922

The current plan Chapter III budget of LE 1.28 billion, represents an increase of 28 percent over the previous five years. The current budget request for the next plan period is LE 2.38 billion or an 86 percent increase over the current plan. Even though the GOE has placed more emphasis on increasing investments in irrigation, this level will most likely not be obtained unless there is significant donor assistance.

Policy

Policy issues are both external and internal to the irrigation sector. An overriding set of external policy issues affecting irrigation farmer incentives include such things as price fixing, crop quotas and subsidies. These limit the potential for increasing agricultural production using improved technology and management.

Socioeconomic/Technological Issues—Current Status

Loss of Agricultural Land

Losses of Agricultural land to urbanization and other uses is currently estimated at 25,000 to 50,000 feddans/yr. New lands development is, at least in part, an attempt to replace these lands. Most, but not all, of the water formerly used on these lands has been committed to irrigate old new lands and new lands.

Soil and Crop Management

Crop production is constrained by farming practices relating to soil management and fertilizer. Some minor element (zinc) deficiencies, particularly for rice, are apparent. The root zone is restricted by high water tables and salinity is often present. Lack of timely availability and quality control of fertilizer may cause some problems. Mechanization will be required for substantial increases in cropping intensity. Most new land soils, generally because they are coarser, are harder to manage and wind may affect efficiency of sprinkler irrigation on such new lands.

On-Farm Water Management

Inadequate land preparation in the form of rough seed beds is a major constraint to efficient irrigation, and results from the lack of proper equipment. Water control operations at the farm level result in the coverage being too long or too short. Size of stream may not be optimal; generally, use of larger streams would give better coverage to fields. Lack of scheduling and other operational problems in mesqas, including lack of maintenance, result in over-supply to farmers at head end and reduced supply to those at the tail. Usually, water is delivered to mesqas below field level and must be lifted to the field. Animal and human endurance limits inhibit night irrigation, which means that 40 to 50 percent of the supply is released to drains. Water released to drains is not necessarily lost to the system as much of it is diverted or pumped for reuse. Recently, small gasoline and diesel powered pumps have begun to replace animal and human powered saqias.

On-farm water management (OFWM), which strives to integrate all water delivery, field irrigation, land development, cropping systems and cultural practices at farm and mesqa level to optimize irrigated crop production is a relatively new concept. Field studies of OFWM began under the USAID-supported Egyptian Water Use and Management Project (EWUP) in 1977. This project laid the groundwork for comprehensive implementation of improved on-farm water management. Under its National Irrigation Improvement Program (NIIP), Egypt is currently extending improved irrigation concepts to eleven large pilot areas totaling 850,000 feddans in all governates. Technical assistance to this program is being provided by the UNDP and the USAID Regional Irrigation Improvement Programs (RIIP).

Canals and Distributaries

Eight large Nile River barrages divert 80 percent of the water supplied to Egypt's 31,200 km network of canals with the remainder diverted by pumps. Though farm irrigation efficiencies are quite good, canal system efficiencies are low — 30 to 40 percent -- largely because of lack of adequate control structures. Distribution is by rotation on main canals to mesqas.

Commissioning of Lake Nasser changed the function of the canal system in Upper Egypt from spreading flood water to supplying irrigation water as needed by crops. It also changed channel maintenance requirements from principally silt removal to control of aquatic weeds. This shift is being made, but requires different machinery and techniques. Most of the thousands of canal structures such as gates and bridges and pumping stations are old and in need of repair or replacement. Replacement of canal structures is proceeding under a USAID sponsored program, and USAID and IBRD projects supporting pump replacements are now in their final stages. Some barrages have essentially served out their economic structures. These include Damietta, Esna, Nag Hammadi and Assiut. Replacement will improve navigation and produce large amounts of hydropower, as well as benefit irrigation.

Drainage and Salinity

Besides its canals, Egypt has in place 16,333 km of main system open drains which receive surplus water from canals and fields, and from tile drains. For many drains, surplus water must be returned to the Nile or lifted into canals for reuse by pumping. The maintenance problems for drains are similar to those for canals. Lowering of water table has been found to increase crop yield potential significantly. Of the country's 6 million feddans of irrigated land, an estimated 5.2 million would benefit from tile drainage and as of 1985 this had been provided for 2.8 million feddans. The program has been supported by IBRD financing and is now proceeding at the rate of about 200,000 feddans/yr with combined IBRD and ADB financial support under the Drainage V Project.

Farmer Involvement

Financial returns for conserving water per se are very low, or zero. In contrast, water is an effective substitute for labor and management. Returns to improved on-farm water management apparently are low also, partly because of restricted crop options and low prices, but farm budget information is lacking on this point. With these constraints, farmers apparently have elected to optimize their economies by investments in labor-saving technology such as gasoline powered pumps, etc., rather than go in for higher yields. Significant increases in yields, however, have been achieved on demonstration areas using packages of improved water management, fertilizer and other inputs and practices. Where these have been concurrent with increases in commodity prices, yield increases are even more dramatic. Egypt's human farmer resources and the resources it commands, given these two incentives, could possibly achieve a four percent annual growth in agriculture.

Inputs, Research and Technology Transfer

Egypt has in place a Soil and Water Research Institute and associated crop commodity institutes under MOA's Agricultural Research Center (ARC). An Institute for Irrigation Methods and Water Distribution is in place under MOI's Water Research Center (WRC). Fourteen universities have faculties of agriculture and these are all well staffed with a high proportion of Ph.Ds. Installed capacity for research is adequate, but problems of compartmentalization and management inhibit efficiency. The same is true of agricultural extension; however, preoccupation with policy management means that true agricultural extension is only rudimentary.

Farm Economics

Positive net returns to water are consistently reported; however, farm incomes remain low, in part because of low level of net returns; they are consistently lower for controlled crops and areas planted under controls set by Government. Demonstrations show, however, that increases in yield of 30 to 60 percent are possible without substantial increases in capital investment. In one project, nearly 100,000 feddans in ten governates participated in demonstrating these program packages during 1984. These farmers and their neighbors are reported to be continuing use of the improved practices. There are further opportunities to increase yields even more, but this next round will cost more. Full productivity of Egypt's lands will require adjusting field sizes to accommodate mechanization and an enlarged extension program with irrigation specialists. Productivity on new lands is less than for old lands because of lower soil quality, but the production potential of these lands has not been achieved. Improved management appears to be the key factor in improving productivity on new lands.

Overall System Management

Efficient operation of a main system, which includes the canals, the Nile, Lake Nasser and the watershed above Lake Nasser, requires timely and accurate translation of crop water requirements to flow distribution in canals, pumping, operation of barrages, operation of the High Aswan Dam (HAD), and improved estimates of water production upstream. Use of improved data collection, communications and modeling technology can continue to refine overall system management with consequent savings of water now lost through operations. A new telemetry system for transmitting real-time canal water level data using meteor burst technology is being installed currently. An "operational distribution model" which could articulate the operation of barrage gates more accurately is in place, but needs further development. Rules for optimizing releases from HAD have been developed by joint use of two models, a stochastic simulation model and a linear program model.

Private Sector Involvement

GOE has provided considerable inducements to encourage private capital to develop new lands. Besides physical infrastructure, credit has been made available at low interest rates with grace periods on repayment schedules and various subsidies. More encouragement could be provided by decontrolling produce prices and area quotas and providing an information transfer system.

Both private and public companies are involved in construction, replacement and maintenance of irrigation infrastructure. Thus, a large share of GOE irrigation investment is spent in the private sector.

Policy and Institutional Considerations

Significant factors which will affect future water policy in irrigation include: (1) rapid population increase; (2) accelerated migration to urban areas; (3) the need to consolidate fields for mechanized agricultural operations; (4) transfer of surpluses from the agricultural sector; (5) the high cost of reclaiming new lands; (6) changing water quality; (7) eventual scarcity of water supplies; (8) inter-Ministry coordination; (9) in-service training and training of farmers; (10) cost of O&M; and (11) the need for interdisciplinary approaches to problem solving and management.

Medium and Long-Term Planning Issues

Expansion of New Lands

Field studies sponsored by the MLR have identified a total of 2,380,000 feddans of new lands suitable for irrigation by surface water and 213,000 feddans by groundwater. The MOE estimates that water will be available for approximately 1.7 million feddans after Jonglei is completed and major improvements have been implemented to increase the overall water use efficiencies within Egypt. For the remaining 680,000 feddans additional water supply from the other Upper Nile Projects will have to be made available. These projects will supply water from savings in evapotranspiration and losses from swamps.

Soil types fall into three classes: clayey soils, fine sandy and calcareous soils and coarse desert soils. Clayey soils are to be settled by small farmers and university graduates on 4-feddan and 15-feddan plots, respectively. These soils are typical of old land soils and present no special problems. Tentatively, about 40 percent of the area of fine sandy and calcareous soils is to be settled by small farmers andgraduates and the remainder will be developed under State farms at least initially, but may later pass in part into the private sector. Several critical technical and management questions (management of drip and sprinkler irrigation, markets for fruit and vegetable crops, etc.) remain unanswered, which increases the risk of settlements on these lands. Coarse desert soils will be developed under State farms through joint ventures with private capital.

New lands development during the current Five-Year Plan period has proceeded more slowly than planned (about 70%); however, this is being accelerated. There is an opportunity, nevertheless, to reexamine and evaluate options for new land development using additional information from actual experience. While the public sector may have an advantage in land reclamation, entrepreneurial and management skills are the comparative advantage of private capital. There are questions of priorities, additional institutional questions regarding extension, staffing and training and inter-Ministerial coordination. Although new land development is not directly a MOI responsibility, the national commitment to it and the magnitude of resources required (about one-half of the agricultural investment budget), finding the best way to more efficiently utilize Egypt's water resources regarding new lands development should be a major issue in the country's overall irrigation strategy.

Groundwater Development

Groundwater in the Nile Valley and Delta is not a new source because it originates from the Nile, but its use can improve the efficiency of overall system delivery. In effect, it can be used as a surrogate for inefficient surface channels by locating wells where canal service is least reliable. The MOI has been assigned responsibility for developing limited resources in Sinai.

Soil and Crop Management

Research and extension (R&E) are the keys to the improved production on both old and new lands. Vertical development process on old lands is the most immediate and economic source of improved crop production. Human resource development for R&E is critical. Improved technology has produced yield increases on large pilot projects (EMCIP, EWUP and ERRAT) of 52, 54 and 81 percent for wheat, rice and maize, respectively. Priority technical issues relate to evapotranspiration from the water table; land preparation; soil, water, fertilizer crop interactions; amelioration of hardpan formation; harvesting; post harvesting losses and mechanization; and managing sprinkler and trickle irrigation on new lands.

On-Farm Water Management (OFWM)

Large-scale extension of improved on-farm water management along the lines formulated by the EWUP represents the most significant shift needed in Egypt's irrigation strategy. Targets through the current and next Five-Year Plan periods, 1982/83-1991/92 total only 800,000 feddans over a ten-year period; 200,000 feddans in the current Five-Year Plan period. Tentative plans for the upcoming Plan period add 600,000 feddans at an estimated cost of LE 510/feddan. This portends an eventual investment of LE 3,000 million to cover the entire country. While EWUP defined a process for implementation, it did not devise a replicable model and OFWM, now modified into the more comprehensive Irrigation Management Systems Concept, must still be regarded as being at the pilot project level.

On the technical side, evapotranspiration supplied from groundwater will be reduced and soil reservoirs increased as water tables are lowered by drainage. This has implications for the amount and timing of surface irrigation applications for shallow-rooted crops grown on sandy soils, and for aggravation of both head end and tail end distribution problems unless mesqa operations are improved. Land smoothing along with improved seed bed preparation and the use of larger streams of water in accordance with soil type could result in about the same level of improved irrigation application efficiencies as the more costly precision land levelling method. Small-scale mechanically-powered tillage equipment is needed for land preparation. While small tractors are available, mainly from Japan, they may need to be adapted to Egyptian conditions. Use of larger streams would require some changes in the scheduling of rotations to mesqas and use of mechanically-powered pumps where water is delivered below field levels. Gravity delivery, which usually requires installation of pumps at the heads of mesqas, is being tried and may spread rapidly. Adequate maintenance of mesqas will require mechanically-powered implements, and these need to be developed. Furthermore, an effective program of irrigation extension is needed.

Drainage and Salinity

Tentative upcoming Five-Year Plan allocations are LE 450 million for providing tile drainage and improving open drains to serve 850,000 feddans under IBRD/ADB support. In addition, drainage using wells may have useful application in limited areas and is now under study by WRC.

Diversion and Distribution Works

Barrages. Tenders have been issued for replacement of the old earthen dam at Damietta with a modern barrage with locks and gates. Estimated cost is LE [illegible]4 million. Replacement of Esna barrage is scheduled in the next Five-Year Plan at a cost of LE 274 million. A 78-MW hydroelectric generating capacity will be included. Replacement of Nag Hammadi and Assiut barrages at an estimated cost of LE 300 million is also targeted.

Operations. Cost of operations as such is a recurring cost and does not appear in the investment plan. Shifting from rotational to continuous delivery for canals would have some advantages, such as permitting smaller channels. Shifting to gravity operation of mesqas by using a one point lift system will require installation of pumps. In principal, farmers should also repay their capital costs. Use of improved regulation structures, and automatic control of water levels in some cases, could greatly improve operations. In many cases, canal cross sections and slopes are such that channels need major rehabilitation in order to meet service requirements for improved irrigation. The MOI's policy is to schedule investment for and implement rehabilitation under its Irrigation Management Systems Program.

Maintenance. With IBRD and USAID collaboration, PPD has developed a 12-year maintenance plan. Under this plan the present heavy silt dredging machinery will be replaced with weed control equipment, operators will be trained and required management changes introduced. Use of chemical weed control will be increased, and biological control using grass carp will be initiated on a pilot scale. World Bank support for implementing this plan is sought. A field appraisal was completed in October 1985 and discussions are in process regarding the scope of the program.

Channel Structures and Pumps. The USAID-supported program to replace 11,000 channel structures and bridges will be continued into the next Plan period. The MOI schedules investments for canal structures replacement under its Irrigation Management Systems Program. There are opportunities to improve selection and design of canal structures and some innovations are being tried. These should be monitored and evaluated by WRC, at least on a sample basis. There is still a backlog of old and inefficient pumps and associated pumping station equipment, such as screens and electrical service components. The PPD has recently completed an analysis of a project to rehabilitate the backlog of old pumps.

Farm Economics

Application on a nationwide scale is anticipated for various research and extension activities now being tested. The MOI is planning a country-wide effort to improve water delivery systems and their MOA's proposed National Agricultural Research Program (NARP) has similar countrywide goals. The efforts of the MLR will have beneficial results, not only for new lands, but for old lands, also. Jurisdictional boundaries need to be defined so that attention is addressed to this virtual no-man's-land that exists between the canal and use of water on the farm. The full productive potential has not been achieved, but based on pilot efforts, the outlook for substantial gains in agricultural production is optimistic. Egypt can no longer afford the high cost of having each farmer learn by trial and error; thus, a strong R&E effort is needed.

Supporting Activities

Agricultural Research and Extension. In order to achieve the needed level of R&E efficiency, a firm and effective communication between MOA and MOI R&E personnel must be established. Irrigation deliveries must be matched with crop growth stages and other irrigated farming activities such as planning, fertilizer application and pest control. One of the most useful outputs of interdisciplinary on-farm water management research is the development of crop response functions for use in the development of extension packages.

Water Research. A wide range of research activities are needed to support the irrigation sector. Most relate to field research (adaptive or operational) in areas such as the relationship between ET and depth to ground water, improved irrigation techniques, weed control, hydraulic design, continued side effects of HAD, improved coastal protection approaches, social factors effecting irrigation efficiencies, etc. All research activities are specifically designed to support the ongoing and proposed irrigation improvement program.

Overall System Management

There is as yet unmeasured potential for application of operations research (OR) type technology to improve main system management and operation. Some parts of an overall OR-type system are already in place, i.e., meteor burst communication of water level information, an operational distribution system for the Nile barrages, reservoir optimization models, a hydraulic model of the Nile River in Sudan above Aswan and a rainfall/runoff model for the Nile watershed. These generally need further calibration and exercise. Stochastic simulation of crop ET requirements could provide look-ahead capability in forecasting water requirements. Use of satellite information about crop status could be a useful input to such a model. Unit command area models such as one being developed by Water Management Synthesis II could provide refined demand predictions at the mesqa level. Operational hydraulic modeling of main systems canals could improve their capability to deliver water when and as required. There is some potential for estimating rainfall totals on the Upper Nile watershed using satellite information about cloud cover. Investment in some of these features is included in the tentative upcoming Five-Year Plan.

Institutional Development Needs

The MOI and MOA should delineate and reinforce areas of parallel and overlapping responsibility in regard to research for on-farm water management. The most productive program occurs when irrigation engineers are working in a fully collaborative mode on and around the focal point of evapotranspiration and other issues relating to surface and subsurface drainage and water quality.

The MOA has a mandate to develop and maintain an effective agricultural extension program in which extension irrigation engineering is specifically named as a component. However, assigning an irrigation engineer to the Agricultural Extension organization may be anomolous. The MOI/WRC's proposed Irrigation Advisory Service should be charged with providing assistance at the mesqa level to farmers for mesqa operation and maintenance, irrigation scheduling, on-farm land development and irrigation methods. Agricultural Extension should develop the capability to provide advice on irrigation needs, cultural practices and fertilizer and pesticide needs for irrigated crops. In the interim, R&E assistance will be critical on Irrigated Management Systems pilot projects, and these services will probably need to be mobilized at the pilot project level on an ad hoc basis. The MOI is proposing that these projects be implemented by a new Irrigation Management Systems Authority. The MOI has proposed expanding its in-service training activities, and creation of a National Irrigation Training Institute (NITI) would be the first step. These institutional development activities must be well coordinated. This package would appear to be an attractive one for international donor support.

Policy Issues

Agriculture's Share of Egypt's Investment Capital and Farmer Involvement in Mesqa-Level Management. Compared to agriculture's share of total employment (35 percent) and its proposed share in contribution to gross domestic product (20 percent), agriculture's proportion of total investment (about 11.7 percent) under the current Five-Year Plan does not seem consistent with its growth target (3.7 percent/yr). Actually, labor in agriculture does not appear to have increased; perhaps this is because without higher prices and credit for mechanization, yield increases have not been sufficient to absorb more labor. Thus, a substantial credit program for development and mechanization, and organization of water user associations seems necessary. In view of this, we recommend that the Agro-Economic Model be used to study the effects of mesqa-level credit programs and private and public investment.

Water Charges and Recurring Costs. There is general agreement that water users should pay water charges equal to O&M costs plus some share of capital costs. Measuring water volumetrically to individual users is technically difficult and very expensive and can be expected to have only marginal effects on system efficiency in most cases. Pumping costs, however, are truly marginal costs per unit volume. For this case volumetric charges could be expected to influence efficiency, but water is only a fraction of total input costs. In Egypt determining a fair water charge needs to take into account the costs to farmers of price fixing and crop quotas. For the purpose of raising revenue, there may be better alternatives. Water charge collections usually accrue to the general revenue account and may thus bear little relationship to appropriations for O&M. Earmarking them specifically for O&M and possibly decentralizing their collection and use would internalize water charge collections and support for O&M.

Other. Several other policy issues are listed in Chapter III, but in the interest of brevity, are not repeated here.

Recommendations

1. Intensify extension and on-farm water management demonstrations for new lands on clayey soils. Consider having settlers provide their own housing for such developments.

2. Allocation of water resources for new land development should be subject to feasibility studies on a project by project basis. Feasibility of providing suitable sprinkler and trickle irrigation technology which settlers can manage, and the future of markets for fruits and vegetables are germane to the success of these developments and need rigorous evaluation.

3. Private enterprise should be given the task of developing agriculture on coarse desert soils. The rate of reclamation of these soils should be kept in line with prospects for private capital development.

4. Continue evaluation of new lands project priorities using the Agro-Economic Model and the latest information, generally giving preference to private development.

5. Develop workable systems of sprinkler and trickle irrigation that can be managed by settlers on new lands and provide extension and support for these systems and for farm production generally. Success of these systems requires disciplined operation and maintenance and a cash flow economy so that replacement parts and services can be purchased. Planners must be sure that these will occur.

6. Implement an interdisciplinary program of basic and field research on soil, water and crop interactions and related topics, including the amount of water that crops are drawing from water tables. The MOA and the MOI should establish a more formal working relationship for this purpose.

7. Establish the proposed Irrigation Management Systems Authority for implementing the pilot-level programs under the NIIP, including provision for recruiting the necessary disciplines, and for such training and technical assistance as required. This item is strongly recommended for international donor support.

8. Clarify the responsibility and develop improved capacity for R&E for irrigation water management at mesqa level and on individual farms by implementing and supporting the proposed Irrigation Advisory Service and supporting development of an improved irrigation water management capability in the Agricultural Extension Service. The IAS should be

responsible for all mesqa level activities, land development on farms and farmer organizations; the Agricultural Extension Service should provide information on irrigated cropping systems and irrigation requirements, and developing production packages.

9. Gravity operation of mesqas appears desirable, but needs more testing and study. The MOI should provide technical support; benefitted farmers should pay for pumping costs, including fixed costs of capital repayment.

10. Identify or develop machinery suitable for small farm operations and mesqa maintenance.

11. Stimulate incentives for farmer investment in yield raising technologies by adjusting or removing commodity price ceilings and crop quotas.

12. Strengthen "management by objectives" techniques in research operations.

13. Continue as scheduled the multi-purpose program of barrage improvement or replacement.

14. Implement a program for channel maintenance along the lines described in the Maintenance Plan report. International donor support for this effort should have high priority.

15. Concentrate efforts to remodel and rehabilitate canals in the NIIP pilot areas. Implement a program of monitoring and evaluation of various types of channel structures and modes of operation so that future selections are optimized. Strongly consider adopting continuous flow delivery in main canals wherever possible.

16. Improve compatability of pumping station equipment procured from different sources as units are replaced, and install automatic screens where screen clogging has become serious.

17. Accelerate feasibility studies, implementation and exercise of Operations Research type technology for improving main system operation.

18. High priority should be given to early funding and implementing the various planning studies proposed by WPG.

19. Consideration should be given to targeting a larger share of development investment capital to the agricultural sector.

20. The MOI, the MOA and the MLR should seek ways to improve interaction, especially at field level, and for R&E. Because virtually all of Egypt's land is irrigated, the irrigation and the agricultural sectors are essentially identical.

21. Degree level curricula for education in agricultural engineering comparable to those in the United States should be implemented in some of the universities. These would be new curricula, not modifications of present ones in agricultural disciplines. More women should be recruited for this and related fields.

22. Continue the dialogue on water charges and recurrent charges. Any plan to implement collection of water charges must take into account present costs borne by irrigators as a result of price and crop quota policies.

Assistance by International Donors

The irrigation sector's objective is to support the national goal in achieving a 3.5 to 4 percent annual growth in agriculture.[2] An optimal investment strategy should successively target relatively more resources to relieving the current most critical constraint to achieving the sector's objective goal. Rankings for donor investment may differ from those of the Ministry overall. Donors have a comparative advantage in facilitating institutional change and the transfer or development of advanced or new technology. These considerations were weighed in developing the priorities listed below. Institutional support, technical assistance, research and training and advanced technical infrastructure generally should be given priority over associated construction infrastructure for any item.

The most critical problem in achieving the sector's objective is optimizing delivery of water to farms and integrating irrigation and all other factors optimally on farmer's fields. The National Irrigation Improvement Program, labeled "Irrigation Management Systems," in the MOI's tentative estimates for the next Five-Year Plan represents Egypt's effort in this regard. Critical to this program in the long-term is development of a more effective R&E apparatus for irrigated agriculture. With about one-half of its agricultural development budget committed to new lands development, improving the productivity of these lands is of great importance to Egypt. Improving the operations management of the main system primarily through utilizing advanced data sensing, processing and communications technology, modeling and automation promises large returns by decreasing water loses and improving system performance. These items are assigned the first three priorities in the table shown on page 16. The other activities listed were not ranked due to their equal importance. The costs shown are in 1984 prices and are indicative only. The level of investments shown for the next six years (mid term) are the amounts required to meet the currently planned improvement levels in overall water use efficiencies. If available resources are lower, most if not all of the activities, will be undertaken but at a slower pace.

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[2]Vice Minister for Irrigation, Eng. Ismail Badawy, November 4, 1985.

No.	Description	Mid Term (1)			Long Term (2)
		FC(3)	LC	Total	LC
1.	Irrigation Improvement Program Includes R&E for Irrigated Agric.)	89	261	350	3,000
2.	New Lands Development (El Salam Canal)	14	107	121	50
3.	Main System Management	40	5	45	40
4.	Esna Barrage	184	90	274	-
5.	Pump Replacement	72	108	180	-
6.	Channel Maintenance Program	105	203	308	185
7.	Damietta Barrage	10	24	34	-
8.	Planning Studies	5	2	7	10
9.	National Irrigation Training Institute	16	8	24	-
10.	Drainage Improvements	130	411	541	263
11.	Shore Protection	28	126	154	19
12.	HAD Improvements	19	45	64	?
13.	Water Research at WRC	14	35	49	50
14.	Survey Equipment & Mapping	7	21	28	-
15.	Groundwater Development	32	163	195	105
16.	Runoff Estimates	8	2	10	-
17.	Nile River Model	1	2	3	-
18.	New Lands Development (Al Nasr-Nassery & Ismailia Canals)	36	191	227	-
19.	Long Range Planning-Upper Nile	6	35	41	-
	TOTALS (L.E. 1,000)	816	1,839	2,655	3,722

1) 1986/1987 - 1991/1992
2) Additional to next Five-Year Plan up to the Year 2000
3) Total of column is equivalent to US $983 million

CHAPTER II

SOCIOECONOMIC/TECHNOLOGICAL ISSUES--

CURRENT STATUS

Introduction

Chapter II describes the current status of a series of issues which the Team judged to be relevant to Egypt's Irrigation Strategy. Strategy, of course, is related to the country's program for investment, but this is not the whole story. Only new investments are budgeted in the Five-Year Plans. Recurring costs are not included. This distinction is reflected in the country's appropriations. Chapter II funds cover recurring costs; Chapter III funds cover new investments. Many strategy considerations, however, involve Chapter II-funded activities; e.g., maintenance of irrigation and drainage channels, research, etc. Besides investment in capital infrastructure like completing tile drainage, the investment budget may also include investment in interventions, e.g., the National Irrigation Improvement Program (NIIP) and the complementary AID-supported Regional Irrigation Improvement Program (RIIP) under the Irrigation Management Systems Project. Total costs involve both recurring cost and investment financing, but the first is often not readily visible. One interesting example for which all estimated costs are displayed may be found in the plans for improving channel operation and maintenance (O&M) under the section on Diversion and Distribution Works in Chapter III.

Loss of Agricultural Land[1]

The loss of old lands to agricultural production for various reasons --urban encroachment, waterlogging, using the soil for brick-making, industrial uses and erosion--poses a serious problem for Egypt. These losses have been estimated at various levels, but the most commonly accepted current rate is 45,000 feddans/year. Unless losses are curbed or lands are replaced, the country's current agricultural land base of about 6 million feddans would be reduced an additional 675,000 feddans by 2,000 A.D.

Egypt's strategy is to increase its land base by reclaiming new lands, either in the Delta or adjacent desert. This has substituted up until now for lost land through urbanization and other purposes. The amount of land that can be reclaimed is constrained by available water supply. Loss of old lands does release irrigation supplies, but industrial and municipal needs still have to be met; thus, additional water is needed for full replacement. This will have to come through

[1]References: 22, 41.

increased irrigation efficiency in the remaining old lands and from schemes such as the Jonglei canal to reduce evapotranspiration losses from swamps in the upper region of the White Nile.

Replacing the old lands is very costly. Egypt has taken some steps to decelerate the loss of old lands by establishing industry and new communities on desert lands, by zoning areas around urban centers, and by prohibiting brick manufacturing from the soil of agricultural land, but stricter enforcement is needed.

Soil and Crop Management

Old Lands

Traditional methods of soil and crop management rely heavily on animal power and human labor. This results characteristically in rough, uneven fields, poor irrigation water distribution, tillage hardpans (repeated passage of buffalo and bullock draft animals has the same effect as a sheepsfoot roller), poor seedbed and uneven seed germination and crop establishment. Hand-applied fertilizer is not spread uniformly, and together with lack of incorporation into the soil, fertilizer/plant use efficiency is low. Customary methods of harvesting and threshing, especially for grain crops, leads to lost productivity and decreased product quality.

The return of crop residues to the soil for the purpose of sustaining soil fertility, organic matter and good tilth is minimal. This is because crop residues of all kinds are scavenged for use as fodder livestock and culinary fuel. Animal manure is also collected for fuel, minimizing the benefit of this resource as a fertilizer and organic amendment.

Recent research and extension data show that Nile Valley and Delta soils are severely deficient in nitrogen fertility (except for legumes) and moderately deficient in phosphorus. In addition, soils are deficient in zinc for several crops, especially rice. These fertility elements need to be managed carefully or the potential crop yield will be reduced regardless of the care given to on-farm irrigation.

Customary irrigation management practices, together with inefficiencies in water conveyance systems, result in a sustained high water table throughout much of the Nile Valley and Delta. Secondary salinization is associated with high water tables; soil salinity and sodicity is distributed in localized spaces throughout the irrigated areas with the problem increasing in extent and intensity toward the north end of the Delta.

The Egyptian Water Use and Management Project (EWUP) estimated that when the water table impinges on the crop root zone and contributes more than fifty percent of evapotranspiration, crop yield is reduced because of decreased effective root zone and decreased oxygen for root respiration. EWUP data show that the water table contributed 25 percent, 35 percent and 50 percent of ET, respectively, at Abyuha, Beni Magdul and Abu Raya. These are fairly typical of the lower Valley and upper and lower Delta areas. Thus, in addition to soil salinity control, drainage is necessary for high crop production potential.

Summer crops consisting of rice, cotton, maize, sorghum and soybean are followed by winter crops of wheat, barley, berseem and vegetables. Sugar cane, of course, is cultured throughout the year, as are a limited amount of tree fruit crops.

Overall, cropping intensity in Egypt averages 1.90. The potential exists to increase cropping intensity to 2.5 and higher, but this potential cannot be achieved without extensive mechanization, including especially land preparation, tillage, harvesting and threshing. Tractors are now being used for land preparation and other activities. The use of tractors will probably increase if the rural labor shortage of 1985 continues. The application of other types of farm equipment needs to be demonstrated.

Crop management inputs, fertilizer and pesticides are purchased through the cooperatives where limited amounts are available at subsidized prices, and from commercial outlets. Many questions exist as to the quality of these inputs in terms of the guaranteed composition of the materials and the ability of these materials to satisfy specific needs in different fields. Availability of inputs sold by cooperatives and commercial outlets is a constraint to timely application in the field.

Old New Lands

A major distinction between old new lands and old lands is the nature of the soil. For the purpose of this report the current Five-Year Plan (1982/83) new lands development plans for reclaiming 636,700 feddans is included in this section on old new lands. The old lands, lying on the river flood plain and delta, are generally fine-textured including clays (vertisols) and silty clay loams and clay loams (entisols). By contrast, the old new lands, located on Valley and Delta fringe areas, are sandy loams to loamy sands, and sands and gravelly sands (inceptisols and aridisols). The latter have a certain amount of indigenous salinity which is subject to transport by percolating waters to lower lying terrain giving rise to secondary salinity.

The 636,700 feddans maintained above comprise 52 project sites located mainly at the eastern and western edges of the Delta; but there are also some in the Middle and Upper Egypt. Major classes of soils are:

clayey soils in the Delta; fine sandy and low calcareous soils; and coarse sandy and gravely soils. Small settlers and graduates will settle the clayey soils, but they will probably not be settled on the coarse desert soils. The fine sandy and low calcareous soil will be settled by a combination of State farms, graduates and settlers.

The old new lands are easier to till but are very susceptible to wind and water erosion. Crop establishment is a special challenge. Surface methods of irrigation are very inefficient, so sprinkler and drip methods are encouraged.

Clayey Soils. Within the current five years, only 24,000 feddans of clayey soils in the Delta are to be settled by 60 percent small settlers on 5-feddan plots and 40 percent by graduates on 15-feddan plots. With new canals and drainage systems and after two years of developmental cropping by MLR, it is assumed that the settlers can complete development of these lands using conventional cropping patterns and lift irrigation at farm or mesqa level. Existing agri-business and cooperatives will extend to provide inputs and credit. These clayey soils are estimated to yield 38 percent of full productivity by the third year, and finally 100 percent of productivity by the ninth year. The farmers, of course, are not on the scene during the design of the project. They must adapt to the system as designed.

Fine Sandy and Calcareous Soils. Nearly half of the projects are found on fine sandy and low calcareous soils. They are being settled—at least initially—by 40 percent settlers and graduates and 60 percent by public-sector State farms. To the extent that the graduates and settlers are successful and that the State farms have completed the development cropping investment phase, more State farm land may be sold or settled privately. These soils compose about one-half of the total 1.7 million feddans estimated to be reclaimable and serviceable within MOI irrigation water projections for the year 2,000 or beyond. If these plans are followed, MLR will be in the business of providing up to 60,000 or more settlers on 4-feddan plots with sprinkler and drip irrigation systems over the next 20 years. Up to about one-fourth that many settlers and graduates are to be settled as the current Five-Year Plan matures. State farms would implement farming systems on the majority of the fine sandy soils. The State farms will also provide settlers with irrigation maintenance services, spare parts and input and commodity markets through Government cooperative stores. The MLR is seeking external assistance from Japan and Germany for extension and training services to settlers. The cropping patterns initially will be aimed mainly at the fruit and vegetable markets of Egypt that currently promise the greatest profits, internal rates of return (IRR) and returns to irrigation water (48).

Coarse Desert Soils. The third major group of project sites are those located on the more difficult coarse sandy soils that are planned for development by State farms and joint ventures with private capital, including international capital. These lands amount to about one-third of the lands to be reclaimed within the current Five-Year Plan.

Because of the low water holding capacity, crops growing in coarse textured soils are far more prone to drought stress. Soil fertility management factors are also peculiar; much greater attention must be paid to soil nitrogen, which includes more frequent application of smaller rates of nitrogenous fertilizers. Soil texture and structure are not very susceptible to change through management practices in sandy soils. The marginal and submarginal productivity of the old new lands is attributable in large measure to this soil characteristic.

On-Farm Water Management[2]

Background

Field studies of on-farm irrigation water management were initiated on a pilot scale in 1977 under EWUP, a joint project supported by USAID. This project was conducted at three sites, ranging from 1,200 to 6,300 feddans in area, and was completed in 1984. The general accomplishments of the project, which were development of methods for watercourse improvement and packages of practices for better on-farm water use. The value of an interdisciplinary team approach was demonstrated. The work was visualized as precursor to systematic implementation of improved on-farm water management on a larger scale at regional and national levels. The very significant accomplishments of the project have been described in a recent evaluation (53). While a replicable model was not developed, the project did develop a process for systematically improving on-farm water management.

Based on EWUP's experience, the Ministry of Irrigation (MOI) formulated plans to begin a National Irrigation Improvement Program (NIIP). Initially 850,000 feddans has been targeted in 11 areas throughout the country during the next few years as a Regional Irrigation Improvement Program. Complementary support is being provided to RIIP, by the USAID-supported Irrigation (ISM) System Management Project and through the UNDP. Generally the agenda for NIIP and RIIP is broader than EWUP's in that rehabilitation of main and secondary canals are included in addition to on-farm water management. MOI has established an administrative unit and has begun data collection and planning for the eleven RIIP areas.

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[2]References: 16, 17, 110, 113.

Old Lands

The irrigation conditions as they exist in the old lands are the legacy of milleniums of traditional practices. Prio to the early part of the nineteenth century, irrigation came only with flooding from the Nile and entrapment on the lands. With the construction of canals, the flooding was extended to lands that were above the normal flood plains. Basic to efficient use of water is management of the soil reservoir. Factors which control this are:

* The proper preparation of the land surface;
* The method of water delivered to the farm; and
* The skill of the irrigator.

Land holdings of most Egyptian farmers are small, generally in the one to five feddan range. Such small holdings require a complex network of distribution canals and an even more complex on-farm delivery system below the mesqa inlet. In order to control the water on the farm with only limited power and limited equipment, the small farms are further divided into small plots, each bounded by bunds, or contained within furrows. Water is delivered to each of the plots by marwas, small hand-made ditches within an individual farm.

Proper land preparation is a major constraint, but there are possibilities for relieving this constraint, as noted in Chapter III Most of the farmers have limited pulling power available, usually donkeys or buffalos. This also limits the degree to which the land surfaces can be prepared. Seedbeds are generally very rough, even when tractor-drawn chisel plows are used, and inhibit flow of water over the surface. This is particularly true in the heavy soils of the old land area. Land smoothing equipment is very limited. It usually consists of small drags which are not very effective, especially if the soil has been allowed to dry out immediately after cultivation or plowing and the clods become very dry and hard. Under these conditions some farmers will "pre-irrigate" the field to soften up the clods.

Construction of the marwas, bunds and furrows is almost all done by hand. This is very time consuming, and to some degree will limit the area that one farmer can operate. The principal tool is a heavy hoe, which is not well adapted for the kind of operations needed in controlling water. Within the field there are virtually no control structures except the earthen dikes and dams. To get from one plot to another water must sometimes be run through some plots for long periods of time; hence, those plots receive too much water. An essential ingredient to good irrigation efficiency is good control. This is difficult under current conditions.

In recent years new equipment and new methods are being introduced. Local farm cooperatives have limited amounts of tractor-powered equipment which can be rented by farmers. However, neither the supply nor the reliability of the available equipment is adequate. This condition, however, will improve with time. Some small tractors are also being used. The increase in availability of pulling power will also permit better use of surface preparation equipment, including land smoothing equipment, ditches and border-dike makers, all of which will make on-farm control of water easier.

Water flows continuously in the main canals which deliver water to the branch canals on a rotational basis. The branch canals and mesqas are grouped into at least two or three groups along the main canal. All the branches within one group receive water at the same time according to the following rotations:

(a) 2-turn rotation (7 on days and 7 off days) for cotton areas.

(b) 2-turn rotation (4 on days and 4 off days) for rice areas.

(c) 3-turn rotation (4 on days and 8 off days) for most of the crops in the summer or 5 on days and 10 off days in the winter.

Each mesqa receives enough water to cover the area of land it supplies in the given on-time period, assuming a 24 hour per day irrigation schedule. Usually the farmer at the head of the channel has the chance to get the water as he wants more than the next farmer. These conditions give rise to the classic head-end and tail-end distribution problems, that are common.

In allocating the water to the mesqa, the assumption is that the water will be delivered on a 24-hour per day basis. Since most of the water in the system must be lifted from the mesqa to the marwa by either animal power or human power, no irrigation is done at night. Hence, water intended for the field is left in the canals and in turn runs into the drains. Thus, water is used for only 8 to 12 hours per day, depending on the season. With half of the water allocated for an area going into the drains, water at field level is in short supply.

Equitable delivery of water to farms is compounded by another problem. In those mesqas where water is delivered to the marwa by gravity the size of the pipe leading from the mesqa to the marwa is fixed by the area the outlet is to irrigate. The head, or water level, in the canal is assumed to be fixed, and because the size of the pipe is fixed, the discharge is assumed to be fixed. In reality, that is not the case.

Since there are few if any head control structures on the mesqas, as soon as any water is removed from the mesqa the quantity is decreased, the head lowered and the amount delivered to the downstream users is reduced.

Inadequate deliveries to the farm cause at least two major problems that lead to inefficient irrigation and decreased production. First is the inadequate supply itself. There is simply not enough water delivered to the farm to meet its needs; hence, optimum production cannot be achieved. The inadequate supply to the farm is not usually because of inadequate supplies in the system, but is a function of the system itself. Under present constraints the system cannot meet peak demands. The second problem is stream size. In surface irrigation, there is a very delicate balance among surface roughness, land slope, length of run and soil infiltration rate. If the stream size is too small, and limited field observations indicate that in many instances this is the case, water will move too slowly over the surface of the field, resulting in deep percolation losses to the water table. These two conditions lead to another detriment to equitable water distribution; illegal outlets from gravity mesqas or larger pumps.

As stated earlier, much of the water is delivered to farms from the mesqas by pumping. The official policy of the Government has been to build canals so that water levels will be below field surfaces. Until recently, the only method for farmers to lift water from the mesqa to their fields has been with a tambour, a human-powered Archimedes screw device, or with a saqia, an animal-powered water wheel. Both of these devices tend to constrain irrigation to daylight hours and to hours of operation within the physical endurance limits of the human or animal power supply. Neither of these are consistent with 24-hour per day irrigation schedules. Recently, small gasoline and diesel engine powered pumps have become available at prices that farmers can afford, and are being adopted.

In most instances, the only equipment available for maintenance of mesqas is a hoe. With it, farmers must remove both weeds and sediment and do whatever repair work is needed. As a result, many mesqas are not in good repair, and in some instances, the work is rarely done. A cooperative effort is generally required, but here again, head-end/tail-end problems occur. Farmers at the head of the mesqa get all the water they need and do not feel a major responsibility to clean their section of the mesqa to make water more available to farmers at the tail-end.

When conditions get to the point that cleaning is beyond the capability of the farmers, the MOI will use power equipment to clean them, but will charge the farmers for the work. The equipment most often used is a backhoe. When this is done, the size of the canal cross section is increased beyond what is needed for the design hydraulics, and maintenance and loss problems are compounded. Use of the mesqas for animal watering and as buffalo wallows also causes problems.

Weed control is a serious problem. Weeds grow rapidly and are hard to kill. When they choke the mesqas, water moves slowly, increasing the wetted cross section, and seepage and evaporation losses, reducing delivery to the tail-end. Some mechanical control has been tried, but this has not proved to be very successful on mesqas. Experiments are now being conducted with chemical control which may have some promise.

In virtually all of the old land areas, high water tables exist. As a result, Egypt has embarked on an intensive drainage construction program in an effort to lower the water table to acceptable levels. Some studies (16, 88) have shown that the high water tables have limited the rooting depth of the plants to the upper 30 cm of the soil profile. Thus, the size of the soil reservoir is limited, a condition which requires frequent, light applications of water for efficient irrigation. Furthermore, upward movement of water from the water table causes salt accumulations in the root zone. These require removal by the application of excess water, or overirrigation, which in turn raises the water table.

In some regions of the country, particularly at the EWUP study area in Abu Raya, overirrigation when water was available was shown to be a direct contributor to the high water tables. This is probably true in most of the irrigated crop lands. Equally important, however, is the contribution to the water table made by the canal and drainage systems. Water is in the canals 11 months of the year, and with few of them lined, seepage losses are high, and high water tables result. Many of the drainage channels are shallow, and seepage from them also contributes to the water table. Deeper drains, which should be lowering the water table, are filled at night with water from the canals. All of these conditions must be examined if proper control of the water table for efficient irrigation and optimum yields is to be achieved.

In gaining control over the water table, the contribution that the water table makes to the water supply of the crops must not be overlooked. Some studies have indicated that as much as 50 percent of the water used by plants comes from the water table. For example, in the El Hammami area, the soils are very sandy, and hence have a low water holding capacity. Yet, water is delivered for only four out of every 12 days. The soils in that area cannot store enough water to last for a 12-day irrigation cycle; the difference must come from groundwater. This must be true for other areas also.

Old New Lands

Old new lands are mainly Delta lands that have been reclaimed from brackish water areas along the Mediterranean and reclaimed desert lands. Conditions on the old new lands are essentially the same as they are on the old lands in the Delta. As with farmers on the old lands, the degrees of freedom for on-farm water management are limited by the delivery system. Maintenance problems are similar and water table levels create some problems.

Soil texture and structure have an overriding influence on on-farm water management in terms of irrigation frequency, amount and method. Thus, the old new lands are more sensitive to haphazard irrigation practices. Land managers on these new lands must be more dedicated and skilled than their old lands' counterparts to achieve equivalent yields. The old new lands are easier to till but are very susceptible to wind and water erosion. Crop establishment is a special challenge. Surface methods of irrigation are very inefficient, so sprinkler and crop methods are encouraged.

These areas are generally on higher lands and the water must be raised to them by pumps. Soil texture and structure have an overriding influence on on-farm water management in terms of irrigation frequency, amount and method. Thus, the old new lands are more sensitive to haphazard irrigation practices. Land managers on these new lands must be more dedicated and skilled than their old lands' counterparts to achieve equivalent yields. The lighter soils require more frequent applications, and since they are higher, water tables are much lower and do not contribute to crop water requirements. The on-farm distribution systems have the same problems as other areas, and with surface irrigation and prevalent means of water spreading, deep percolation losses are high. These losses, combined with the seepage losses from the canals, are in some cases moving down-slope back toward the river, causing salt problems in some of the highly productive old land areas.

Some areas have closed water distribution systems which pose special operation and management problems. Water-borne solids cause abrasion and plugging of nozzles and emitters. The focus is on uniformity of water application. The proper amount of water may be delivered, but poor in-field distribution means excessive deep percolation in some parts and drought in other parts. Wind further complicates the problem with sprinkler-applied water.

Canals and Distributaries[3]

Old Lands

General. Egypt's present irrigation water delivery system was developed over the past century with initiation of barrage construction on the Nile in 1861. Eight barrages now serve 13 principal gravity canals which account for about 80 percent of irrigation water delivery from the river source; the remainder is nearly all pumped. At Damietta an earth dam prevents intrusion of sea water into the Nile upstream. Two barrages, one on each branch of the Nile near Cairo, one barrage on the Damietta Branch at Zifta and one near the sea on the Rosetta Branch, serve the Delta. The remainder of the barrages are on the main river between Cairo and Aswan. Some of the canals are quite large and unusually long. Besides 21 minor gravity canals, there are 460 irrigation pumping stations on the Nile, but 80 percent of the pumped Nile supply is provided by the 40 largest stations. Groundwater is added to the supply by 360 additional pumping stations.

Principal canals branch into main canals, branch canals and distributaries eventually supplying mesqas. Farmers pump or divert by gravity from mesqas directly to the fields or to field channels or marwas. The total length of the "main" canal system, exclusive of mesqas and marwas, is 31,200 km. Attachment 1 provides a schematic of the canal system of Egypt.

Besides the current five million feddans of old lands served in the Nile Valley and Delta, Nile supplies serve about 1,200,000 feddans of old new lands.[4] Prior to initiation of High Aswan Dam (HAD) service in 1968, the function of the canal system was primarily to distribute flood waters to fields during the annual flooding season in an area of one million feddans in Upper Egypt and provide perennial irrigation in Middle Egypt and the Delta. Since that time, with full reservoir regulation of the river, perennial service has been extended to all of Egypt. Aswan storage has also had an effect on maintenance of canals because of decreased silt deposition and increased weed growth.

Operation. Operation of the canal system is the responsibility of the MOI. The Ministry consists of two departments (Irrigation, Mechanical-electrical), the headquarters including the planning sector, five authorities (Drainage, High Dam, Public Sector, Coastal Protection and Survey), seven public companies and the Water Research Center with

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[3]References: 7, 8, 9, 10, 26, 41, 69, 72, 80, 110, 113.

[4]The area reported is the total "reclaimed" through 1984-85. Not all of the area is receiving water. The commonly estimated current irrigated area is 800,000 feddans.

11 institutes. For administrative purposes, the country is divided into 19 Directorates (which are not necessarily the same areas as the Governates), 48 Inspectorates and 167 Districts. The job of the district engineers and their gatekeepers is to maintain the specified levels in the main canal system serving the mesqas. The 1984-85 investment budget for the Ministry was LE 253 million.

The Irrigation and Mechanical Departments, the High Aswan Dam Authority and the Egyptian Public Authority for Drainage Projects (EPADP), along with the Ministry Headquarters, are responsible for Operation and Maintenance (O&M). The 1984-85 O&M budget was LE 120.6 million.

Generally, the system is designed to deliver water to mesqas at levels below fields with a lift of 0.5 to 1.0 meters. Delivery to mesqas is usually by pipe outlet. Canals are designed to provide 25 cm head above pipe outlets. Information regarding water release needs is communicated daily by telephone from district to directorate level and to Cairo headquarters. Water is usually delivered to mesqas by rotation at the main system level. For one mode the time that water is on equals the time it is off, e.g., four days on and four days off (two rotation systems). In the other mode. time off is twice the time on, e.g., four days on and eight days off (three rotation systems). For a three rotation system, one-third of the branches would be served in the first rotation; after completion, a second reach of the main canal would be served, and so on.

While farm application efficiencies are reasonably good, the delivery system is quite inefficient. This could be improved by better control. Up to 50 percent of the water delivered to the main system is thought to be wasted to drains. This condition is aggravated because farmers do not usually irrigate at night. Wastage to drains tends to aggravate water table problems, especially in the Delta, where drainage water has to be pumped back into the system. Resulting increases in weed growth in drains further decreases their efficiency.

Channel Maintenance. In addition to maintaining 31,200 km of irrigation canals, the MOI maintains 16,333 km of open drains, of which 5,369 km are maintained by Egyptian Public Authority for Drainage Projects (EPADP). Present practice is to shut down the main system during the peak annual maintenance cycle in January. During this period, water continues to be released from Lake Nasser for power generation and navigation, but has to be released to the sea. This is a significant component in overall system efficiency.

Expenditures for maintenance totaled LE 39.34 million for 1983-84. Maintenance operations involve excavation to remove silt and weeds, mowing weeds and chemical weed control. By far the major expenditure is for excavation, and even though Aswan Dam has reduced silt deposition, earth work excavation has increased from 28.5 million m^3 in 1978 to 100.2 million m^3 in 1983-84.[5] Between 1977 and 1981-82 the area de-weeded varied between 12 and 20 million m^2, but rose to 32.8 million m^2 in 1983-84. In 1983-84 87 percent of channel maintenance was done by five public dredging companies; nine percent by small private contractors and four percent was spent for weed control chemicals. Under Egyptian law private companies may compete with public companies and awards are made to the lowest qualified competitors. Also, public companies subcontract to private companies, particularly for manual maintenance of channels. Of the LE 34.2 million paid to the public companies, LE 33 million was for excavation and LE 1.2 million for de-weeding. The current amount of sediment deposition from the Nile is estimated at 6.4 million m^3/yr. The large difference between this amount and the estimated excavation results from shifting of sediments by erosion and redeposition in the channels themselves and because, with present equipment, weed removal may be primarily by excavation.

MOI has recognized that the strategy for maintenance now needs to be shifted from emphasis on excavation to emphasis on weed control. This means a major shift in the type of machinery used from heavy dredging machinery like draglines to lighter excavating machinery, weed harvesters, and mowers and to chemical control. This shift will require new operator skills and management arrangements. MOI would like to reduce the manual component; currently done for 65 percent of the length of channels, mostly smaller ones. Mechanical control costs about one-third the cost of manual. Chemical control costs about 60 to 70 percent of manual costs. There is a substantial problem in maintaining rights-of-way for access by machinery along canal banks, particularly in urban areas and where channels pass through villages. The MOI is currently discussing with the World Bank the possibility of proceeding with an extensive channel maintenance program.

Keeping in mind that the time was the end of the maintenance year, the Team observed channels at all stages of disrepair. The large share were in reasonably good condition, but many canals, certainly not the majority though, were in serious condition.

Structures and Pumps. Besides the barrages on the Nile and the earthen dam at Damietta, structures consist of thousands of channel control structures in a wide range of sizes such as gates to regulate canal water levels or divide the water among branches, outlets to mesqas, and pumps and pumping stations. The two Delta barrages serving the

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[5]These figures are said to be inflated. They represent "pay" volumes based on a "pay" depth of 30 cm, whereas actual depth of excavation may be less.

Rosetta and Damietta Branches were replaced in 1939 and three other barrages (Assiut, Esna and Zifla) were remodeled between 1938 and 1954 (89). The barrage at Esna needs replacement, and the earthen dam at Damietta should be converted to a controllable barrage.[6] Two other barrages will need to be replaced over the next few years. An additional barrage on the Rosetta branch between Cairo and the sea has been considered. For environmental reasons, partly water logging hazard, a policy decision not to build additional barrages on the Rosetta branch has been taken. Instead, diversions from Delta barrages to serve the Western Delta have been constructed.

Many canal structures are old and inefficient. Some are cracked and broken. Water levels cannot be controlled accurately, and there is often scouring and widening downstream from structures due to eddy currents. Wooden flash boards rather than steel are usually used on these old structures. Bridges over canals are also very important and many are cracked and the steel reinforcing is exposed and corroded. These bridges were not designed to carry the heavy truck loads now desirable to serve farms and villages. Roads which are an essential part of the marketing system, are not constructed by MOI, but MOI has the responsibility for providing bridges for rural roads over its canals.

Many pumping stations are old and inefficient. This results in unreliable service and high cost of operation. The problem may be worse for drains than for irrigation canals because of increased water logging hazard and higher cost of maintenance. AID has supported a program of pump replacement at 37 sites in upper and middle Egypt since 1977. The current AID project is scheduled for completion in 1986. IBRD has also supported a program of pump replacement. Phase I of this program for rehabilitation of 30 irrigation and drainage pumping stations is under implementation and Phase II is scheduled to be contracted during 1986/1987 for rehabilitation of 59 additional pumping stations.

Replacement of barrages requires large one-time sums of non-divisible capital, so this program has to be approached individually for each case. For canal structures and pumps a systematic continuing program on a sustained basis is needed. This may need a higher level of activity at the beginning in order to catch up, but should phase to a more or less constant level in the future.

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[6] The dam at Damietta and the barrage at Rosetta, besides providing water for canals, also prevent intrusion of sea water into the lower Nile.

Old New Lands

Most of the O&M problems of canals and distributaries for new lands are the same or similar to those for old lands. This section will discuss some of the differences.

Operation. Pumping is usually required to lift water into the main canal systems serving old new lands. In some cases water is delivered on a rotational basis to farms, especially where gravity flow is used. In other cases, especially for large farms using trickle or sprinkler irrigation, water is needed continuously. As for old lands, pumping costs from the public canals generally are the responsibility of the farm entrepreneurs.

Maintenance of Channels. Canal losses from seepage are apt to be more of a hazard on these canals than on those serving old lands because of their elevation in some reaches and because they pass through lighter soils. Accordingly, some of these canals are lined and lining may be needed in certain other cases, depending on local conditions. Lining poses some special maintenance problems, for example, weed growth in joints between present concrete sections as observed on the Nasr Canal near the Desert Highway crossing. Additionally, action of the water through the joints had removed large pockets of earth from behind the lining at elevations above the water surface. Most of the caulking material had weathered or eroded away. Even though the joint cracks were fairly wide, 2 to 3 cm, there may not be much seepage loss because of sedimentation into the joints below the canal water level.

Structures and Pumps. Because they are newer, one would expect canal structures for old new lands' canals generally to be in somewhat better condition than for canals serving old lands. This would not necessarily be true of pumps because of their shorter lifetimes. A structure and pump replacement program for the old new lands' canals should be integrated into the general program for the old lands, giving priority to replacing the structures and pumps in the poorest conditions on a total system basis.

Drainage and Salinity[7]

The high water tables found throughout the entire Nile River Valley and Delta present a high risk situation for the buildup of salinity and sodic problems. There are a few areas in the Delta where there are some serious problems, and problems are starting to appear because of seepage loss and return flow from over irrigation of newly developed projects.

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[7] References: 2, 3, 7, 28.

In an effort to avoid serious salinity problems, a well designed system of surface drainage has been installed. This greatly reduced salinity hazards. However, many field research studies carried out by Egyptian and foreign agencies, actually begun in 1942, have shown that a system of subsurface tile drains will substantially improve the physical and chemical characteristics of the soil and improve productivity. In some situations where the tile drains have been installed, there has been an estimated 17 to 25 percent improvement in production on Nile Delta lands and a 12 to 16 percent improvement on Upper Egyptian lands.

Studies have shown that Egypt has a total of 5.212 million feddans that can benefit from a subsurface network of tile drains. With the help of foreign donors, loans from international banks, and from its own resources by October 31, 1985, 2.815 million feddans had been provided tile drainage. In addition, under the auspices of Egypt's first Five-Year Plan, 1,467 km of open drains have been built or rehabilitated. Land areas provided with tile drains through October 31, 1985 with the support of specific financial sources are given in the following table.

Delta Land		
World Bank - First Agreement		952,000
World Bank - Second Agreement		338,000
Dutch		44,000
Ministry of Irrigation		594,000
Upper Egypt Land		
World Bank - First Agreement		300,000
World Bank - Second Agreement		298,000
Ministry of Irrigation		289,000
	TOTAL	2,815,000 feddans

Farmer Involvement[8]

Options for Labor and Resources

In general the current marginal financial cost of water and drainage to the farmer is so low that certain yield increases, by using more labor, management, capital and/or organizational intensive alternatives are financially infeasible; i.e., for the farmer, water is a cost-effective substitute for labor and management. For example, if labor, management and farmer organizational efforts were not constraints and water was, micro land-leveling techniques could simultaneously increase yield and save up to four or more centimeters (168 m^3/feddan) water requirements per 14-day rotation period; if capital for mechanization were not a constraint, dragging or disking of plowed seedbeds could reduce percolation of irrigation water and the time required for initial irrigations after plowing; and if farmer organizational efforts were not constraints, water distribution schedules, mesqa maintenance and strategic marwa locations to provide all farmers with minimum requirements for all fields could increase yields for tail-end farmers and for the total system without increasing total water requirements.

Individually and collectively, these practices could also reduce costs of recycling drainage water by retaining higher quality water in the main canals. Drainage water could be reduced to the minimum required to control salinity levels in the farm soils.

In sum, the financial returns to the farmers for conserving water apparently are very low, or zero. The increased financial returns from potential crop yield increases that could be realized from additional resources invested in on-farm water management are either not evident or not sufficient to encourage farmers to make these investments, but this may be more because of price levels for farm products than low cost of water. If these observations are correct, EWUP studies should provide some insights about whether farmers simply need demonstrations and training on proven, profitable, on-farm water management techniques or whether the profitability incentives are insufficient. However, since no comprehensive farming system analysis is available, the opportunity cost of family labor (children, women and men) and management cannot be estimated directly. (In general, hired labor costs of LE 3.00 per day for children and women and LE 5.00 per day for adult male labor might be used as proxy estimates).

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[8]References: 51, 57, 123, 124, 125.

The Egyptian agricultural labor force is still growing, but appears to be peaking at about 4,300,000. As a percent of the total labor force, agriculture has declined from about 43 percent in 1976 to about 37 percent in 1981-82. In current factor costs, agriculture's contributions to Egypt's gross domestic product (GDP) has more than doubled during this five-year period, but total GDP has tripled. In spite of a two plus percent annual growth rate over the past 20 years, Egypt's agriculture has gone from a net export surplus to importing about 50 percent of the country's total food needs.

If agriculture is to continue providing employment at its current level (almost entirely family farms), farm productivity and profits must increase and capture a greater share of the growing demand. Growth requires investment and investors. The vast majority of investors in Egypt are small farmers. With the right incentives, they represent a tremendous reserve of managerial skills and labor capital. Furthermore, they possess limited, but under-exploited land, and solar and water resources that are unexcelled worldwide. With modest investment in available technology packages and socially compatible farmer organizations, combined with coordinated farmer organization, MOI and MOA research and extension input; substantial increases in agricultural production has already been demonstrated in Egypt. Using lessons learned, these programs can be expanded economically and efficiently with similar results. Productivity increases subsequent to the exploitation of the currently available technology packages will depend upon more advanced research, agricultural transportation and communications, farmer organizations, market incentives and investments, but the stage is set for a more dynamic agriculture. Farm youth (age 20 to 40 years) would still be looking for career opportunities off their small farms, but they would have a technically and organizationally richer farm background from which to build. The human resources produced by such farms will no longer be unskilled labor, but increasingly they will be entrepreneurs and engineers, graduates or not, but capable of creating jobs for themselves and others. The more dynamic agriculture could in itself provide opportunities beyond the old lands' farm gates.

Production Improvements

The Egyptian farm economy is currently involved in a very interesting natural experiment that can be analyzed to guide policy on a positive course for the rest of the 20th Century. If policy analysts can agree on the proposition that "prices of cereal and cotton crops are regulated to the extent that farmers have typically allocated their incremental capital, labor, management and organizational resources to the production of nonregulated crops, to construction and furnishing of improved housing, and to the education of their children," a relatively consistent analysis of the potentials for increased farmer involvement in food crop production follows.

Consistent with the above proposition, it may be argued that to allow reallocation of resources previously invested in production of the regulated crops, Egyptian farmers are making investments in timesaving technology (renting or buying irrigation pumps, hiring backhoe operators to clean mesqas) to the exclusion of proven complimentary yield increasing practices such as field preparation; improved seed; optimum plant populations and fertilizer rates; hoeing and thinning; weed and pest control; or simply harvesting the crop once it has been dutifully grown.

These production-increasing practices require capital, organization, labor and management that are currently rewarded at higher rates elsewhere. Two types of rewards, however, are currently attracting these resources back into cereal production. First are the cereal production and water management pilot projects that have used intensive human relations and advocacy programs to sell project farmers on the merits of the package of yield-increasing and efficient irrigation practices. Initially, the rewards of the pilot projects are the privilege of participating in a novel intensive extension demonstration effort and the promise of higher yields. Until this year, farm prices in real terms were actually declining in recent years. However, to the extent that promises of higher yields were realized, farmers report continued use of many practices. In general, the pilot project yield gains have been a dramatic 50 percent or more.

Secondly, experience with price increases for the regulated crops this year (1985) demonstrate clearly that farmers will return resources to cereal and cotton production if the price is right. Twenty-eight percent increases in cotton prices this year, after several years of declining real prices, have resulted in significant production increases (or at least farmers have found more labor to pick up their crop); producers of cereal crops are responding as well.

The response could be even greater if both rewards were combined. This is indicated by the results of the various cereal pilot projects. The yields of rice on 25,000 feddans grown by some 14,000 pilot project farmers last summer (1985) have been estimated to be near world record levels of 10 metric tons/ha (mt/ha) compared to a current national average of 5.9 mt/ha (4.2 tons versus 2.46 tons per feddan). Previous smaller pilot projects without the benefit of higher real prices were yielding nine tons per hectare (3.8 tons per feddan). Increases in the important straw crop have been equally dramatic. These pilot project gains have been accomplished through intensive extension demonstrations of currently recommended practices. With the recent price increases of 24 percent for rice, the intensive extension efforts, which have taken several years to cover 25,000 acres, may be spread more rapidly and economically to the farmers of Egypt's nearly one million feddans of rice. Similar successes are being experienced in the other major cereals pilot projects (e.g., EMCIP).

Without either of these incentives—pilot projects or prices—yields of cereal farmers have stagnated. Farmers' investments in irrigation pumps have not resulted in higher yields, but they have resulted in saving time and labor that can be transferred to other farm enterprises (e.g., meat and milk production or vegetable production) or to construction jobs in the city where food prices are low and rents are free if one lives in the building under construction, or to go abroad, where wages are attractive. Wages for unskilled labor are often quoted to be LE 5.00 per day for men, and LE 3.00 for women and children. If the farmer is to become more involved in farming and water user organizations, he will have to see the promise of greater returns to his efforts. Egyptian farmers have demonstrated organizations that have evolved in response to different social-ecological environments. Large gravity flow systems of the Fayoum have evoked different organizational responses than have the Delta lift systems, but in each case farmers have organized to maximize their utility from the irrigation delivery system. Organizational resources of farmers are not much different than capital, labor or managerial resources. The main difference is that the benefits must serve the goals of the whole organization and its membership, rather than just the family. For most Egyptian farmers, those goals are not greatly different, however.

Egyptian policy makers, including those in MOI, have much to contribute and to learn from this rather grand national experiment. One of the greatest lessons may be that the Egyptian farmer may command sufficient resources to greatly expand the current total public and private sector investment in agriculture, and as a result, easily achieve 4 percent growth rates in Egypt's agriculture for the remainder of the 20th Century. Higher irrigation efficiencies will also be possible.

Adjustments induced by policy actions may not bring about maximum food production because that maximization does not coincide with the farmer's goal of maximum economic benefit. This is the case on the old land farms in Egypt. In a free market arrangement where supply and demand regulate economic rewards and penalties, maximum production and maximum economic benefits approach each other within the limits imposed by annual uncontrollable variations in natural forces. However, when farmers are free to react to economic pressures, they generally move to a totally higher production function which generates more production than the old one forced by external control procedures.

Under certain circumstances societal forces may dictate that a disequilibrium exist in any one or among all of the sectors in a country. This is well recognized, and has been the situation in Egypt for some time. However, the unnatural constraints on agriculture should be removed as soon as possible. Let the agricultural sector strike its own equilibrium over the next few years and food production will increase dramatically. Also, water now wasted in the irrigation system will be reduced.

Inputs, Research and Technology Transfer

Old Lands

In Egypt there is a wide array of agencies concerned with and conducting applied and basic agricultural research. The Ministry of Agriculture and Food Security (MOA) administers the Agricultural Research Center (ARC) which contains 13 Research Institutes. The most important of these, in terms of on-farm water management, are the Soil and Water, Cotton, Sugar Crops, Field Crops and Horticultural Crops Research Institutes, respectively.

The MOI administers the Water Research Center (WRC) which contains 11 institutes. The Irrigation Methods and Water Distribution Institute represents the main WRC focus on on-farm water management.

In addition, there is the National Research Center that contains soils and biology staffs pertinent to agriculture and the Academy of Scientific Research and Technology which participates in agricultural research through its Food Council. Most significantly, Egypt maintains an extensive system of higher education; there are 14 universities with faculties of agriculture, several of which award M.S. and Ph.D. degrees. Thesis and dissertation research projects are often done in collaboration with the research institutes. All agricultural research is managed at the national level.

The research centers and universities are staffed with a high proportion of researchers and teachers holding Ph.D. degrees. These degrees have been awarded by Egyptian universities and also a wide array of European and American universities. The installed capacity for effective agricultural research and development should not be a limiting factor in Egypt.

Despite the size and quality of the agricultural Research and Extension R&D establishment, there are general inefficiencies as a result of two limiting factors. First, lack of effective research management, and second, actually related to the first, lack of research coordination and communication among the disparate agencies. Research is highly compartmentalized with inadequate communication with and between institutes and within and between research centers.

With regard to agricultural extension and technology transfer, the picture is somewhat different. The extension system is housed in MOA jointly with the respective governates. Although the Research Centers are expected to communicate with production agriculture through extension, there appears to be little awareness or desire on the part of ARC, WRC and NRC researchers to spend time on the farm. Currently extension is largely preoccupied with administering government crop (principally wheat and cotton) planting and general subsidy programs. As such, the Extension Service is serving mainly as a policy management agency. Egyptian agricultural extension, in its true meaning, can be characterized as rudimentary at the present time.

An important exception to the foregoing generalization may be seen in the results of three AID-supported programs that have recently (or are in the process of being) phased out. These include the EMCIP (Egyptian Major Cereals Improvement Program), the EWUP (Egyptian Water Use and Maintenance Project) and the ERRAT (Egyptian Rice Research and Training). All of these programs were largely extension oriented, with most of their efforts devoted to on-farm demonstrations and farmer training. Large increases in yield, up to 65 percent, were realized very quickly under these programs. The most notable single aspect of these crop production improvement programs is that Egyptian farmers are ready, willing and able to adopt more productive and profitable agricultural practices if these are made available to them. In other words, the Egyptian farmer per se appears not to be a general or specific constraint to higher productivity on the land.

Old New Lands

The Egyptian Research and Extension (R&E) system is outlined in the discussion of old lands above. One observation is added here with regard to old new lands. These lands have peculiar management requirements, and therefore peculiar R&E objectives and methodologies. Irrigation engineering R&E carries the major burden for improving irrigated crop production on sandy soils, which require highly specific and timely operations and inputs.

Farm Economics[9]

Old Lands

All reports dealing with farm or crop economics show positive net returns per feddan and to water. However, total farm net income is low because of the small size of farms and the low level of the net returns. Also, for controlled crops the net income is lower than for those not controlled by prices or areas planted as set by the Government. Thus, total net farm income is artificially low because of the controls. Other economic issues will be discussed in the remainder of this section and all have a bearing on farm economics. In Egypt, water is a critical input; but it must be managed along with many other factors at the farm level. The payoff for all of the extensive water delivery system is at the user level. Farms and farmers are where water system values of the agricultural sector occur.

Ninety-five percent of the farmers own less than five feddans, or on an average farm, about two feddans. Therefore, there are approximately three million holdings. If the average size of farm family is six people, there are about 18 million people on old land farms. There are probably less than 18 million, because evidence indicates that many owners rent their parcels of land to other farmers. At any rate, large resources of land and people are involved in old land farming. They all depend upon water delivered near their farms in canals built and maintained by the Government. No charge is made for water as such; however, farmers must generally lift water from the mesqa to their fields. Because of uncertain deliveries along the mesqas, poor seedbed preparation, other agronomic problems and poorly maintained mesqas, there is a tendency to overirrigate when water is available. Very little irrigation extension work is done with farmers except as a few projects have obtained funds for that purpose. Production on old lands is low relative to its potential.

Farmers will adjust to constraints over time to maximize their economic benefits. As constraints are removed, they adjust to a newly perceived maximizing situation. Often adjustments for the total farm population come about slowly because not all see changes in the same way, nor are they sure that changes are permanent. This is true especially when changes seem to be arbitrary.

Opportunities do exist on the old lands for increasing production substantially. Studies confirm that 30 to 60 percent increases in yield of food grains, rice, lentils, maize and other crops are possible without

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[9]References: 7, 11, 16, 17, 20, 22, 40, 42, 43, 53, 58, 59, 61, 64, 66, 70, 71, 72, 77, 78, 81, 82, 83, 84, 86, 90, 91, 94, 95, 96, 97, 98, 106, 109, 112, 115, 116, 119, 120, 121.

large increases in capital investment. Increased yields were realized by farmers adjusting their agronomic packages, including changes in irrigation practices. The packages were recommended by Agricultural Extension agents using practices determined by research. In one project nearly 100,000 farmers in 10 governorates participated in demonstrating the programs in 1984. The economic benefits were obvious and most of the farmers continued using the new agronomic packages after they left the program. Also, neighboring farmers changed their traditional farming methods to be in line with the demonstrated packages.

There are opportunities for further incremental increases in yields, but they will cost more. The economic benefits will not be obvious. The next round of increased yields will require more capital investment, a better and more broadly informed extension program, some mechanization and more refined farm management skills--especially in irrigation practices.

Full productivity in Egypt's old lands will require adjusting the size of operating units to accommodate mechanization. Large on-farm controlled irrigation systems to replace the great number of independent systems now extant will need to be developed. An enlarged extension program with irrigation specialists for farmer education in irrigation methods and rates of water use in relation to the other complementary factors of production will be needed. In addition, the basic agronomic and irrigation research necessary to keep ahead of the farmers' needs will have to be supported. As the benefits become more subtle, research in the fields of economics and sociology can make the difference in farm level decisions.

Implementing the above suggestions will take time. During the development period, confusion will exist, but in the long run the benefits will exceed the costs many times, and Egypt will more nearly approach the goal of reaching maximum potential food production on the old lands.

Old New Lands

As part of the program to increase the area on which food can be produced, new lands have been reclaimed. Canals were built, drainage systems installed and farmers moved into the areas. Some areas were organized as public farm companies with farmers receiving a wage for their labor and a share in the profits, if any. Villages were established for farm workers and their families. A public farm company is administered by a chairman and a board of directors.

Most of the old new lands were marginal agricultural lands and they still have unique problems that restrict their potential productivity. However, they do have the potential to produce more than they are at present. The internal and external constraints are much the same as on the old lands.

Management is the most important factor in improving productivity on these lands, which are more fragile than the old lands. Management decisions must be made regarding the sensitive reactions of the land resource to continuous farming, slowly deteriorating water quality, light sandy soils, etc. Hesitation in recognizing approaching problems can amplify those problems and sometimes create irreversible situations. Managers must be wholly committed to their farms and to their workers' physical and social requirements. Bonuses for reaching reasonable productivity levels will encourage more attention to solving production problems.

Private farmers on the old new lands areas face the same problems as private farmers on the old lands areas, plus they face the other unique problems mentioned above in order to maximize economic production. With knowledge available now, yields could be raised for most crops by adjusting agronomic and irrigation practices. Again, a well staffed and trained extension service including water management specialists, agronomists and others working at the farmer level can make a difference in old new land productivity. These lands have not reached the ceilings in yields under the present institutional arrangement. Reaching the full potential will require shifts in size of farm, mechanization, irrigation methods and other institutional situations, as discussed in other sections of this report.

Overall System Management[10]

The Nile system, in oversimplified terms, is comprised of the watershed above High Aswan Dam, Lake Nasser which provides annual carryover regulation, and the Nile River itself. Achieving the objective of the system to deliver water in the amounts and at the times needed for optimal crop production within available supplies means translating time wise evapotranspiration needs to barrage operation, pumping and releases at Lake Nasser. Use of improved data collection and communications technology and modern modeling techniques can continue to refine overall system management, with consequent savings of water now lost through operations.

[10]References: 17, 81, 114, 118.

Nile River Sources

About 84 percent of the Nile River flows available at Aswan come from the Ethiopian Plateau comprising the Blue Nile, River Atbara and Sobat River. The White Nile flows from Lake Victoria in Kenya, Uganda and Tanzania and supplies approximately 16 percent of the total. It passes through southern Sudan and joins the Blue Nile near Khartoum. Nearly half of the White Nile supply is lost through evapotranspiration from swamps in its upper reaches in south Sudan and on the Victorian Plateau. There are opportunities to reclaim much of this loss through channelization. One project, Jonglei Phase I, which would increase flows into Lake Nasser by an estimated 2.0 billion m^3/year, has been started but has been suspended because of political conditions in the region. In addition to the potential for increasing supplies, more accurate prediction of runoff into Lake Nasser using rainfall and river flow modeling could also improve system operations. Work has been initiated using two models using the Sacramento type rainfall-runoff model developed in the U.S.A. by the Weather Service is used for runoff predictions and a mathematical model for the Upper Nile from the outlet of Lake Albert on the Victoria Plateau to Aswan uses a constrained linear system approach (CLS) developed in the IBM Scientific Center at Pesa, Italy. Flow is simulated on a ten-day basis.

Irrigation Requirements

Currently annual and monthly irrigation demands are estimated each year and are based upon cropping patterns furnished by the Ministry of Agriculture. Deliveries are adjusted throughout the year as demand dictates. Water level data is now transmitted by telephone and discharges are adjusted accordingly. A telemetry system using meteor burst VHF technology is being implemented under a USAID-funded program. This will collect data from 255 stations and transmit it every two hours to central location to provide the information needed to improve the management of the overall distribution system.

Nile River and Barrages - Operational Distribution Model

The operational distribution model currently under development considers the operation of the barrages on the Nile and the principal canals that are gravity fed from the river. A primary concern is the reduction of water losses though excessive wastage to the Mediterranean and unnecessary consumptive use. This hydraulic simulation model can calculate changing conditions such as water levels and flows. Time delays in water movement are automatically included and the model will provide gate movement schedules to meet the various water requirements without violating system operating constraints. The model will take into account the effects of local barrage operating decisions on the entire system to a degree not now possible and will provide day-to-day operational planning.

High Aswan Dam Current Operating Policies

The High Aswan Dam is currently operated using two reservoir control rules; an upper which enables the reservoir to be drawn down in anticipation of the annual Nile flood, and a lower rule which enables the demands placed on the reservoir for irrigation and water supply to be met with the desired reliability. The use of the reservoir for flood control conflicts with the future objective of maximizing energy production.

Two models are used. A "dynamic programming" model (prepared by the Water Planning Group of the Irrigation Planning Sector) has allowed energy production to be maximized within the constraints of meeting the irrigation and water supply demands and of maintaining the storage required for flood control. The operating rules for the High Aswan Dam can be tested through a separate simulation model, in which all inputs, outputs and losses are accounted for on a monthly time scale. The simulation model is essentially a simple water balance model in which losses through evaporation, seepage and bank storage effects are considered.

Private Sector Involvement[11]

The Government of Egypt has provided considerable inducement to encourage private capital to be turned to new land reclamation. It has provided most of the infrastructure such as power lines, roads, communication, and where surface water is available, the canal delivery system. Credit has also been made available at low interest rates with grace periods on repayment schedules and other types of physical and financial assistance. Some of these latter concessions are in the form of subsidies on input prices; however, these are offset to some extent by Government established low prices for some crops. Out of a total of LE 34.1 billion for total investment in its present Five-Year Plan, 23.5 percent is expected to come from the private sector (See Table 1).

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[11]References: 5, 27, 32, 33, 37, 41, 46, 48, 95, 98, 100, 104, 110, 121; notes on the next Five-Year Plan.

Most studies indicate that net farm returns per feddan are low and often negative on new lands farms. The possible explanation for low productivity is management having to learn to cope with the fragile environment. There are some examples of farms showing high returns. At the same time, a large investment must be made initially and losses incurred for three to five years or more before positive net incomes can be expected. The risks are high and the number of individuals or groups of people willing to take those risks are relatively few. After a few risk takers have proven success can be realized, more people will invest in new lands development. At the present time private and Government interests are in the learning process—learning how to tame these wild resources. Government can provide more encouragement to the private sector by decontrolling all product prices and area quotas and providing an information transfer system while continuing its infrastructure contribution. Private involvement in the old lands and old new lands areas is in the form of capital investment for pumps, animals, energy, labor and original land values.

The private sector gets involved in the water management development works. Private companies as well as public companies contract for various infrastructure jobs in the system. Therefore, money spent by the MOI creates employment of many types and for many people. The following table gives the anticipated public investment in water programs for the next Five-Year Plan:

Public Companies	LE. 63 mil
Water Research Center	43
Survey Authority	24
Aswan Dam Authority	50
Shore Protection Authority	130
Drainage Projects	450
Mech. and Elec. Dept.	146
Irrigation Department	1,217
Irrigation Systems Development	258
TOTAL	2,380

It is estimated that the private sector will be more involved in the development of the old lands, old new lands and new lands by investing about 35% of the total national investments in the agricultural sector during the next Five-Year Plan as compared to 27.5% in the current Five-Year Plan.

Policy and Institutional Considerations

Factors Affecting Water Use Efficiency[12]

At the time the Aswan Dam was constructed, a general feeling existed that Egypt had enough water to satisfy all anticipated future uses. Lately that optimism has faded. Those responsible for managing water resources in Egypt are concerned about the future and are making plans to encourage more efficient water use in agriculture as well as in other economic sectors. Some of the factors which will affect the future are as follows:

1. Population is increasing rapidly. A million people are added every ten months. By the year 2,000 population is expected to reach about 67 million. The number of people is increasing faster than food production. The large food imports create serious balance of payment deficits which have to be paid for by external loans.

2. People have been moving from the rural areas into the cities at a high rate to take advantage of work opportunities. Farm labor costs have risen to about LE 5.00 per day for a man, about 500 percent higher than 15 years ago. Egypt's agriculture is still labor-intensive and children and women make up a large share of the present labor force on the farms. The labor shortage for some crops is serious, especially during planting and harvesting periods.

3. In 1952 Egypt instigated a land reform program that reduced the amount of land a person could own. This was a necessary social adjustment required by pressures of modern times, and made former farm laborers owners. Many beneficial effects have resulted. However, over 95 percent of the farmers have less than five feddans, and a large part of those control less than 1.0 feddan. The negative results have been to effectively place a ceiling on technological change in agriculture. Farmers cannot afford the modern machines which would boost yields above the human labor methods used. This is especially observed in on-farm water management. Government can get water to the mesqas, but it cannot change on-farm water management when the farmers can only afford a short-handled general purpose implement.

4. Agriculture is the oldest and most stable sector in Egypt. In order to help the other sectors develop, the Government made some social decisions. Food prices were held below world prices to help the poor.

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[12]References: 6, 9, 10, 13, 17, 26, 27, 32, 33, 37, 46, 48, 54, 57, 59, 60, 64, 67, 71, 73, 75, 81, 82, 90, 91, 94, 95, 97, 98, 104, 105, 106, 108, 111, 112, 113,116, 119, 120, 121.

Major food crop prices were also kept below world prices. This resulted in a transfer of agricultural surplus (income over that necessary to keep farmers producing) to other sectors needing serious attention. Farmers are required to plant specified percentages of their land to controlled crops (rice, cotton, wheat, etc.) at appropriate times of the year. They could not legally produce that combination of crops and livestock that would maximize their net incomes. The Government, through farmer cooperatives, provides seed, fertilizer, some machines for rent, and other inputs at subsidized prices. Governmental programs of this kind, though defended on social grounds, reduce the farmer's income incentives to change as economic conditions shift. Because of the transfers, many of the other sectors are better able to serve, e.g., communication, education. However, the surplus transfer out of agriculture has a negative effect on food production.

5. The high cost of reclaiming new lands, as well as the three or more years required to produce positive net returns over operating costs, dampens the interest of investors. However, given the increasing food shortage in Egypt, the best of these lands must be developed. In the long run the payoff will justify their development. However, these land resources are extremely fragile and improper development could spoil them forever. There are enough opportunities in the identified new lands areas to absorb all of the private and public capital available for many years. Generally speaking, private capital will do a better job of development because individual, family or group wealth is committed. Present Government concessions in interest rates, grace period for repayment of loans, production loans, absorption of the costs of delivering surface water to the sites, etc. will encourage private capital. A few successes will attract more and more private capital. However, the Government can speed up the process by providing research, information transfer services, superstructure in the form of roads, power lines, communication services, etc. A most important contribution to Government is a well-received research and extension program. In these new lands, large farms are needed because modern, large-scale machines and equipment are needed. There may be a need for an economic surplus shift from the rest of the economy to encourage a more rapid and secure development of these agricultural resources.

6. Water quality is changing. Nile water has been suitable for irrigation for centuries. Now under controlled irrigation some areas are developing saline soils as a result of water management techniques. The water table, drainage systems, increased salinity of water supplies, etc. all affect farm production negatively. Correcting these potentially resource damaging problems will be costly once they have reached the stages where simply modifying irrigation practices can no longer correct them.

7. Water supplies may eventually become scarce. Water as such now costs a farmer nothing. He has to have a saqia powered by animals or a pump using fuel or electricity, but he does not pay directly for the amount of water he uses. He pays indirectly in the form of the power he uses to lift water, a land tax, a crop tax, etc. However, most of these costs are fixed costs. They are not connected with the quantity of water used. Therefore, he has no incentive to use less water. There is no economic constraint to overirrigation while the water is running. If water is scarce and the farmer knows it, he will tend to reduce its use to the highest economic crop yield per unit of water, which will be less than the maximum crop yield; yet it will place him on a higher production function. Introduction of water charges based on the volume of water used has been proposed as a means for encouraging more efficient use of water. The issue of water charges is discussed under the Policy Issues section of Chapter III. How water management is done is a problem to be solved by farmers and appropriate MOI and MOA personnel. There are localized water shortages now and many farmers do not get all they want. Whether the amount they want is what they need to maximize their economic position is a question for research.

8. Inter-Ministerial coordination takes place now. The MOI, the MOA, the MLR and other MInistries have committees that study joint problems, but these activities need to be extended to field level. Research and extension development should receive the main emphasis of the committees. Members should spend full time on their committee assignments and should be multi-disciplinary and free to attack problems in the field, not only at the administrative and planning levels. Farmer involvement should be required.

9. Farmer training is necessary if farmers are to understand the importance of methods of irrigation and the costs and benefits associated with them. Before farmers can be approached, people have to be prepared to carry the message of water management to them. If someone can demonstrate to farmers that benefits will come by changing irrigation methods, they will change. Benefits do not necessarily need to be in monetary terms. The person who does farmer training does not have to be the scientist who designed a structure in the system. The farm irrigation extension people have to understand farmers and their total operation. Virtually everyone who studies Egyptian water management problems emphasizes training. There are three types of people to be trained -- scientific research people, scientific extension personnel and the applied "scientific" farmer. Each area requires the necessary support institutions, facilities, transportation, operating budgets and policies.

10. In virtually all reports written on water use in Egyptian agriculture, operation and maintenance are stated as important components of any irrigation system. Budgets for these activities are usually

underestimated. New structures and equipment are financed easier than maintenance needs. The results are broken, inefficient systems that have to be replaced at half-life. Cost of preventative maintenance and well-trained operator personnel can save money in the long-run.

11. Water is only one factor in the production of food in Egypt. Improved varieties, fertilizer, labor, land preparation, irrigation schedules, timeliness of each operation, etc. are all complementary with water in the science and art of food production. All of the factors together can increase yields beyond those experienced by each factor separately. Thus, an interdisciplinary approach should be taken to on-farm water management research and application, with the farmer participating in the applied areas.

CHAPTER III

MEDIUM AND LONG-TERM PLANNING ISSUES

Expansion of New Lands

Potential Development

Studies recently conducted under the Land Master Plan (41, 115) by GARPAD (General Authority for Rehabilitation Projects and Agricultural Development), an agency of the MLR, identified a total area of 2.6 mil feddans of new lands suitable for reclamation. Table 2 provides a detailed accounting of the reclaimable areas throughout the country. Additional water resources identified by the MOI for irrigation of the new lands includes the water to be developed by completion of the Jonglei Canal Phase I, improved overall water use efficiencies, and water released from withdrawal of old agricultural lands. The area that could be reclaimed using these additional resources is estimated to be 1.6 mil. feddans.[1] Reclaiming the balance necessitates the implementation of Upper Nile projects in addition to Jonglei Phase I.

Considerations by Soil Type

Based on the Team's review of the New Lands development to date, the following comments are offered regarding the settlement of New Lands by the three major soil types.

Development on Clayey Soils. Because of their traditional old lands nature, MLR expects that no special extension services will be needed in these areas. However, EWUP and ERRAT successes with packages of on-farm water management and agronomic practices in the Northern Delta projects suggest that settlers on these surface-drained, heavy clayey soils could benefit greatly from intensified extension and on-farm water management demonstrations. The costs of intensive extension demonstrations to MLR could be offset by reduced investment in settler housing. Since settlers are eager to farm these lands, some consultants have recommended that settlers provide for their own housing. As seen in Table 1, private sector investment in housing (population) accounts for about 44.2 percent of all private sector investment, more than three times the private sector investment in agriculture. Therefore, the recommendation is not unreasonable.

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[1] These estimates differ slightly from those given in Chapter II because of differences in estimates of consumptive use rates per feddan.

Development on Fine Sandy and Calcareous Soils. Two overriding trends led several observers to a similar conclusion that new lands development involving settlers must proceed with considerable caution and research (5, 12, 14, 41). First, the fruit and vegetable markets underpinning favorable feasibility studies of new land development (48) are highly speculative and could be saturated rapidly. Depending upon the success of currently maturing joint ventures in the new lands the rate of private investment could accelerate and saturate local markets. The competitive nature and quality requirements of the international markets, especially the European market, would require the expertise and market links commanded only by the large joint venture farms on the new lands. Therefore, the prospects of settlers producing for international markets appears dim. Second, as those markets approach maturity, the sprinkler irrigation system of settlers on sandy soils, based on observations of old new lands settlements, will have degenerated to surface irrigation efficiencies (12, 15). The IRR and returns to water for rehabilitation of the system at that time are not likely to be favorable.

At that point, the question as to whether the old lands or the new lands are the most productive use of scarce water resources will be moot. That question should be given more serious attention now. Research should be designed and implemented now to clarify the choices. Can research find or produce sprinkler, gated pipe or other water-efficient irrigation technology that can be maintained by settlers with no more expense, labor, organizational or managerial skill, and/or technical expertise than is required for surface irrigation systems, and increase the settlers productivity at the same time? Alternately, is new land farming on fine sandy soils by settlers sufficiently profitable that they could be charged for water, providing them incentives to learn to maintain more efficient irrigation systems?

If positive answers cannot be foreseen to any of these questions, it appears expansion of new lands for settlers must remain at the level of modest test projects. Apparently, there are a large number of settlers already in place on sandy old new lands that could be incorporated into rehabilitated pilot projects (5). Once positive answers can be demonstrated with settlers already in place, new land pilot projects may be worth the risk.

Development of Coarse Desert Soils. Justification for early development of coarse desert soils is and should be couched entirely in their potential to generate foreign investment and foreign exchange savings and/or earnings over the next ten to twenty years. The high level of risk and high-tech skills associated with the development of these lands should not be assumed by settler and graduate small-holders. Similarly, the Government of Egypt should not assume the majority of risk associated with production on these lands. If the public sector has an advantage in land reclamation, entrepreneurial and management skills are the comparative advantage of private capital.

Egypt's public sector should keep its rate of reclamation of these lands in line with prospects for private capital development. This appears to be the emerging philosophy of Government policy for these lands.

Private and Public Sector Relationship

The reduced pace of new lands reclamation does offer Egypt's policy makers some important opportunities. Since the country's agricultural sector budget is about equally split between investment in new land reclamation (horizontal expansion in MOI terms) and investment in old lands and old-new lands reclamation (vertical expansion), some important tradeoffs are emerging as new information is generated.

The overriding opportunity is to reevaluate the allocation of scarce water resources to maximize agricultural production within the next ten years. Since public sector investment in agriculture is estimated to be more than 2.6 times that of the private sector (LE 2.9 billion versus LE 1.1 billion) for the current Five-Year Plan (Table 1), it is important that the relationship between public sector investment be understood.[2] If incremental public sector investment and expanded water resources go hand-in-hand, then private sector investment is almost sure to follow, but the more important question is to what extent and with what results. The public sector investment should be designed to accelerate private sector investment. Ultimately, private sector investment in agriculture needs to exceed that of the public sector if agriculture is to become dynamic and self-sustaining.[3] That, of course, will not happen unless the results of private investment are more profitable. This principle holds for the millions of traditional small farmers as well as for the larger farmers.

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[2]Note that these figures are current revised figures. The original plan document indicated public sector investment of LE 2.7 billion versus private sector of LE 1.0 billion. This would suggest that the private sector responds at a rate only equal to the increase in public sector investment.

[3]It is understood that substantial private sector "profits" have been transferred to the Government through regulated prices and markets for cereals and cotton, but the public sector investments are not achieving the dynamic growth potentials of the agricultural economy.

If it is understood that the purpose of public sector investment is to encourage the acceleration of private sector investment and improve the results both economically and financially, the evaluation of current public sector investment opportunities becomes much more focused. First there is the opportunity to evaluate the tradeoff between using scarce water resources on relatively more horizontal (new lands) development or relatively more vertical (old lands and old new lands) development.

On the old lands, the Agro Economic Model has been used to extrapolate the success of pilot cereal demonstration projects to the nation's total agricultural productivity (41). Pilot project successes were achieved largely through extension techniques while holding prices constraint. New data in 1985 offers the opportunity to extrapolate increasingly favorable pilot project results. Next year's data will provide the opportunity to evaluate the full impact of 1985 price increases for rice, wheat and cotton. With the new price incentives, extension demonstrations should be able to show accelerated adoption of the higher yielding practices. If both price incentives and extension demonstrations are used, the national goal of 4 percent growth rates for agriculture may not be unrealistic.

With respect to the new lands, opportunities exist to incorporate research findings into improved on-farm irrigation and water management designs using latest information and revisions in evaluation methodologies. Experience since the initiation of the current Five-Year Plan has provided valuable information on both old new lands and new lands that would be useful. In fact, the success of existing private sector projects on new lands is certain to be the single most influential information to private investors for making the decision of whether or not to risk additional investments in new lands.

Reevaluation of Project Priorities

While fewer public sector projects can be implemented on schedule, project selection can be based on their potentials to attract the most private investment. Urbanization and industrialization are proceeding in the regions of some of the projects. In some cases, access to roads and markets are increasing and making the rates of return for a given project more attractive than ever. Returns to extension inputs and private agribusiness also increase with the higher level of economic activity. In other cases, project locations may remain relatively quiet.

The original Water Master Plan Office economic evaluation of the new lands projects provides two criteria to rank each of the 52 project's value to the economy, IRR and Return to Water (48). Both criteria can be recomputed as new data becomes available. For example, changes in local wage scales could alter the rankings. Also, local transportation or marketing costs might be incorporated to reflect more or less efficient markets as localities urbanize. Many other economic costs may have changed that could be factored into the updated analysis.

All Ministries concerned with reclamation projects are generating data relevant to updating project priorities. Agro-economic model and other computer evaluation and simulation used routinely and updated regularly by the MOI Water Master Plan Office need to be used more intensively between Ministries to analyze their data (41).

Matching of Irrigation System Designs With Management Levels and Soils

Success in rehabilitation of certain projects in the old new lands (over one million feddans since 1952, of which 450,000 feddans are still operating at submarginal levels) may now be a better indicator of what to expect of new land settler development than anything else currently available. Successful experience is particularly needed in settling small farmers on the fine sandy soils. The new lands reclamation plan calls for as many as 60,000 settlers on these soils, but the recent World Bank Review (5) was not able to find encouraging examples of what the small farmers on large projects have been able to achieve on sandy soils. The basic flaw in the system was again diagnosed to be the lack of a reliable and timely water supply to individual farms. The movable sprinkler systems were in total disrepair and farmers were carrying water in buckets from the canal to watermelon patches. Both workable sprinkler irrigation designs and farming system packages with efficient extension training techniques remain to be developed. Once developed, sufficient credit and inputs (including spare parts) must be available to settlers and graduates. Finally, markets for the small farmers schemes must be at hand; then and only then can settler schemes be developed into intensive livelihood enterprises that can be replicated in other similarly favorable situations.

In the new lands, Winrock International (14) found both encouraging and discouraging examples. The latter were judged primarily to be due to selection of improper irrigation techniques for specific soil conditions and management capabilities. The encouraging cases were special cases and usually well located with respect to markets.

Staffing and Training

The continued loss of engineers suggests that Egypt's Education System and GOE public sector has a comparative advantage in producing and training engineers that pays off in private sector development and foreign exchange remittances. Perhaps MOI, MLR and MOA should consider joint sponsorship of accelerated university training of larger numbers of qualified agronomists and irrigation engineers to meet their own requirements and help supply the demand elsewhere. Projects that fail to be implemented on schedule result in losses to inflation as well as lost opportunities to train more engineers. If universities could produce engineers more efficiently and rapidly at least inflation of engineering, wages could be controlled.

Women in Egypt's agriculture is another related issue. Female engineers and trade school graduates should be considered more frequently for field positions. In turn, female engineers would have an advantage in recruiting bright farm women as farm organizational leaders and farm girls to take diploma and engineering degrees. The economic return to training farm women in the university and on the farm may be greater than training more men. The women are closer to the issue of putting food on the table than are the men. They often stay closer to the farm than do their spouses, and once trained they probably communicate farm skills to their neighbors at least as much as do their husbands. Similarly, female engineers would be less likely to go abroad after they are trained.

Interdepartmental and Interministerial Coordination

One GOE interministry mechanism that is already being used with flexibility could be used more generally. Contractual arrangements between agencies and public companies in competition with private sector companies is common. Similar mechanisms could be developed to do research on new land irrigation. In effect, the MLR has the equivalent of contracts or joint ventures with large private investors to demonstrate new land irrigation techniques and crops. Private capital—particularly that of international origin—probably has a comparative advantage in doing that kind of research.

However, with respect to settlers on fine sandy soils, drip and sprinkler technologies may not be sustainable. If domestic fruit and vegetable markets become saturated, cost-effective irrigated food production technologies for the settlers' new land will be needed. The possibility of this scenario is the major emphasis of Winrock International Institute's study of Egypt's irrigation techniques for the new lands (14). New efficient surface irrigation techniques (e.g., surge flow) for the fine sandy soils may be satisfactory in some areas. Easily maintained sprinkler systems are more likely needed to avoid seepage problems in most areas. In this capacity, the proposed Irrigation Advisory Service of the WRC may have major comparative advantages (84).

Commodity research teams from the MOA might be contracted to work with MOI on irrigation schedules for newly drained old lands. The IAS may be of immediate use to MLR in the Middle Delta new land project.

These modest examples illustrate a strategy for the more general need to coordinate development of extension and research activities of MOI, MOA and MLR. Rather than duplicating on-farm water management research and extension strategies within each Ministry, a general strategy of specialized task forces within each Ministry or agency needs to be agreed upon (Shaner, 110). Then, through contractual arrangements, each Ministry could draw upon the specialized skills of the other Ministries. Rather than sending personnel from one office to another for projects of short duration, whole teams could be kept together over longer periods of time to serve various projects of different Ministries. Lessons learned from various projects would be retained and more readily transferred to other engineers and professionals through both in-service training workshops and live field demonstrations.

Shore Protection

Because of its relevance to loss of the use of old lands, activities to reduce shore erosion at the Mediterranean coast are included in this section. These are carried out by MOI's Shore Protection Authority. Donor support for technical assistance for this program is being sought.

Strategy

The MOI does not have the lead role in formulating strategy for new lands development, but its estimates of available water supply set the boundaries for expansion. Its role in providing physical infrastructure is a reactive one. For the next six years, a target of 600,000 feddans is anticipated. MOI plans to provide canal infrastructure for this development and has tentatively targeted LE 292 million for the upcoming Five-Year Plan to complete the Al-Salam Canal serving the Eastern Delta Area, the Al-Nasr and Nassery canals in West Nubariya and the Ismailia Canal serving the East Delta. An additional LE 28 million is targeted for drainage reuse for horizontal expansion. The current Five-Year Plan carried LE 75 million for Jonglei Phase I, but this will not be spent because of interruption of construction. This sum is carried over into the upcoming Plan with the hope that construction will be resumed soon. Additionally, the MOI has proposed international donor support for a pilot study of water management in West Nubariya (15), and feasibility analysis for improving crop production in old new lands (26).

For shore protection, the upcoming plan target is LE 130 million. About one-half is for protection of the Damietta Promontory. Included is LE 22 million for studies and research.

Meanwhile, MOI will refine its estimates of available water supply and consumptive use requirements so that long-range new land targets may be more accurately defined. The Team recommends that the MLR take steps to improve the social and economic evaluation of new lands projects and the effectiveness of new lands development by monitoring and evaluation of ongoing development and by strengthening research, extension and supporting services, as discussed above. The role of the private sector should be continued; in fact, consideration should be given to expanding and broadening it, including involving it in assisting in devising development strategies and providing services for small farmers.

G. oundwater Development

Some opportunities for further development of groundwater sources for agricultural expansion exist. Groundwater supplies have been identified in the Nile Delta, the desert oases, the Nubian aquifer, in the West Desert and aquifers in the Sinai.

Nile Delta and Valley

All of the water in the Nile Delta and Valley comes from the Nile River. Therefore, any groundwater yield from this source will have to be considered as part of the 55.5 billion m^3/yr allotted to Egypt as its share of Nile River water. It cannot be considered as a new source, and must be calculated as part of the total river budget. The groundwater source, however, can be used conjunctively with surface water supplies as part of the distribution network for the Nile. Judicious location of wells could reduce canal sizes, equalize flow regimes and improve services, especially to tail-enders. The aquifer can serve as a surrogate for inefficient surface canals. The Groundwater Research Institute estimates the potential to be 4.9 billion m^3/yr. Its contribution to new lands will be measured by its contribution to increased system efficiency through improved management. Extreme care will have to be used, however, to be sure that extractions from the lower Delta will not accelerate salt water intrusion from the Mediterranean into the aquifer.

Western Desert-Nubian Aquifer

The Nubian Sandstone aquifer underlies a large portion of southwestern Egypt, southeastern Libya and northwestern Sudan. The aquifer is a porous sandstone, and has been faulted by ancient tectonic activity. The recharge to the aquifer comes from the southwest from Chad and Libya. The actual quantities of water that can be safely extracted have not yet been determined, but investigations are proceeding in order to estimate that amount. Joint investigations are moving forward with the Sudanese Government, but efforts to include Chad and Libya in the studies have not been successful. Attention is being given to effects of possible connections to other groundwater supplies.

Desert Oases

Water from groundwater sources appears on the surface of at least five desert oases located in a more or less circular arc to the west of the Nile and comprising the Kharga, Dakhla, Farafra and Bahariya oases. There is sufficient information on water supplies to support the development of an additional 100,000 feddans. There is some indication that there may be an interconnection between the Nubian aquifer and all of these oases. Further study is required. The potential to upset current water balances if major development takes place is a matter of concern. Current plans include development if the studies do not indicate adverse affects.

Sinai

Exploitable groundwater resources exist in Sinai in both alluvial and sandstone aquifers. In order to fully determine the extent of these resources, the MOI, with the participation of the EEC have adopted a project for water resources development. The project is assembling meteorological and hydrological data to be used in the water development studies. To achieve this purpose, a number of meteorological as well as flood monitoring stations have been constructed at different sites in the North Sinai. The research Institute of Water Resources Development of the MOI is currently running the project tasks.

Based on studies completed to date, plans have been developed for optimum utilization and integration of ground and surface water resources in several areas of Sinai.

Strategy

Groundwater development in the Western Desert is the responsibility of MLR,[4] but MOI has this responsibility in the Sinai and the Nile Valley and Delta. For the six-year short-term the Nile aquifer will be developed to better serve old lands, and a program of development will be started in the Sinai. A total expenditure of LE 190 million, including LE 110 million (including some surface water development) in the Sinai,

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[4]MLR's responsibility here is inherited from its predecessor agency. MOI's responsibility stems from a recent decree based on its supporting technical capability.

is targeted for the coming Five-Year Plan. International donor support for a feasibility study of ground and surface water supplies in the Nile Delta and Valley has been proposed by MOI (26).

Soil and Crop Management

Old Lands

The most immediate and most economical source of improved crop production in Egypt will be obtained by vertical development of the old lands. This will be followed in measure, not through water and land resource development, but through human resource development. Research and Extension (R&E) are the keys to the vertical development process.

Egypt's old lands are already producing at well above world averages for countries in similar stages of development. The Egypt Major Cereals Improvement Project (EMCIP), Egypt Water Use and Management Project (EWUP) and Egyptian Rice Research and Training Project (ERRAT) demonstrated that yield rates improved by 52, 54 and 81 percents, respectively, for wheat, rice and maize with improved technology. There are real input costs associated with these increases, but the single largest factor in achieving them is farm management skill. To expand the success of these crop production improvement programs, Egypt should emphasize human resource development, including both professional (R&E) agriculturalists and the land managers.

The "immediate" gains can be achieved with demonstrated, in-hand technology. Other gains can be anticipated when R&E "fine-tunes" the production inputs, especially as they relate to on-farm water management and associated interactions.

Priority Technical Issues. Fine-tuning of on-farm water and irrigated crop production management at the farm level needs first to be fine-tuned at the R&E level of human resource development. Issues that should be attacked immediately include the effect of improved on-farm water management on the water table. This will necessitate an evaluation of water table contribution to ET and eventually an evaluation of on-farm adjustments in water management procedures needed to satisfy ET after lowering the water table. A full understanding of the water table in the crop root zone should have top priority in irrigation engineering and soil science R&E programs. Water table control will have important meaning to soil salinization and its prevention or elimination. Water table control, together with improved irrigation, will also improve the efficiency of fertilizer nitrogen. In addition, water table control will simplify land preparation and speed up the transition between crop cycles, leading to increased cropping intensity.

Another aspect that needs R&E attention is the presence and amelioration of hardpans or tillage pans. When hardpans are present in soil they affect rooting depth, water infiltration and redistribution, water holding capacity and make the crop more drought-prone. The solution to soil hardpan problems first depends on an awareness of their existence.

There are several concepts of questionable validity commonly accepted by the R&E community. These concepts lead to questionable research objectives and methods in some cases. They also lead to invalid extension recommendations. The following concepts deserve to be challenged through well-designed and implemented research programs.

1. Calcareous soils, i.e., soils that contain calcium carbonate, become cemented at the surface upon irrigation.

2. High lime (i.e., calcium carbonate) content soil is a specific cause of plant nutritional disorders. (Some of the world's most productive soils are desert calcareous irrigated soils.)

3. Soil fertilization or foliar spraying with synthetic chelated minor elements represents a real solution to minor element deficiencies. (This is rarely, if ever, cost-effective; there is a need to utilize iron-efficient plant varieties.)

4. High line content soils represent a special problem in management of soil phosphorus fertility. (See note above on productivity of irrigated calcareous soils.)

In a different vein, vertical development of old lands should include improved harvesting (e.g., grain threshing) processing and storage of the harvested materials. Typically, 25 percent or more of the harvested crop is lost to spoilage and contamination before it reaches the consumer. Postharvest technology development could provide a rapid gain in food supplies with essentially no change in land productivity. If this is ignored, the increased productivity that will occur sooner or later will have a high risk of loss because the marketing and processing system is not geared to a larger volume.

Another facet of improved irrigation and soils management in the old lands is the potential for increased cropping intensity. This will require some mechanization, as previously stated, but shifting cropping intensity from the present 1.9 to 2.5 or higher on old lands would have marked impact on overall productivity.

Old New Lands

The marginal and submarginal productivity of the old new lands has been mentioned frequently. These lands in general include lower quality soils, but another important feature of old new lands developments should be brought into focus by the MOI and the MOA. This has to do with the experience factor. The settlers were transplanted to a completely different environment and were unprepared at the outset to manage difficult new problems. MOI, characteristically, delivered water to the mesqa level and left the land settlers to their own devices to learn entirely new irrigation methods such as sprinkle and drip irrigation and irrigation scheduling needs. The fact that cropping intensity is less than 1.0 on many old new lands can be ascribed in large measure to the isolation of the land managers and the lack of R&E backing that should have been available in both the MOI and the MOA.

The coarse texture, rapid water intake rate and low water holding capacity of many of the old new lands puts a special burden on irrigation engineering R&E. After on-farm water management is well developed, other factors of soil and crop management will fall into place.

Strategy

The foregoing discussion argues for strengthening and improving research and extension related to soil management and mechanization on irrigated farms. Emphasis should be given to further development of human resources for providing those services.

On-Farm Water Management

Background

Given existing conditions regarding on-farm water management in Egypt, the MOI realizes that if maximum production from limited resources, both land and water, is to occur, some modifications must be made to existing systems and management techniques, both on farms and in the delivery system. Various proposals have been made; some may have a greater impact than others, and some may have some effects which have not yet been considered.

Because the purpose of an irrigation distribution system is to deliver water for crop production, crop requirements dictate deliveries, and the delivery system should be geared and managed to meet those needs. An irrigation system, including the on-farm application, does not water a crop; it fills a reservoir from which plants draw water. How the water gets into the reservoir is immaterial to the plant; the crop is only sensitive to whether the water is there or not. The soil reservoir contains that water which it can hold by capillary action and cohesion against the pull of gravity. The capacity of the reservoir is dependent on soil type and the depth of the root zone of the crop. Irrigation efficiency simply measures how well the irrigation system performs in keeping water in the reservoir for crop use. If too much is applied, it runs off in the form of surface runoff, or drains out to the groundwater system. If an insufficient amount is added, production is reduced or nonexistent. With these principles in mind, conditions as they exist in Egypt and some of the policies and long-range plans which will govern actions of the MOI during the next one and one-half decades are discussed below.

The Nile River basin in Egypt is essentially a closed water system. All of the water that enters the valley comes in through the Nile and exits through it and through the diversions from it. The only losses are consumptive use by crops, weeds, animals, industries and people; surface flows out to the sea through the river and drainage water pumped to the sea and the northern lakes; escape into the Mediterranean by way of the groundwater aquifers; and possibly some recharge to the Tahrir aquifer northwest of the Delta. The available groundwater originates from the Nile itself.

Currently, the river system supplies are pretty well in balance with needs. For most of the year, water levels in the canals are constant. Irrigation is more or less constant also for a given canal command area and water tables and releases to the sea are fairly stable. Studies (41) have shown that the entire system, from Aswan to the Mediterranean, is about 65 percent efficient. That is, 65 percent of the water released through the Aswan Dam is used for productive purposes. Those same studies indicate that in order to maintain a salt balance in the system, an irrigation efficiency should not exceed 78 percent, which corresponds to a Nile system efficiency of 81 percent. For higher efficiencies, salt and saline conditions adverse to crop production will occur. These data indicate that the system as a whole is well managed.

Evapotranspiration Supplied by Groundwater

In contrast, quite low irrigation efficiencies ranging from 5 percent to about 40 percent, with an average around 30 percent, have been reported (60). These percentages are based on storage in the root zone only, and no consideration is given to waters going directly to the water table. Water tables under the fields are high (50 cm to 150 cm below ground level) due to deep percolation losses on the farms and seepage losses from canals and mesqas. The shallow depths to the water table restrict root growth, and hence the soil reservoir is reduced. Irrigation deliveries range from 8 to 12 days during the summer to 5 to 15 days during the winter months.

An analysis of the above conditions indicates that high water tables contribute significantly to crop ET requirements. Since the overall efficiency of the river system is currently 65 percent and some of the extractions are for nonirrigation purposes, the application efficiencies on the irrigated land must be considerably higher than the 30 to 40 percent being reported. First, some water from every irrigation is lost to the water table; second, with the restricted capacity of the soil moisture reservoir in the root zone, the extended time between irrigations, and considering computed evapotranspiration rates, plants could not survive from one irrigation to another, nor could production be optimized without additional water; third, crops do not appear to be heavily damaged by the long periods between irrigation. The conclusion is that plants must be drawing significant amounts of water back into the root zone from the water table by capillary actions. Thus, the actual soil reservoir under Egyptian conditions consists of two parts, the normal capillary soil reservoir plus the water table. Accordingly, when on-farm irrigation efficiencies are computed, the extraction from the water table must also be considered in the computation.

A specific example will illustrate this. In EWUP Technical Report No. 4 (60), some specific data from experiments conducted in fields served by the El-Hammami Canal are cited. On one particular field, 62 mm of water was applied to the field in one irrigation,. Only an estimated 25 mm could be stored in the root zone, so all of the remainder went to the groundwater. The irrigation efficiency was reported at 100(25/62), or 40 percent. The same study estimated that the evapotranspiration between irrigations was 50 mm with the balance coming from the water table. Because the water got into the water table from the irrigation in the first place, the irrigation efficiency should be computed as 100(50/62), or 80 percent. In the sandy soils of the area, the water from the root zone alone would have lasted for only half of the time between irrigations, and crop growth would have been severely retarded.

Another important contribution of the water table is evening out of head-end/tail-end deliveries along the mesqas. Water percolating to the water table tends to spread out over the entire area, making a higher contribution to ET at the tail-end and a larger contribution to groundwater at the head-end.

With the exception of recent EWUP reports, most of the analyses on irrigation efficiencies have ignored the groundwater contributions. This cannot be done when water budgets are prepared or more water will appear to be available in the system than really exists. This may mean that estimates of available water for agricultural expansion are likely to be revised downwards. This contention is also supported by Stoner (114). Careful attention should be given to the amount of groundwater uptake for evapotranspiration by crops. In general, there appears to be insufficient information on this matter.

The MOI is proceeding with a program for complete coverage of all old land farms with a system of tile drains. This will have many positive benefits to crop production, but will also necessitate some changes in irrigation methods. Lowering the water table will permit better root growth, which in turn will improve production. It will also reduce the amount of water the plant can draw from the water table; therefore, more water will have to be stored in the root zone. This will require more skill by the irrigators, better control of water and better balance between advance and recession times on fields. Also, the water table will no longer act as effectively as a buffer for redistributing the water along the mesqas, requiring greater control of water and cooperation among farmers. Increased delivery frequency may also be required. With these changes, matching delivery schedules to crop needs will be very important. Administrative "policy" designed to fit the whole country may not fit "typical" field situations.

Technology

Land Preparation. To accomplish the improved management of water that coming changes will demand, some essential farm practices must be widely adopted. One of these is improved seedbed preparation and many reports have made this recommendation. Tillage practices are needed which leave the land in a smoother condition before planting. This will permit faster movement of water over field surfaces and will, in itself, result in better distribution of water to the cropped areas.

Much has been said about precision land leveling. This practice will be a major step forward, and where it can be combined with other reclamation projects such as raising mesqas, may prove feasible. Due to the high level of investment required to carry out a major precision land leveling effort and demand for resources on priority projects, it is not likely that such an effort will be undertaken in the near future. However, much can be done using some simple on-farm control techniques to make intermediate improvements. As reported by EWUP (60), a three cm differential elevation across a particular irrigated area will not cause too much of a problem. This will be particularly true in loams and sandy soils where intake rates are relatively high. The difference in time for the water to cross the field will have a greater effect on the nonuniformity of the irrigation than the difference in elevation will. If areas are bunded, a practice with which farmers are already familiar, and are bunded, and are so designed that elevation differences are less than three cm, then approximately the same efficiencies as with precision land leveling will be obtained.

Size of Stream. The other component needed in order to have efficient irrigation without major land leveling is to use larger streams of water and more control within the field. Larger streams can only come by gravity delivery from mesqas to fields using higher heads and/or larger openings; or from increased pumping power. If farmers are required to pump from mesqas, then larger pumps must be used; saqias and tambours will not be adequate. Serious consideration ought to be given to EWUP's recommendation to explore purchase, or fabrication in Egypt, of small axial flow pumps as replacements for the saqias and tambours, and presently-used centrifugal pumps. All of these are inefficient for pumping from mesqas. Once larger streams are available, then better control of water within the farms will be necessary to make sure that water is not held on any one area for more time than is needed to fill the root zone. A major step which would help improve control would be to introduce canvas dams and shovels.

Larger flows to the fields also will require some changes in the ways water is handled in mesqas. Since the total volume inflow to the mesqa will be the same, larger streams will necessitate shorter time periods for each farmer. He will need to know how to adapt to the new system. A fixed, rigidly adhered to schedule will probably need to be adopted for each mesqa.

Amount and Timing of Irrigation. With changes in practice, changes may also need to be made in delivery schedules. With the lowering of water tables by drainage in the lighter, more sandy soils, less water for ET may be available from the water table. This could mean more water would need to be stored in the root zone or irrigation frequencies increased, especially for shallow-rooted crops. This possibility should be considered. Adoption of continuous flow in the branch canals and irrigation schedules along canals to mesqas may be desirable.

Irrigation Methods. For sandy soils, which include most of the new land development as well as portions of the old land areas, on-farm water application should be limited to sprinkler and trickle methods and their use enforced. In addition, innovative approaches to sprinkler and trickle irrigation should be considered. Given the small holdings under land tenure patterns which now exist, and those which are being developed for settlers and graduates for new lands, use of large, centrally managed irrigation units such as center pivot systems may not be practical. For example, in Latin America, in an area where land holding patterns are similar to those in Egypt, a system has been developed were water is delivered under pressure to a pipe outlet at one or two points on each field. By using a simple garden hose and sprinkler, a farmer can irrigate his entire plot simply by moving the sprinkler. Such a system could readily be adapted to Egyptian conditions.

Mesqa Maintenance. Mesqa maintenance is and will continue to be a problem as long as farmers are expected to do it with hand labor. Channel cross sections will be hard to maintain, and will continue to be choked with weeds. Conveyance losses will also be high because of the resulting increased evapotranspiration losses in the mesqa, and because of increased operational losses.[5] Both a long-range and a short-range program to move from present manual methods to power cleaning or chemical weed control, and more frequent maintenance operations are needed. In very light soils, serious consideration should be given to lining the mesqas.

Provisions for power cleaning should be made in any rehabilitation program for the mesqas. This will mean that structures for outlets from mesqas to the marwas or fields will have to be kept on the outside banks, and not placed inside where they will interfere with maintenance operations. Different types of structures than are now being used will probably be required. Concrete pipes sticking out into the mesqas preclude power cleaning.

While farmers are responsible for their individual fields, much of irrigation improvement requires services beyond farm boundaries. The MOI and the MOA cannot provide all of these required services themselves; therefore, an effective extension program of some kind to teach the farmers how to do much of the work will be required. For farmers to do their share will require techniques that are within their technical capability using equipment they already have, can rent, or that they can afford to purchase.

Strategy

The strategy for implementation of improved on-farm water use and management is to develop pilot areas in all directorates toward achieving the goals of the National Irrigation Improvement Program (NIIP). The

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[5]These are losses occurring when the system does not deliver water to the right place at the right time. Such water usually is wasted into drains or floods fields that do not need it.

EWUP identified most of the technical and some of the socioeconomic issues involved and contributed a great amount of information toward their solution. It also evolved a very promising process for pilot scale interventions, but replicable models still need to be developed. Besides implementing improved on-farm water management, the issues raised under the section on Soil and Crop Management above, it should also be studied at field level on these pilot sites. Generally, the program of rehabilitation (but not of routine O&M) of canals will be restricted to NIIP pilot areas known as the Regional Irrigation Improvement Program (RIIP). About 600,000 feddans are projected for the upcoming Five-Year Plan, bringing the total to about 800,000 feddans. Development of an "Irrigation Management System Authority" is proposed. The main objectives of this authority during the next Plan are:

* Remodeling of irrigation network in 600,000 feddans;
* Development of field irrigation in 400,000 feddans by recent control and distribution technologies;
* Minimizing water losses from irrigation canals;
* Developing of programs and principles for the management and maintenance of irrigation networks;
* Training of the technical staff; and
* Conjunctive use of groundwater, drainage réuse and surface water for irrigation.

Tentative investment cost estimates for MOI for the period through 1991-92 are LE 373 million, of which LE 25 million is for 1985-87. The MOI proposes creation of a separate Irrigation Management Systems Authority and has separately budgeted LE 258 million of the total of the next Five-Year Plan funds toward that end. The balance of LE 90 million is for support by the Irrigation Department. The investment costs (Chapter III funds) do not cover the full costs of activities on the pilot area, only the cost of new interventions. Much of the actual cost, including ongoing staff, will come from the recurring cost budget (Chapter II funds). One of the difficult tasks will be to assemble the needed multidisciplinary teams for the pilot projects. This will require cooperation of other Ministries, particularly MOA. The EWUP team by now is largely scattered.

The problem of improved irrigation systems management (on-farm and off-farm) is the key to vertical expansion of crop production in Egypt; accordingly, this activity may be the most crucial in the irrigation strategy portfolio. Six-year targets are to develop replicable models, and over the longer-term extend these as rapidly throughout the country as possible. How fast this can be accomplished will depend on the success of the shorter-term effort and the long-range availability of capital and human resources. The ultimate investment cost is estimated at LE 5,580 million.

On the technical side, the amounts of water contributed to crop ET by such high water tables, its effect on water balance calculations and the implications to irrigation practice by farmers of lowering those water tables, needs increased research. In addition, research is needed to show the effects of improved land smoothing, of increasing the size of streams delivered to fields and of improved mesqa maintenance on the level of efficiency.

Drainage and Salinity

Status

By the end of 1986, the area provided with tile drainage will total an estimated 3.1 million feddans. This is about two-thirds of the area requiring it (3). In 1984, the MOI, with African Development Bank (ADB) assistance, formulated a ten-year program to extend drainage to an additional 1.33 million feddans identified as having high water tables. The plan will install subsurface drainage serving 1.12 million feddans and remodel open drains serving 417,000 feddans. As stated in Chapter II, the estimated area of agricultural land that could be benefited by drainage totals 5.212 million feddans.

Subsurface drainage to date has been almost entirely by tile. While technically feasible using closely spaced open drains for subsurface drainage is impractical in Egypt because they use up too much land. Open drains are used to collect flows from the tile drains and wasted surface water from canals. In some areas, vertical drainage using wells may be a desirable alternative to tile, but this appears limited. It has not yet been tried on a practical scale and is under study by WRC's Groundwater Research Institute.

Strategy

Installation of drainage is expected to continue at a rate of about 200,000 feddans/yr, with final completion targeted before 2,000 A.D. Concurrent with the installation of the tile drainage system will be the construction and rehabilitation of the surface system required to go with it. Pump stations needed to lift the drainage water back into the Nile will also be installed.

Preliminary targets for the upcoming Five-Year Plan are to provide tile drainage to 750,000 feddans in the Delta and 100,000 feddans in the Nile Valley. Open drains would serve 500,000 feddans in the Delta and 280,000 feddans in Upper Egypt. Total cost is estimated at LE 450 million.[6] Completing the planned service to a total of 1.3 million feddans is estimated to cost an additional LE 263 million.

Diversion and Distribution Works[7]

Barrages

Three of the present Nile barrages have been in service for more than 80 years. The newest ones are the Edfina Barrage, built in 1951, and the two Delta barrages, which were rebuilt in 1939. Therefore, the barrages generally are approaching or have exceeded the normal service life for structures of this type. Concrete and masonry deterioration and cracking, rusting of gates, failure of metal parts and difficulties in gate operation are the common problems. Degradation of the Nile because of reduced silt load since the High Aswan Dam was commissioned is also a factor. Use of modern technology for gates (better materials, lighter and stronger designs, improved devices for raising and lowering gates and their automation, as well as improved structural design of the dams themselves) can greatly improve efficiency and reliability of operation. With old structures, the risk cost of failure or inadequate performance becomes increasingly high. With the reservoir regulation provided by the HAD, substantial opportunities to produce firm power at barrages and to improve navigation have been created.

Strategy. For the short-term, the targets are to replace Esna barrage and the earth dam at Damietta with modern barrages, including first-class navigation locks. Hydroelectric facilities at Esna will provide 78 MW of firm power (520 million kwh per year). The structure will also provide a modern 70-T capacity bridge serving a principal highway. The Damietta barrage will permit implementation of the El Salam Canal, which is essential part of the new lands program. Additionally, new locks and hydroelectric generating facilities will be provided at Nag Hammadi and Assiut barrages.

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[6]Estimated unit costs for open drains turn out to be about LE 120/feddan. In the Delta, for tile drainage, these average about LE 325/feddan, but LE 1,000/feddan in the Valley.

[7]References: 7, 8, 9, 10, 15, 16, 26, 39, 68, 69, 72, 79, 80, 110, 113, 117.

The estimated investment cost through 1991-92 is LE 594 million. Esna is expected to cost LE 260 million (Foreign Exchange Component [FC] LE 80 million); Damietta, LE 34 million (FC, LE 10 million) and Nag Hammadi and Assiut, LE 300 million (FC, LE 150 million). The annual replacement cost of the barrages has been calculated at LE 38.56 million.

For the longer terms, the condition and safety of the remaining barrages will be examined in the short-term, and plans for any needed replacement or rehabilitation developed so that by 2,000 A.D. works to bring the entire barrage system into a modern condition will have been initiated or planned for initiation within the succeeding few years. The Team attempted no quantitative review of benefits. Those from reduced O&M costs, increased reliability, improved navigation and hydroelectricity are substantial,[8] but the overriding consideration is the risk costs. Failure of a barrage to function fully or only partially would be very costly to Egypt's economy.

Operation

Lack of control of water is a serious constraint to increasing agricultural production. One of the main causes of poor drainage and soil salinization is poor water distribution. A principal cause of this problem is the poor condition of channels and control structures, including pumps. The situation is aggravated because farmers usually do not irrigate at night. Excess wastage to drains tends to aggravate water table problems, especially in the Delta where drainage water has to be pumped back into the system. Pumping capacities are exceeded, resulting in increased weed growth, thus compounding problems of drainage inefficiency. Further, rotation schedules may not match water requirements. Schedules are relatively fixed, whereas crop water needs change seasonally and throughout the growing season.

Another problem is variation in quantities delivered to mesqas or available for pumping between head- and tail-end reaches of mesqas. Studies under EWUP showed wide variation in amounts delivered by the Mansouria Canal to three of its branches, for example. This situation is

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[8]The financial cost for electrical energy is cited as LE 0.007/kwh, but its economic cost is calculated at LE 0.0736 (a factor of 10.51). The economic value of the energy attributable to the investment for Esna barrage, assuming O&M costs of 10 percent, is thus LE 34.3 million. Economically, the Esna investment appears to be justified for hydroelectricity alone. Financial returns, of course, would be about one-tenth the above amount.

aggravated by weed growth and sedimentation. In many cases rehabilitation will be necessary, as for the Serry Canal near El Menya, where this is being done as part of the Regional Irrigation Improvement Pilot subproject of the USAID-supported Irrigation Management Systems Project. With the increasing use of larger gasoline engine powered pumping machines, the difficulty of unequal deliveries from mesqas can be expected to increase because of increased drawdown of canal water levels by upstream users. With increasing water scarcity and increasing availability of gasoline-powered pumps to replace saqias, and the possibility of gravity delivery from mesqas, farmers may be more willing to irrigate at night, but this remains to be seen.

Strategy. Present thinking is that remedying operational problems will be done primarily under the MOI's Irrigation Management Systems Program (National Irrigation Improvement Program). This program was described in the section on On-Farm Water Management above. Funds for operations are budgeted as recurring costs (Chapter II funds) and do not appear in the investment plan. Some of the interventions under consideration for field testing in this program are discussed below.

Consideration is being given to shifting from rotational to continuous deliveries to mesqas. This would reduce the size of channels required for main and branch canals, with consequent reduction in capital costs of remodeling and providing structures, and also of weed control and removing silt. Savings in canal rights-of-way could be used for roads or to increase cropped areas. Also under consideration is provision of water to farms by gravity. This usually will require installation of pumps at the heads of mesqas. Rotation would then be by farms on each mesqa. User organizations could have a meaningful function in group operation and maintenance of mesqas; but they would need technical advice.

The traditional policy of delivering water below field level was implemented in Egypt as an incentive to not overirrigate. Gravity operation of mesqas has been studied on an experimental basis by WRC at Mansouriya. If pumping at mesqa or branch canal level instead of field level is done, farmers should nevertheless pay for the pumping costs, including capital recovery. The Irrigation Ministry could ill afford this extra cost. Such a move would shift incentives from individuals to groups, which could be less effective than current practice. In some cases, there are opportunities to raise water levels on gravity canals by using more hydraulically efficient check and control structures and reducing their number. This could reduce or, in some cases, eliminate pumping lift, but would require raising canal banks and structural rehabilitation of canals. This approach is planned for the Serry Canal in order to gain effective slope and to increase capacity.

Canal operations are currently based on maintaining water at specified levels in canals. This criterion will be shifted to delivering adequate volumes for crop needed and will require volumetric measurement at controlling stations in the main canal system. Of course, the proper water levels still will have to be maintained. Automatic upstream water level control gates and verniered gates so that flow rate can be controlled accurately, and having controls preventing overdraft are being installed at pilot level, Consideration might be given to automatic downstream water level control, which would ensure water levels to tail-enders, but this may or may not be compatible with volumetric control. Use of broad-crested weirs as water level regulators and combined measuring devices has been tried successfully on a pilot basis in India. These are economical to construct and will operate with low hydraulic head loss.

Reuse of drainage water complicates the problem of matching water delivery schedules more closely to crop needs, especially because of inadequate data. The Water Master Plan has a distributional flow model which can be useful in making water delivery allocations. The strategy objective for the operations subsector is to implement operations that are fully responsive to the new farm management requirements defined by the pilot projects in a timely fashion as needed. International donor assistance will be sought for institutional development, training and technical assistance, including enlargement and enhancement of the flow distribution model, application of environmental isotopes to water management and improving the irrigation system in canal commands (26).

Rehabilitation and Maintenance of Channels

This section covers both irrigation canals and drainage channels. Channels where the cross section or alignment is of the wrong size or elevation or had been altered by erosion to the point that routine maintenance activities of silt removal and de-weeding will not provide or restore channel effectiveness to meet water delivery requirements will need rehabilitation. Such canals are candidates for conversion to continuous operations, control by measurement and automatic water level control. Generally, if channels are stable and water supply requirements are being met, reshaping the channel simply because it does not meet design standards for shape and alignments is not recommended. The Research Institute for Weed Control and Channel Maintenance has developed "regime" equations for Egyptian conditions. These are based on empirical data collected on stable channels carrying the reduced sediment load under HAD operation. These are available for the larger channels, and are being refined for use on smaller ones. They should provide good guidance for designing rehabilitated channels.

As stated in Chapter II, introduction of reservoir regulation by operation of the HAD has resulted in a dramatic shift in channel maintenance needs, from emphasis on silt removal to emphasis on weed control and de-weeding. MOI has begun to make this shift, but this will take time because present heavy dredging machinery needs to be replaced with lighter de-weeding machinery, operators need retraining and new management techniques need to be introduced.

Two "pilot" projects have been started by the MOI in order to gain experience with hydraulic mowing buckets and other weed harvesting equipment. The Research Institute of Weed Control and Channel Maintenance of the Water Research Center has an ongoing program to study: (a) all methods of weed control; (b) design of tables for open channels; and (c) maintenance of channels where transmission is low.

Besides mowing studies, the Institute has identified weedicides and defined application rates and safety standards for them for the various conditions: emergent, immergent and bank weeds. A plan to use Chinese grass carp (biological control) is under study at pilot level. This technology could replace weedicide in main canals where water turns are not rotated. A breeding station at Delta Barrage is currently producing 0.5 million stockable fish per year.

The USAID-supported Irrigation Management System Project seeks to devise an O&M management model which can be replicated generally throughout Egypt. This is under development in Gharbia Directorate; however, the plans developed so far need to be made more specific to actual field conditions.

Strategy. Concurrently, on a more comprehensive scale, the Program Preparation Department in the MOI, with AID and IDA support, has developed, in draft form, a 12-year plan for shifting channel maintenance technology and administration from its current emphasis on sediment removal to primary emphasis on weed control. This plan involves four basic elements:

1. Field staff of MOI and the Public Excavation Companies;

2. Machines, equipment and chemicals;

3. Weed scientists and equipment specialists; and

4. A unified management organization with resources to develop and implement new, responsive and up-to-date channel maintenance techniques.

Currently, the relative strengths of elements (3) and (4) are insufficient. One of the elements of the plan will be continuous monitoring and research to keep abreast of changed conditions and new technological advances. Tentatively, a three-phase program has been laid out. During years 1-3 the basic changes in approach will be implemented; during years 4-7 the integrated approach will be consolidated and biological weed control introduced; during years 8-12 the integrated approach will be refined and biological control will be substituted for chemical as much as possible. The IDA completed an appraisal visit for this activity in October 1985. The estimated cost of needed donor intervention for the first seven years is LE 105 million, consisting mostly of machinery and chemicals, but including training and technical assistance elements also. The concurrent cost under the plan not included in the intervention is LE 202.7 million, for a total cost of LE 307.8 million. MOI investment costs under the next Five-Year Plan are estimated to be about LE 63 million, but most of the GOE costs are in the recurrent cost category (Chapter II funds). Intervention costs over the entire 12-year period are estimated at LE 170.4 million, with a total cost of LE 493.1 million, so that international donor support is a necessary element.

Planning estimates indicate that the initial year cost of LE 51.6 million will progressively reduce to LE 32.2 million in the seventh year, and will thereafter vary from LE 33 million/year to LE 43 million/year, depending on machinery replacement purchases. Current recurring costs for silt removal and de-weeding are about LE 40 million/yr.

As a technological intervention, this plan seems very attractive. It involves state-of-the-art transfer and adaptation (machinery and weedicides); development of new technology, e.g., weeders, biological control; relatively low risk and relatively simple institutional development. Economically, returns are estimated at 31 percent. The plan is still in draft form and awaits further appraisal.

Channel Structure

Adequate canal structures are key to controlling water in the delivery system. Bridges need to be improved or replaced and new ones capable of carrying modern trucks need to be built in order to serve villages and farms. A major problem confronting the irrigation sector is the large accumulated backlog of deferred replacement.

AID has a program supporting replacement of 11,000 of these structures under its Irrigation Management Systems Project, and at the same time improving planning, design and implementation procedures in MOI. The first phase of the subproject began in 1981 and completed 3,078 structures valued at approximately $20 million located in five Directorates. The second phase ($70 million) will replace 8,500 additional structures in the remaining 14 Directorates. This subproject was evaluated in December 1984. One problem identified by the evaluation is quality control in mixing and placing concrete. Based on its field inspection, the current Team strongly reiterates the recommendations of the Evaluation Team on this point. A number of new types of gates, including some that automatically maintain upstream water level, devices to prevent overdraft, and multiple gates so that discharges can be more accurately controlled were also observed. The Team felt that in some cases design could be improved. This point was also noted by the Evaluation Team.

<u>Strategy</u>. The strategy for the short-term is to reduce substantially the backlog of deferred replacement and to fully modernize structures in the pilot areas designated under the Irrigation Management Systems Program, or NIIP.[9] Investment costs are tentatively included in the pending Five-Year Plan under that title. Concurrently designs and performance will be monitored in order to optimize design from the point of view of improving technology. International donor support is being sought to study feasibility of automatic control for structures in the water delivery system (26). Additionally, more advanced types of designs will be reviewed and, if promising, field tested under actual conditions. This is an activity that could properly be undertaken by the Research Institute for Weed Control and Channel Rehabilitation, but this would not be feasible unless their present technical staff could be expanded.

For the longer term, the strategy objective would be to achieve a system which is fully modernized and to provide replacements as needed so that a backlog does not accumulate, and to have in place a monitoring and research effort so that structures will continue to improve. One would expect, not only continued improvement of structural and hydraulic site specific configuration, but the potential to introduce new, more durable and lighter weight materials also.

No economic evaluation of structural replacement was noted; however, this value must be substantial. Replacement cost for irrigation water has been estimated at LE 5.8/1,000 m^3. If control structures were to reduce system losses by 10 percent (e.g., from 50 percent to 40 percent), the value of the water saved on a diversion of 40 billion m^3/year would be about LE 25 million/year.

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[9] A distinction needs to be made between the USAID-supported Irrigation Management Systems <u>Project</u> and the Irrigation Systems Management <u>Program</u>, the title used by MOI in its tentative upcoming Five-Year Plan documents, the next step under the country's National Irrigation Improvement Program (NIIP).

Pumps

Investment in new pumps and replacement is scheduled under the budget of the Mechanical and Electrical Department. The annualized replacement cost of pumping stations has been estimated at LE 20.41 million, but there is a backlog of old and inefficient pumps. Fortunately, use of multiple units in pumping stations insures against complete shutdown; but enough units are frequently out of service so that operation of pumping stations is at times only partial. In some cases, associated civil works need to be replaced or rehabilitated. There are also problems of compatibility of and spare parts for electrical equipment furnished by the USSR.

Strategy. Through the next Five-Year Plan additional emphasis will be given to improving electrical service and to installing mechanized screens, in addition to usual routine rehabilitation and replacement. In the past decade, floating trash in canals has greatly increased clogging problems at screens beyond what can be handled manually. The program is formulated on the basis of reconnaissance surveys of facilities and gives attention to some 60 stations serving more than 1.5 million feddans in Upper Egypt and the Delta. A new station will be completed for Mahmoudia Canal which provides irrigation in Beheira and Alexandria Governorates and municipal water supplies for Alexandria. Pumping stations will also be provided for wells constructed by the Irrigation Department. MOI's targeted investment in pump replacement through 1987/88-1991/92 is LE 146 million. This should permit some catchup. No systematic evaluation of benefits has been made. Financial costs for electrical energy are estimated at about LE 6.0 million at LE 0.007/kwh, but economic costs are estimated at LE 63.6 million (0.0736/kwh). A 10 percent reduction in energy use would thus net LE 6.36 million per year. There will be significant savings in labor also. By far, however, the main saving is in reduced risk cost of failure or interruption of water service and drainage. Technologically, the art of pumping is well developed, but there are opportunities for substantial improvements in selection of equipment, comparability of equipment components, operating reliability and automation. In the long-range, the goal is to fully eliminate the replacement backlog with equipment having up-to-date state-of-the-art efficiency and reliability.

Farm Economics[10]

Old Lands

Each of the various research and extension activities currently being tested are anticipated for use on a countrywide scale. The MOI is

[10]References: 4, 8, 10, 11, 16, 20, 24, 31, 35, 39, 42, 45, 53, 58, 59, 60, 61, 63, 70, 71, 73, 81, 83, 84, 92, 93, 95, 97, 104, 105, 109, 111, 115, 119, 120, 121.

planning a countrywide campaign to improve water delivery systems under NIIP, including comprehensive regional programs, RIIPs. The MOA is planning a sector approach also. Its proposed National Agricultural Research Program (NARP) is being designed to apply programs and practices developed by past and current pilot programs nationwide. The MLR is planning to extend considerably its reclamation programs based on its past experiences. MLR programs will have beneficial results, not only on new lands, but also on old lands. Jurisdictional boundaries need to be defined so that there are no dead spaces receiving no attention.

Energetic cooperative efforts will be required if the share of food needs supplied from domestic production are to increase. Egypt's population is expected to increase at a rate of 2.7 to 2.9 percent for the next several years; thus, increased productivity of the old lands is imperative. Yields in the Nile Valley and Delta are already above world averages for crops grown on these lands. However, under improved management, they have the potential to double (and in some cases, triple) yields. Even if this vertical development of the old lands occurs by the year 2,000, Egypt will still need to import food to satisfy the 67 million Egyptians expected by that time, but the country could go a long way toward producing its primary requirements by then, especially if new lands can supplement old lands production.

In the short run, the old lands can increase domestic food supply more rapidly than developing new lands. The potential, even under present constraints, is considerable. Several recent projects have demonstrated that yields can be increased by adjusting the agronomic packages for many of the main grain, legume and forage crops. The agricultural extension agents and researchers identified and implemented the most productive agronomic packages possible under present general farming conditions. In these packages, irrigation was adjusted to reduce water used, to improve field flow and to modify irrigation schedules. These adjustments, combined with the other recommended complementary factors, resulted in yield increases from 30 to 60 percent for each of the several important crops included. Very little capital investment was required. In 1984, one project demonstrated the program on about 90,000 feddans, including nearly 100,000 farmers in ten governates. An analysis of the data (collected over four years, using different farmers each year) indicated that the obvious economic benefits resulted in the farmers' continuing to use the recommended packages after they left the demonstration programs. Also, neighboring non-participant farmers began to use the packages after observing the demonstration activities on neighboring farms.

In addition to noting the yield increases, other things were learned.

1. Farmers are fiercely independent and have a "show me first" attitude. They will not change simply on the word of an expert; he must demonstrate the benefits resulting from the suggested changes. However, they will respond to suggestions that are obvicusly to their benefit. Farmers cannot afford to do the research themselves.

2. A team of specialists interested in farmers is required to develop the program, and the farmer must be a part of the team.

3. The changes suggested must not require money, knowledge or equipment beyond the farmer's ability to acquire or comprehend in the short run.

4. Recommendations not compatible with small farm size will be ignored. Farmers are not interested in the purchase of large-scale farm machinery until other institutional changes are made.

5. A strong, well-trained extension service will be accepted if the agents have only one purpose--farmer education.

6. The farm is where the production problems are expressed. That is where they will be solved. Research has its place, extension has its place and the farmer has his place. By working together, the potential of the farm will be reached. Each of the partners will find a new direction for his various activities, which will lead to increased production if each works on farmer-defined problems.

After a short period of increased productivity under a no-capital investment scenario, further increases are possible through institutional adjustments in size-of-farm, mechanization, on-farm water management and research and extension (R&E) development. These will be more difficult to assess because positive economic benefits will not be so obvious.

In Egypt, irrigation is a prime factor of production. It cannot be ignored in the search for more food from the old lands. At the same time, improved irrigation alone will not bring the old lands to their potential level of productivity. Water in the canal is like fertilizer in the cooperative in the sense that both are dormant as far as agricultural production is concerned until they are applied on farms. At the farm level, both resources become factors of production, with economic consequences to the farmer and society. A farmer can learn about how, when and how much of each factor to apply by trial and error, or he can save time and money by asking someone who already knows the answers. A food-short domestic economy, as in Egypt, can do without the losses resulting from each farmer using trial and error means of gaining knowledge. A strong, well-trained extension service is therefore needed.

New Lands

About 700,000 people live on approximately 912,000 feddans of old new lands. Forty-two percent of these lands are in the Delta; the rest are located in the Sinai, Middle and Upper Egypt, New Valley and barren areas intermingled with the old lands.

A mixed tenure pattern exists on these lands. About 42 percent are controlled by private farmers or groups; 45 percent are controlled by Government agencies and companies; the other 13 percent are in the form of infrastructures and undistributed areas. About 460,000 people have private holdings; public farms serve about 240,000. Studies show that private farms generally produce higher yields per feddan than do the public farms. Additional areas planned for development are classified as new lands. Farm economics, which include the combination of water and all other production resources to reach farmer's and society's goals, is the same as for the old lands. The same technical principles also apply to farms operated in the private or public sectors. Improvement in yields as well as farm family well-being is necessary.

The MOI and other related Ministries are planning to help farmers increase their productivity in these areas. More on-farm research and extension activity is planned. As on the old land farms, a virtual no-man's-land exists between the canal and use of water on the farm. All involved Ministries must recognize that their success or failure depends on how farmers use the water resources on their farms in conjunction with all of the other production factors. Therefore, considerable attention should be given on-farm water management.

Supporting Activities

Agricultural Research and Extension

Egypt has recently enjoyed outstanding crop improvement successes in specialized programs and localized areas, as reported by the EMCIP and ERRAT in the MOA and EWUP in the MOI. With respect to on-farm water management, plans are to expand the EWUP model into a Regional Irrigation Improvement Program and ultimately to a National Irrigation Improvement Program.

The EMCIP, the ERRAT and the EWUP were predominantly extension programs. They involved the transfer and adaptation of improved technologies already in existence. The heart of the ERRAT and EMCIP programs was improved seed varieties which were made available from the International Agricultural Research Centers. The EWUP, working with a highly site-specific factor, tested on-farm water management procedures that were oriented to soil conditions peculiar to the Nile system.

For the immediate future, MOA/AID is developing the National Agricultural Research Project (NARP) (USAID Project 263-0152) to provide research backstopping, which is critical to any new ERRATs or EMCIPs. There is no activity within the MOI equivalent to the NARP at this time.

In order to achieve the needed level of (R&E) efficiency, firm and effective communication among MOA and MOI R&E personnel must be established. The NARP leaves an open door for interdisciplinary exchanges with irrigation engineering. However, based on experience, the invitation probably will not be accepted unless it is mandated through the mechanism of R&E budget allocations and work assignments within a jointly administered R&E agency.

The development of irrigation resources, including diversion, delivery and distribution of water on the land, is the single most costly factor of irrigated agriculture. This is true in terms of both initial and recurring costs. It is also true in terms of the human skills and dedication needed for effective irrigated crop management. Irrigation must be applied repeatedly during the crop growth cycle at the proper time and in the proper amounts. By contrast, all other irrigated crop management factors (planting, fertilizing, pest control, etc.) are applied one, two or three times during the crop cycle. Nevertheless, the wrong time or rate of application of any of the other factors can nullify the investment in irrigation per se.

One of the most useful outputs of interdisciplinary on-farm water management R&E is the development of crop response functions. Response functions quantify the linear and curvilinear dependencies of crop yield to individual crop growth factors such as soil moisture and fertility, but also quantify the interactions between these factors. Crop response functions are generated using research designs that employ two or more controlled research variables, each in three or more controlled levels. Ideally, in an irrigation-soil fertility collaborative study, the engineer will design and implement the delivery system to provide the intended number of soil moisture levels. The soil scientist, working in a split-plot statistical design, will implement the soil fertility variables and soil tillage, crop establishment and other routine agronomic practices.

The crop response function not only defines quantitatively the proper combination of inputs to achieve maximum yield, but it also allows for an analysis of different mixes of input levels on both sides of the optimum. Using crop response functions, it is sometimes possible to demonstrate a significant reduction in input costs while obtaining a minimal reduction in yield. Conducting interaction-focused R&E increases the skill of the R&E technicians, both in terms of interdisciplinary work and in demonstrating and teaching skills to farmers.

Water Research

A total of LE 42 million is proposed as investment in the next Five-Year Plan for the Water Research Center and its research institutes to conduct applied research, studies and experiments in the fields of:

* Development of field irrigation and water management systems;

* Irrigation water duties and requirements;

* Development of canals and drains design;

* Drainage research for reuse and control of water quality;

* Completion of development of groundwater in the Nile Valley, Delta and regional aquifers in northeast Africa; study of groundwater in Greater Cairo; development of a hydrogeological map for Egypt;

* Study and economic evaluation of water resources of Sinai;

* Side effects of the High Aswan Dam and the protection of the Nile bed;

* Hydraulic studies by physical models;

* Aquatic weeds control;

* Soil mechanics and foundations;

* Shore protection studies and laboratory experiments;

* Survey studies; and

* Mechanical and electrical studies.

MOI has proposed international donor support for technical assistance for introducing and developing modern technologies in water management (26).

Overall System Management

Introduction

Use of improved communication systems and mathematical modeling has already begun as means for improving the efficiency of overall Nile system management. The status of these interventions was summarized in Chapter II. There is an unmeasured potential for applying additional operations research (OR) type technology to improve system management and operation. In sequence from fields to the watershed, the following linked components could be visualized:

1. Crop evapotranspiration requirements;

2. Unit command system models that translate these to required deliveries to mesqas and minor canals;

3. Similar models for main system canals whose outputs are diversion requirements at principal canal headworks;

4. Operational distribution of diversion demands for the Nile River;

5. High Aswan Dam;

6. Reservoir operating rules for Lake Nasser;

7. Hydrograph routing for the Upper Nile system;

8. Rainfall-runoff predictions for the Nile watershed/watersheds; and

9. Improved system-wide communication and information processing.

A project for real time reporting of water levels is being implemented now (part of Item 4). An operational distribution model has been developed for the Nile River (Item 4), both a linear programming and a stochastic simulation model are being utilized for Lake Nasser operations (Item 6), a simulation model for flow in part of the Upper Nile is under development (Item 7), as is an initial rainfall/runoff model (Item 8). MOI has proposed international donor support totaling $1,000,000 (total cost, LE 2.5 million) for improving the Nile River model (26). Water balance studies of the Victorian Plateau, where there are large ET losses from swamps and evaporation from lakes, have been made (part of Item 7).

In many cases state-of-the-art or near state-of-the-art techniques are available and could be adapted. In other cases, this is not yet the case. In some cases, resources necessary to implement OR techniques may not be cost-effective, and this risk may be very difficult to assess. In any event, OR technology useful for water resources management is progressing rapidly and what may be infeasible today may change substantially over the planning horizon. Real-time information is always a major input, but a look-ahead component is essential. The needed time-scale for look-ahead varies from days for translating crop ET requirements to HAD releases, to months or even several years for reservoir operations at Lake Nasser. There are several OR approaches to "look-ahead" such as stochastic simulation and linear programming, but there may be new analog type approaches, such as rainfall versus cloud cover measured from satellites, also.

An in-depth review of the status and needs of OR activities now under way was not possible by this study. These, of course, need first priority; the potentials for additional advanced or more esoteric techniques will need careful, and even skeptical scrutiny, but these should not be ignored. More detailed comments follow.

1. Crop Evapotranspiration

Stochastic simulation models considering real-time state variables such as area, stage and condition of crops, and soil moisture levels could lead to rule curve approaches. Satellite information about crop status as a means of estimating ET requirements has been advocated for the last two decades. The Team does not understand how this could work in the absence of an OR-type model such as that mentioned above; however; satellite data could be an efficient way to provide real-time input for such a model. The stochastic simulation approach to ET is being utilized within the unit command model being developed by the USAID Water Management Synthesis II Project (WMSP II), and has been used under World Bank-assisted projects in Gujarat and Maharashtra in India. The MOI has proposed $2 million international donor support plus LE 200,000 local costs for initiating crop census using remote sensing.

2. Unit Company Hydrographs

A unit command model (supported by the WMSP II) is nearing first generation completion. It uses stochastically generated weather patterns that are statistically similar to historical ones with crop, soil and application and transmission efficiency inputs to generate demand hydrographs for unit commands (mesqa-level). One would not need to operate such a model for all of the mesqas in Egypt; a valid sample would be adequate.

Egypt's currently operational agro-economic model could be used to optimize returns to water, or determine the best water-use strategy to optimize economic returns to the agricultural sector. This model examines a number of options for increasing agricultural production in Egypt, such as intensified land reclamation, drainage, improved cropping techniques, more extensive use of modern inputs, increased mechanization, more efficient water delivery and application, changes in cropping patterns, improved incentives to farmers through the price system, etc. Currently, the model projects a cropping pattern for each of the 15 aggregated canal commands. It has been utilized for ranking potential new land projects, evaluation of programs for improving production of rice, wheat, maize and lentils on the old lands, and estimating the effects on the reduction in the national economy when prime agricultural land is converted to other uses. Applying the model to annual and eventually short-term planning of Nile system operations could link Nile operations with national and farm-level economic objectives. For irrigation, this approach probably could best be applied on a sample basis at mesqa or distributary level.

3. Main Canal Systems

Water Management Synthesis II has a first generation model for main canal systems nearing the field testing stage. This is essentially a hydraulic model, but it has turned out to be surprisingly complex. It uses unit command area demand hydrographs as inputs. Stable channel design using the WRC Research Institute for Weed Control and Channel Maintenance regime equations (79) could doubtless be programmed for computerized solution, either separately or as a subroutine for a main channel model such as the one being developed by the WMSP II.

4. Operation Distribution of Diversion Demands

The operational distribution model considers the operation of the barrages on the Nile and the 14 principal canals that are gravity fed from the river. A primary concern is the reduction of water losses through excessive wastage to the Mediterranean, or unnecessary consumptive use. This hydraulic simulation model can calculate changing conditions such as water levels and flows. Time delays in water movement can be automatically included. The model can provide gate movement schedules to meet the various water requirements without violating system operating constraints. The model could take into account the effects of local barrage operating decisions in the entire system to a degree not possible now. It could provide day-to-day operational planning. Although a first version of the model is presently operational within the WPG of the MOI, pre-planning for a longer term using a look-forward algorithm is visualized as a necessary component of the model.

5. High Aswan Dam

Various improvements, fortification of the dam against emergencies. siesmic studies, replacement and renewals and development of measuring devices, are planned for High Aswan Dam. Two spillways had been constructed, one at Toshka and the other at the left bank, with a total capacity of $10^9 m^3$/ day. Implementation of standard routine "Safety of Dams' program is needed.

There are 13 siesmic and peisometer sites around Lake Nasser. The data from these sites are transmitted by radio to the control center continuously. More sites are required for the safety of the dam.

Regarding development of measuring devices, sensors for upstream and downstream water levels will be installed this year through the IMS Telemetry project. For the operation of the dam, more water level sensors are required to cover the River Nile upstream; and for discharge measurements, an acoustic flow meter is required to be installed in one of the penstocks of the High Aswan Dam.

6. Reservoir Operating Rules for Lake Nasser

The High Aswan Dam is operated using two reservoir control rules; an upper rule which enables the reservoir to be drawn down in anticipation of the annual Nile flood, and a lower rule which enables the demands placed on the reservoir for irrigation and water supply to be met with the desired reliability. The use of the reservoir for flood control conflicts with the future objective of maximizing energy production which is a function of the discharge released (up to the maximum capacity of the turbines), and of the available head.

The use of the "Dynamic Programming" model (DP) (prepared by the Water Planning Group of the irrigation planning sector) has allowed energy production to be maximized within the constraints of meeting the irrigation and water supply demands and of maintaining the storage required for flood control.

The operating rules for the High Aswan Dam derived from the DP model can be tested through a simulation model, in which all inputs, outputs and losses are accounted for on a monthly time scale. The simulation model is essentially a simple water balance model in which losses through evaporation, seepage, and bank storage effects are considered. The effect of a diversion to the Toshka depression is incorporated through a spillway with variable parameters. The simulation model can accept as inflows naturalized synthetic flows into which the effects of upstreamreservoir and abstractions can be incorporated, historical flows with the effects of upstream reservoirs incorporated, or fully naturalized historical flows.

The DP Model as well as the Simulation Model are fully developed and are presently operational on the HP 3000 computer of the WPG.

7. Hydrograph Routing for the Upper Nile System

Routing the flows of the River Nile from Lake Albert exit to Lake Nasser has been developed to evaluate the impact of a number of water conservation projects proposed for the watersheds of Bahr El Jebel, Bahr El Ghazal and Mashar Marshes. Two basic approaches were used to set up a mathematical model for that purpose. The first was Linear regression in which records were not continuous and the second was the Constrained Linear System (CLS) in which long series of continuous data were available.

Although the model needs further improvement, it is now being used (by the WPG) as flow routing took, it could also be used as a rainfall-runoff model for daily prediction purposes based on anticipated precipitation index.

Estimation of run-off from rainfall records for different watersheds in Ethiopia could be obtained using models such as the Sacramento mathematical model developed by the U.S.A. Weather Service Department. The model uses the concept of the unit hydrograph to predict the daily runoff from daily rainfall records and either daily or monthly evaporation values. Further studies are strongly recommended for the application of such techniques on the Ethiopian Plateau which yields more than 6/7 of total inflow to Lake Nasser at Aswan.

8. Rainfall-Runoff Predictions

Cloud patterns are related to rainfall, particularly in tropical areas, and may be used to estimate rainfall in the absence of rain gauges where data from meteorological satellite are available. The instantaneous nature of meteorological satellite measurements makes the estimation of daily or longer period rainfall difficult, but where a time series of measurements are available, as from a geostationary satellite such as Meteosat, daily estimates of rainfall may be made. The satellite data are usually calibrated against ground data, but where no such data are available, as in Ethiopia, then radiance data may be related to streamflow data measured at the outfalls from the catchment areas.

The procedures would be to accumulate data about the thickness and cloud top temperatures of precipitating clouds through some long period (say, ten days) and relate this to streamflow. In order to handle the large amounts of satellite data quantitatively, digitally based methods of analysis are necessary. Feasibility could be tested by acquiring data from Meteosat for a certain period. This could be used for the calibration of the relationships between the remotely sensed rainfall data and the streamflow for the catchments of the Sobnat, Blue Nile and Atbara.

Improved System-Wide Communication and Information Processing Strategy

AID has approved a communication system for the Ministry of Irrigation Headquarters and f..e Directorate Offices. This system is to provide communication capability from mobile field units (operation vehicles) to Directorate Offices and communication capability between headquarters and Directorate Offices. It has been proposed that the system be expanded to cover all of the irrigated area with five stations for long distance transmission repeater stations to transmit VHF signals and 75 fixed or mobile VHF units.

Presently an AID-financed "Nile River Irrigation Data Collection System" (NRIDCS) is under the Telemetry subprojects of the IMS is being installed to gather water level data throughout Egypt's irrigation and River systems to be used to improve system operations. Subsequently, MOI has proposed, and AID has approved, financing of $2,000,000 for an acoustic flow meter system to be integrated with NRIDCS. This system will provide velocity and discharge data at key river and canal sites. These two components will need to be expanded in the future as the management of the system becomes more precise.

The proposed strategy, systems operation management, is to: (1) bring the reservoir operations models and the new telemetering system into full operational use; (2) support the full development and implementation of the OR technology now in place or under development, giving priority to the operational distribution model, the rainfall/runoff model and the Lower Nile Model, in that order; and (3) initiate feasibility studies, including field testing, for utilizing satellite information on cloud cover to estimate rainfall or runoff; a main systems model and a unit command area model, including computerized design of regime channels in connection with the main systems model and satellite information on crop cover, socioeconomic optimization in connection with a unit command area model, and system-wide communication and information processing. Priorities would have to await at least reconnaissance level studies. Political conditions in the Upper Nile watershed may delay or preclude further initiatives in that area; this will have to be determined as time goes on. The systems management strategy package is a large order in terms of technical effort, if not in relative cost. Efforts should be toward perfecting each component piece by piece rather than trying to accomplish everything all at once.

Other strategy efforts are to improve HAD safety and operational efficiency. For this purpose, investment of LE 50 million is tentatively included in the upcoming Five-Year Plan; improve equipment, survey works and mapping production within the Survey Authority at a similar cost of LE 24 million. The MOI has proposed international donor support for technical assistance in updating current topographic maps and maps of irrigation and drainage systems using modern mapping techniques.

Institutional Development Needs

Organizational Responsibility and Coordination

On-Farm Water Management. In order for Egypt to achieve its full potential in irrigation water conservation and improved crop production, the MOA and MOI need to come to grips with their technical programs. Specifically, they should delineate and reinforce areas of parallel and overlapping responsibilities in regard to on-farm water management.

Historically, the MOI has been concerned with water delivery to the mesqas. But there are great opportunities for water savings in and beyond the mesqa by improved water delivery to and distribution on the field. The MOI has a Research Institute for Water Distribution and Irrigation Methods under the WRC. The MOA, through its Water and Soil Research Institute, has a major responsibility for on-farm water management research and extension. Logically, the MOI would research water delivery and on-farm distribution, including irrigation methods, amount and scheduling. The MOA would research and demonstrate soil water use efficiency by crops together with the interaction between soil moisture and soil fertility, soil management, and crop type and variety. These are clearly end-to-end research functions, but there is an important aspect of research where irrigation engineering and soil science are juxtaposed. This has to do with evapotranspiration and all of its ramifications. ET is indeed the focal point of on-farm water management and irrigated crop production. The irrigation engineer is concerned with water infiltration into, redistribution in the soil, crop rooting depth and the factors controlling water consumption by plants. The most productive research program is where the irrigation engineer and soil scientist are working in a fully collaborative mode on and around the ET focal point, as well as on other issues relating to surface and subsurface drainage and water quality.

The MOA and MOI should be concerned with how this collaboration can be established and maintained for the overall improvement of irrigation efficiency, soil water use efficiency and increased crop productivity. A productive collaboration in this area is needed to assume an effective extension and technology transfer program in on-farm water management.

Agricultural Extension. Research is fundamentally a process of information development and has its own peculiar management needs. By contrast, extension is fundamentally a teaching function and has its own special management needs. In order for research and extension to interface and collaborate efficiently, these important professional and personal distinctions must be taken into account.

The MOA has the mandate to develop and maintain an effective extension program. However, extension remains in rudimentary form, generally lacking any effective connection to research. Extension irrigation engineering is specifically named as a component of MOA extension. It may, however, be anomolous to assign an irrigation engineer to an organization only tangentially related to the engineering discipline. This issue is elaborated below, but it should be emphasized that to be effective, and R&E management system must provide disciplinary leadership to all involved disciplines. This means monitoring, evaluating and expanding the capability of each professional in his area of expertise.

Irrigation Improvement Pilot Projects. Responsibility for research and extension on pilot projects under the Irrigation Improvement programs needs clarification. The MOI is proposing an Irrigation Management Systems Authority. If this proposal is implemented, the question is how the multi-disciplinary resources of other agencies, particularly the MOA, will be mobilized. In Egypt, a jurisdictional problem arises. Which agency has the responsibility for educating the farmer about how to organize the use of all of his production resources to maximize his goals, and at the same time do his share to produce food products at a rate to maximize agricultural sector returns to the Egyptian economy?

Particularly, there seems to be a "no-man's land" in the use of water at the farm level. This is a common problem of irrigation in most developing countries. It involves farming practices on individual fields and group responsibility for operating and maintaining mesqas and requires a "marriage" of agricultural engineering and agronomy. The agency who identifies proper rates, timing, kinds and gives advice to farmers in fertilizer use is the MOA. Research is done in the MOA and passed on to farmers by an Extension Service. One proposal is that the MOI handle the job of delivering water to farmers through the canal the mesqa system, and the MOA take the responsibility for an on-farm use, including mesqa, operation. While this solution appears to have long-term viability, it has not been very successfully implemented in developing countries. The decision is complicated because mesqa operations are communal, in contrast to cultural practices related to irrigation on farms, which are under the control of individual farmers. For EWUP, the capability was assembled at Project level, and this arrangement may be desirable for the NIIP and the RIIP on at least an interim basis. This general approach is also used by the MLR. The MOI has proposed development of an Irrigation Information Service (IAS), but the problem is a general one not restricted to pilot project. In any event, some strategy and policy decisions need to be made soon on this important issue.

Recommendations.

1. MOI and MOA need to explore ways of improving coordination and integration of the efforts of engineers and soil scientists in basic applied irrigation production research on a sustained basis.

2. Initially, the Irrigation Management Systems Authority will probably have to organize its farm- and mesqa-level irrigation extension efforts on an ad hoc basis for its pilot projects. The proposed IAS should be charged with providing assistance to farmer groups, or WUAs, on development improvement, maintenance and scheduling problems of mesqas and marwas, and pumping and land development on farms. Concurrently, the Agricultural Extension Service should develop capability for assisting farmers with irrigation water requirements, fertilizer and pest control, and cropping technology related to irrigation farming.

Training and Personnel Development

Recently, the MOA inaugurated its Center for Agricultural Management Development (CAMD). The purpose is to improve personnel management of the 150,000-member organization by training 3,000 mid-level managers. The CAMD will improve the non-technical operation of the MOA. The MOI has 90,000 employees and is planning to avail itself of the CAMD building site and is drawing up plans for a National Irrigatic Training Institute (NITI). The NITI will give post-graduate training to its technicians and engineers by means of short courses covering up to 50 subjects. All of the in-house skill-building programs will no doubt have a marked impact on agency efficiencies.

Special attention should now be given to R&E administration in MOI and MOA. Directors of centers, institutes and programs who are now essentially personnel managers only, should be trained in the technical aspects of program administration. There are some important management tools that are not now being developed and utilized in Egypt. Research directors should understand the function of each of the following items in research management. These are based on the concept of management by objective, sometimes called mission-oriented research.

1. Use of a job description that outlines all of the technical details of the position for all principal and senior investigators, to provide a true base of reference for evaluating job performance. This should be reviewed periodically to assure that the researcher is fulfilling his job requirements. If the job requirements change, then the job description should change.

2. Research monitoring and evaluation using the project outline plan of work, annual or other periodical progress reports, interim technical reports, final technical reports, scientific publication in journals and bulletins and participation in scientific conferences, all with attendant peer review.

The research program manager should be concerned first and foremost with the professional development of each of his staff members.

The same can be said for extension, recognizing the objectives and methods peculiar to this profession. For example, the job description of a full-time extension worker has more to do with technology transfer (teaching) than technology development (research). Accordingly, the extensionist would not be expected to be evaluated on the basis of research publications. Provision should be made in the job description of an extension leader for involvement in aspects of research, and vice versa. Job performance in parallel or collaborative modes should be evaluated and given the proper weighting in the rewards offered for effective professional performance. MOI/USAID have, in final stages of completion, a study of in-service training needs.

Policy Issues

Agriculture's Share of Egypt's Investment Capital and Farmer Involvement in Mesqa-Level Management

Agriculture's Share of Investment Capital. Compared to agriculture's share of total employment and its contribution to gross domestic product (GDP), the proportion of total investment, public and private, expected for agriculture during the current Five-Year Plan does not appear consistent with the high priority given to increasing food production and employment in agriculture, or the high potential of the available technology.

The current Five-Year Plan as proposed initially included a total of LE 4.0 billion for agriculture and land reclamation, irrigation and drainage, of which about LE 1.1 billion was from the private sector. The total is about 11.7 percent of all investment projected in Egypt during the Plan period. In contrast, agriculture employed about 35 percent of the labor force, and its contribution to gross domestic product was about

20 percent. Employment in agriculture was expected to grow at 2.2 percent, and output at 3.7 percent per year during the five years. Through improved management of all inputs, this was to be achieved without increased consumptive use of water (41).

Employment in Agriculture. Assuming that new land reclamation will only offset the labor force displaced by urbanization and other loss of old lands,[11] then the 98,000 expected annual growth in the agricultural labor force would have to be generated by the already labor-intensive agriculture on the old lands. In other words, the growth in agriculture was expected to be primarily labor-intensive.

In reality, labor in agriculture has probably not increased, although productivity has, but at a slower rate than planned. Data on labor absorbed by new technologies and high yields in the pilot projects (EMCIP, ERRAT) were not available at this writing; however, the yield-increasing technologies have probably increased the labor required at harvest time. This requirement may have been met by reallocation of existing labor from other crops or from time saved by increased diesel or gasoline-powered pumping of irrigation water over traditional techniques. The implication is that higher yields on old and new lands, plus new lands expansion (replacement of old lands) without higher prices or credit for mechanization have not been sufficient to absorb more labor in a competitive labor market. If farmers could double and triple their production through increased cropping intensity and higher yields, their share of the nation's capital investment in agriculture could double as well. They might even retain more family labor at home.

If sufficient new labor cannot be induced into agriculture to perform all the tasks necessary to increase cropping intensity such as harvesting the larger crops, cleaning the mesqas and preparing the land more rapidly, mechanization will be required. Mechanized threshing and tractors for mesqa maintenance and land preparation (plowing and smoothing) can reduce the turnaround time from harvest to planting. Of course, efficient mechanization of land preparation implies larger fields than are common in Egypt. Egypt's farmers may be more willing to consolidate fields than previously thought. The EMCIP has successfully demonstrated to thousands of small wheat farmers the advantages of consolidating fields (by maintaining boundary markers) for mechanized plowing, seedbed smoothing and application of irrigation water.

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[11]If 60 percent of the 50,000 feddans of the clayey deltaic soils, 40 percent of the 300,000 feddans of calcareous and fine sandy soils, but none of the 300,000 coarse sandy soils were distributed to graduates and settlers according to the Five-Year Reclamation Plan, there would be a potential increment of 30,000 in the agricultural labor force each year This would assume an unlikely labor intensity of one laborer per feddan on the new lands. Offsetting this would be the labor force no longer occupied on the 30,000 feddans of old lands lost to urbanization and other uses each year.

<u>Farmer Involvement and Credit</u>. To be successful, equipment must be accessible to farmers when they need it. This appears to have occurred for irrigation pumps, and there is no reason to believe that it couldn't occur for other types of machinery. Farmers will need greater access to credit so that they can purchase the equipment themselves and do custom work for their neighbors on a timely basis, as they have with the irrigation pumps. Also, equipment appropriate for the task should be identified in advance. Pending higher fuel costs to the farmer, attention should be paid to the fuel efficiencies of pumps, tractors and threshers sponsored by the credit program. A substantial mechanization credit program and organization of Water User Associations (WUAs) would be necessary.

With increasing cropping intensities and more precise scheduling of mesqa maintenance, land preparation, irrigation and harvest, mesqa-level WUAs or farmer organizations would probably have to assume a larger, more intensive, role than they have traditionally assumed in Egyptian agriculture. In addition to scheduling, WUAs might get involved in organizing payment to farmers contracted to clean mesqas or in plowing and harrowing consolidated fields. Ultimately, they might hire a ditch tender to maintain irrigation schedules, interface with the MOI engineers and collect a consolidated user fee. Mesqa WUAs with technical support similar to the IAS idea, and if legally organized, could even finance and contract the raising of their mesqas for gravity flow to marwa and single-site pumping into the mesqa. Two examples elsewhere are the Bakel Project in Senegal and the Irrigation Service Associations in the Philippines.

This scenario suggests that the macro-level goals of the Five-Year Plan will require more capital investment in the agricultural sector and that capital investment could be forthcoming from the private sector. This will require a bottoms-up component to the overall irrigation improvement program. The proposed multi-disciplinary IAS would play a key role in helping selected mesqa-level farmer organizations demonstrate to themselves and to other mesqa organizations their potential to organize access to new credit resources and invest them for optimum mesqa production with minimum pumping costs and water use.

<u>Conclusions</u>.

1. More capital, including access to credit, is needed to develop the water, land, labor, technology and management potentials available to Egyptian farmers in old and new lands if production is to be increased more rapidly. Capital resources can be greatly increased through greater farmer involvement in mesqa-level management.

2. To help farmers demonstrate the economic potentials to themselves and others, and to help them learn the management skills required, a multi-disciplinary advisory service is needed. Since most Egyptian agriculture requires coordinated use of scarce water resources made available at the mesqa inlets, an irrigation-centered advisory service could serve this function efficiently. The proposed IAS is appropriate.

3. Inasmuch as farmers have a guaranteed market at a guaranteed price for major food crops, the financial returns to various investments in new technologies are highly predictable. The profitability of the use of credit for various irrigation-related mechanization and mesqa improvements can be calculated in advance, and rational decisions can be made. With some technical assistance from IAS and assistance in securing credit, various profitable demonstrations can be undertaken by WUAs at mesqa level.

4. Profitability, productivity and efficiency of Egyptian agriculture can be increased for both the farmer and the economy as a whole through integrated development of mesqa-level water, land, labor and farmer organization and management resources.

5. Mesqa-level, as well as macro-level outcomes, can be modeled using the Agro-Economic Model and data generated to study the impact of mesqa credit programs and private and public investment. Farmer involvement can then be measured as an endogenous variable as a substitute for other GOE capital resources that might be required to increase productivity if the farmer is not increasingly involved. International donor support is being sought for technical assistance in applying the Agro-Economic model for policy planning.

Recommendation. As has been done in pilot projects with the various cereals, technology packages for demonstration projects highlighting the profitability, productivity and efficiency of mesqa-wide investments and management by member farmers and their WUAs is needed, both by the farmer and the GOE, to achieve their development goals. An agency such as the proposed IAS would be needed to assist selected WUAs in implementing dynamic demonstration projects.

Water Charges and Recurring Costs

The issue of what charges should be made to farmers for irrigation water is of primary interest to international donors as well as to the GOE. Donors are very concerned about the rapid deterioration of irrigation capital infrastructure because of inadequate provision for recurring maintenance needs. There is a wide agreement by international experts that farmers should pay water charges for public irrigation supplies equal to the cost of operation and maintenance, plus some share of capital repayment. Water charges are not assessed in Egypt now, nor have they been traditionally, and changing this tradition could be difficult.

Issues. In arriving at a water charge policy, several issues commonly emerge.

1. As a result of price fixing and subsidies in most developing countries, the farmer pays a very substantial assessment in hidden form. Egypt is no exception. Authorities are in fairly good agreement that the question of water charge amount cannot be approached rationally unless the costs of these distortions to irrigation farmers are taken into account; they also seem to agree that assessing how much these costs are is a very complex, and perhaps analytically intractable, problem.

2. The purpose to be served by collecting water charges needs to be considered. Is the objective to raise revenue or to increase water use efficiency, or both? In the first case, there may be better ways to raise revenues, e.g., reducing subsidies for other production inputs.

   Usually, water charges simply accrue to the general revenue account. In this case, they have little or no effect on resources made available for operation and maintenance because these are appropriated by the legislative process. In the rare cases where water charge revenues are earmarked for use at local, district or national levels for O&M, they directly influence the amount of money available for O&M.

3. Many authorities argue that charging for water by volume would promote its efficient use.[12] Aside from the technical impracticality and the tremendous cost of installing and maintaining metering devices, volumetric changes are not apt to be very effective on most gravity systems. The cost of producing a farmer's continuing share in such a system is largely an annual fixed cost. If this is paid or due at the time of allocation, it tends to be sunk.[13] It is analogous to a connection charge for electrical service. If water is scarce, a farmer will plan his cropping strategy to use his full share if he needs it. If the farmer is in a position to increase or decrease his use, increasing charges (or costs) will result in more efficient use; however, water may continue to be substituted for other inputs,

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[12] Here, application efficiency, the volume of water stored in the root zone for use by crops, divided by the amount delivered at the farm.

[13] Basic Moslem law provides that all irrigators receiving water from a particular canal have an equal right to the water according to their holdings. With few exceptions, this same principle applies to irrigation worldwide, whether or not the country is Moslem.

particularly labor, if this is more economical.[14] Moreover, most of the inefficiencies occur in the distribution system, not on farmers' fields.

4. The above argument does not hold if water is pumped. In this case, cost of pumping should be added. Here, only the capital cost is sunk and water volumes delivered are usually easier to measure.

   In many cases, pumping of water is already in the private sector, and except for subsidies, is paid for automatically. Where water is pumped jointly into gravity facilities, as at the heads of canals, individual metering and service on demand, or strict scheduling would be needed before volumetric charges could be expected to influence efficiency of use.

5. Water charges should be borne by all farmers in proportion to their share in the system. They should not be reduced or waived for small or poor farmers. To do so defeats the principle of internalizing costs and benefits. The water account should not be used for welfare. Without the full participation of millions of small farmers, collections will fall far short of costs.

6. Where multipurpose functions, such as navigation, hydroelectricity production, flood control and provision of municipal and industrial water supplies are involved, costs should be equitably prorated among the various users. Revenues from one use should not be used to subsidize other users.

Regardless of the debate on water charges, the problem of providing for the recurring costs of operating and maintaining public irrigation systems is serious. If O&M budgets are appropriated from general revenues; however, the issue is largely separable from the question of water charges.

There are no time-tested or easy solutions to the recurrent cost problem. One possibility would be a mix of recurring and capital cost financing by donors associated with a plan for increasing appropriations for O&M. Performance toward achieving the Plan's objectives could be a factor in reimbursement. An attractive alternative would be internalization of water charge collections and O&M responsibility at local and area levels, including the possibility of shifting all or part of the responsibility to farmer organizations. Interestingly, it turns out that Egypt's draft plans for maintenance of canals and drains follow the first strategy, but with the added bonus that shifting to a technology that is more appropriate for current conditions in Egypt will likely reduce recurrent cost needs.

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[14] It may cost less to use more water than needed instead of paying for the extra labor required to manage it more carefully, for example.

Capital Repayment. For public systems, the issue of what share of capital costs should be repaid by the farmers is complicated because some of the benefits accrue to the economy generally. Farmers cannot be expected to fully repay the capital costs for public systems unless the B/C ratio is substantially larger than 1.0. In conventional B/C analysis for public irrigation projects, the benefits are the estimated direct increases in net income to farmers from crop production less annual O&M costs. No indirect benefits are included. For B/C = 1.0, the present value of the benefit stream over the life of the project exactly equals the present value of the capital investment. The cost of repayment would therefore equal the total net benefits. If farmers pay O&M costs and fully repay capital costs, their share of the net returns would be zero. In fact, it would be less than zero because farmers must pay certain transfer costs, e.g., land taxes, which are not included as costs in the B/C analysis.

Initial capital costs may probably best be repaid as a betterment levy rather than as a recurrent charge, but this probably would not be true for capital costs of rehabilitation or replacement (R&R). In the private sector, returns for investment in pumps and wells can be significantly higher than B/C = 1.0, and farmers are usually able and willing to repay the capital costs.

Recommendations.

1. Egypt's long-term goal should be to recover the recurring financial costs of O&M, and the annual fixed costs of capital repayment for rehabilitation and replacement from irrigators, but partial or full implementation should proceed only as price ceiling and crop quota policies and subsidies are eased, taking into account effects on farm incomes.

2. Water charge receipts should be earmarked to defray O&M and R&R costs. Collection and administration of these funds should be decentralized, say to Directorate level if possible, recognizing that some fraction will have to be allocated for common facilities such as barrages, HAD, etc.

3. MOI should test on a pilot basis (EWUP findings) the raised mesqa with one point pump lift for gravity operation to the farmer fields, but should avoid taking on the responsibility for operating and maintaining these by organizing farmers and providing them with technical assistance. The same principle should apply to costs of pumping water from canals to farms under new lands development.

4. It is proposed that consideration be given to developing a program for recovering part of the fixed capital costs of irrigation infrastructure for new lands. The part to be recovered from irrigators should be decided taking into account the indirect benefits of irrigation to the new lands economy.

Other

A number of other issue questions have been raised in this report. Principal ones include:

1. The overriding need to reexamine price support, crop quotas and subsidies in agriculture with the view to increasing production incentives to farmers;

2. Strengthening efforts to reduce the loss of old agricultural lands to urbanization and other uses;

3. Continuing reevaluation of agricultural and development strategy for new lands;

4. Expansion of the role of private sector development in divising and extending agricultural production technology for new lands;

5. Clarification of Ministerial responsibility for mobilizing interdisciplinary resources for supporting on-farm water management activities, including an integrated research institute, Irrigation Advisory Service, Irrigation Management Systems Authority and the role of the Agricultural Extension Service;

6. Whether or not and to what extent gravity delivery from mesqas will be encouraged;

7. Continued refinement of Nile water balance, taking into account such things as improved estimates of ET from the water tables and its effect on horizontal and vertical expansion of agricultural production, continuing hydrographical measurements and probability of sustained drought;

8. The possibility for increasing the number of graduates in agricultural and irrigation engineering, including training more women, as means of reducing shortages in this area and for increasing technical services in this area as an exportable resource; and

9. The possibility of implementing degree programs in agricultural engineering similar to those that are taken in the U.S. Graduates would supply the needs for agricultural extension in this field. Some would obtain higher degrees and join soil scientists and irrigation engineers in research on irrigation water management problems.

10. The MOI needs to develop a procedure to attract highly qualified new personnel and to keep the present staff by raising salaries, incentives, and/or other fringe benefits as necessary.

Policies being implemented relating to maintenance of channels, pilot projects for instituting the national irrigation improvement program, eliminating the backlog in rehabilitation and repair of physical infrastructure and improving main system operation appear to be heading in the right direction, although technological and management problems will continue to arise as these programs evolve.

CHAPTER IV

ASSISTANCE BY INTERNATIONAL DONORS

Framework for Selection of Priorities

The task of irrigation in Egypt is to support the national goal of achieving 3.5 to 4 percent annual growth in agricultural production.[1] All parts of a national irrigation system must function reasonably well or the system will fail or fall far short of its objectives.[2] Usually, all parts of an irrigation system need improvement in more or less degree; thus, improvement choices are not mutually exclusive, but are relative. Judgments can be made about which components currently are most critical in terms of their constraining effects upon the overall production of the system. The most critical ones should be attacked first. Usually, interventions for this purpose require new capital in combination with some reallocation of local resources.

Common situations where critical constraints occur include: (1) activities that may have been neglected or ignored, like distribution of water at mesqas, because institutional responsibility was not defined or was mismatched; (2) where new technological and management practices promise large returns -- like the introduction of high-yielding varieties in combination with carefully-designed production and input practices; or the introduction of meteor burst communication of water levels; (4) where large capital investments are committed on social grounds, but the technology and management for success is undeveloped as for the new lands; and (5) where an emergency or very high risk situation exists.

Economic rate of return is important and the rule that expected IRR should equal or exceed opportunity cost of capital should stand, but because of the diverse nature of the several irrigation subsectors, IRR is more useful between or among sectors. Confidence in how well B/C analysis accounts for indirect and social benefits and costs varies greatly among subsectors and must be considered.

Rankings of priorities for donor investment could be different than the country's overall priority rankings. In fact, from MOI's viewpoint, all items on the list below have equal priority. International donors have a comparative advantage in facilitating institutional changes and

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[1]Vice Minister for Irrigation, Eng. Ismail Badawy, November 4, 1985.

[2]Here the system is viewed as extending all of the way from the watershed to the farm, including producing, harvesting and marketing the crops.

facilitating transfer or development of new or advanced technology. Activities where a large indivisible sum of FC capital is needed may be attractive under some conditions because of its relative simplicity; in other situations a donor may prefer programs where capital is relatively divisible. The following list of programs and projects are summarized from Chapter III and are grouped into four general categories requiring improvements: Command Areas, New Lands, Main System Management and Watershed Management.

Priority Programs and Projects

Irrigation Improvement Program - Command Areas

Management of Pilot Project, Irrigation Management Research and Extension (R&E). The most critical issue in meeting Egypt's agricultural goals is increasing vertical productivity. The key initiative being implemented is MOI's proposed Water Management Systems Program. Two serious problems are faced; developing the interdisciplinary management capability for this program to the EWUP level, and putting into place an effective irrigation management R&E program. These are prime candidates for donor-supported intervention. Inter-ministerial commitments are necessary in each case. MOI has suggested a Water Management System Authority which, with the assistance of the Water Research Center, could integrate these two elements into a viable program including the IAS and coordination with the Agricultural Extension Service. Cost estimates for development of these institutions and programs have not been made, but costs could be in the range of $15 to $50 million for each over the next Plan period. To carry out the required A&E effort within MOI over the next Five-Year Plan, LE 42 million is allocated to the WRC and its eleven research institutes. Besides general support, special technical assistance, special studies and training components in such areas as interactive research—ET, crop, soil sodicity, water table interreactions, fertilizer; development of water user associations; mesqa maintenance; small-scale farm machinery; feasibility studies for improving the irrigation system on canal commands;[3] and on-farm irrigation extension deserve high priority. Cost could range from $200,000 to $1,000,000 each.

Physical Infrastructure. While not exclusively physical infrastructure, the basic support tentatively scheduled for 1987/88-1991/92 is LE 310 million, generally not including the interventions and technical assistance described above. Projects include 11 areas under the RIIP and projects such as the North Zifta improvement program. Programs of replacement of canal structures and channel rehabilitation are included in this item.

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[3]Preparatory Assistance Document has been submitted to UNDP.

Long-Term. The Irrigation Improvement Program being initiated under RIIP will require sustained support along the lines outlined above as the National Irrigation Improvement Program gets underway. Efforts will have to be multiplied substantially if significant effects are to be realized in this century. The size of post 1991-1992 targets cannot be estimated at this time, but the total investment cost of extending the program to all irrigated land would appear to be approximately LE 3,000 million at 1984 prices.

Productivity of New Lands

Critical, though in terms of magnitude of effects on Egypt's agricultural production, probably less significant than vertical expansion, is horizontal expansion. Attention needs to be given to improving productivity, especially on private and public company farms, a responsibility of the MLR. This needs to be further explored with the MLR. The WRC should increase its adaptive research efforts on developing ways to improve productivity on the old new lands and developing revised planning and design criteria for new land development.

Proposals include technical assistance, special study and training support for continuing evaluation of new land alternatives; irrigation methods for coarse and fine sandy desert soils; a water management study for West Nubariya;[4] and feasibility analysis for improving crop production in existing old-new lands.[5] Cost range for each would probably be in the $1,000,000 to $4,000,000 range with 50 to 75 percent foreign currency costs. One such study is underway by the PPD of the MOI which is performing a feasibility study for Wadi El-Farigh Project which has as its goal the development of 250,000 feddans in the Western Delta using some of the water released during winter closure period. The expected costs of this project is estimated at LE 160 million.

Physical infrastructure support of the Al-Salam Canal (LE 97 million) has highest priority for donor support, with a lower priority being accorded to El-Nasr, Nassery and Ismailia canals, totaling LE 195 million. Also included in this area is the shore protection program discussed in Chapter III. The estimated costs for the next plan period is LE 127 million plus TA of $1.7 million and LE 1.8 million. The estimated FC component is LE 22 million. (Support has been requested from the UNDP.)

Main System Management and Improvements

Telemetry. Included are implementation of sonor flow measurement (FC cost, $2 million; LC cost, LE 2000,000; duration, two years); automatic control of barrages and intakes (FC cost, $50 million; LC cost LE 5 million; duration 18 years); crop census by remote sensing (FC cost,

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[4,5] Op. cit.

$2 million; LC cost LE 200,000; duration, 18 years); technical improvement of monitoring capability at HAD (FC $3 million, LC LE 2 million); and a feasibility study of automatic control.[6]

Operational Distribution Model. This should be enlarged and enhanced for real-time use in operations. Estimated cost is $110,000 in foreign currency.[7]

Unit Command, Canal System and Related Models. These include a stochastic (and possibly linear programming model) for predicting crop evapotranspiration, a unit command model, a main canal systems model and linking cropping systems to the agro-economic model for optimization. Feasibility studies should proceed. In some cases, these might include limited field testing. Cost range is FC $1,000,000 to $4,000.000; LC 300,000 to 500,000. Feasibility studies should also be undertaken on improving communications on the main Nile system.

Esna and Damietta Barrage. Over the past several years the MOI and the "International Panel of Experts" have reviewed the conditions of the main barrages on the River Nile. Based on these recommendations the MOI has carried out a detailed feasibility study and determined that the Esna Barrage should be given top priority for replacement. Total estimated cost of the construction of the New Esna Barrage is LE 274 million, with a foreign currency component of LE 184 million.

Replacement of the eastern dam at Damietta is also given high priority because of its importance in controlling water levels upstream, preventing saline intrusion into the Nile, and completion of Al-Salam Canal. Total estimated cost is LE 34 million, with an FC component of LE 10 million.

Pump Replacement. Pumping must be reliable to ensure delivery of irrigation water where pumped diversions are used and for acceptable operation of pumped drains. Many pumping stations still have only marginal reliability or less and their rehabilitation deserves high priority. Total estimated investment 1987/1988 - 1991/1992 is LE 146 million.

Channel Maintenance. Because of the critical effect of improved maintenance on effective water delivery to farms and the removal of excess water through drains, the initial Channel Maintenance Plan, or an improved version of it, should have high priority. The costs (1986/87-1993/94) is estimated at LE 308 million, with LE 185 million estimated for 1993/94-1998/99. Estimated total costs include LE 105 million over the next six years for required intervention of technical assistance, machinery, chemicals and training.

[6,7] Op. cit.

Studies in Support of Planning. This topic includes several studies for which MOI has suggested UNDP assistance and cuts across all improvement categories. Estimated cost of the package is FC $5.527 million, LE 1.720 million. Duration time ranges from one to four years.

- Rehabilitation and Improvement of Water Delivery System in Old Lands.
- Application of Environmental Isotopes in Water Resources Management.
- Provision of current Maps of Topography and of Irrigation and Drainage system.
- Technical Assistance to the Shore Protection Agency.
- Assistance to the WRC in Introducing Modern Technologies in selected programs.
- Hydrological Maps of Egypt (Groundwater Map).
- Proposed Plan to study the Ocean Currents in the Egyptian Mediterranean Coastal Zone.

National Irrigation Training Institute. A recently completed study indentified the overall training needs of MOI and recommended the development of a National Irrigation Training Institute (NITI). The NITI would be constructed at a total estimated cost of LE 24.0 million, with a foreign currency component of LE 16.0 million. The NITI would be developed by expanding the current Training and Manpower Development Unit within the USAID supported Irrigation Management Systems Project to accommodate approximately 2500 trainees per year in a wide range of subject matter areas. The NITI would also coordinate and utilize other training facilities in and outside of Egypt.

Drainage. Donor funding support for the drainage program through 1991/1992 appears to be in place with IBRD assistance at a cost of LE 541 million. In the long term, an additional LE 263 million will be needed.

Technical Improvements at HAD. Estimated cost is LE 64 million over the next Five-Year Plan, including an FC component of LE 19 million. Improvements are needed in the right bank and for river training works downstream. Indicated costs include operation equipment, discharge measuring equipment, workshops, etc.

Improved Geodetic and Cadastral Survey Equipment and Mapping. Most of the costs of this program are for equipment, with some software. Estimated FC costs are LE 7 million with LC costs totaling LE 28 million.

Groundwater Development. Estimated investments for the next Five-Year Plan are LE 80 million in the Nile Valley and the Delta and LE 110 million in Sinai, including surface water development such as the construction of Wadi El-Maghara and Wadi El-Karm Dams, as well as several small dams on the distributaries of Wadi El-Arish and Wadi El-Garafi. Also the utilization of groundwater available in the Nubian sandstone aquifers in Central Sinai is considered. Pre-feasibility studies are now proceeding for specific areas such as El-Mahara and El-Karm areas.

Watershed Management

As discussed in Chapter III, there are several components of the overall system management that rely on accurate and timely information on inflows to Egypt. These include:

Nile River Model. There remains a reach of the Nile River that requires modeling to link the current models of Aswan Lake to the models of the equatorial lakes. It has been estimated that LE 3.0 million is required for this effort over a five-year period.

Long-Term Planning for Upper Nile Projects. This activity relates to the continuation of the current planning efforts regarding the reclaiming of the water currently lost to ET in upper Sudan and the Victorian Lakes region. This planning effort may require as much as LE 41 million over the next six years.

Runoff Estimates. The MOI needs to explore the possibility of using improved data collection and analysis techniques to provide short and long-term runoff predictions. Initially, MOI is planning to carry out a study to determine the feasibility of developing a project to:

- Examine prospects for extending Nile streamflow predictions, including time-flow probability distributions and long range rainfall forecasts.

- Examine prospects for long range rainfall prediction, using historical analyses, diagnostic and predictability studies, forecast experiments.

- Exploit satellite capabilities, utilizing remote sensing and ground truth to support prediction development and real-time monitoring and assessments.

- Develop cooperative data management system to establish an Egyptian data and analysis center connected to U.S. centers.

If the initial study indicates the desirability of proceeding with the project, estimates at this time indicate a need for LE 10 million over a five to six-year period to have a system fully operational.

Resource Requirements

The Table at the end of Chapter 1 summarizes the total MOI budget requirements for those items listed above and recommended for consideration by donor agencies. The total requirements are approximately LE 2,660 million over the next six GOE final years computed at 1984 prices and include a foreign exchange component of LE 980 million. In the past the O&M budgets (Chapter II) have been inadequate to maintain the infrastructure being built with Chapter III funds. Starting in 1980, as agreed to under the IMS project, the O&M budgets have been increased by 170 percent from 1980 to 1986 and it is planned to further increase Chapter II funds by 50 percent by 1992 to provide an adequate maintenance capability.

The projected fund requirements for activities of interest to the donor community, beyond the next Five-Year Plan to the year 2000, is approximately LE 3.7 billion.

Table 1

TOTAL FIXED INVESTMENTS IN THE PRESENT FIVE-YEAR PLAN
Distributed Between Public and Private Sectors Along Economic Sectors
(LE Billion)

Economic Sectors	Public Sectors	Relative Weight %	Private Sector	Relative Weight %	Total	Relative Weight %
Agriculture	2.9	11.7	1.1	14.3	4.0	12.3
Industry & Mining	6.7	26.0	1.8	23.2	8.5	26.0
Petroleum	1.4	5.6	--	--	1.4	4.3
Electricity	2.6	10.4	--	--	2.6	8.0
Construction	0.4	1.6	0.5	6.5	0.9	2.8
Total Commodity Service Sectors	14.0	56.2	3.4	44.1	17.4	53.4
Transport & Commun.	5.1	20.5	0.3	3.9	5.4	16.6
Other Productive Service Sectors	1.4	5.6	0.3	3.9	1.7	5.2
Total Productive Service Sectors	6.5	26.6	0.6	7.8	7.1	21.8
Population	0.2	0.8	3.4	44.2	3.6	11.0
Public Utilities	2.0	8.1	--	--	2.0	6.1
Education & Health	1.5	6.0	--	--	1.5	4.6
Other Social Service Sectors	0.7	2.8	0.3	3.9	1.0	3.1
Total Social Sercice Sectors	4.4	17.7	3.7	48.1	8.1	24.8
Total Distributed Fixed Investments	24.9	100.0	7.7	100.0	32.6	100.0
Undistributed Investments	0.3	--	--	--	0.3	--
Total Fixed Invest-ments	25.2	--	7.7	--	32.9	--
Land	0.3	--	0.3	--	0.6	--
Investment Expenditure	0.6	--	--	--	0.6	--
Total Investment Uses	26.1	--	8.0	--	34.1	--
Relative Weight %	76.5	--	23.5	--	100.0	--

RECLAIMABLE NEW LANDS

(Land Master Plan)

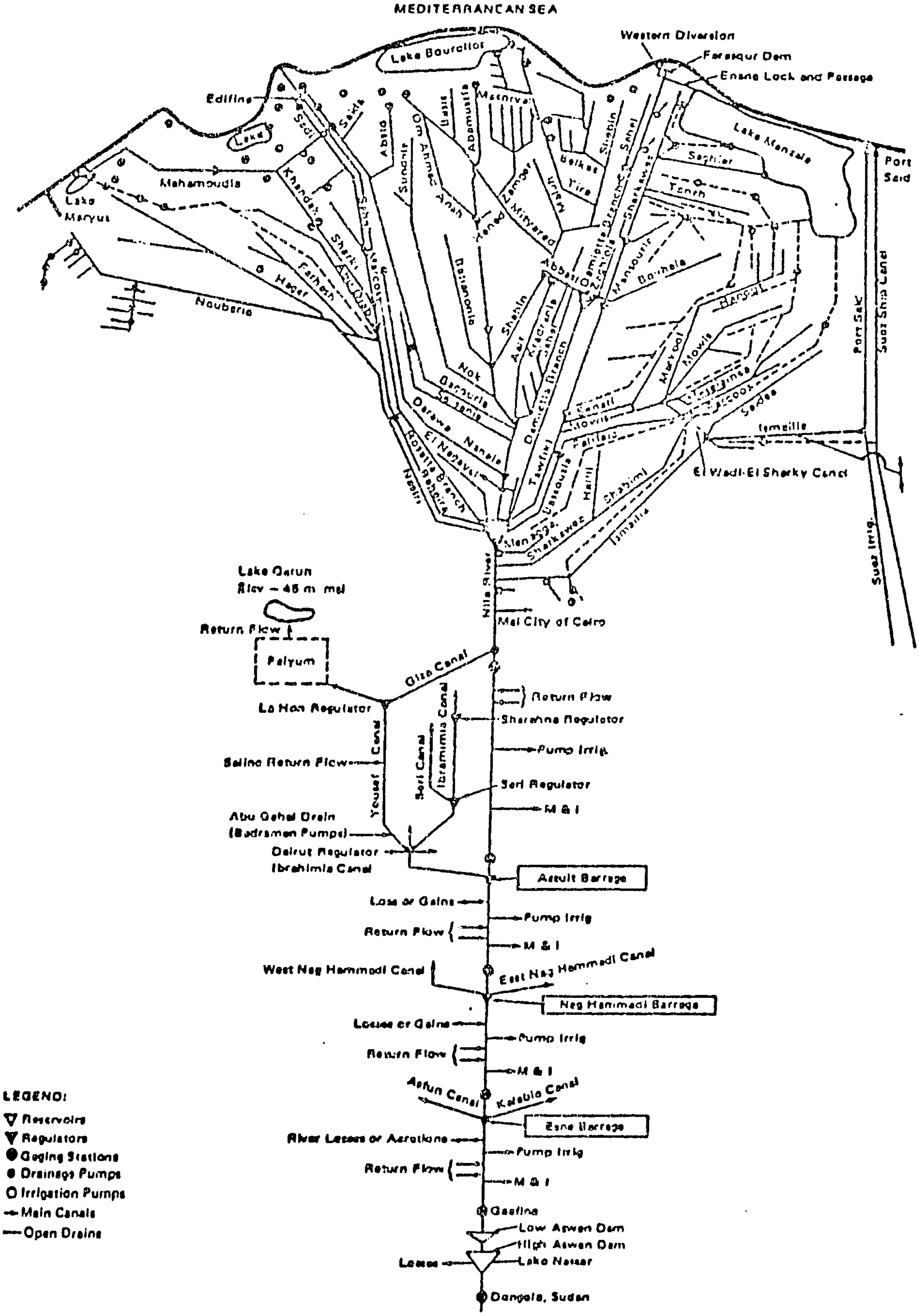
No.	Region & Area	Area 1,000 Fds
	I- BASED ON SURFACE WATER	
	1- East Delta (E.D.)	
1	Cairo Ismailia Road	30.2
2	Desert Fringes Belbis	11.6
3	Adleya & Extension	13.8
4	Ramsis/Tenth of Ramadan	31.5
5	Youth Province (Shabab)	47.5
6	El-Manayef	37.5
7	South of Cairo Ismailia Road	103.6
8	West of Bitter Lakes	33.2
9	El-Khattara	27.3
10	Salhiya Desert	56.0
11	Along Hosseiniya Canal	17.0
12	South Port-Said	62.5
13	East Bahr El-Baqar	11.8
14	South Hosseiniya	75.8
15	North Hosseiniya	66.0
16	South Port-Said Plain	43.5
17	El-Matariya	8.9
18	Fariskur	5.0
	Total East Delta	687.7
	2- West Delta (W.D.)	
1	Lake Maryut	11.0
2	Barseek (Idko)	27.0
3	El-Hagger	17.0
4	East Desert Road	56.9
5	Kafr Dawoud-Sadat	99.6
6	El-Bostan	30.3
7	Bostan Extension	18.9
8	Beheira	92.0
9	Nasr Canal Exten.	67.0
10	Zawyet Sidi Abdel Aaty	22.0
11	El-Hammam	18.0
12	Ras El-Hekma	43.0
13	El-Daba'a	31.2
14	Shukry Valley	35.0
	Total West Delta	570.9
	3- Central Delta (C.D.)	
1	Burullus Drying	55.3
2	Baltim & Khasha'a	3.7
	Total Central Delta	59.0
	4- Middle Egypt (M.E.)	
1	Upper Wadi Assyut	25.0
2	Lower Wadi Assyut	5.1
3	East Assyut	36.7
4	West Manfalut	19.1
5	West El-Qussiya	12.3
6	West Dayrut	20.5
7	Abu Sir	3.7
8	South El-Saff	15.6
9	North El-Saff	23.5
10	Wadi Arian	10.5
	Total Middle Egypt	172.0
	5- Upper Egypt (U.E.)	
1	Wadi Kharit	16.5
2	Wadi Sheit	9.5
3	Wadi Natash	80.0
4	Tributaries Wadi Natash	22.5
5	Koum Ombo West	345.0
6	Wadi El-Kobaniya	18.8
7	El Sa'ayda	1.8
8	El Sa'ayda West	81.6
9	Wadi Seraf	8.4
10	West Nasim	3.3
11	Hagaza	3.7

RECLAIMABLE NEW LANDS (Cont.)

(Land Master Plan)

No.	Region & Area	Area 1,000 Fds	No.	Region & Area	Area 1,000 Fds
12	Qift	5.5		6- Sinai (Si)	
13	Wadi El-Laqeita	48.5			
14	Wadi Qena	1.4	1	Tina Plain	50.0
15	West Qena	26.3	2	North Coastal Area	56.0
16	Wadi Samhud	3.5	3	East Bitter Lakes	27.5
17	West Gerga	3.9	4	East of Suez	42.0
18	West Tahta	24.2			
19	Wadi Abu Shih	2.3		Total Sinai	175.5
20	El-Ghanayem	3.5			
	Total Upper Egypt	710.4			
TOTAL RECLAIMABLE BASED ON SURFACE WATER					2,375.5
	II- BASED ON GROUNDWATER				
	New Valley (N.V.)			El-Arish	1.5
1	El-Zayat	1.5		Un-identified Areas	6.5
2	El-Dakhla	29.0		Total Sinai	14.0
3	West El-Mawhub	2.0			
4	Abu Mengar	4.5		Eastern Desert	
5	Farafra	31.5		Wadi Natash	11.7
6	Karawein	30.0		Wadi Abbadi	6.8
7	El-Bahariya	53.5		Wadi El-Laqeita	3.9
				Wadi Qena	10.05
	Total New Valley	152.0		Total Eastern Desert	32.45
	Sinai			North Western Coast	
	North Coast	3.0		Un-identified Olive Cultivation	19.0
	El-Qua'a	2.0		Total North Western Coast	19.0
	El-Kontella	1.0			
TOTAL RECLAIMABLE LANDS BASED ON GROUNDWATER					217.45
GRAND TOTAL RECLAIMABLE NEW LANDS					2,592.95

ARAB REPUBLIC OF EGYPT
SCHEMATIC DIAGRAM OF IRRIGATION SYSTEM



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