INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE
EGYPTIAN NATIONAL COMMITTEE ON IRRIGATION AND DRAINAGE

Background Report
On

Application of Country Policy Support Program (CPSP) for Egypt

Cairo-Egypt

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SECTION I

INTRODUCTION

1.1 Introduction

Water is a finite resource that is essential for agriculture, industry, and human existence. In arid and semi-arid countries, where water resources are quite limited, challenges for achieving the highest possible water use efficiency are particularly difficult (Tawfik et al., 1997). It is important to save and conserve water while providing necessary quantities to satisfy social and economic requirements as well as conserve the environment. However, due to the increase in population and associated rise in the standards of living and human economic and social activities, the demands on water are significantly intensifying. Decision-makers have adopted several planning tools to secure water allocation and distribution. Simulation and optimization mathematical models are proven examples of such planning tools.

Water resources policy analysis deals with the protection of people from the harmful effects of water and assurance of a constant, adequate supply of usable water. Population and regulatory pressure, political and economic instabilities, and climatic variation can all be expected to further stress water supply resources. Developing policies for managing water systems for human needs in such an environment is difficult, slow and very costly.

The development of a reliable model to be used within the water policy analysis framework that relates development plans in the different socioeconomic sectors with water as a natural resource, as the national strategic level, is a very elaborate task (Meadows et al. 1982, 1992). For a country like Egypt (our case study) with five main socioeconomic sectors dependable on scarce water resources, this task becomes more laborious. Complexity of water policy analysis requires a set of modeling principals. These principals should guide and simplify the mode development, and reduce the dimensionality problem.

1.2 Background

The International Commission on Irrigation and Drainage started a project to support policies and decision making for integrated water resources within river basins using new computer aided tools. In the first phase of the project two countries were selected for the adoption of PODIUM Sim model; India and China. Two river basins have been selected in each of the two countries. A workshop on the subject was held in Cairo, Egypt on August 3rd, 2004 to present and discuss the results of the application in the different river basins.

Egypt and Mexico are the following candidates for the application of the model. It is planned in the second phase that a modified version of the model will be utilized for the analysis of water policies within the Nile Valley and Delta in Egypt.

1.3 Scope of the Report

This report includes four main sections. In Section II a general background on the Egyptian water resources system is presented. A general review of Egyptian water policies starting from 1975 up till now is also presented. In this section a comparison between the different policies is illustrated. Section III of the report exhibits some of the available computer aided tools for water resources policy analysis that have been successfully implemented by the different sectors and research entities within the Ministry of Water Resources and Irrigation (MWRI). The current version of the proposed model (Basin Holistic Integrated Water Assessment, BHIWA model) is being reviewed and analyzed in Section IV. Section V presents the proposed steps for the adoption of the tools for the Nile Basin.

SECTION II

WATER RESOURCES AND UTILIZATION IN EGYPT

2.1 WATER RESOURCES SYSTEM ORGANIZATION

Egypt is divided administratively into 26 Governorates. On the other hand, irrigation system in Egypt is divided into 18 Central Directorates (CD). Each CD represents MWRI in the region under its control where it is responsible for managing all water resources aspects. All the CDs work directly under the head of the Irrigation Sector in the ministry's headquarters. Each CD includes one or more General Directorate for Irrigation (GD). There are 27 GDs cover all Nile Delta and valley governorates where each governorate represents by one or more GD depending on the complexity of its local irrigation network. The boundaries of the GDs are defined by specific control structures on the irrigation network; therefore, it is different than the administrative boundaries of the governorates.

There is one Central Directorate for Water Distribution (CDWD) under the Head of the Irrigation Sector. The main function of this central directorate is to coordinate with all the Central Directorates for water resources and irrigation all over the country to estimate the annual water requirements for different uses at the irrigation directorates' level. These requirements transferred to a water budget for each irrigation directorate and accumulated together to estimate the annual water requirement for Egypt. Then, the CDWD transfer these requirements to a schedule of 10-days period releases from High Aswan Dam and specific control structures on the irrigation network that separate between the GDs. The High Aswan Dam Authority is responsible for operating the HAD to meet these planned releases and communicate on a daily bases with the CDWD to adjust the daily releases from HAD based on the actual requirements.

The Drainage Authority is responsible for maintaining the drainage network and implementing the new drainage projects to upgrade and enhance this network. The Mechanical & Electrical Department is responsible for operation and maintenance of the irrigation and drainage pump stations according to the schedule of releases prepared by the CDWD.

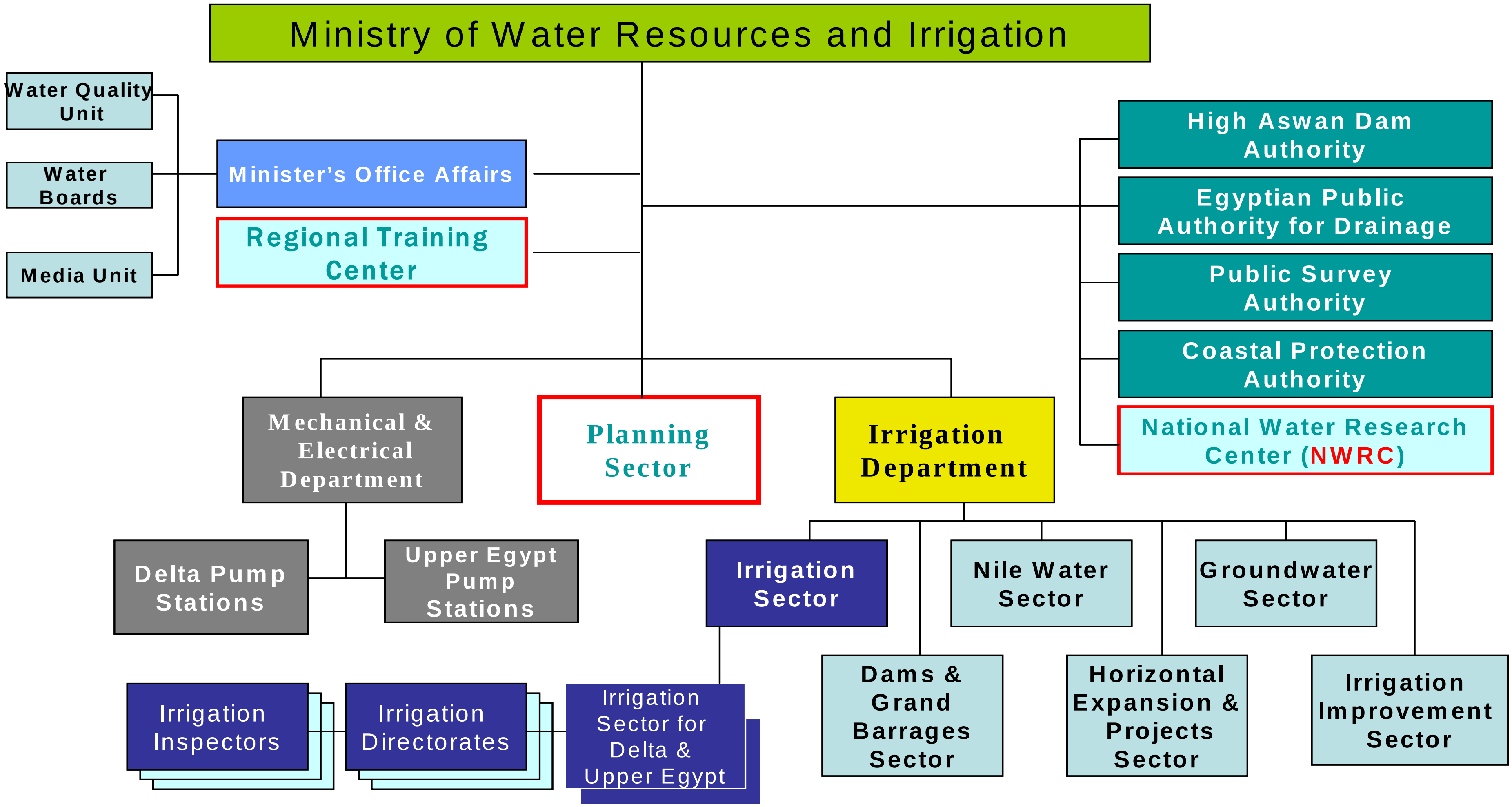

Figure (1) MWRI Organization Structure

2.2 SURFACE AND GROUNDWATER RESOURCES

Water resources in Egypt are limited to the Nile River, rainfall and flash floods, deep groundwater in the deserts and Sinai, and potential desalination of sea and brackish water. Each resource has its limitation on use, whether these limitations are related to quantity, quality, space, time, or exploitation cost.

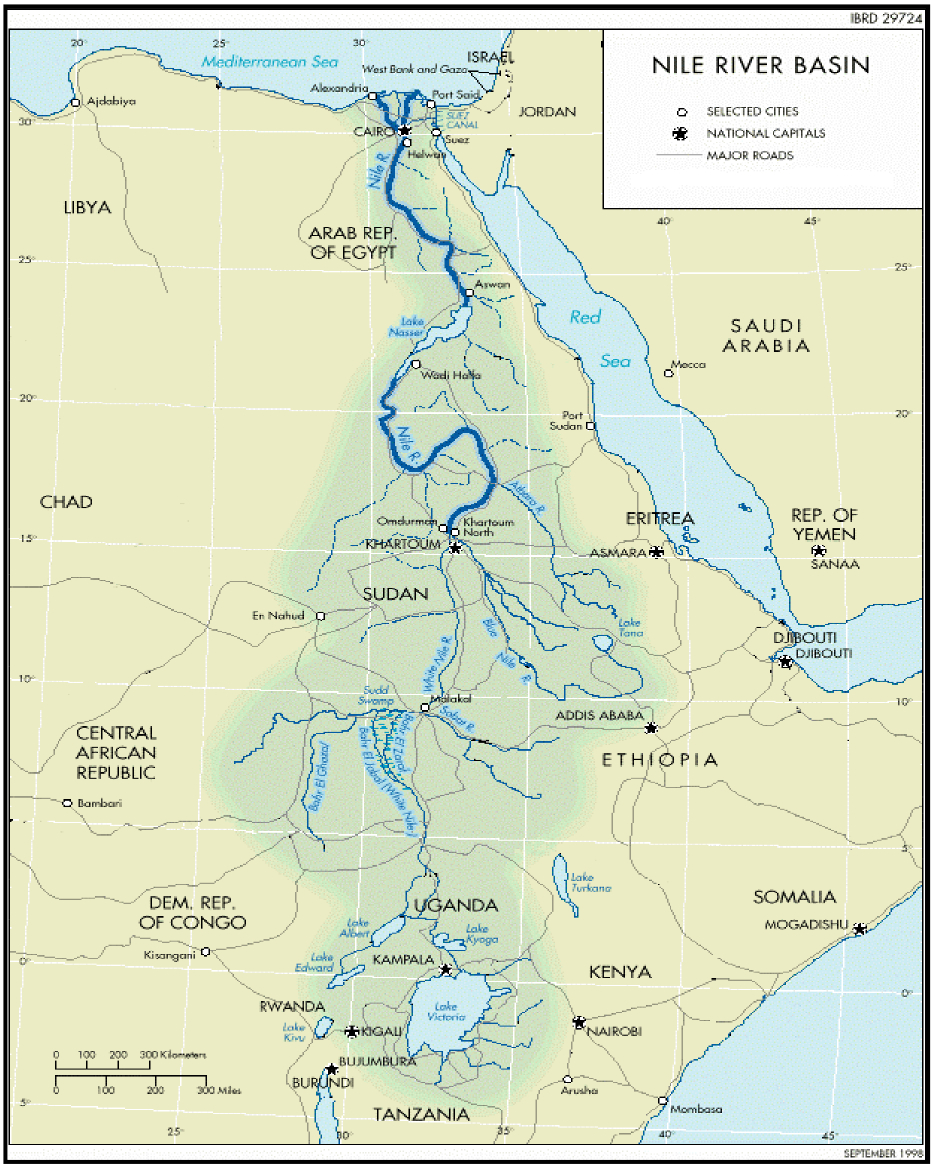

Figure (2): The Nile River Basin

Egypt receives about 98% of its fresh water resources form outside its internationals borders. This is considered to be a main challenge for water policy and decision makers in the country as the river provides the country with more than 95% of its various water requirements. The average annual yield of the Nile River is estimated at 84 billion cubic meters (bcm) at Aswan. The discharge of the Nile River is subject to wide seasonal variation. The natural river flow can be divided into two periods: 1) A short 3-month long high muddy flow season, and 2) a longer 9-month long flow clear season. According to the 1959 Agreement with Sudan, Egypt's annual share of the river water is determined by 55.5 bcm. The agreement also allocated 18.5 bcm for Sudan, while about 10 bcm are considered as various water losses at the Aswan High Dam (HAD) reservoir site.

The High Aswan Dam (HAD) was constructed at about 6 km south of Aswan. It is considered to be the major regulatory facility on the River. It has been operating since 1968 ensuring Egypt's control over its share of water and guiding its full utilization. Downstream HAD, the Nile water is diverted from the main stream into an intensive network of irrigation canals. The main function of these canals is to provide water for agricultural use. The agriculture drainage water is then collected through a network of tile and open drains. In Upper Egypt, most of the collected drainage water flows back to the Nile as return flow, while in the Delta, drainage water is pumped into the Mediterranean and the northern lake.

Egypt's present irrigation water delivery system was developed over the past century with initiation of barrage construction, on the Nile in 1861. Eight controls structures (barrages) (see figure (3)) serves 13 principal gravity canals account for about 80 percent of irrigation water delivery from river source; the remainder is nearly all pumped. These barrages were constructed to fulfill two main objectives. The first was to guarantee basin irrigation in low floods, and the second was to allow the conversion of basin irrigation to perennial. The main canals and drains networks, exclusive of mesqas and marwas (private and ditch canals), are about 35000 and 16000 kilometers respectively. Operation and maintenance of the canals and drains network are the responsibility of MWRI.

Egypt is an arid country that receives an amount of rainfall that seldom exceeds 200 mm per year along the northern coast, declines very rapidly from these coastal areas to inland, and becomes almost nil south of Cairo. Also, rainfall along the Mediterranean coast decreases eastward from 200 mm/year at Alexandria to 75 mm/year at Port Said. The average annual amount of rainfall water that is effectively utilized is estimated to be around 1 bcm per year.

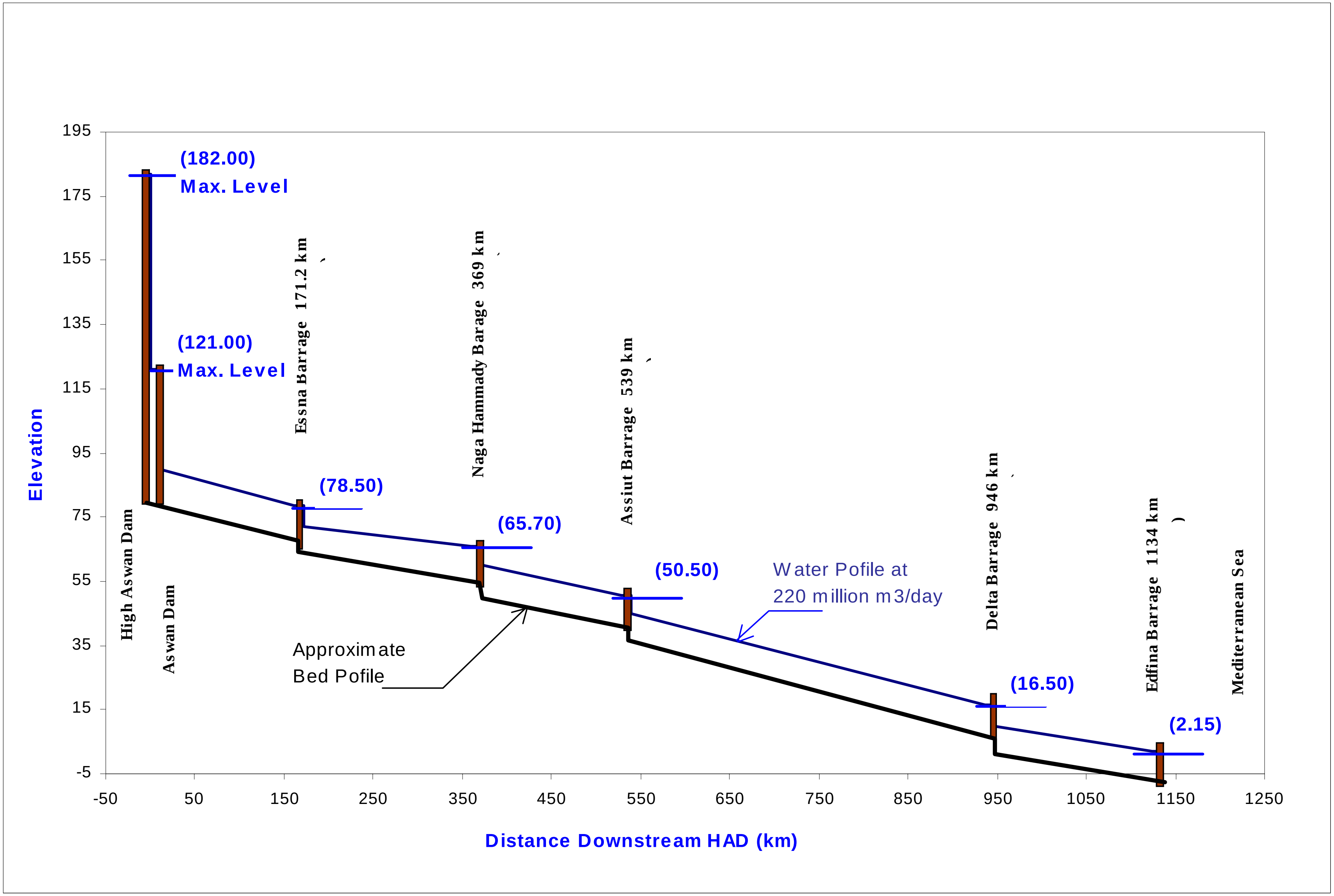

Figure (3): Profile of the River Nile Downstream High Aswan Dam

On the other hand, flash floods occurring due to short-period heavy storms are considered a source of environmental damage especially in the Red Sea area and Southern Sinai. This water could be directly used to meet part of the water requirements or it could be used to recharge the shallow groundwater aquifers. It is estimated that about 1 bcm of water on average can be utilized annually by harvesting flash floods.

Groundwater occurs in the Western Desert in the Nubian sandstone aquifer, which extends below the vast area of the New Valley governorate and the region east of Owaynat. It has been estimated that about 200,000 bcm of fresh water are stored in this aquifer. However, such groundwater occurs at great depths and the aquifer is generally non-renewable. Therefore, its utilization depends on pumping costs and depletion rate versus the potential economic return on the long run.

The groundwater aquifers in the valleys of Sinai are recharged from rainfall and especially from heavy storms. The annual rainfall on Sinai varies from 40 mm to 200 mm/year. Although most of the shallow aquifers in Sinai are renewable, only 10 to 20% of the deep aquifers are recharged by rainfall and flash floods. The total amount of groundwater abstraction in the Western Desert in 99/2000 was estimated to be about 0.817 bcm while it's only 0.09 bcm in Sinai.

Desalination of seawater in Egypt has been given low priority as a water resource because the cost of treatment is high compared with other sources. Desalination is actually practiced in the Red Sea coastal area to supply tourism villages and resorts with adequate domestic water supply where the economic value of the water is high enough to cover the treatment costs. It may be crucial to use such resource in the future if the growth of the demand for water exceeds all other available water resources. However, its use will depend on technological development in this field.

There exist other non-conventional sources of water which include the renewable groundwater aquifer underlying the Nile Valley and Delta, the reuse of agricultural drainage water, and the reuse of treated sewage water. These water sources cannot be considered independent resources and therefore, cannot be added to Egypt's fresh water resources. In fact, using these sources is a recycling process of the previously used Nile fresh water in such a way that improves the overall efficiency of the water distribution system.

The groundwater aquifer underlying the Nile valley and Delta is a renewable aquifer. This aquifer can be used as a source of water to meet part of the water demands at peak periods and then recharged again during low demand periods. Current abstraction from this aquifer is estimated at 6.127 bcm in 99/2000.

The amount of water that returns back to drains from irrigated lands is relatively high (about 25 to 30%). The agricultural drainage of the southern part of Egypt returns directly to the Nile River where it is mixed automatically with the Nile fresh water to be used for different purposes in the downstream. The total amount of such direct reuse in addition to unofficial reuse done by farmers themselves, if they are short of canal water, is estimated to be about 1.881 bcm in 99/2000. The total amount of official reuse of agricultural drainage water was estimated to be 5.96 bcm in 99/2000. Reuse of agricultural drainage water is limited by the salt concentration of the drainage water. Therefore, more efficient irrigation, inevitability, leads to the same amount of salt dissolved in a smaller volume of drainage water. That means a more efficient distribution system will result in smaller quantities of reusable drainage water. The total amount of drainage water that was pumped to the sea was estimated to be 15.662 bcm in the year 99/2000. This amount is more than the average annual volume of drainage water to the sea that amount to 12 BCM per year. This high release was due to the high flood occurred in year 2000 and the previous two years.

Treated domestic sewage is being reused for irrigation with or without blending with fresh water. The increasing demands for domestic water will increase the total amount of sewage available for reuse. It is estimated that the total quantity of reused treated wastewater in Egypt is about 0.7 bcm in 99/2000. Table (2.1) shows the available Water Resources in Egypt in year 99/2000

Table (2.1): Water Resources In Egypt in year 99/2000

Conventional Water Resources	
River Nile Annual Flow	55.5 BCM
Rainfall	1.0
Flash Flood	1.0
Groundwater in Western Desert	0.817
Non-Conventional Water Resources	
Groundwater in the Nile Valley & Delta	6.127
Reuse of Agriculture Drainage Water	5.96
Reuse of Treated Sewage Water	0.7

2.3 WATER REQUIREMENTS

Egypt's water requirements increase with time due to the increase in population and the improvement of living standards as well as the government policy to reclaim new lands and encourage industrialization. The cultivated and cropped areas have been increasing over the past few years and will continue increasing due to the Government policy to add more agricultural lands. The largest consumers of irrigation water are Rice and Sugarcane because they have high water requirements in addition to occupying a considerable area. The average crop consumptive use for year 99/2000 was estimated to be 41.441 bcm. The total diverted water to agriculture from all sources (surface, groundwater, drainage reuse, and sewage reuse), which includes conveyance, distribution, and application losses, in 99/2000, was about 60.731 bcm. The water policies of the 1970 and early 1980's gave a significant advantage to new lands development. However, recent changes in price and other policies particularly the reduction/elimination of government fertilizer and energy subsidies place farmers in the new land at a disadvantage.

Annual evaporation from open water surfaces is estimated using the total water surface area of the river Nile inside Egypt and the irrigation network (canals and drains) and an average annual rate of evaporation. The main river surface area is estimated to be about 1000 km^2 and the total water surface area of the canals and drains network is about 260 km^2 with an average evaporation rate 6.0 mm/day. Based on these estimations, the total annual evaporation from open water surface of the Nile River and canals and drains network is estimated to be 3.0 bcm for the year 99/2000. This amount varies slightly from one year to another according to climatic conditions as well as the rate of infection of the canals and drains with aquatic weeds.

Municipal water demand includes water supply for major urban and rural villages and was estimated as 4.6 bcm in 99/2000. A part of that water comes from the Nile system and the other part comes from groundwater sources. A small portion of the diverted water (about 1 bcm) is actually consumed while the remainder returns back to the system. The major factor affecting the amount of diverted water for municipal use is the efficiency of the delivery networks. The studies showed that the average efficiency is as low as 50%, and even less in some areas. The cost of treating municipal water can be reduced significantly as the efficiency of the distribution network increases.

There is no accurate estimate for the current industrial water requirements especially with the new government policy to encourage private sector participation in industrial investment. The estimated value of the water requirements for the industrial sector during the year 99/2000 was 7.53 bcm per year. A small portion of that water is consumed through evaporation during industrial processes (only 0.79 bcm) while most of that water returns back to the system in a polluted form.

The river Nile main channel and part of the irrigation network are being used for navigation. Water demand specifically for navigation occurs only during the winter closure period when the discharges to meet other non-agriculture demands are too low to provide the minimum draft required by ships. This water goes directly to the sea as fresh water. After changing the winter closure system by dividing the country into 5 regions instead of two, the amount of water released for navigation is considered to be insignificant. However, in the year 99/2000, an amount of 6.517 bcm of fresh water went directly to sea because of the high flood occurred this year and the past two years. Normally, the release of fresh water to sea is about 0.26 bcm per year (year 95/96) due to leakage from barrages gates.

Each element of the water system whether it is an input or output has a certain salt concentration. The total salt load inputted to the system is estimated to be about 19.8 million tons while the total amount of salt leaving the system is estimated to be about 31.43 million tons. It is obvious that the system is unbalanced concerning salt loads where the output exceeds the inputs with more than 11 million tons. This unbalance might be due to various reasons, e.g. seawater intrusion in Northern Delta is considered a major source of salt loads entering the system.

Egypt’s national water balance for the year 99/2000 is illustrated in Figure 2.1. This figure shows the different water supply sources in relation to the demands. Currently release from HAD was estimated to be 67.06 bcm.

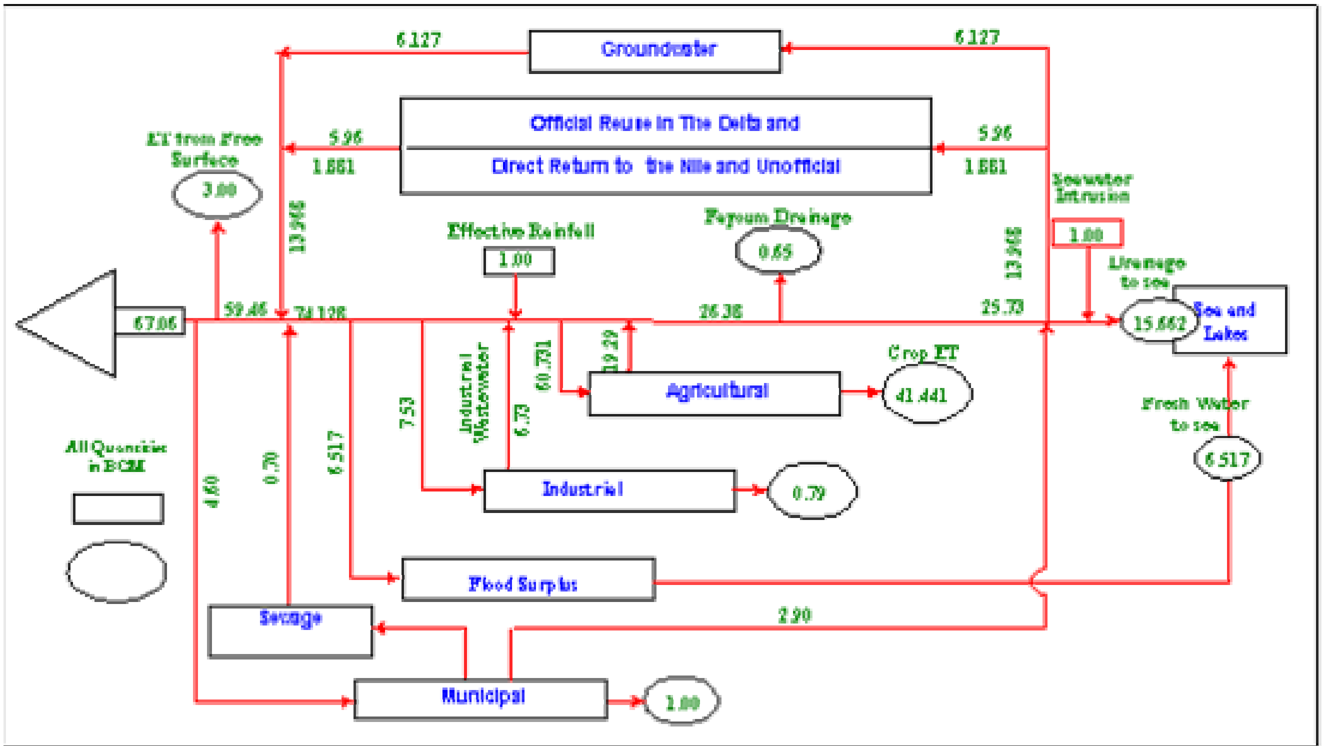

Figure (2.1): Egypt's national water balance for the year 99/2000

Currently groundwater abstractions from the Nile aquifer amount to 6.127 bcm. An amount of 5.96 bcm of drainage water has been reused either directly or after mixing with fresh water in the Delta. The figure also shows an additional amount of 1.0 bcm of effective rainfall and 0.7 bcm of treated sewage that have been used. Agricultural demands reached 60.731 bcm, of which 41.441 bcm have been considered as crop evapo-transpiration. Water diverted for industry was 7.53 bcm, of which 6.73 bcm returned back to the system. Municipal use during 99/2000 was 4.6 bcm.

SECTION III

EVALUATION OF NATIONAL WATER POLICIES IN EGYPT

After the completion of the High Aswan Dam, a series of water resources policies have been developed in Egypt to have better management of the available water resources in order to match the currently and projected water supply and demand for all sectors. Most of the national water polices were not flexible, consequently, they could not cope with uncertainties. One source of uncertainty is the lack of addressing future changes in these policies whether these changes were in technology or in the country's priority issues that may affect the behavior of water users. One of the major changes was the government decision to shift from the central planning economy to the free market economy allowing free cropping patterns based on market needs. Another source of uncertainty is nature itself. These policies could not reflect changes that happen naturally like drought or flood periods. One technique that copes with uncertainties in forecasting and estimating policies numbers is to generate different scenarios, which simulate the different changes that may occur in the future and estimate different values for policy parameters. Therefore, the policy will have different scenarios reflecting the different predictable changes. The next sections describe briefly the previous water policies and their main objectives and assumptions.

3.1 Water Policy for the Year 1975

After the completion of the High Aswan Dam, a detailed water policy was prepared in 1975. This policy tried to discuss and evaluate the available water resources at that time and aimed at determining the available excess water that would be used in agricultural land expansion. This policy estimated that the amount of excess water in the near future would be about 16.76 Bcm per year and the agricultural area that could be reclaimed using that water will be 2.5 million feddans. The 1975 policy estimated the available excess water based on the balance of future available water resources with existing demands. This means, the policy neglected the future increase in all water requirements except in the agriculture sector.

It suggested the required development actions to achieve the reuse of 12.16 bcm per year of drainage water. It also considered the amount of water that could be saved from the Nile water conservation projects in the far future stage to be 9 bcm per year. It gave little attention to the availability of groundwater uses whether in the near or the far future scenarios. In addition, it neglected the industrial water demand since it was very small at that time.

3.2 Water Policy for the Year 1980

In 1980, the Ministry of Irrigation evaluated the available water resources and its distribution among the different uses. It projected the water resources status every five years starting from 1980 till year 2000. The 1980 water policy main assumptions were:

- About 5 bcm per year would be saved on the long run as a result of the full application of the Irrigation Improvement Project.
- Additional water saved in the upper Nile by constructing Jonglie Canal is 2 bcm per year.
- By the year 1985, the reuse of drainage water would reach 6.3 bcm and by year 1990, it would reach 10 bcm

The 1980 policy considered the amount of renewable groundwater in the Nile valley and Delta as one of the resources that could be developed over time to reach 4.9 bcm per year by the year 2000.

It also considered the development of agricultural drainage water reuse as a major source to meet part of irrigation demands. The policy realized that the Irrigation Improvement Project is a long term project and its effect on water conservation might not be available before a long time, therefore, it did not consider any water savings by that project in all the scenarios till year 2000.

The agricultural water demand was considered to be fixed at 49.7 bcm per year based on 6 million feddans of irrigated old lands. The domestic and industrial water demands were considered to increase over time based on population growth and future development in the industrial sector. The amount of water allocated for navigation, power generation and regulation were considered fixed to the existing amounts at that time (4 bcm per year).

The policy concluded that the available excess water by year 2000 would be 7.9 bcm per year. This amount of water could be allocated to agricultural horizontal expansion projects to reclaim about 1.58 million feddans.

3.3 The Egyptian Water Master Plan, year 1982

In 1982, Egypt Water Master Plan (EWMP) was prepared and developed to assist in water planning and management. The long term objectives of that plan were to optimize the development and use of the available water resources and to reinforce the government capacity in water planning in order to be able to support socio-economic development.

The immediate objective was to prepare a master plan for the optimal development and use of the available limited water resources. The plan main outputs were:

- Policies for water development and use.
- Programs of investment in water resources development.
- Procedures for operation of works, continuing analysis and development of available human resources.
- The project had been implemented in three consecutive phases:
- Phase one included basic data gathering, developing of planning tools, and presenting three future scenarios for the expected growth of land reclamation;
- Phase two had the short term planning of water resources as a major objective together with the institutional development for planning;
- Phase three was to apply the planning and management systems and models that have been developed in phase two.

3.4 Water Policy for the Year 1986

In 1986, the Ministry of Irrigation revised the year 1980 policy to update some of the basic assumptions of that policy. The major changes were the halt of Jonglie canal and the expected effect of the Irrigation Improvement Project on the quantity and quality of agricultural drainage water reuse. These factors were the main reason for that revision especially with the increasing attention of environmental impacts of using pollutant water in agriculture and its effect on both water and land quality.

The main objective of this policy was to sustain the use of water resources in order to close the country’s food gap. Therefore, it evaluated the available water resources and its different uses at that time. It made a projection every 5 years till the year 2000. The policy checked the national water balance at the end of the national five-year plan in 1992/93. It also projected the national water balance at the end of year 2000.

The main assumptions for that policy were:

- Jonglie Canal would be in operation before 1992/93, which will add 2 bcm per year to Egypt's share in Nile River fresh water.
- 50% of the Nile Valley and Delta groundwater utilization projects would be accomplished before 1992/93. These projects would increase the available renewable groundwater in the Nile valley and Delta from 2.3 bcm to 4.0 bcm by year 1992/93. This amount was projected to be 4.9 bcm by year 2000.
- Some pump stations would be constructed to expand the agricultural drainage water reuse program. The estimated value for drainage water reuse in delta was 3.4 bcm by year 1986/87. The policy projected this amount to be 6.3 bcm by year 1992/93 and to be 7.0 bcm by year 2000. The policy did not take into account the amount of return flow to the Nile in the Nile Valley resulting from drainage in the southern part of Egypt that enters the system again.
- About 1.5 bcm per year of the winter closure period water would be used or saved in the Borollus and Manzala Lake.
- About 2.5 million feddans would be covered by the Irrigation Improvement Project by year 2000, which would conserve about 2.0 bcm per year.

According to the 1986 water policy, the average amount of water that could be saved by 1992/93 would be about 7.7 bcm per year after meeting all water demands. This amount of water would be increased to 9.3 bcm per year by the end of year 2000, as the Irrigation Improvement Project would spread out to cover more areas. The policy suggested using the saved water for agricultural expansion in new lands. The expected area of new lands that could be reclaimed by year 2000 utilizing that water was about 1.7 million feddans.

Although, the 1986 water policy suggested a surplus of 7.7 bcm per year in water availability by the end of year 1992/93, in reality the situation was rather critical in that year. The available water resources exceeded all requirements in this year by only about 2.3 bcm per year. Moreover, the 1986 water policy estimated agricultural water requirements at 49.7 bcm for 6 million feddans while in reality, the assessment for year 1992/93 resulted in a much larger area of more than 7.4 million feddans.

The policy considered the effect of restricting the amount of water for navigation, power generation, and regulation. The estimated amount of that water was decreased with time to reach 2.5 bcm by year 1992/93 and 1.5 bcm by year 2000. This indicated the importance of applying the winter closure staggering scheme and finishing the implementation of Esna barrage and New Nag Hammadi lock to reduce navigational water requirements. This policy also assumed that the rate of growth of domestic demand would be lower than the value used in the 1980 water policy.

The estimated amount of domestic water demand would increase from 3.7 bcm to 4.9 bcm by the end of 1992/93 and to 5.9 bcm by the end of 2000 while it was expected to be 6.8 bcm in 1980 water policy. That was mainly because the 1986 policy assumed that there would be an improvement in the domestic water distribution network to decrease the losses and increase the efficiency. The industrial water requirement was estimated to grow from 3.0 bcm in 1986/87 to reach 3.5 bcm by year 1992/93 and to reach 5.0 bcm by year 2000.

3.5 Water Policy for the Year 1990

In 1990, the 1986 water policy was reviewed and updated in order to accommodate for the following main factors, the drought that lasted almost eight years, the halt of the upper Nile conservation projects (Jonglie canal was halted in 1983), and the formulation of the new agricultural expansion policy.

The new assumptions for the 1990 water policy can be summarized as follows:

- Jonglie Canal would be in operation by year 2000.
- Drainage water reuse had the potential to increase from 4.7 to 7.0 bcm per year by year 2000.
- By year 2000, extraction from the deep groundwater in the desert and Sinai could be increased 0.5 to 2.5 bcm while groundwater utilization in the Delta and the Nile valley could be increased from 2.6 to 4.9 bcm per year.
- Fresh water that flowed to the sea during minimum requirements period would drop from 1.8 to 0.3 bcm per year by the year 2000.
- The Irrigation Improvement Project might save 1 bcm per year by the year 2000.

- 1.6 million feddans were expected to be added to the present agricultural land at that time (7.4 million feddans in 1990).
- Municipal network efficiency would increase from 50% to 80%; therefore, the domestic requirements would not increase till the year 2000.

The 1990 water policy considered the utilization of treated sewage water while that source was not included in any of the previous policies. The expected amount of reuse of treated sewage water was about 0.2 bcm at that time and it would reach an amount of 1.1 bcm per year by the year 2000.

3.6 Water Security Project, 1993

The development objective of the project was to promote the most efficient use and allocation of Egypt's scarce water resource. The project was to develop realistic projections of water availability and demands over the following 20-years period and to identify and schedule infrastructure development and/or measures aiming at meeting this demand and optimizing resources allocation. Demand segments included were: irrigation water supply for old lands, domestic and industrial requirements, water supply for the development of new lands, as well as water required for navigation, hydropower and fisheries.

The main findings of this project include:

- Present overall water use efficiency below the HAD was about 70%. The most promising efficiency improvement would involve using more of the drainage water leaving the basin, some of 12-13 bcm at that time. The limiting factors to its use were the available amounts of fresh water and the salinity standards set for irrigation.
- About 1.5 bcm of fresh water escaped to the sea during the winter closure period. This could be reduced by staggering the canal closure period. The improvement of irrigation efficiency would reduce releases of fresh water but would reduce the drainage flows substantially.
- Reclaimed desert was expensive to develop and less productive and less economic than irrigation in the old lands in terms of its water use. The more land to be reclaimed, the less secure would be the water supply. Taking into account all water demands up to year 2000, it appeared that about 1.0 million feddans would be sustainable with the

available Nile water. Some mining of groundwater would be possible in the western desert and in Sinai but this development would not be sustainable on the long run.

3.7 Water Policy for the Year 1999

In 1999, the Planning Sector in MWRI prepared a conceptual framework for water resources planning based on the provision of quantitative and qualitative information using mathematical modeling and computer techniques to achieve the objective of resolving conflicts between different water uses. The major objective of the MWRI future policy and associated strategies needed to meet these objectives was summarized as follows:

- Maximizing water losses and improving irrigation efficiency,
- Apply Appropriate Mechanisms for Cost Recovery of water services,
- Shifts in cropping pattern,
- Development of renewable and non-renewable groundwater resources,
- Reuse of drainage water,
- Reuse of wastewater,
- Development of Jonglie canal and upper Nile projects,
- Desalination of brackish water,
- Harvesting of flash floods water,
- Water quality management,
- Public awareness,
- Continuous monitoring and evaluation of surface and groundwater quality,
- Users participation in water management,
- Upgrade of MWRI organizational structure and coordination between MWRI and other Ministries,
- Updates of law and decrees,
- International co-operation, and
- Adoption of new technologies in water use.

To overcome the shortcomings of previous water and land policies, social, environmental, and economic impacts of proposed strategies have been incorporated in the analytical framework. Mathematical models were used as tools that can predict these impacts in an integrated way by using different assessment criteria that is shown together on a one-page score card for each proposed strategy. Thus, the decision-maker can easily compare and select the strategies that better suits his perception of objectives. The system can be further developed to use Multi Criteria Analysis that depicts different preferences of different decision-makers to make the decision-making process easier.

In addition, uncertainty was addressed by the generation of pessimistic, average (or expected), optimistic scenarios of future water demands. These scenarios should be included in the water/land resources plan to account for uncertainty in estimating future water demands in the agricultural, industrial, and domestic sectors.

3.8 Assessment of Previous Water Policies

Egypt's water policies have been aimed at different water resources development objectives. It is so clear that all policies considered the agricultural sector as the largest user of water where its share exceeds 80% of the total demand for water. This sector comprises about 40% of the total Egyptian employee force. In addition, the share of agricultural production in the National Gross Production (NGP) is relatively high (18%). Therefore, the success of Egypt's economic development plans and economic growth is closely linked to its ability to develop and implement appropriate water policies that secure and conserve water for the new national projects, like El-Salam Canal Project and the New Valley project. The sustainability of these projects will depend mainly on the level of success in implementing such water policies.

Water policy development in Egypt faces a number of challenges; mainly, the mismatch of water supply and demand that resulted from increasing demands for water in all sectors. The rate of demand growth is linked directly to the growth in population and the rise of the living standards. In spite of that increasing demand rate, the available water resources in Egypt are limited and the rate of its development is much slower than the rate of increase of the demand side. This means that the gap between available resources and water requirements will increase over time and Egypt will be facing water scarcity in the near future.

The existing agricultural land in any policy before the 1990 policy was considered to be about 6 million feddans with water requirements equaling 49.7 bcm per year. In the 1990 water policy, the existing agricultural land was assessed to be 7.4 million feddans with the same amount of water requirement stated in previous policies.

All policies emphasized on allocating any excess water to land reclamation projects. Therefore, the projected agricultural expansion varied from one policy to another based on the available excess water. In the 1990 water policy, it was expected that the maximum agricultural land expansion would be 1.6 million feddans by year 2000 with a total water requirement of 10.2 bcm per year.

The amount of water allocated for power generation, navigation, and regulation had been decreased from 4.0 bcm in the 1980 water policy to only 0.3 bcm in the 1990 policy. That was decided after the drought period that lasted for almost 8 years (1979 to 1985). The total inflow to Lake Nasser was far below the average and the available storage of the lake reached its minimum level. It was decided to stop any additional water releases for power generation and to minimize water releases for navigation.

Accordingly, the Ministry of Electricity started a national program to implement more thermal power generation stations to reduce the dependence of the electrical distribution network on hydropower stations. Additionally, the Ministry of Irrigation issued a new system for staggering the winter closure into 5 regions, which reduced the amount of fresh water going to the sea during that period.

The estimates for municipal water requirements by year 2000 decreased from 6.8 bcm in the 1980 water policy to only 3.1 bcm in the 1990 policy. The large difference between the two estimates resulted from the fact that the 1990 water policy assumed that the efficiency of the Domestic water distribution network would be increased from 50% to 80% saving more water in that sector.

On the contrary, industrial water requirements of the year 2000 increased from 4.0 bcm in the 1980 water policy to 6.1 bcm in the 1990 policy. That is mainly because of the government new policy to encourage private sector investment in the industrial sector. Therefore, the country would enter the 21st century with a big expansion of the industrial sector. Accordingly, water demands for that sector will largely increase over time. In addition, the amount of industrial wastewater will also increase. This type of water is a major source of pollution; therefore, plans and studies of its environmental impacts of such expansion must be conducted.

On the supply side, all policies have taken the upper Nile conservation projects into consideration as long term scenarios. The 1975 water policy was very optimistic about the completion of these projects. It suggested that all projects would be implemented in the far future (non-specific time horizon probably by 2000) increasing Egypt’s share in Nile waters by 9 Bcm per year. In the following policies, only the Jungle Canal construction project was taken into consideration. This project was estimated to conserve about 4 Bcm per year that would be shared equally between Egypt and Sudan. This project has been facing some problems since 1983. Hopes are not lost yet to finish the construction of Jonglie Canal before the year 2017.

Groundwater development has been given more emphasis in recent policies. The 1975 water policy gave agricultural drainage water reuse much more emphasis than groundwater. It considered only that 0.5 bcm per year of groundwater would be developed as abstraction from the renewable groundwater aquifer in Delta region. The 1980 and 1986 water policies mentioned the possibility of abstracting about 4.9 bcm of groundwater by year 2000. The 1990 water policy introduced the possibility of fossil groundwater exploitation to satisfy part of the agricultural new land expansion. This amount of water was estimated to be around 2.5 bcm per year from the western desert and Sinai aquifers.

Agricultural drainage water reuse has been considered a major part of the available water that could be used to meet the increasing agricultural demands. The 1975 water policy assumed that the amount of the available agricultural drainage that could be reused in delta region to be 7.6 bcm per year by the year 2000. This water policy was the only policy to consider the return flow to the Nile from upper and middle Egypt’s drains. This amount of water was estimated to be about 4.4 bcm per year by year 2000.

The year 1980 water policy considered the available agricultural drainage water for reuse in the Delta region by year 2000 to be 10 bcm per year while in the 1986 and 1990 water policies; this potential was decreased to 7.0 bcm per year. This amount is constrained by the fact that a part of the drainage water must be discharged to the sea to maintain the salt balance of the Delta region. It is also constrained by the quality of agricultural drainage where chances of reusing that water decrease northwards because of seawater intrusion.

The year 1990 water policy considered the effect of the implementation of the Irrigation Improvement Project on the availability of drainage water where it is assumed that this project will decrease the losses on the farm and mesqa levels. This would decrease the available water that could be reused from drains and would deteriorate its quality.

Only the 1986 and 1990 water policies took into consideration the water to be saved from the implementation of the Irrigation Improvement Project. The 1986 water policy assumed that by 2000 the project would cover about 2.5 million feddans and the expected total amount of saved water would be 2 bcm per year. In reality, the project proved to be very slow and costly to implement. Therefore, the 1990 water policy estimated for water that could be saved by this project to be only 1.0 bcm per year by the year 2000.

None of the above mentioned water policies, except 1999 water policy, took into consideration the use of non-conventional water resources like desalination of seawater or brackish groundwater. Looking to the future and the coming water crises, these kinds of resources may be feasible use in the future, especially with the expected improvement and development of technologies in that field, which may reduce the cost of production of such water.

3.9 The National Water Resources Policy (NWRP), 2002

A few years ago, attention was mainly given to water supply management. At present, integrated water resources management, which seeks an efficient blend of all available resources (fresh surface water, ground water, precipitation and drainage water) to meet demands of the full range of water users (including agriculture, municipalities, industry and in-stream flows) is becoming an integral part of MWRI’s policy vision to meet these challenges. A more integrated management approach requires much closer coordination among concerned government institutions and the active participation of water users in planning, management and operation of water collection and distribution systems. It also necessitates the establishment/enhancement of the legal basis for water allocation, conservation and protection as well as user participation in water management. Training and capacity building of the MWRI and other stakeholders is also essential to face these challenges, and to be able to manage the ongoing, as well as the anticipated, reform activities of the water policies. To cope with these challenges, the MWRI has developed a national policy with three major pillars of: 1) increasing water use efficiency; 2) water quality protection; and 3) pollution control and water supply augmentation.

The National Water Resources Plan describes how Egypt will use its water resources in a sustainable and responsible way and how Egypt should use these resources in the best way from a socio-economic and environmental point of view. The planning horizon is the year 2017. The population is rapidly growing, new land is being developed for agriculture and there is a threat of more pollution. There is a need therefore to reduce water use (demand management), to optimize the supply (supply management) and to abate water pollution (pollution control).

The Draft Plan which also comprises of an investment plan was completed in March 2004. The Plan addresses all water related activities and considers both the technical, managerial and institutional interventions. Important decisions on allocation of resources and priority setting of interventions are indicated.

SECTION IV

WATER RESOURCES MODELING: EGYPTIAN EXPERIENCE

4.1 Introduction

Egypt's water resources system is characterized by its dynamic and uncertain nature. It is a large system that is composed of many interacting components and interfaces with social, economic, and environmental systems. Egypt has relied for many centuries on the Nile River to satisfy almost 95% of its water requirements. Currently, the country is approaching a situation where water requirements are expected to significantly exceed the availability of fresh water resources.

Formulation of Egypt's water resources for the 21^{st} century requires a major shift from the classical paradigm used in water resources planning and management to a new innovative paradigm (Abu-Zeid, 1997). Dynamic interrelationships among water resources system components impose the integrated approach on policy makers. Past experience shows that when an action or a strategy is planned and implemented in isolation from other system components, disruptive impacts are perceived. Using the ecological, social, and economic systems as boundary conditions for the water resources system is an obsolete assumption. A multi-disciplinary dialogue has to be adopted in the policy formulation.

Several mathematical models have been used to describe, simulate, and optimize the planning and management process of the water resources system in Egypt. These models included models for water demand and requirement calculation (WMP, 1981b, 1983b), water allocation and distribution among various water users (WMP, 1981b, 1984), derivation and analysis of the operating policy for the Aswan High Dam (AHD) reservoir (MWP, 1981a, 1983b), simulation of pollutant loads in the waterways, etc. The use of these models in actual planning and management has been limited because most of these models focused only on one aspect of water resources and neglected the integration of the other aspects.

In the following sections some of the available planning tools are described. Some of these tools have been developed through international cooperation agreements between sectors of MWRI, the National Water Research Center (NWRC) and international academic institutions.

4.2 Decision Support Systems

4.2.1 Background

A decision support system (DSS) is defined as a system that supports technological and managerial decisions making by assisting in the organization of knowledge about ill-structured, semi-structured or unstructured issues (Sage, 1991). The decision support system consists of a database management subsystem (DBMS), a model-base management subsystem (MBMS), and a dialogue generation and management subsystem (DGMS). Figure 4.1 presents the DSS components and their interrelations with the DSS users and decision-makers.

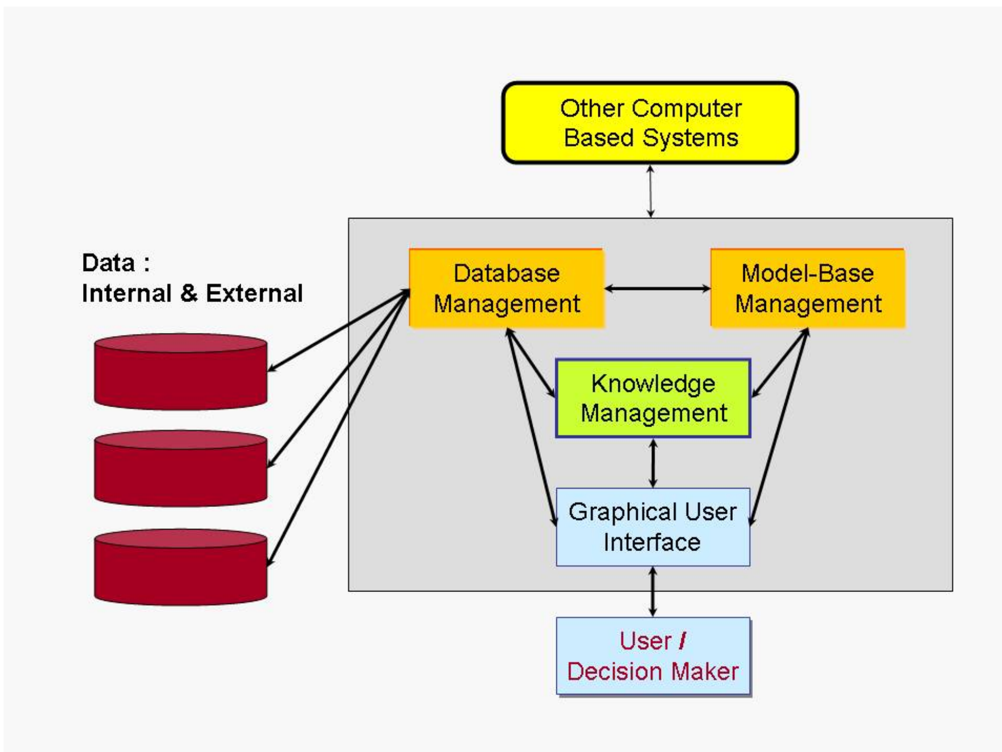

Figure 4.1 Different Components of a Typical Decision Support System

4.3 Integrated Water Resources Model for Egypt's Sustainable Development (IWRMESD)

An integrated framework for the analysis of Egypt’s water policies has also been formulated as a research activity. The integrated framework utilized the simulation approach and was developed using an object-oriented environment. The model represented Egypt as one global system. The object oriented environment allowed for addressing other water related issues such as economic, social, and environmental issues when drafting Egypt’s future water policy. A pre-processor expert system was developed to assist in the scenario generation and a post-processor multi-criteria analysis procedure was also implemented to analyze the simulation results and evaluate different scenarios simulated by the model. Because the model was implemented in an object-oriented environment, it was easy to be view and evaluate its produced graphical outputs. The framework captured policy analysis process through the following set of tasks: (1) structure development (objects and links), (2) selection of policy variables, (3) selection of policy evaluation indicators, and (4) dynamic system simulation.

4.3.1 Implementation of the Proposed Framework for Egypt’s Water Policy Analysis

The proposed framework is applied to build a reliable policy analysis model for Egypt entitled the Integrated Water Resources Model for Egypt's Sustainable Development (IWRMESD). The model relates various development plans in the different socioeconomic sectors with water as a natural resource at the national (strategic) level. Agriculture, industry, domestic demand, power and navigation are the five socioeconomic sectors that depend directly on water. Development plans in these sectors involve large numbers of decision (policy) variables and inputs. Satisfying these plans from the different water resources pertains to another set of policy variables. The Egyptian Ministry of Water Resources and Irrigation (MWRI) controls only some of these policy variables. Integration between policy variables and their impacts are monitored through a diversity of state variables (indicators) in the social, economic, and ecological domains. The number of policy variables involved, level of control of MWRI, and diversity of the indicators made the structure development of IWRMESD a very elaborate task. Aggregation and hierarchical decomposition principles are adopted to guide and simplify the model development and to reduce the problem size. Clearly, aggregation of the data to the macro or national level masks some temporal and spatial variability. Nevertheless, it still preservers the general trends and helps get some quick simple answers to questions usually asked by policy makers . In principle, the hierarchical decomposition of each socioeconomic sector into smaller units is against aggregation principle. Therefore decomposition of the main sub sectors should be avoided unless it is extremely necessary. It should be also noted that hierarchical decomposition principle is used only to facilitate the conceptualization and model development process.

The main objective of IWRMESD development is evaluation of water process formulated to satisfy long-term socioeconomic plans on the national level in five sectors. The time horizon of most socioeconomic plans is 25 to 30 years. Seven conventional and no conventional water recourse should be modeled. Evaluation of the water policies is carried out using several indicators in the areas of water availability, ecosystem quality, social standard of living, and economic growth. Having a large complex problem (in terms of the number ob input/output variables) necessitated the use of aggregate data. On the time scale the model time increment is chosen to be 1 year. No geographical distribution is assumed; that is, Egypt is modeled as one geographical unit rather than dividing it into regions.

Although spatial and temporal variability was reduced to a large degree through aggregation, the complexity of modeling all socioeconomic sectors and linking them to the water sector is very high. The hierarchical decomposition is implemented in modeling the socioeconomic development in each of the five sectors and the water resources sector separately. Some of these sectors have been decomposed to sub sectors and/or smaller basic components. Each sub sector is then modeled, using crops as basic components. The agriculture sector is decomposed into two sub sectors because of the significant difference in the characteristics with respect to cropping pattern, soil type, and irrigation system. The sub model of the water resources sector is used as an integration module that is linked to each socioeconomic sector through two variables: total water requirement and the return flow from the sector.

Water use sectors are not connected except through demands placed on water. This assumption is made to reduce the degree of complexity. For example, the agro-food industry is not linked to the agriculture production. It is obvious that such a relationship is very important if the model is economically oriented, but it is less significant in the case of water use orientation. In terms of water, priority is given to domestic and industrial sectors and then to agricultural. Navigation and hydropower generation are given the lowest priority as they are almost non-consumptive uses. Practically, water shortages occur in the agriculture sector only. Therefore the model is designed to have an automatic feedback from the water balance sector to the agriculture sector. The purpose of this feedback link is to linearly reduce the agriculture water use by the percentage of water shortage with respect to the total agriculture water requirements.

Most of the water sources are conceptualized in the model as reservoirs with no maximum storage capacity. On the basis of the storage available in each one of them, there is a constraint on the level of withdrawal. The available storage depends mainly on the inflow to these reservoirs. In the case of desalination the inflow is infinite. In the case of surface water resource the inflow is finite and comes from the release made by HAD, return flow from agriculture in Upper Egypt, and industrial and domestic effluent. Return flow, as percentage of different water uses is computed on the basis of the ratio derived from the most recent annual national balance. This ratio, as non-policy variable, is assumed to be constant over the planning horizon.

The model comprises six sectors: the five socio-economic sectors that depend on water and the water sector. A model sector is a system that is formally defined as :

$$MS_i\ (I_{pc},\ I_{pu}, I_{np}, t)\ \rightarrow O_i(O_{env},\ O_{wat},\ O_{econ},\ O_{soc},\ t)$$

Where

MS	is the Model Sector
i	is the model sector number (i=1, 2, 3, ….6)
I_{pc}	is the policy input variable controlled by MWRI
I_{pu}	is the policy input variable uncontrolled by MWRI
I_{np}	is the non-policy input variable
t	is the time domain
O	is the output vector
O_{env}	is the environmental indicator
O_{wat}	is the water security indicator
O_{econ}	is the economic indicator
O_{soc}	is the social indicator

MWRI controls mostly the water supply variables. Demand side policy variables and inputs are totally or partially controlled by other stakeholders. The entire policy variables are dynamic variables; that is, they take different values over the planning time horizon. Non policy variable are assumed to be deterministic, the known values over the planning horizon, and should remain unchanged from a model run to another process. They are classified as uncontrolled policy variables (for example, population growth rate, and inflow to HAD). Theoretically, there is no limitation on identifying variables as policy or non policy. It is the user's choice to determine which input variables are policy variables and which are not on the basis of the nature of model application.

The water policies are assessed using a set of indicators. Table 4.1 lists these indicators covering various aspects of water resources.

Table 4.1 Different indicators used for the evaluation of water policies

Sector	O_{econ}	O_{soc}	O_{env}	O_{wat}
Agriculture	net return present value	employment, food sufficiency	fertilizers and pesticides use	agriculture water requirements
Domestic	net return present value	employment, health	total load of pollutants and/or water quality index	domestic water requirements
Industrial	net return present value	additional employment, power satisfaction	total load of pollution	industrial water requirements, industrial efficiency
Power generation	net return present value	employment, power satisfaction	total load of pollution	power water requirements, effluent of thermal power
Navigation water	net return present value water resources cost	employment	total load of pollution	losses to sea, water balance

Each step of the modeling process is visible and clearly explained, providing the user with an opportunity to comprehend the modeling knowledge with ease. This by itself helps planners and policy makers increase the public awareness of the water resource related issues and acquire wide range of support for suggested solutions.

4.4 Decision Support System for Water Resources Planning

4.4.1 DSS Objectives and Functions

It has been recognized that an integrated, multidisciplinary approach must be adopted. It is also important to consider the interrelations among the socio-economic and environmental aspects and the water resources system, integrate the different projects and strategies into a national vision, and present the trade-off analysis for solving problems of resources-requirements match under different water policy alternatives. The proposed DSS has three main objectives namely; optimal current utilization of available water resources without compromising future generation shares, assessing measures of quality of life, and evaluating the degree of user satisfaction.

The DSS considers the integration of environmental and socio-economic aspects through the analysis of water resources development and measures scenarios. The conceptualization of the water resources system in Egypt is provided in a block diagram representing the water resources system and its different socio-economic and environmental aspects including the interrelationships among them.

The proposed methodology considers the significant efforts made by the different planning, operational, management, and research organizations within MWRI as well as other concerned ministries. A set of anticipated scenarios is adopted to evaluate the short- and long-term effects of the adopted strategies on the water resources system. Moreover, specific development measures are defined and suggested for implementation. The DSS runs under assumptions of different cases comprising alternative development measures and scenarios. It analyzes the state of the system for each case through a set of pre-specified indicators for water resources as well as their socio-economic and environmental aspects.

4.4.2 Proposed DSS Structure

The developed DSS consists of three main subsystems: a database and GIS component, a simulation modeling component and a graphical user interface (Figure 4.2). A brief description of each component is provided in the following sections as well as their integration under the selected software.

Hardware/software: Advanced Visualization System Express (AVS)

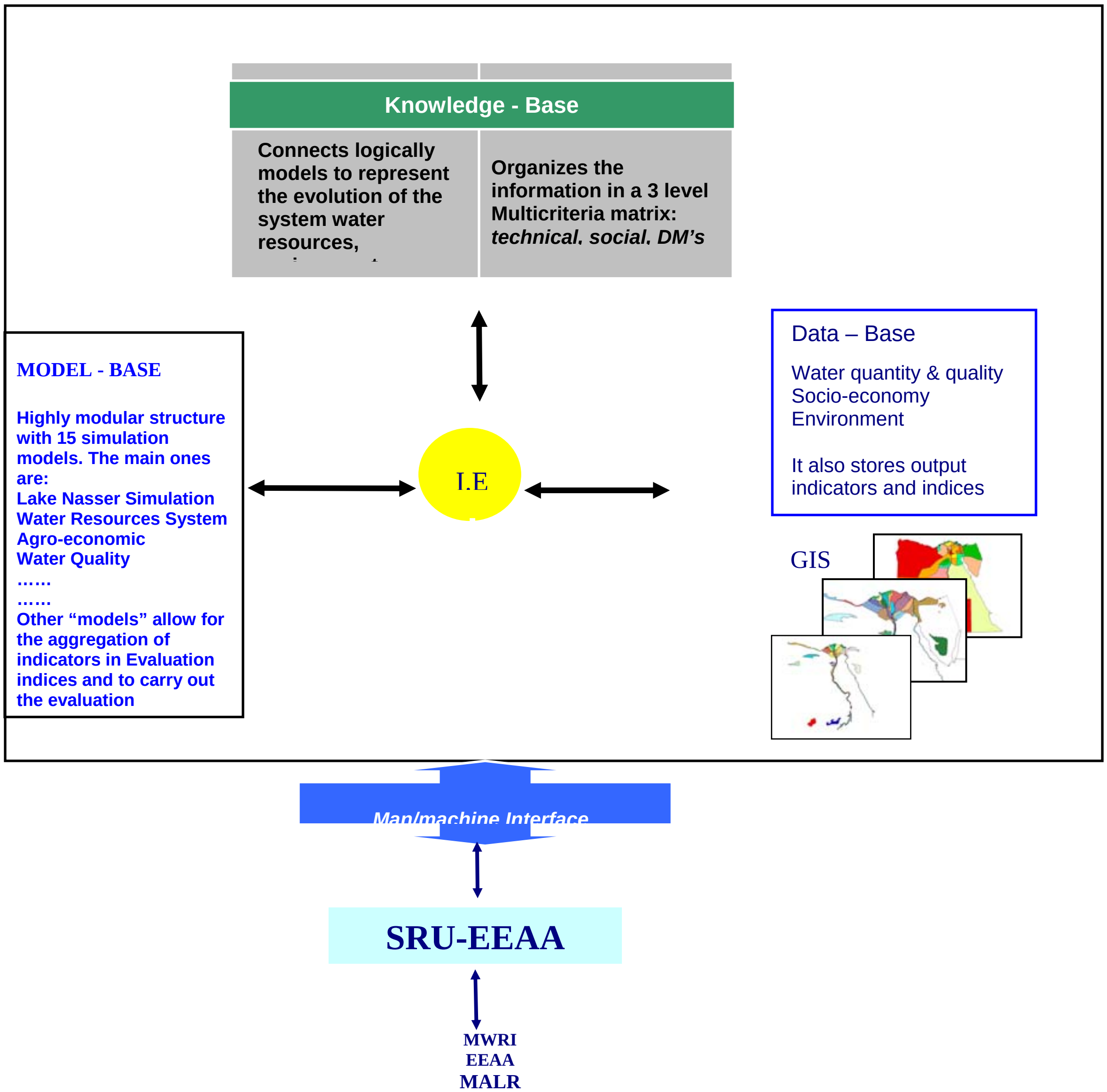

Figure 4.2 Components of the Decision Support System for Water Resources Planning

4.4.3 The database and GIS component

The DSS required a significant and diverse amount of data and information to run the different modules simulating economic, social, and environmental aspects of the water resources system. The database is intended to ensure optimal management of enormous raw data, which requires massive computational effort to fit the required model variables and parameters. It is also designed to handle information about proposed development measures and scenarios to be investigated. Because most of model information is referenced to some geographic characteristic (e.g. cropped areas, soil characteristics, social data, etc.), a geographic information system has been also designed and linked to the database.

The database is implemented in Microsoft ACCESS where all collected data is sorted and catalogued into data tables for 6 main categories linked either to a geographic area or to a point-wise location. Table 4.2 displays the categories and their links to the other data tables.

Table 4.2 Data Tables and Corresponding Categories of Data

Data Table		Categories of Data
Data_1	Irrigation	Irrigation, Drainage, Canals, Stretches, Pumping stations
Data_2	Groundwater	Groundwater, Desalination, Domestic, Industrial
Data_3	Agriculture	Land, Crops, Reclamation, Livestock, Fisheries
Data_4	Environment	Water quality, Lakes quality, Meteorology
Data_5	Economy	Socio-economic, Agro-economic
Data_6	Social	Demography, Quality of life

The database management system is designed to support maintenance of the data tables and relationships, generate reports, and perform simple statistical analysis on stored data. An ARCVIEW GIS has been linked to the database to allow usage of geo-reference information in models calculations.

4.4.4 The modeling component

The model base comprises 15 models to simulate the water resources and requirements system in addition to its socio-economic and environmental aspects. Table 4.3 exhibits the main categories of models and their main functions and anticipated outputs.

Table 4.3 Models categories, functions, and anticipated outputs

Model Category	Functions and Anticipated Outputs
Water resources models	
Water-planner Nasser-pol Nasser-sim Net-sim GW-quant	Allocate and distribute water from all sources among various users all over the country.
Economic models	
SE-setting Agro-econ	Determine economic output from the agricultural sector.
Social models	
Layout Demographic Admin-setting	Assess urban and rural population growth and migration flows.
Environmental models	
Net-qual GW-qual Lakes I&M-loads Y&S-loads Health Ecosystem	Evaluate water quality parameters in the surface irrigation and drainage networks, groundwater, and inland lakes

4.4.5 Graphical User Interface (GUI)

The flexible structure and the intelligent design of the interface allows for data entry through simple formatted screens designed to handle data entry, modification, and updating in DB tables, performing general and specific queries on stored data, and carrying out simple statistical analysis. Query programs are designed in an easy to understand MS/ACCESS format to allow answering the decision-makers' questions concerning all types of stored data. The query facility allows for searching for data with a certain criterion and links this data to a geo-referenced areal, line or point location. It allows viewing the value data of any entity or feature on the related maps. The simulation system is evaluated through a set of pre-specified indicators. The GUI allows the user to monitor and evaluate the changes and progress of a specific indicator or a set of indicators in both time and space.

4.4.6 Evaluation of Development Measures and Scenarios

The DSS is designed to help in assessing technical aspects, and provide a framework for evaluating development projects from the point of view of quality of life of farmers to answer the question of what development projects to be adopted. Identification of a development measure is based on careful analysis of the policies and plans involved in the management and planning of land and water resources. In general, water saving and improvement of water quality and the environment are priority issues in defining development measures. Indeed, the quality of water resources has a strong impact on their final allocation, because low quality waters could not satisfy specific water uses. Therefore, keeping the quality of surface and groundwater at high standards is another way of contributing to increasing the amount of available water.

Development Measures (DM) represent alternatives, which may be either structural (e.g. new canals like El-Salam canal, land reclamation projects, wastewater treatment plants), or policies (e.g. economic incentives, land-use constraints, resettlements, management policies for Lake Nasser, etc.). DM can be also a combination of projects and polices. They may focus on either the demand side (e.g. saving water), or the supply side (e.g. resources development).

Scenarios represent hypothetical future patterns of any uncontrollable and uncertain variable or a set of variables (e.g. population growth rate, pattern and rate of industrial growth, hydrological climate induced changes, unscheduled implementation of development projects) related to water resources system and its socio-economic and environmental aspects.

The *development measures* considered in the DSS are classified into six main groups, according to the conceptual model setup for the water resources system and its socio-economic and environmental aspects. These groups are listed as follows:

- National development projects.

- Water resources development projects.
- Environmental management policies.
- Water resources availability projects
- Water management policies.
- Agricultural sector policies.

Under each group these exist a number of projects and actions that contribute to a *development measure*. The DSS allows considering of various combinations of development measures and scenarios to identify their corresponding impacts. These combinations are called cases. It is then possible to evaluate the impacts of these projects and policies, and compare the different cases and alternatives under considerations. The results of the technical assessment and evaluation are translated into a clearly understandable and manageable form for the decision-makers.

4.4.7 Evaluation Procedure and Evaluation Indicators

The DSS starts with evaluating current national water availability from all different resources and assigns their allocations based on the pre-computed demands and requirements for all users. These allocations take into account priorities for the development measures already implemented and chosen by the DSS user. Thereafter, the impacts of these allocations on the other life aspects such as environment, social behavior, economic, health, and people’s migrations are determined using the different the modeling component. Finally, all these outputs are aggregated to develop certain indicators representing the status of the system not only from the water-resources point of view but also from other life aspects points of view.

Each individual model within each modeling category produces a certain output fulfilling the main objectives of this model. These outputs are very detailed and do not indicate directly the major impacts of the water resources planning and management as well as the impacts of development measures on aspects such as environment, socio-economic, health, and people’s migration. Therefore, an indicators module is designed and formulated within the DSS framework to aggregate models outputs into indicators representing the different life aspects that are mainly affected by the water resources policies. The indicators module allows for calculation of three different levels of evaluation indicators as follows.

Technical Assessment Of Alternatives

The first category of the evaluation process is the technical assessment of the different alternatives. Under the umbrella of this assessment there are three categories of evaluation indicators; water balance, state as well as response indicators.

The water balance information is specific to a particular hydrologic scenario, year, and geographic unit. It includes first the demand required for each user, particularly agriculture, municipal (urban and rural), and industry; and the water supplied from each source, such as irrigation network, shallow and deep groundwater, as well as drainage water. In addition, the overall deficit and total supply for each user is also evaluated.

The state and response indicators computed by each model include

- Economic efficiency of water in agriculture
- Physical efficiency of fertilizers in agriculture
- Reclamation success
- Reservoir annual losses and loss ratio
- Lakes water quality
- Pollutant loads
- Land losses

Figure 4.3 illustrates the calculation of health index using the outputs of three models.

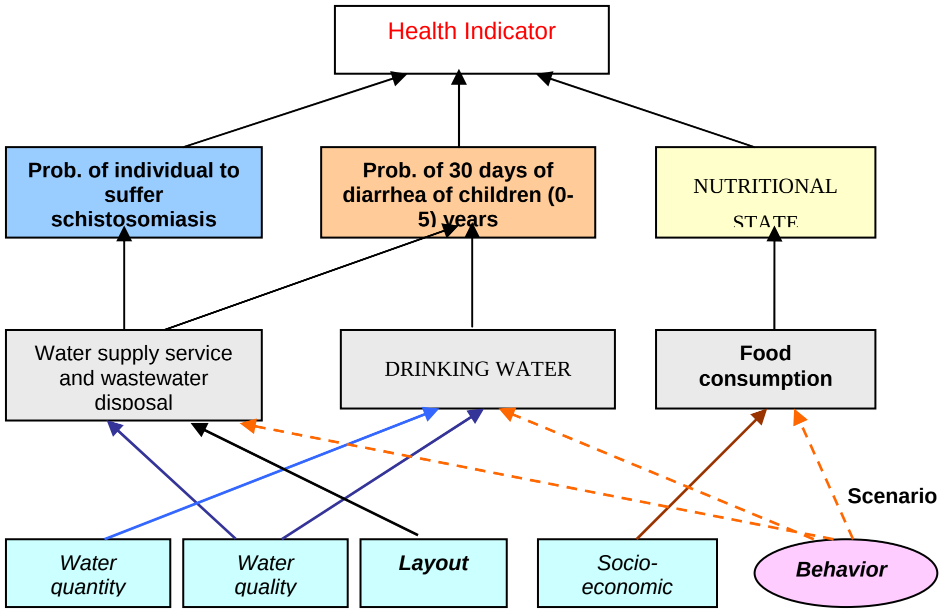

Figure 4.3 Aggregation of the Health indicators from the outputs of four models

National Level Indicators

These indicators are formulated to allow judgment on national impacts of the water resources alternatives. These indicators can be listed as follows:

- *Social Indicator:* represented by a yearly un-employment aggregated national value.
- *Population Migration:* defined as the global annual migration flow of rural households to urban settlements in each geographic unit.
- *Food-self-sufficiency:* defined as the self-sufficiency ratios for each importable item.

4.5 Other Models related to water management

The water management models used within the Planning Sector of MWRI include three major groups; agro-economic models for prediction of cropping pattern and water demands, water distribution models, and water quality models.

4.5.1 Agro-economic Models

The Agriculture Sector Model

The Agriculture Sector Model for Egypt (ASME) has been developed over a long period of time and passed through several stages of modification and upgrading to reach the existing version (ASME 97). The early planning effort in 1980's led to the development of the first version called "Egypt model" in GAMS format. The revision of that model has been carried out by the PS with assistance of IFPRI. The last version was developed by Binder in 1997 through the auspices of RDI. In 1999, MALR and MWRI requested the assessment of many proposed actions and measures under the umbrella of the Agricultural Policy Reform Program (APRP), that helped in evaluating and upgrading the last version of ASME model.

The ASME model is a static partial equilibrium model in which social welfare in the forms of consumers plus producers' profits from agriculture production (crops and livestock) are maximized. There are four main constraints to the model, which are the resources, technical production, balancing, and policy constraints. The resources constraints are land, labour and water availability. There are several kinds of technical relationships: resource and other input requirements for crop and livestock production; yield levels for crops and livestock, and processing and by product yields.

The model has three growing seasons: summer winter and nili. Seasonal water requirements are given in rates per fed/crop/ region. Adjustment factors for alternative planting dates are specified (early, late and normal). There are several levels of water deficit ranging from 5% to 50%.

Within ASME model an assumption of the spatial dimension has been applied by dividing Egypt into 13 regions, where 4 regions represent the Nile Valley and 9 regions represent Delta and Suez Canal region.

The model requires extensive data sets as inputs to perform the simulation of the agriculture sector in Egypt. These input data include parameters to represent crop and livestock production, crop processing, and agricultural inputs. The model requires also the distribution of population and water resources availability as inputs to calculate the optimal cropping pattern.

The Nile Economic Model (NILECON)

The water security project in the PS developed the Nile Basin Simulation Model (NBSM) as a detailed simulation model of the Nile basin including Lake Nasser and the upstream abstractions, which influence water availability to Egypt. It can simulate one year or a twenty-year period out of the range of historic inflows.

The model output includes crop yields, surface water balances, drainage water generated and the changes in salinity of surface water. The model contains also provisions for meeting municipal and industrial demands. Therefore, the model is considered a powerful tool for investigating Egypt wide water supply/ demand issues under many alternatives scenarios. The major weakness of the NBSM lies with its embedded allocation schemes. The model also doesn't have a provision to alter regional allocations based on user-supplied priorities or to optimize water allocation based on some criteria.

NILECON was designed to avoid these deficiencies using optimization technique for the economic returns to Nile water in its various uses. The simulation model and the NILECON are used conjunctively. The simulation model will produce an allowable release from Lake Nasser and the optimization model should then optimize the use of those releases. This is used to achieve the following:

- Optimize water resources allocation for a given year and a given lake Nasser operating procedure.
- Produce estimates of the marginal economic value of water at different points on time and different points in the system.
- Analyze alternative development plans on economical basis

NILECON is a non-linear mathematical programming model. It is solved by general algebraic modeling system (GAMS) language with its attached non-linear solver MINOS5. The main data sets required for the model are the crop evapo-transpiration per region, the irrigation efficiencies, crop yield prices and water demands for municipal and industrial uses. The model divides the Nile Valley and Delta into 11 regions in addition to Fayoum area as a separate region. Calculation of the surface water balance at each region is performed by the model to determine the Nile water out flows from that region. Water allocations in the model are driven by the economic returns to water. Economic and social returns of municipal and industrial (M&I) users are assumed to be greater than those of irrigation. Thus, M&I allocations always take precedence. The only other consumptive use of water recognized by the model is irrigation water that will be allocated to irrigation whenever its economic returns are non-negative. If water is in plentiful supply, all irrigation needs will be met and the entire potential cropping pattern will be achieved and all crops in all regions will receive their full evapo-transpiration requirements.

When water is short, and allocation must be curtailed, the model determines when, where and which crops to allocate the shortages so as to minimize the economic cost of the shortage.

Water Demand Forecasting and Effects Model

The projections of water demands were estimated using simple functions based on the current level of consumption and the planned interventions. The overall National Water Quality and availability management project (NAWQAM) designed and implemented a framework for water demand forecasting model. This model provides the PS with a useful tool to evaluate policy alternatives and the ability to anticipate changes in demands according to the different combinations of policies.

The NAWQAM experts suggested two comprehensive frameworks to determine the past, present and future water demand for various water use sectors. These sectors include industrial municipal, agriculture, livestock and fish farming. The implementation framework for the water demand forecast model is based on providing several options for carrying out the forecast according to the type of data available and the level of reliability of the data sources. For each water use sector, three directions were defined with different reliability levels. The forecasted output of each direction will be accompanied by a certain level of confidence.

It must be noted that all these directions give only the guidelines for calculating the future demands based on the availability of data. In applications, the water resources analyst could be confronted with conflicting data collected from different sources. The experiences of the water analyst will be required to filter and screen these data from inconsistencies to obtain the best set of data that could be used to predict the future demands. These data sets can be further iterated once more accurate data are gathered based on water demand. Forecasting a water demand estimate is obtained for each demand component. Using fuzzy logic modeling, various elements for water demand forecasting effects can be listed. The water resources analyst will define the variation of each effect based on his own judgment and experience. The impact of each effect on the forecast is estimated based on past historical data and experiences. The system parameters and their effect are model in the form of fuzzy system where these effects are varying from one usage to another.

4.5.2 The Water Distribution Models

Operational Planning Distribution Model (OPDM)

The Operational Planning Distribution Model (OPDM) was developed by the department of biological and irrigation Engineering, Utah state university to be used in the planning for water resources and training. It can also be applied in design and analysis studies of agricultural irrigation systems. The model was developed to perform simulation of water distribution and crop yield response for irrigation and other uses in complex canal and drainage networks. Crop water requirements are calculated based on specified cropping patterns and weather information and simulated flows are routed through the systems from main supply sources and open drains.

The model is highly interactive with powerful capabilities for system layout and configuration the canal and drainage networks which are built interactively by inserting and arranging nodes graphically. OPDM can generate system flow requirements based on calculated crop water needs specified hydrographically. Daily water balance calculations are preformed for soil water and canal reach storage in the supply and drainage system. The model can estimate relative crop yield reduction due to root zone water deficit, soil water salinity, and water logging. Crop yield results are also used to generate tables of expected gross revenue from crop product based on specified maximum production values.

The OPDM calculates crop water requirements by one of five ET methods according to the user's choice. Up to three separate planting staggers of each crop can be specified for each command area. Each crop type can have up to five growth stages with different crop coefficients, root depths, durations and yield factors. The model used nodes in the system layout to represent specified physical feature that occur in a real irrigation and drainage system. The connection between selected node types become reaches which can have capacity and flow data, and which are managed on a daily basis by the model during a simulation.

River Basin Simulation Model (RIBASIM)

It is a generic model package for simulating the behavior of a river basin under different hydrologic condition. The model was developed on the conceptual basis of the model MITSIM that was developed by MIT Cambridge, USA. The model links the hydrologic inputs of water supplies at different locations to the various water using activities. The model determines the water allocation to the different users and the generation of hydropower based on the infrastructure, the water requirement, and the operation strategies.

The model simulates the river basin behavior for each time step and for a specified simulation period. The river basin is schematized in a network of nodes and branches. The network configuration represents the spatial relationships between the elements of the river basin system where the nodes represent activities of water use or conservation and the branches represent the Nile main reaches or the canal network.

The level of detail in the schematization of the water system should be sufficient to enable the simulation of all major potential measures. On the other hand, the more detailed the schematization is, the more complex and less flexible the model will be. Also, data availability and accuracy is another limiting factor to the level of detail in schematization.

The model requires input data on the meteorological and hydrological conditions in addition to the water use activities data. The model simulates the water distribution in two consecutive phases: the target setting phase and the allocation phase. In the target setting phase the amount of water required at all nodes of the network is defined. The water demand by different users is either converted to certain amount of water released from resources or diverted flow at diversion. While in the allocation phase the water is routed through the network of nodes and links. The model applies the priority list, otherwise the model applies the first come, first served principal.

The model is a useful tool in evaluating the possible effects on water demand allocation resulting from different combinations of technical, operational and institutional measures and answers the decision maker's questions in this respect. The main outputs of the model are the average annual river basin water balance of the simulated network configuration over specific period and the crop yield and crop production costs.

Simulation Of Water Management In The Arab Republic Of Egypt (SIWARE)

Since 1983, the Drainage Research Institute (DRI) started an intensive program for the development of a mathematical model in collaboration with the Institute for Land and Water Management Research in the Netherlands. This model simulates the irrigation and drainage processes in the Nile delta. A special emphasize in the model was made towards the reuse of drainage water for agriculture purposes

The SIWARE (Simulation of Water Management in the Arab Republic of Egypt) was developed to predict the future change as a result of changed conditions in the water management, agronomic changes or changes in hydraulic conditions. The model was applied for the Nile delta where all relevant physical and functional relationships have been combined in a simplified and schematized way.

The computation start with the distribution of irrigation water from the main inlet of Delta Barrage, through different orders of canals until it reaches the lowest order of these canals. During distribution, part of the water is lost through evaporation and seepage and part of it flows unused to the drains through the tail escapes.

Due to the complexity of the process involved, the SIWARE model is divided into a number of sub models where each has a specified function in the water management simulation. Two types of processes are simulated with the SIWARE model:

- Physical processes, such as the water flow through the irrigation canals and control structures.
- Human behavior processes, such as: decision related to the allocation of irrigation water among the irrigation command area and the determination of target water levels at control structures in the irrigation system

  The input data, which are required for performing model simulation, can be categorized into three main categories:
- Input data that define the water management strategy, such as cropping pattern, allocation water duty and water supply data.
- Model input parameters which determine the system's physical characteristics and behaviors
- Initial input data for moisture and salinity conditions of each soil layer for each crop in each calculation unit considered.

4.5.3 Water Quality Modeling

Water quality changes in rivers are due to physical transport processes and biological, chemical, biochemical, and physical conversion processes. Physical transport includes advection and turbulent diffusion, which are separately described through hydraulic models of one sort or another. Chemical impacts are generally modelled by means of computer programs, the sophistication of the model being proportionate to the relative risk and complexity of the discharge and/or the receiving environment. The type of model required to assess receiving water quality depends on whether the discharge is continuous or intermittent and the nature of the receiving waters.

The Waste Load Model (WLM)

The Waste Load Model estimates the emissions to the surface water from different sources. It consists of two main modules, a waste load production module, and a waste load treatment module. The waste load production module specifies what kinds of waste loads are produced in the water system and calculate the amount of waste load that generated in each command area. The waste load treatment module specifies the volume of treatment whether it is natural or artificial that can be taken place in the system. The model is used to calculate the amount of waste load produced in the basin, the amount of waste reduced by treatment and the resulting amount of the waste reaching the river.

The model calculated the waste load based on production and level of treatment for both point sources and non-point sources. The calculated waste loads are specified as boundary concentration or as load to the water quality model. An economic model (COIN) is attached to the WLM that computes the capital costs and the operation and maintenance costs related to the proposed measures.

The model requires a schematization for the waste loads including all different kinds of waste loads in the Nile valley and Delta as well as the various kinds of treatment and natural purification. Each different type of waste load and treatment included as a separate node type in the system schematization. The model computes the waste loads for 12 different substances and it requires data related to domestic waste loads, industrial waste loads, and waste water treatment plants. The emission variables, emission factors and locations are also part of the input data required for the model.

Delft Hydraulic Water Quality Model (DELWAQ)

Delft Water Quality Model is used to simulate the water quality in the network based on advection-diffusion equation with source-sink terms for waste loads, physical, chemical, and biological processes. The model takes into account the interactions between various substances.

The substances and the processes influencing concentration levels of the substances are available from a built-in library which includes more than 100 substances and more than 1000 processes.

The basis of the DELWAQ model application are the computational elements (segments) and the links between them. In each segment, there is a volume of water that has specific temperature and may contain dissolved and suspended material. Between the segments, there is exchange of material either due to the flow of water or due to mixing two sources of water.

The model requires the data on the flow of water that is computed by any water distribution model and the data on waste loads that provided by the waste load model. In addition, the model requires more data about chemical and biological processes. The model outputs can be enhanced when better data on pollution sources and water quality are available for calibration.

The model can be used as a basis for the comparison of the present water quality situation with the ones under different assumptions for scenarios and measures.

4.6 Summary

IWRMESD is introduced for water policy analysis. It integrates the object-oriented modeling approach with systems analysis and captures a policy analysis process through (1) structure development, (2) selection of policy variables, (3) selection of policy evaluation indicators, and (4) dynamic system simulation. The proposed framework provides distinctive set of advantages for the water policy analysis in developing countries. The Egypt case study, used for illustrative purposes, confirms that the purposed framework presents a powerful tool for analyzing the different policy options and helps in understanding their long-term implication. Its transparency allows for more participation and empowerment of the public and all the stakeholders. The suggested framework provides a feedback mechanism that facilitates reaching solutions that enable the society to move away from the status quo according to its present priorities and objectives. Object oriented approach, which is used in IWRMESD development, has an inherent flexibility and transparency. The flexibility allows primarily for the application of the hierarchical decomposition principle during the model development.

The DSS was developed to assist the decision-makers in drawing sustainable water resources planning policies and finally improve their management. The developed DSS consists of three major components linked under the umbrella of an advanced visual system. The three components are: an MS ACCESS database linked with an ARCVIEW geographic information system (GIS), a simulation model component, and a graphical user interface. The MS ACCESS database is to provide required areal, line, and point data and information to the modeling component of the DSS. In addition, the developed database is designed in such a way to include all the raw data collected and required by the DSS and to facilitate any separate inquiries that may be required by the decision-maker. On the other hand, the modeling component is first conceptualized to simulate the reality in the water resources planning and management and to investigate their impact on the other life aspects from environment, social behavior, socio-economic, people's health, and people's migrations flows. Therefore, the modeling component consists of several categories to represent the formulation of the conceptualized idea. Each category consists of several modules to achieve the general function of their modeling category.

One major section in the developed DSS is the implementation of the different development measures (national projects and policies) and scenarios in the simulation. Within each DSS simulation the decision-maker chooses certain development measures to be implemented along with all their features and certain hydrologic scenarios. Thereafter, the DSS simulates for the chosen number of years all the water resources considering the involvement of the predefined development measures under each hydrologic scenario and produce several results concerning water allocations from each resource and the impact of this planning on the environment, social behavior, socio-economic, and people's health and their migrations. The several individual results obtained from the whole simulation are then aggregated in certain fashion to finally produce pre-specified indicators to clearly show the results of the different scenarios and alternatives from all the life aspects point of views. Evidently, these indicators are meant to help and assist the decision-maker in evaluating and comparing alternative water resources projects and policies, thus drawing sustainable water policies based on a comprehensive and complete vision of the different consequences.

SECTION V

BASINWIDE HOLISTIC INTEGRATED WATER ASSESSEMENT MODEL (BHIWA)

5.1 Purpose

The overall goal of the Country Policy Support Program is to create an improved knowledge base in regard to the basin studies, and to support new policies initiatives. Basinwide Holistic Integrated Water Assessment (BHIWA) model can demonstrate the benefit of Integrated Water Resources Development and Management (IWRDM), used in a participatory and transparent mode.

BHIWA is a simulation model that is used to evaluate water related policies at the national or basin levels. Water supply and requirements for food, people, and nature are assessed at the basin level through the integration of the water needs for the following sectors: agricultural, domestic, drinking, sanitation, industry, energy, and eco-system.

The BHIWA model is utilized to simulate alternative development scenarios and management polices and evaluating their impacts on the surface and groundwater regime (ICID, 2004).

5.2 Structure And Mathematical Formulation

BHIWA model simulates one hydrologic year, with a month time increment, per scenario. Such a year can be in the past to be used as comparison reference or target year in the future under specific assumption for development (scenario). BHIWA model is applied to one basin that encompasses five sub-basins. Each sub-basin is an aggregation of 25 five parcels representing different land use and coverage categories.

The mathematical formulation is based on the mass balance principle, which is carried at the parcel level and then aggregated up to the basin level. In partitioning the water among the different hydrologic elements, ratios or proportions are used in such a way that keeps the water balance respected. However, none of these ratios is a function of any hydrologic element, which gives the model its simple linear formulation. In other words, no iterative process to compute any variable is taking place.

The BHIWA model consists of four main modules (refer to Figure1):

A. Soil profile module which calculates water balance for the upper and lower zones vis. soil profile and groundwater system for each land use category. Calculations are based on the given values of soil moisture capacity, rainfall, and other climatologically data. The soil profile component of the model partitions the rainfall into actual evapo-transpiration and excess water.

B. Hydrologic impact module that depicts hydrologic impacts due to anthropogenic influences. The natural component of this module is designed to estimate the hydrologic impacts due to changes in land use such as, conversion of forestlands or barren lands to rainfall agricultural. A separate component of the module is dedicated to estimate other man made impacts. Estimates are made to come up with the following:

- requirement of additional water for irrigated land parcels to meet the whole or the major part of the difference between the potential ET needs of the crops and those fulfilled through natural rainfall.
- division of these additional water requirements for irrigation that is to be met through surface water and groundwater sources of irrigation.
- withdrawals from surface and groundwater to meet this balance ET requirements, including percolation from irrigated paddies, at the given level of conveyance, distribution and application efficiency relevant to surface and groundwater irrigation.
- withdrawal requirement for all the domestic and industrial needs, and the consumptive components of these waters.
- total return flows of the water withdrawal, in excess of the ET need.
- “wasteful” return, that will be lost through evapo-transpiration from swamps/waterlogged area.
- contribution of the remaining return to the surface and groundwater system.
- exports and imports of water

C. River (surface water resources system) module, which depicts all inputs to the river, flow viz. quick runoff, base flow and returns from irrigation and domestic and industrial surpluses and wastes. It has been structured to allow sub-basin wise computations in terms of space, and in monthly units with provision for separate water balance and annual summaries.

D. Groundwater reservoir module which aggregates all inputs viz. deep percolation from natural rainfall, return from irrigation, and industrial supplies induced recharge from the river.

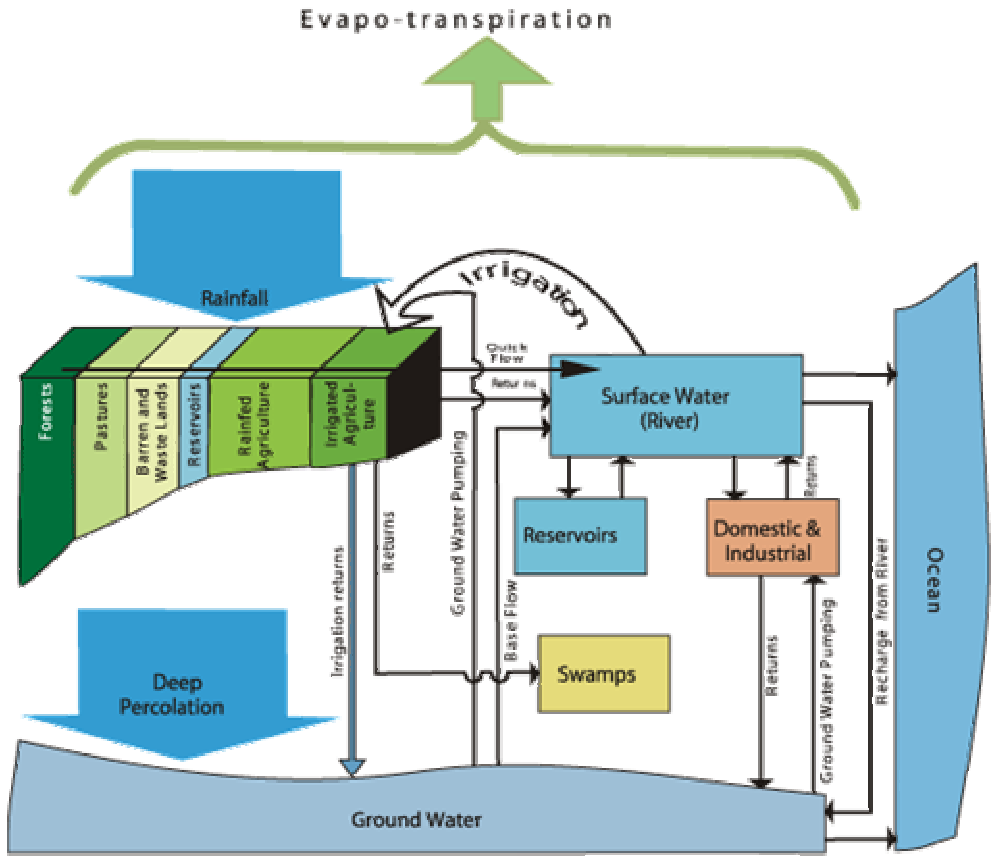

Figure 5.1 Schematization of the Model Components (ICID, 2004)

The monthly balance for every parcel is carried by calculating the following:

- actual evapo-transpiration, natural recharge and quick runoff from rain;
- irrigation withdrawals;
- irrigation returns; and
- evapo-transpiration by sectors.

At the sub-basin level, the following components and balance are computed:

- domestic and industrial withdrawals and returns;

- inputs to groundwater, outputs from groundwater excluding base flow, and groundwater balance;
- inputs to river, output from the river and storage, and river water balance; and
- overall water balance.

Topolgy (interconnection), of the sub-basins, is used to compute the different hydrologic elements and balance at the basin level.

5.2.1 Inputs

In general, inputs to the model can be categorized into the following categories:

- hydrological,
- demographic,
- domestic and industry related land use,
- crop related (both rain fed and irrigation),
- Model development and management information including imports, exports and environmental requirements, and
- Topology of the sub-basins

The provided data changes in four dimensions: time, parcels, sub-basins and scenarios. Some of the data varies in two or three dimensions while others considered being constant in all dimensions. Table 5.1 provides almost a complete input data inventory classified according to data variability in the four dimensions.

Table 5.1 Data variability

Data Variability	Data Type
1. Data does not change with time, parcels, sub-basins, and scenarios (Constants)	• Proportion of rainfall that meets PET requirements and soil. • Proportion of excess rainfall after meeting PET requirements and soil. • Exponential index linking soil moisture availability to the AET/PET. • Recession coefficient for groundwater reservoir. • Sub-basin topology
2. Data which does not change with scenarios	• Land use description • Soil moisture capacity for each land use in (mm)
3. Data which changes with scenarios but not with sub-basins or time	• Proportions of return flows evaporating through water logged and areas and swamps from surface irrigation • Proportion of residual flows returning to surface waters from surface irrigation • Proportion of residual return flows returning to ground waters from surface irrigation. • Proportion of return flows evaporating through water • Proportion of residual return flows returning to surface water • Proportion of residual return flows returning to groundwater • Surface water conveyance and distribution efficiency • Groundwater conveyance and distribution efficiency
4. Data which changes with time and land use but not with scenarios and sub-basins	• Crops Factor
5. Data which varies with scenarios, land use and sub-basins but not with time	• Areas of land use for different scenario
6. Data which changes with time, sub-basins and scenarios	• Proportion of surface irrigation to total irrigation. • Import (from outside the basin) • Export (out of the basin) • Surface storage filling& depletion • Net groundwater import from outside basins • Rainfall data

7. ***Data which changes with sub-basins and scenarios but not with time and land use***	• Domestic and industrial withdrawals, consumptive use and returns • Domestic and industrial withdrawals, uses & returns • Environmental flow requirements

5.2.2 Outputs

The results of the BHIWA model are aggregated at the annual, and basin level. They come in a form of tables and charts. The following items are aggregated:

- monthly river flows;
- annual summary of main results;
- overall water balance;
- river and surface water balance;
- groundwater balance; and
- water situation indicators.

Several reports and tables can be generated from the aggregated data as well as more than twelve charts are produced such as:

- overall water balance;
- river and surface water balance;
- groundwater balance;
- irrigated cropped areas and withdrawals for irrigation;
- net irrigated area by source; and
- composition of withdrawals.

5.3 Software Platform

The BHIWA model is developed in a Microsoft Excel. No interfaces were designed to facilitate the user mission of model application, data entry or results retrieval except for a macro for report generation. The model consists of 24 worksheets: 4 index sheets, 10 scenario sheets, one input data sheet, 3 output sheets and 5 other sheets, as shown in Table 5.2.

Table 5.2 Model Excel File Structure

Worksheet Type	Worksheet Name
Index	• INDEX_DATA SHEET • INDEX_SCENARIOS • INDEX_Aggregated results • INDEX_CHARTS
Input Data	• DATA-SHEET
Scenarios	• W.S.SC1 • W.S.SC2 • • • • W.S.SC10
Output	• Report Generator • Aggregated Results • Charts
Other	• Sheet Exp • Report Tables • Report Table 2 • Tables1 • Chart-Tables • Land Occupancy

Index worksheet are pointers to the different elements and modules (input data, tables, charts, scenarios…etc.) of the model. The input data worksheet contains almost all the input data organized in tables according to the categories listed in Table 5.1. Output worksheets are: aggregated results, report generator, and charts. The 10 scenarios worksheets are the model engine where the simulations take place (calculations).

5.4 Application

To use the model in evaluting different deevelopment policy option, with confedence, it has to be calibrated and vaildated (refer to Figure 5.2). Previous application experience in India and China ((INCID, 2004) and (CNCID, 2004)) showed that the following parameters can be used for calibration of the model:

1. soil moisture storage capacity;

2. percentage of excess water to yield surface flow (quick runoff);
3. exponential index used in the calculation of actual evapotranspiration; and
4. groundwater recession coefficient.

These parameters are given different values until good match is reach between recorded and calculated values of specific variable. Comparison between calculated and recorded values is based on specific year recored or good, average, and bad hydrologic years. In the previous applications the following variables, among others, were used for comparison:

1. outflow (surface runoff plus baseflow) of a sub-basin and/or the basin;
2. recharge of the ground water; and
3. agriculture water use.

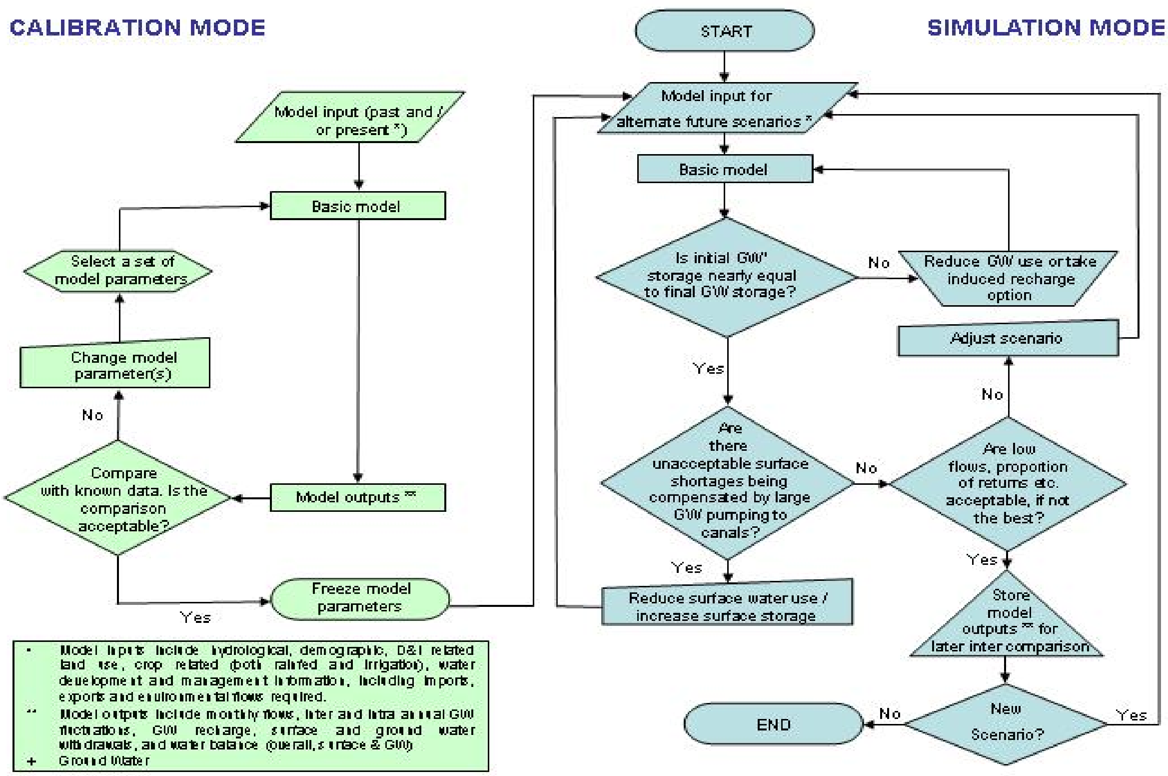

FIGURE 5.2 Model Application Procedure (ICID,2004)

After successful model calibration, scenarios can be simulated and compared with each other. The different future scenarios typically assume changes in the land use such as expansion of forest and barren land, alternate cropping pattern, shift from rain fed agriculture to irrigated agriculture. Other variable like irrigation efficiencies, domestic and industrial withdrawals, and groundwater extractions can change from one scenario to another. If the results (impacts on the hydrologic system or regime) of a certain scenario are not acceptable the scenario is adjusted and re-simulated. The scenario is rejected if output variables, such as surface water shortage, low and return flows, dependency on groundwater, exceeds the acceptable limits of the decision makers.

5.5 Capabilties and Limitations

Mathematical models quality depends very much on their input data accuracy and mathematical formulation. The purpose for which they were developed determines their capabilities and output delivery. However, the selected software platform may impose limitations on the use and application of mathematical models.

5.5.1 Capabilties

The Basinwide Holistic Integrated Water Assessment (BHIWA), is capable of capturing the hydrologic effects of land use changes and the resulting changes in the water regimes of the basin (surface water and groundwater).

The capabilities of the BHIWA Model are:

- modelling in a simplified way the entire land phase of the water cycle including the anthropogenic changes through surface and ground water withdrawals for meeting the requirements of agricultural, domestic and industrial water uses and the return of the unused water to the surface and ground water.
- accounting for evapotranspiration by the use sectors, and further categorising it as beneficiary and non-beneficial component.
- Calculation of surface and groundwater balances separately and allowing depiction of interaction between them as well as impacts of storage and depletion through withdrawals.

5.5.2 Limitations

BHIWA, as adopted currently, suffers from limitations due to its mathematical formulation and software platform. Although the model uses numerous classes of land use (parcels), it is not a (distributed model). It does not depict the spatial variation in rainfall, potential evapo-transpiration, and other variables. It also does not depict the slow horizontal groundwater movement, from under one area to another (sub-basin), within the study.

The model does not take into consideration the water quality, especially in case of return flows, export, and import of water. The monthly river flow for each scenario is the aggregate result of the total input without adding to it the ground water pumping.

The linearity assumption and the time in variance of the model constants and other parameters do not seem to be realistic. Evaluation of the land use changes impacts takes place in the hydrologic domain only. Other domains such as socio-economic and environmental domains should be considered as well.

No doubt, the use of Microsoft excel as a software platform for model development is very limiting compared with object oriented simulation software like STELLA. The underlying assumption and mathematical formulation of the BHIWA are and can not be transparent. The flexibility to make changes to the model is very limited. Its reusability in terms of changing data or applying it to other basin is very risky. The user has to be very knowledgeable not only with the change that he has to do but also with subsequent chain of changes that need to be made. Expandability seems to be another concern. Adding more parcels, sub-basins, scenarios will require almost complete reconstruction of the model's worksheets.

SECTION VI

NEXT STEPS

It is suggested to apply the BHIWA model on the Nile Delta and Valley (35 thousands square kilometers). The BHIWA model is utilized to simulate alternative development scenarios and management polices and evaluating their impacts on the surface and groundwater regime. The total studied area can divided into five sub basins: East Delta, Middle Delta, West Delta, Lower Egypt, and Upper Egypt. Application of the model could take different routes. The simplest is to apply BHIWA as is i.e. minor adjustment to the mathematical formulation and utilization of the Excel platform with no modification. This alternative will utilize the BHIWA with its limitations and will not take into account the accumulated experiences that were developed over years in MWRI in utilizing other mathematical models where Similar Egyptian planning simulation models have been developed. Examples of these models are: Agro-economic model, Operational Planning Distribution model, SIWARE, RIBASIM, IWRAMESD, and others. Most of these models utilized and included more advanced concepts and methods (suit Egyptian conditions) than what have been used in BHIWA, including the software platform.

Therefore, the second alternative is to strengthen the BHIWA with these advanced concepts and methods in the existing planning tools. This can be done through reviewing the available models to extract the useful concepts, indicators, estimation methods. These methods and indicators will be incorporated into BHIWA mathematical formulation without jeopardizing the BHIWA simplicity. Such modifications can be implemented through the current Excel platform with introduction of some automated macros and interfaces that can facilitate the user's mission. Although this alternative will strengthen the BHIWA mathematical capabilities and adaptation to the Egyptian conditions, it will has its limitation concerning the use of Microsoft excel as a software platform for model development. The flexibility to make changes to the model is very limited. Its reusability in terms of changing data or applying it to other basin is very risky. The user has to be very knowledgeable not only with the change that he has to do but also with subsequent chain of changes that need to be made. Expandability seems to be another concern. Adding more parcels, sub-basins, scenarios will require almost complete reconstruction of the model's worksheets.

Therefore, the third alternative is to redevelop the modified model in an object oriented environment which can enhance the model reusability and expandability. This alternative will cover all the drawbacks of the original BHIWA model and adapt it to the Egyptian conditions but it will require more time and resources to be implemented compared to the other two alternatives. Therefore, it is recommended to formulate a project for implementing this alternative where it can provide all the required resources for its implementation. The final product of this project will be a workable version of the enhanced BHIWA model that will be tested and verified on the 5 Egyptian regions. Another major output for this project will be a well trained Egyptian staff on the operation and maintenance of that model.

This project considers the technology transfer and training component to be a key activity in its framework. In general technology transfer refers to all activities related to the transfer of knowledge and skills, in combination with available tools, to institutions and individuals.

The main objective of the training and technology transfer in this project is to establish a well trained operational sustainable tool. Table 6.1 shows the estimated time schedule for implementing this project.

This tool is capable to test the various scenarios and their impacts on the water resources management in Egypt. The training and technology transfer activities may include: i) institution support to different sectors of the MWRI, ii) practical on – the – job – training , and iii) joint execution of the project.

TABLE (6.1): The Proposed Schedule FOR Upgrading BHIWA Modeling Tool

	Item	**Year (1)**				**Year (2)**			
		1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1	Detailed Assessment of the BHIWA modeling tool								
2	Detailed Assessment of the available Modeling tools								
3	Define the available indicators, methodologies, and functions that can be incorporate to BHIWA								
4	Develop a Data Flow Diagram to incorporate data inputs for the BHIWA Model								
5	Develop the Output reporting format								
6	Re-structure the BHIWA to incorporate the new functions and Indicators								
7	Programming the New Model using Object-Oriented simulation SW								
8	Test & Verify the modified model on the available data								
9	On-the job-Training for model Implementation and Operation								

REFERENCES

- Abou-Zeid, S. and Ibrahim, A. (1998). "Data acquisition and remote control decision support system for water resources management", Proc. of the joint Egyptian-Syrian Workshop, Damascus, Syria.
- Abu-Zeid (1997). "Egypt's water policy for the 21st century", Proc. IXth IWRA Congress on Water resources outlook for the 21st century: Conflicts and opportunities, Special session on Water management under scarcity conditions: The Egyptian experience, Montreal, Canada.
- CNCID (2004). Chinese National Consultation on Country Policy Support Programme (CPSP), Beijing, China.
- Georgakakos, A.P., Yao, H., Yu, Y. (1995). A decision support system for the High Aswan Dam, Ministry of Public Works and Water Resources/FAO/USAID, Georgia Institute of Technology, Cairo, Egypt.
- Hassan, M.E., Fahmy, B.S., and Attia, B.B. (1999). "The decision support system for the Nile River", Proc. 7th Nile 2002 Conference, Cairo, Egypt.
- INCID (2003). Indian National Consultation on Country Policy Support Programme (CPSP), New Delhi, India.
- ICID (2004). Background paper on Country Policy Support Programme (CPSP), New Delhi, India.
- Master Water Plan Project (1981a). Hydrologic simulation of lake Nasser, Tech. Rep. No. 14, Ministry of Irrigation, UNDP, IBRD, Cairo, Egypt.
- Master Water Plan Project (1981b). The agro-economic model, Tech. Rep. No. 16, Ministry of Irrigation, UNDP, IBRD, Cairo, Egypt.
- Master Water Plan Project (1983a). The planning distribution model, Tech. Rep. No. 21, Ministry of Irrigation, UNDP, IBRD, Cairo, Egypt.
- Master Water Plan Project (1983b). Adaptive close-loop operation of the High Aswan Dam, Tech. Rep. No. 22, Ministry of Irrigation, UNDP, IBRD, Cairo, Egypt.

- Master Water Plan Project (1984). The operational distribution model, Tech. Rep. No. 26, Ministry of Irrigation, UNDP, IBRD, Cairo, Egypt.
- Sage, A.P. (1991). Decision support systems engineering, John Wiley and Sons, Inc., New York, USA.
- Strategic Research Unit (1999). "Decision support system for water resources planning based on environmental balance: Final formulation", SRU-CIHEAM/IAM-B, Cairo, Egypt.
- Tawfik, M., Ibrahim, A., and Hassan, A. (1997). "Importance of real-time data for efficient irrigation water management", Proceeding of the EWRA Conference on Operational water management, J.C. Refsgaard and E.A. Karalis, eds., A.A. Balkema, Copenhagen, Denmark.
- Todini, E. and Bottarelli, M. (1997). "ODESSEI: Open architecture Decision Support System for Environmental Impact: Assessment, planning and management", Proc. of the EWRA on Operational water management, J.C. Refsgaard and E.A. Karalis, eds., A.A. Balkema, Copenhagen, Denmark.
- Turban, E. and Aronson, J.E. (1998). Decision support systems and intelligent system, Prentice Hall international.