SALINITY MANAGEMENT IN THE NILE DELTA

CASE STUDY: REUSE OF DRAINAGE WATER IN EGYPT

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ABSTRACT

Egypt is mainly depending on the Nile for its water supply. The annual discharge of the Nile at Aswan Dam is fixed at 55.5 billion m^3. The River Nile is the source of livelihood for the inhabitants, water for land irrigation, and hydropower development. The conservation, control and regulation of the Nile and its tributaries, therefore, have a strong direct bearing on the economic development. Meanwhile, increasing pressure on available fresh water resources creates continued interest in the use of marginal quality water for irrigation. Agricultural drainage water is an important and economical source of irrigation supply. Reuse of such water is well developed in Egypt and will continue to be a significant portion of the irrigation supply, particularly in the Nile Delta region.

Monitoring of the water quantity and quality has played an important role in the management of drainage water reuse. The design of reuse schemes was based primarily on water quantity, salinity and the macro-ions in the main drains of the Nile Delta. Until 1980, Systematic information and data collection on relevant water quality parameters was given minor attention. This information was not covering all relevant water quality parameters, so information have to be collected before any program on water quality management could be implemented. There were very few and scattered data on the levels of domestic and industrial discharges except for basic parameters (BOD suspended solids). Data were also required on sources of pollution to determine the nature and extent of contamination problems, their severity and their causes. Without research on this topic, it was difficult to determine what actions had to be taken to control water quality and what effect was likely to result if measures were not taken.

Responding to the recommendations given in the Environmental Action Plan of 1992, the Governments of Egypt and the Netherlands decided to jointly execute the project 'Monitoring and Analysis of Drainage Water Quality', here after referred to as the 'MADWQ project'. It was envisioned that together with the Dutch-funded projects 'Environmental Management of Groundwater Resources' (EMGR), 'Strengthening the Planning Sector' (SPS and 'Design of an Integrated National Water Quality Monitoring Network in Egypt' (INWQM), which were implemented in parallel, a significant contribution could be made to improve water resources management and planning in Egypt.

The main objectives of the MADWQ project are:

- The set-up and implementation of an integrated measuring network to monitor drainage water quality in the Nile-Delta and Fayoum Governorate;
- Use of mathematical models to support drainage water management, maximizing reuse of drainage water of acceptable quality;
- Systematic publication of data and data interpretations;
- Enhancing research capacity, to respond to external requests for management support in drainage water quality issues.

The MADWQ project provided information on the availability and suitability of the agricultural drainage water for irrigation. It is expected that drainage water will contribute 7 billion cubic meters per year to Egypt's water resources. However, increased salinity is expected to limit full utilization of this amount. Intrusion of saline ground water from the Mediterranean contributes to the salinity conditions, in particular in the Northern part of the Nile Delta.

1- BACKGROUND

1- 1 GENERAL

The construction of dams and the creation of man-made lakes affect the river ecosystem. Consequently, dams and lakes create some kind of environmental alteration. The environmental impacts of the Aswan High Dam on water resources includes sedimentation in the reservoir, loss of silt, changes of the river bed and river banks, groundwater conditions, agriculture drainage and soil salinity problems. The basin system continued to be the only method of irrigation in the country until the beginning of the 19^{th}. In 1826, Delta Barrages at the head of the Rosetta and Dameitta branches of the Nile about 23 km north of Cairo have been built. The barrages which were completed in 1861 could not, however, serve their purpose as they were not strong enough to withstand the forces caused by the designed head of water. The barrages were then remodeled and again brought into use. Later, however, they could not cope with the increased irrigation requirements of the Delta. The new Delta Barrage were built at the head of Rosetta and Damietta branches and completed in 1939.

Perennial irrigation has made it possible to grow two or three crops each year in the old lands. After the completion of the Aswan High Dam, the entire cultivated area of Egypt was placed under perennial irrigation. The area cultivated and irrigated before the High Dam (1959) was 5.9 million feddan. With the horizontal agricultural expansion program executed in the following years, the total irrigated area has risen to about 8.0 million feddan.

The beginning of the storage in the Aswan High Dam in 1968 is considered to mark the beginning of a new era. Besides the electric power generated, it was possible to transfer about one million feddan, to perennial irrigation; to plan and apply an adopted crop rotation, and to reclaim and develop new lands. The need for drainage becomes more urgent than ever.

2-1 SALINITY PROBLEM

Following the introduction of perennial system to all irrigated areas, cropping intensities and water use per unit area have increased sharply. A consequence of intensified irrigation has been a rising water table and increased problems of water logging and salinity which has resulted in a deterioration of both soils and crop productivity. In response to this challenge, the Government of Egypt has given high priority to the installation of pipe drainage in existing agricultural lands.

The data from the soil survey during 1958 to 1968 was used to identify the soil salinity problem and groundwater table in the Delta region (El-Nahal et al., 1977). The soils of the southern part of the Delta are generally non-saline soil, as the electric conductivity of their saturation extracts is below 4 mmhos/cm at 25°. Patches of different sizes and different degree of salinity are scattered throughout the body of the delta especially close to irrigation canal and where drainage is either absent or inadequate.

The extremely high salinity in most of the northern part of the delta restricts the growth of most crops and makes the productivity of such soils much lower than what their fertility would allow. The depth of ground water-table in the Delta soils as recorded during the soil survey work which was completed over a ten-year period from 1958-1968 was deeper than 150 cm in the majority of the southern part. In the northern part near the coastal lakes, water table was shallow with depth less than 20 cm from the soil surface and in some areas the soil was submerged under water. In all cases, however, the subsoil in the northern areas was quite wet and showing evidence of poor aeration. The presence of reduced Iron and Manganes concentrations and color mottling at different depths of the subsoil indicates the poor drainage and anaerobic conditions.

Shallow water table in the southern part of the Delta was found in areas subjected to water seepage from the irrigation canals and where drainage was lacking or inadequate. Ground-water-table was deep in areas where no seepage occurred or where drainage systems were constructed. Economic evaluation and statistical analysis of crop yields proved that, after a period of ten years, tile drainage increased crop productivity. It has become most effective way in lowering the salinity hazards. As an example in two regions (each with an area of 3000 feddan), 7300 ton/feddan, salts were removed from the first region within 3 years, out of this came 3440 tons of sulfates per feddan. For the second region, 8350 tons/feddan, of salts were removed out of which 3500 ton/feddan, sulfates were collected. The ratio of sulfates to the total dissolved salts (TDS) in the two regions was estimated at 47% and 42% respectively.

1-3 CROP YIELD

Prior to the introduction of tile drainage, the average maize yield was increased by 46% after the introduction of drainage. In the second region, the average maize yield was increased by 75% after using drainage.

The increase in the production started in the first year after the installation of the subsurface drainage net and reached its ultimate level in the third year. As a result, the increase in the farmer's income was about 100%. With tile drainage, the drainage rate did not exceed 20% of the irrigation duty, as compared to open drainage whose rate was 50% of the irrigation water applied.

2- INTRODUCTION

The reuse of agricultural drainage water is already practiced on a large scale in several countries. Egypt is one of the leading countries in the reuse of drainage water for irrigation. Reuse of drainage water appears to be one of the most promising, practical and economical means of increasing the Egyptian water budget. However, reuse of drainage water has its limitations and drawbacks. Available information shows that the river Nile, its branches, canals and the drains are suffering from an increase in the pollution through wastewater. The drainage system particularly is receiving the heaviest pollution loads. The major sources of water pollution are municipal and rural domestic sewage, industrial waste and agricultural chemicals (salts, nutrients and pesticides). Therefore, dependence on the Nile system makes management of its quality as important as management of its quantity.

Monitoring of the drainage water quantity and quality is one of the mandates of Drainage Research Institute (DRI) of the National Water Research Institute, Egypt, which had already made important steps to such monitoring and analysis programs in the past. Without research on this topic, it was difficult to determine what actions had to be taken to control water quality and what effect was likely to result if measures were not taken. Hence the management of Egypt's water resources, and in particular the planning of more intensive water reuse, called for the collection, analysis and dissemination of water quality data.

Responding to the recommendations given in the Environmental Action Plan of 1992, the Governments of Egypt and the Netherlands decided to jointly execute the project 'Monitoring and Analysis of Drainage Water Quality', hereafter referred to as the 'MADWQ project'. It was envisioned that together with the Dutch-funded projects 'Environmental Management of

Groundwater Resources' (EMGR), 'Strengthening the Planning Sector' (SPS) and 'Design of an Integrated National Water Quality Monitoring Network in Egypt' (INWQM) which were implemented in parallel, a significant contribution could be made to improve water resources management and planning in Egypt.

2.1 PROJECT OBJECTIVES

The project objectives were:

- The set-up and implementation of an integrated measuring network to monitor drainage water quality in the Nile-Delta and Fayoum Governorate;
- Use of mathematical models to support drainage water management, maximizing reuse of drainage water of acceptable quality;
- Systematic publication of data and data-interpretations;
- Enhancing research capacity at DRI, to respond to external requests for management support in drainage water quality issues.

The project aimed at the strengthening the capabilities of the counterpart staff of DRI in the field of drainage water quality monitoring and analysis. Egyptian and international consultants and counterpart staff together established an integrated monitoring network for drainage water management (quantity and quality). The monitoring network was defined in such a way that the resulting information could optimally serve the planning and Irrigation sectors of MWRI, the Irrigation Directorates, the Ministry of Health, the Egyptian Environmental Affairs Agency (EEAA) and other agencies It is hoped that this will, in turn, ensure the availability of water of sufficient quality to contribute to environmental protection, and determine the possibilities of reusing such water to meet increased demands. The water quality program on drainage water includes the drainage water systems in both the Nile-Delta and the Fayoum Governorate.

The project also aimed at strengthening DRI in the field of data processing and interpretation. Uniformity and reliability in data processing and establishment of databases, together with integration of existing databases within the Ministry, is one of the key elements in the project. Overall, the project contributed to strengthen DRI towards an efficient, cost-effective, goal directed and client oriented institute for drainage research, with special attention for water quality. The institutional development of DRI will be evident inside the project and within DRI, as well as outside the project and DRI; in particular at the Ministries, organizations and institutes that have a link with health and environmental issues in Egypt.

The immediate objectives of the project are:

- Upgrading of the already existing monitoring network to include all necessary water quality parameters of drainage water in the Nile-Delta and Fayoum, in order to find critical concentrations of salinity and pollution versus the recognized quality standards;
- Extension of the drainage monitoring network of the Nile-Delta and the Fayoum to cover all critical sites;
- Establishment of a database and information system on the pollution of drainage systems in the Delta and in the Fayoum, including a full range of physical, chemical and biological parameters;
- Assessment of the drain loads for major toxic substances due to agricultural chemicals, heavy metals and bacteria;
- Cost-effective upgrading of the field and laboratory facilities with new equipment to determine the state of drainage water quality, keeping in view the establishment of central

laboratory CLEQM within the National Water Research Center (NWRC) and the existence of specialized upgraded facilities with other agencies;

- Development of interpretation tools and prediction models to meet water quality objectives and efficient use of the scarce surface and ground water resources;
- Ascertain the availability of water quality and waste load models in which the parameters of the monitoring program have been integrated, to simulate the sources the kinetics and the fate of pollutants:
- Strengthen DRI with the well-trained staff in water pollution, field sampling and measurements, and laboratory analysis and application of computer techniques in modeling.

3- ACHIEVEMENTS

The MADWQ project objectives have been set to meet the needs of decision makers in drainage water quality for the Nile Delta and Fayoum. It provides information on the availability and suitability of the agricultural drainage water for irrigation. Through the course of the project, DRI achieved the following main aspects that prove to be invaluable in the field of water quality study and research:

- An implemented integrated measuring network to monitor drainage water quality in the Nile Delta and Fayoum Governorate.

Through the course of the project, the DRI technical staff is being skilled in standard operation procedures (SOP's) for sampling, analysis and verifying data. This includes quality assurance/quality control (QA/AC) procedures for the field and laboratory. This has improved the consistency of the collected information.

Continuous monitoring is applied in the project area through the implementation of automated water quality stations that enable the collection of the different water quality parameters on the continuous basis. This has increased the insights in the temporal variations in the data.

Data screening procedures have been used in order to increase the reliability of the collected data. Procedures for entry and screening of water quality data are improved throughout the course of the project, which has increased the reliability of the data and information produced. A database has been implemented for the storage, processing and retrieval of the drainage water quality over a network of PCs at the DRI. This has increased the accessibility of the water quality data.

- The use of numerical simulation models to support water management, maximizing reuse of drainage water of acceptable quality.

The SIWARE (Simulation of Water Management in the Arab Republic of Egypt) model has been extended throughout the course of the project for the evaluation of the water quality effects of measures and the reuse potentials. Simulation models are valuable research tools as they provide better understanding of the various mechanisms (physical, chemical and biological that control drainage water quality. Furthermore, they have been used for the evaluation of the effect of different reuse policies on water quality.

- The research capacity at DRI to respond to external requests for management support in drainage water quality issues is enhanced.

The presence of models, the insights in the water quality cause and effect relations in the drainage system have strengthened DRI in its role to support the Ministry of Water Resources and Irrigation in evaluating strategies and scenarios for the future planning of water resources management.

- Systematic publication of data and data-interpretation.

The extension of the DRI yearbook with water quality data and information has greatly improved the availability of information about the water quality in drains to the interested government institutions.

4- PROJECT IMPLEMENTATION

The core element of the project is to bring the water quality component of the drainage water-monitoring network at a higher level. It was found that the aim of such an integrated monitoring network is to obtain insight not only in the water quality status in the drains, but also in the total load of contaminants, to provide information for defining priorities for remedial actions and for the safe design and management of drainage water reuse schemes.

As structured information on water quality parameters in the Nile-Delta and the Fayoum Governorate was scarce, the project started with the reconnaissance water quality survey, aimed at quickly obtaining a general insight in the water quality status at a large number of locations in the major drains. Once an overall picture was available, a monitoring program at selected points was designed to obtain a more detailed insight in the water quality and its variability. Finally the quantity and quality programs were integrated into one program. Many activities were carried out in order to achieve the projects objectives: monitoring program, data processing & reporting, modeling and training needs.

5- NET WORKS DESIGN & IMPLEMENTATION

5.1 RECONNAISSANCE SURVEY NETWORK

The reconnaissance survey was the start of the project-monitoring program and forms the basis from which the network is designed. The total number of parameters to be analyzed was 34,

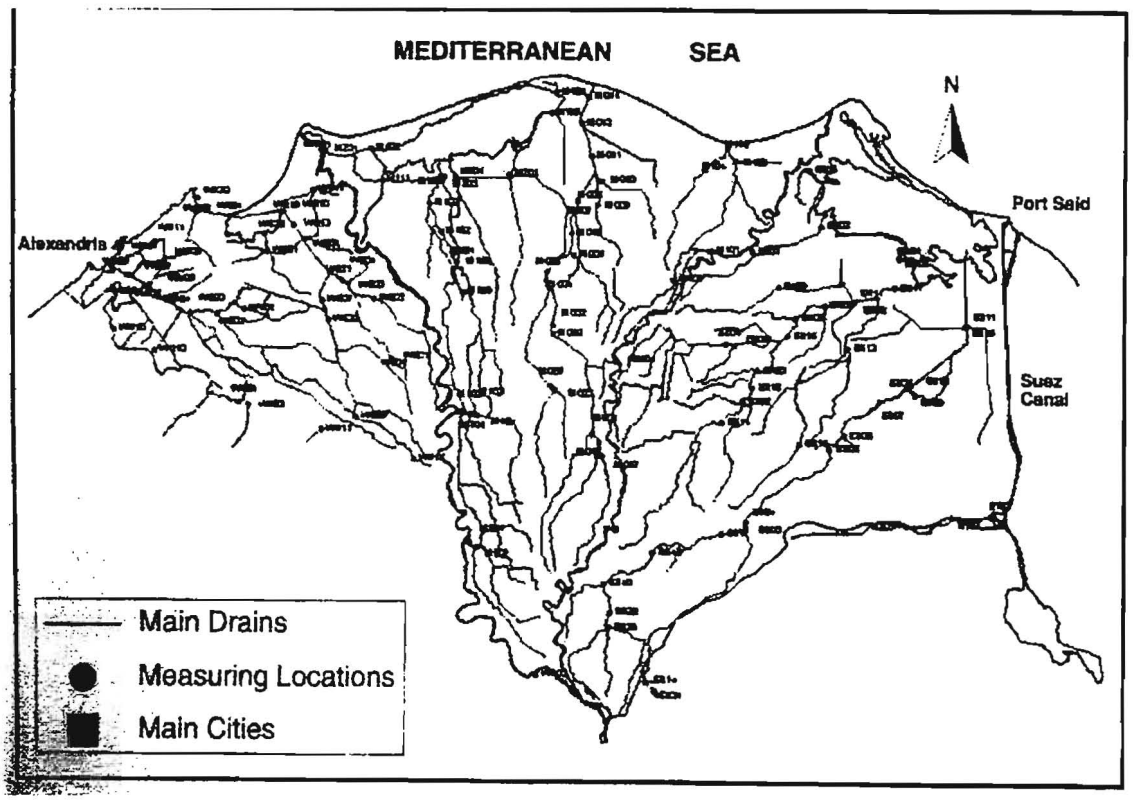
taking into consideration microbiological, oxygen related parameters, nutrients and extended cations, metals and trace elements as well as the classic parameters. The selection of parameters was mainly based on the water quality objective of the network. However, other aspects have been considered, such as, laboratory facilities and the knowledge and experience of the field and laboratory staff. In July 1997, the routine measurement program started and one-month duration was chosen as the frequency of field trips.

Because of correlation between locations that became clear from the reconnaissance survey, the number of monitoring locations has been reduced from 230 all over the Nile Delta and Fayoum to around 120 locations to achieve the project objectives. A summary of the distribution of location is presented in Table 5.1

Table 5.1. Number of monitoring locations in different regions included in the reconnaissance survey

Region	Number of locations		
	Existing Monitoring program	Additional	Total
Eastern-Delta	34	39	73
Middle-Delta	32	38	70
Western Delta	29	40	69
Fayoum area	-	17	17
Reference point	-	1	1
Total	95	135	230

Four automated Water Quality Monitoring Station (CWQMS) were installed at strategic locations in the Nile Delta to provide detailed reliable data on drainage water quality status. Desk study has been carried out into three phases to identify sources of pollution to the drainage system. The sources of pollution acknowledged in this study can be classified into four groups: Domestic (point and diffuse), Industrial land agricultural sources. The measured parameters can be divided into six major groups (oxygen budget related parameters, salts / macro ions, nutrients, physical parameters, bacteria, and heavy metals). The selection of locations has been carefully done and the final selection with brief details is given below. Map 5.1 shows the ultimate set of locations of the Nile Delta.



Map 5.1 The monitoring network of the Nile Delta

5.2 AUTOMATED WATER QUALITY MONITORING STATIONS

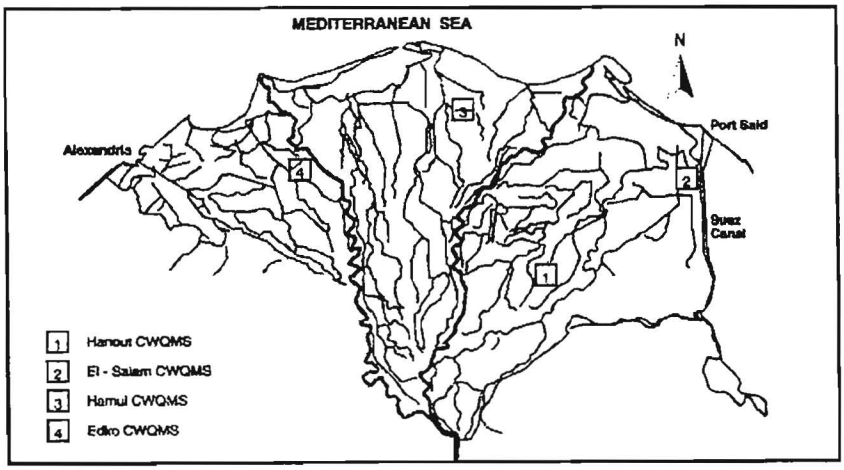
Four automated Water Quality Monitoring Stations (CWQMS) were installed at strategic locations in the Nile Delta to provide detailed reliable data on drainage water quality status.

The continuous water quality monitoring stations are placed at four main open drains where the intake of pump stations exists. Due to the limited number of these stations compared with total number of monitoring network, criteria were used to select the most important strategic locations:

- Potential of drainage water reuse;
- Degree of variation of water quality in the drain; and
- Scale of reuse project.

Using these criteria, the following four most strategic locations (Map 5.2) have been chosen:

- Intake of Hanout Irr. Pump station at Bahr Hadous Drain;
- Intake of El-Salam 3 pump stations at Bahr Hadous drain;
- Intake of Hamul Irr. Pump station at Gharbia main drain; and
- Intake of Edko Irr. Pump station at Edko drain.



Map 5.2. Locations of the continuous water quality monitoring stations in the Nile Delta

6- INFORMATION MANAGEMENT

The ultimate goal of the monitoring and analysis of drainage water program is to obtain accurate information on drainage water status related to its quantity and quality at strategic locations along the main drains in the Nile Delta and Fayoum. The supporting tools for managing this information and make them available to decision makers and the end users are:

- A powerful relational database capable of handling huge amounts of data.
- Simulation models for evaluating the changes in surface water quality.

The information derived such systems will be based on accurate data and observation collected, processed, and presented with respect to actual status in the field. Therefore, it will maximize the value obtained from these information sources and consequently it will be available for final use in policy planning and implementation.

The conceptual approach to manage the drainage water information is given in Figure 6.1.

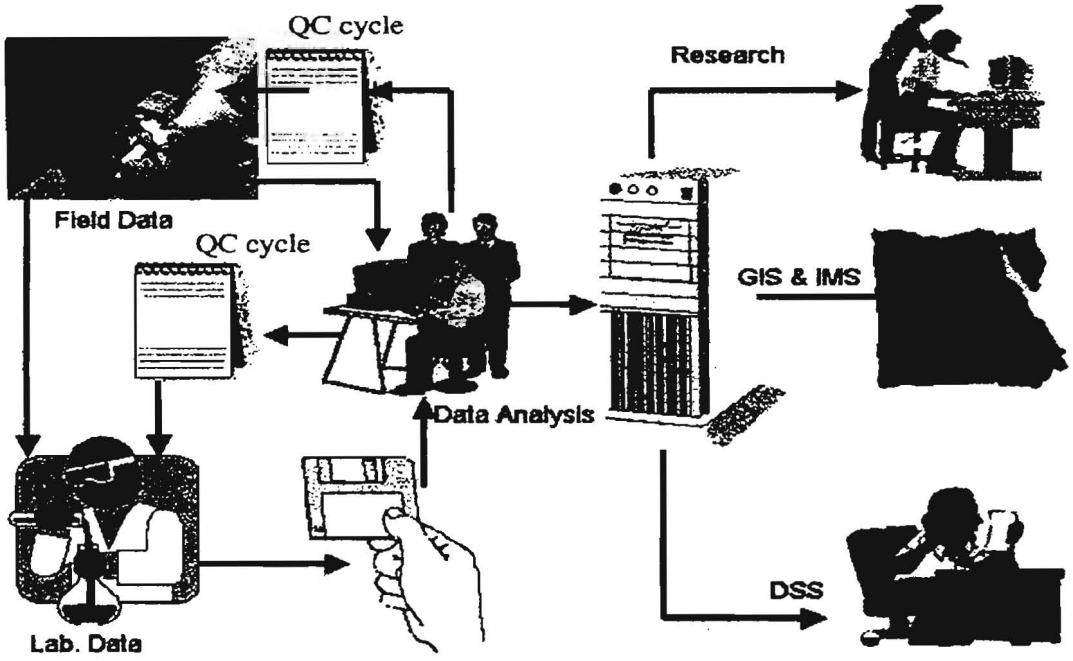


Fig 6.1. conceptual approach to manage the drainage water information

7- MODELING

The SIWARE MODEL (Simulation of Water Management in the Arab Republic of Egypt) was developed in the past to simulate the water management in the three Nile Delta parts (East, Middle and West), Combining different functions, the SIWARE model proved to be especially useful for the realistic estimation of drainage water available for reuse in irrigation and the effects of its salinity on crop yields.

In the framework of the MADWQ project, the SIWARE model and the three Delta models have been adjusted for integration within the Decision Support System (DSS) to evaluate different water management strategies for the future. The computational framework has been called DSSDELTA. In this new set-up, both a waste load model and a water quality model receive input from the SIWARE model, which performs the water balance simulations for the Nile Delta.

The reuse of drainage water plans; the irrigation methods (Irrigation Improvement for surface irrigation; sprinkler irrigation; drip irrigation; deficit irrigation; etc.), and the municipal and industrial use of surface water are part of the strategies to be evaluated and are input to SIWARE. Since the aquifer itself is not part of SIWARE, groundwater use (both for agriculture as well as for M&I) and its salinity are obtained from the Research Institute for Groundwater. The DSSDELTA for water management was used to analysis the present and future water resources management in terms of water quantity, water quality and waste loads.

8- DRAINAGE WATER QUALITY STATUS

The total data set over the project period consists of approximately 150,000 records: about 5000 samples, each analyzed for 30 parameters. The water quality is described for different subsets of parameter relevant for a specific problem. Special features related to regional variability are

highlighted as well as the extent to which the water can be used for different purposes based on the appropriate guidelines and legal standards. Detailed description of the water quality status of the drains can be found in the DRI Technical Reports. Yearbooks and several special report and scientific papers.

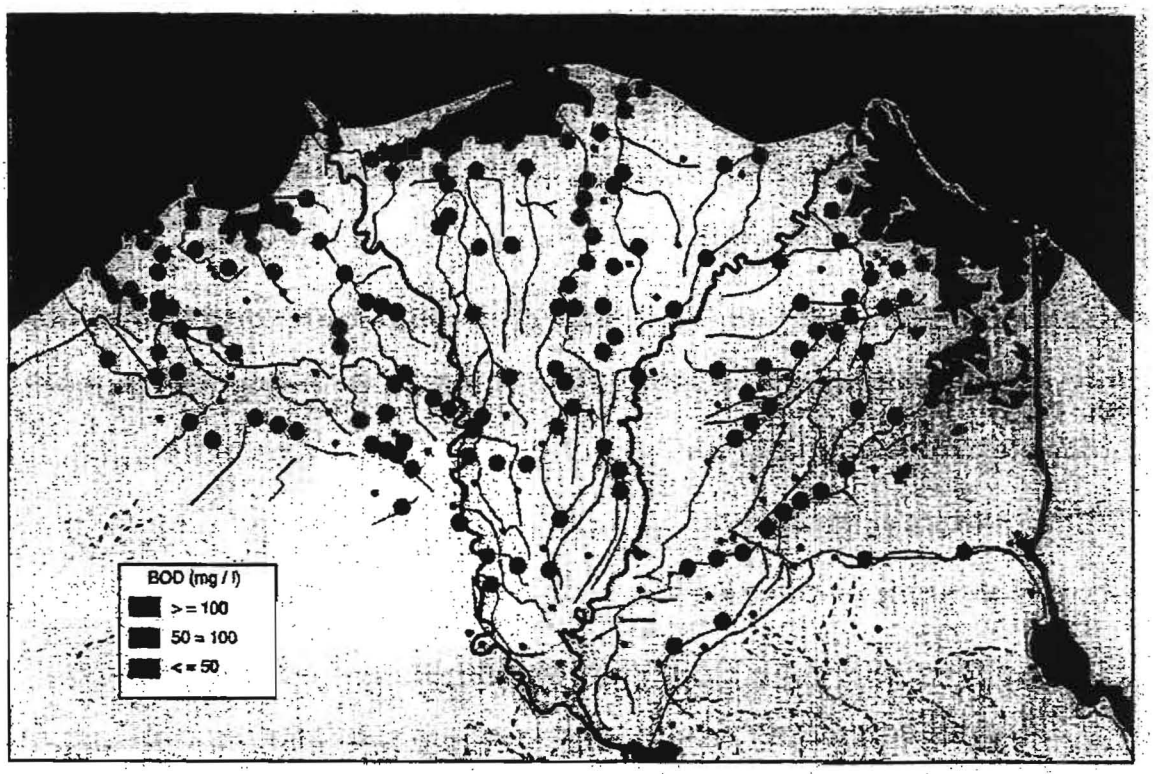
For the first time an extensive survey is available of the water quality in drainage system in the Nile Delta and Fayoum. This allows managers, decision-makers, and also water users to base their actions on concrete information rather than estimates or assumption. Data are now available for the years 1996-2000, but with the continuing of the monitoring network, the data set will be extended to allow for more and other analyses, such as trend analysis.

The present monitoring results indicate clearly that almost all drains suffer from domestic discharges. A number of drains also receive industrial discharges. As a result Coli Bacteria, BOD and COD and sometimes nutrients are often much higher than would normally be expected from agricultural drains. In many locations, this limits the possibilities for safe use of this water directly or indirectly for agricultural purposes.

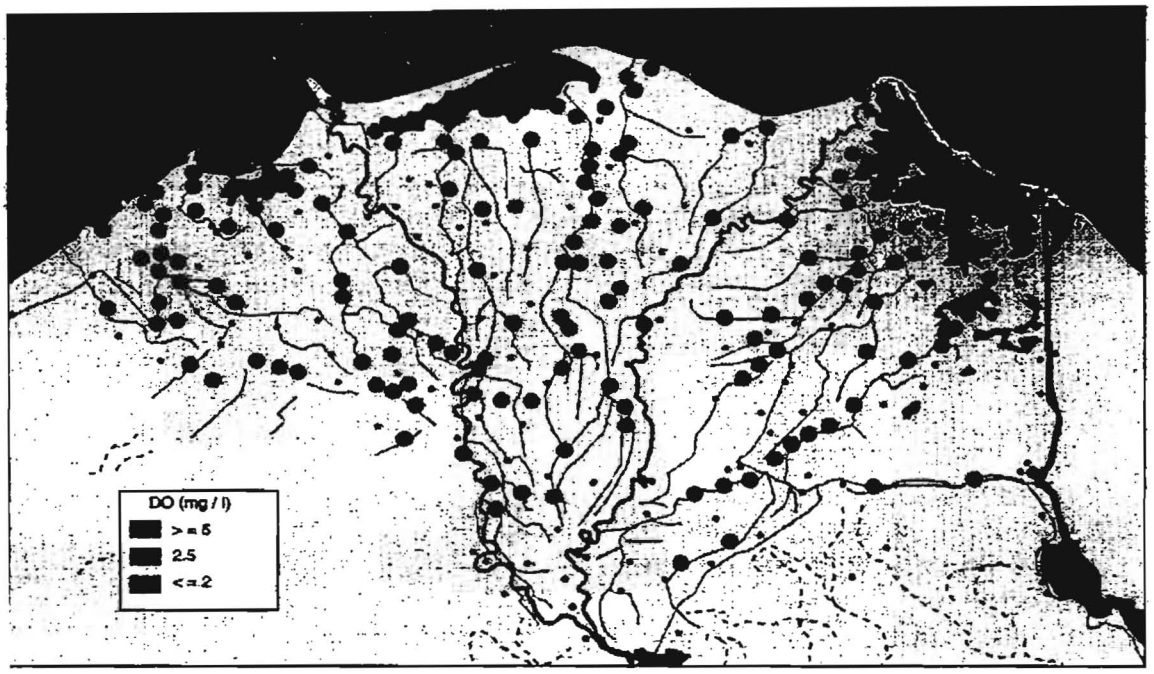
Along the northern coasts, high salt contents also form limitations to the use of the water. The high salt content is caused by evaporative enrichment due to repeated use of the water in agriculture, but also due to flushing of salts from the underground.

The most polluted drains are the Bahar El Baqar in the Eastern Delta, the Gharbia drain in the Middle Delta, and the Umoum and Abu-Keer Drains in the Western Delta. In every case the sources are related to large urban and industrial conglomerates.

These drains show also the highest COD-concentrations with values from 400 to over 1000 mg O_2/l_{as} well as very low dissolved oxygen concentration of below 0.5 mg O_2/l . Maps 8.1 and 8.2 shows the average concentration at each monitoring location in 1997 respectively.



Map 8.1 Average BOD-Concentration in the Nile Delta in Year 1997.



Map 8.2 Average Dissolved Oxygen concentration in the Nile Delta in 1997.

9- FUTURE DEVELOPMENTS

A number of ongoing developments in the field of water quality monitoring and management will influence the benefits that can be gained by the achievements of this project.

- Major efforts are being done in order to prepare the Central Laboratories for Environmental Quality Monitoring (CLEQM) to be the leading laboratory facility for monitoring water quality.

The drainage-monitoring network is being expanded into a national integrated monitoring network. Considering the drainage system in Upper Egypt and the irrigation system.

- Continuous updates of the monitoring program are required. This involves inclusion of recent technologies. Increasing attention to sediments and other organisms and using new methods for toxicity assessment.
- As more data become available and longer continuous time series are available. The statistical analysis of the data will be possible. Trend analysis can provide insight in changes in parameters over a certain period of time. This is important to evaluate impacts and effectiveness of measures for pollution abatement as well as other developments. Statistical correlation techniques can also be used to determine whether the number of monitoring locations can be reduced.
- The use of computer models and techniques is being expanded to include prediction of certain scenarios impacts on water quality. Better understanding of the system, application of GIS for presenting information through visualization and multi-criteria evaluation, and developing protocols for information exchange.

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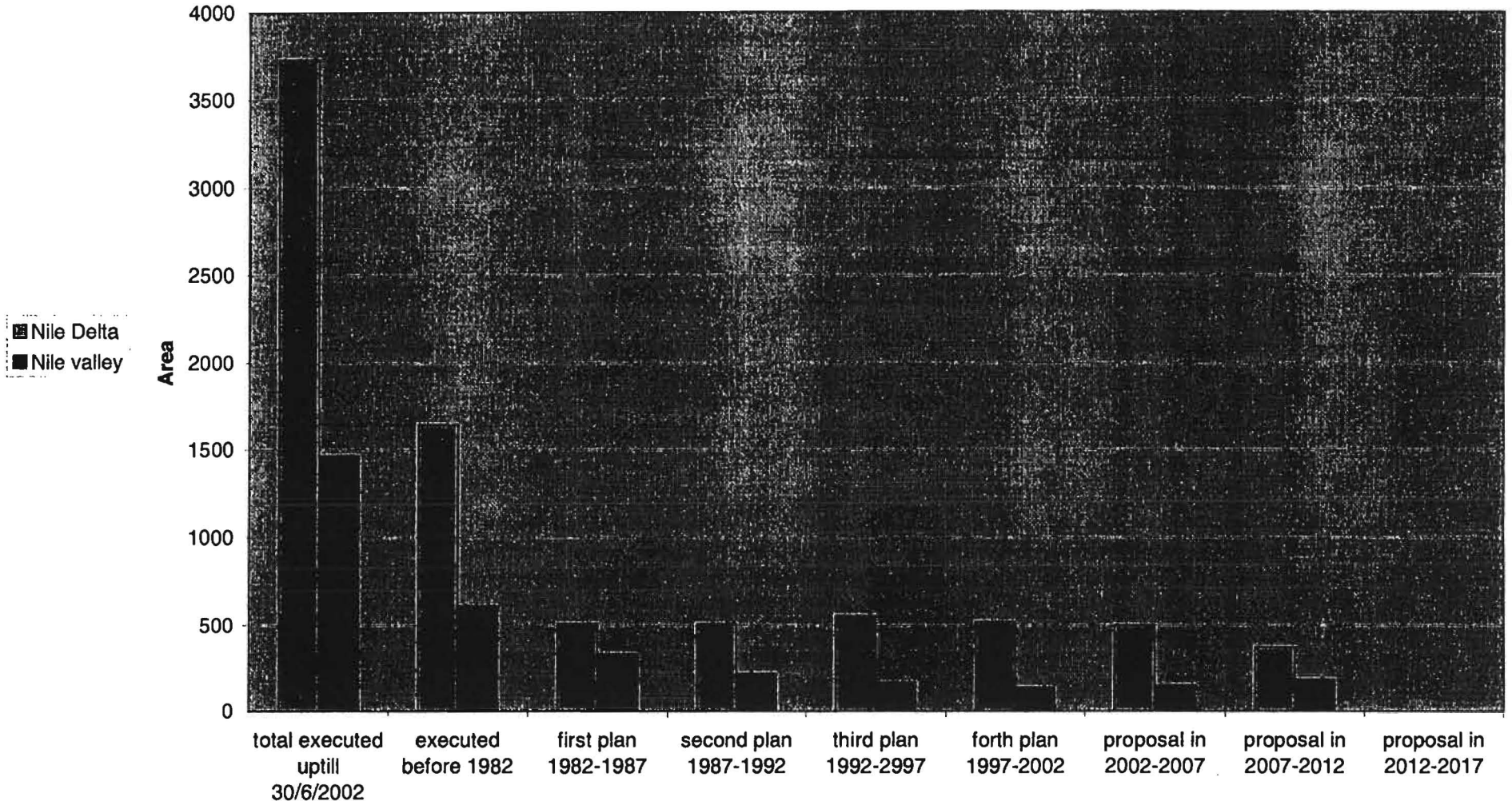
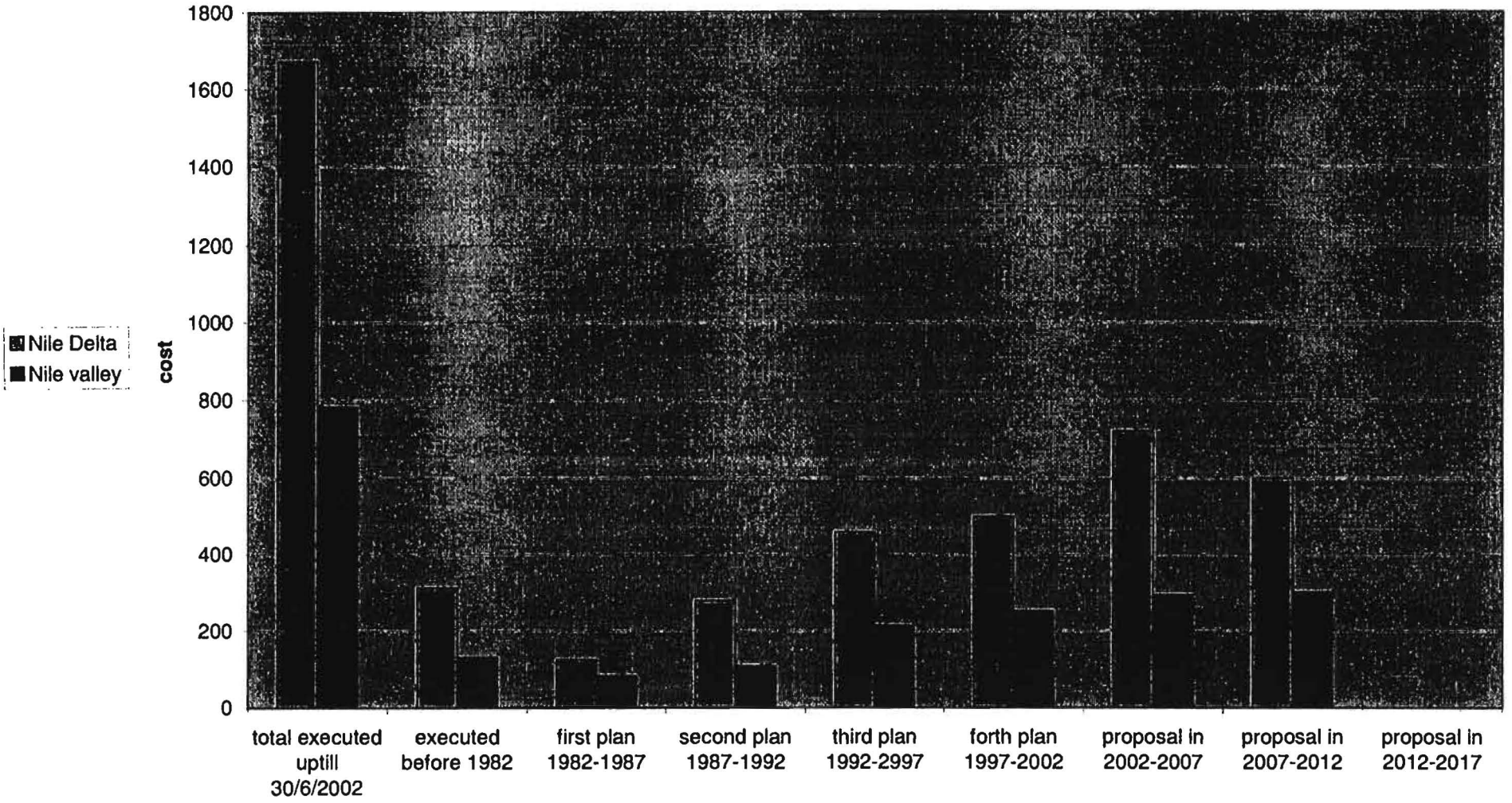
Implementation Program Of Subsurface drainage up to 2017



Implementation Program Of Subsurface drainage up to 2017



Implementation program of subsurface drainage up to 2017

tivity	total executed uptill 30/6/2002	executed before 1982	first plan 1982-1987	second plan 1987-1992	third plan 1992-2997	forth plan 1997-2002	proposal in 2002-2007	proposal in 2007-2012	proposal in 2012-2017
	area	area	area	area	area	area	area	area	area
Delta	3728	1640	509	507	552	520	500	372	0
alley	1465	608	332	220	168	137	150	185	0
tal of surface inage	5193	2248	841	727	720	657	650	557	0

tivity	total executed uptill 30/6/2002	executed before 1982	first plan 1982-1987	second plan 1987-1992	third plan 1992-2997	forth plan 1997-2002	proposal in 2002-2007	proposal in 2007-2012	proposal in 2012-2017
	cost	cost	cost	cost	cost	cost	cost	cost	cost
elta	1670	310	124	277	459	500	720	600	0
alley	782	130	82	107	213	250	292	300	0
tal of urface nage	2452	440	206	384	672	750	1012	900	0