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***NATIONAL POLICY FOR
DRAINAGE WATER REUSE***

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EXECUTIVE SUMMARY

One of the policy reform benchmarks identified and agreed upon by the Ministry of Public Works and Water Resources (MPWWR) and the US Agency for International Development (USAID) under the Agricultural Policy Reform Program (APRP) Tranche II (1997-1998) was the preparation of a draft national policy on drainage reuse. The benchmark states that the “Government of Egypt (GOE) will develop and approve new policies, regulations and criteria to promote drainage water reuse with appropriate incentives and technical support”.

Agricultural drain water reuse, an important source of irrigation supply, is well developed in Egypt, particularly in the Nile Delta region. However, as the demand for reuse keeps on growing, the expansion or even the continuation of drainage reuse has been threatened by the deteriorating drain water quality due to municipal and industrial (M&I) wastewater pollution. The MPWWR is facing multidimensional challenges in sustaining the current reuse and promoting more drainage reuse in the future decades.

To assist the MPWWR in formulating new drainage reuse policies, the USAID-funded Environmental Policy and Institutional Strengthening Indefinite Quantity Contract (EPIQ) team has evaluated the short-term and long-term challenges in drainage management by focusing on the following selected strategic issues in drainage generation and reuse for the development of policy visions and recommendations:

- maximum drainage reuse potential and minimum outflow requirements,
- pollution control in the drain system,
- unofficial reuse and intermediate reuse,
- factors affecting future drainage reuse, and
- institutional aspects in drainage management.

This report summarizes EPIQ team’s technical analyses on these strategic issues, and the recommended policy visions and actions based on these analyses. The report focuses on agricultural drainage reuse development in the Nile Delta region.

Maximum Reuse Potential and Minimum Outflow Requirements

Policy Visions

- 1. Drainage reuse has been and will continue to be an important water conservation measure in the Delta region. Further expansion of drainage reuse in the Delta will be needed as well as possible over the next decades.*

The practically achievable reuse pumping potential in the Delta will be 9.6 bcm per year, which is 5.3 bcm more than the 1995-96 reuse level of 4.3 bcm. This 5.3 bcm additional reuse pumping potential can be achieved by capturing all the drain water with salinity concentration below 2,250 ppm, except for the unacceptably polluted drain water in the Bahr Bagar and several other drains. There will be no immediate threat on crop yields with this reuse target.

The reuse pumping potential includes 4 bcm of the three planned reuse expansion projects (Salaam canal, Kalapsho, and Umoum) and 1.3 bcm of the extra reuse pumping in the Edko drain in the West Delta and in the Nashart drain in the Middle Delta.

Efforts to recapture drain water with salinity levels higher than 2,250 ppm will not be efficient and meaningful, since the incremental capture after that salinity level will be limited to 0.2-0.3 bcm. The only way to obtain reuse beyond the 9.6 bcm reuse potential is to remove the M&I pollution and make the water available in the Bahr Bagar and several other polluted drains reusable.

2. *Minimum drainage outflow should be maintained to sustain freshwater fisheries and environment in the northern lakes.*

The freshwater fisheries in the northern lakes depend on the entrance of the drainage outflows of the Delta for nutrient supply and lake water flushing. The use of the drainage outflow in fish production is a beneficial water use, as valuable as land-based agricultural crop irrigation. The economic value of the fish production in the northern Delta needs to be recognized.

Given the freshwater lake-fish-production objective, the minimum required drainage outflow from the Delta would be 8.5 bcm per year. This allows a reduction of about 4 bcm from the current drainage outflow of 12.5 bcm by exporting 2 bcm to Sinai and reusing 50% more of the Edko drain flow.

Pollution Control in the Drain System

Recommended Policy Actions

1. *Support the existing policies of constructing urban wastewater treatment plants and strengthening enforcement of Law 48 and other related environmental protection laws and regulations.*

Under this general and long-term policy, two specific policy actions are needed:

- Develop a closer cooperation with the Environmental Protection Ministry on drainage water quality management by creating a clearer division of each Ministry's administration responsibility and authority.
 - Strengthen the administrative responsibility and authority of the Egyptian Public Authority for Drainage Projects (EPADP) in drain water quality management.
2. *Promote public awareness of the M&I wastewater pollution in agricultural drains and its effect on the sustainability of agricultural production and the living environment for the Egyptian people.*

The awareness promotion should also be extended to the high-level officials so that an adequately firm political will can be created to accelerate the steps in pollution control and environmental protection.

Under this policy, the Ministry will need to use every possible communication channel at the national level to disseminate relevant information and educate the mass media on the environmental status of the drain system and the losses of the valuable water resources caused by M&I wastewater discharge. The following contents of information would be useful in environmental education:

- Importance of drain water reuse in agricultural production in the Delta.
 - M&I wastewater and the associated pollutants discharged into agricultural drains. General and typical drain water quality status in the Delta.
 - Water consumed by M&I pollution.
 - Law 48 and treatment, separation and diversion of M&I wastewater.
3. *Declare a clear and firm policy against the disposal of large cities' untreated M&I wastes in agricultural drains.*

The misunderstanding of treating agricultural drains as a destination for human wastes must be removed, both from the mass public and the GOE sectors.

Agricultural drain water is reused as part of the irrigation supply in the Delta, and in principle, M&I wastewater disposal in agricultural drains should simply be prohibited. Considering the fact that the land space is limited in the Delta and it is almost impossible for every M&I wastewater source to find different means of disposal than agricultural drains, a realistic policy for the Ministry is to target at rejecting (or at least decreasing) the untreated wastewater discharges from large cities, which account for 70% of the region's total wastewater load. The Ministry will need the approval and support from higher GOE level for this policy implementation.

4. *Promote the policy of "polluter pays".*
5. *Promote a policy to keep poor water away from good quality water and get good quality water out of poor quality water.*

This is a policy aiming at the separation of M&I wastewater from agricultural drains, as an immediate effort to accompany the general, long-term treatment policy in combating the increasing pollution problems. Under this policy, the Ministry may need testing the feasibility and effectiveness of the following separation measures:

Intermediate Drainage Reuse Assign one or two intermediate reuse pilot projects to evaluate the effectiveness and impact of this reuse approach.

Specified Drains as Sewers Test one or two agricultural drains as permissible wastewater carriers in exchange for the agreement and support from other water user sectors on reduced M&I discharge in other drains.

The huge volume of M&I wastewater in the Delta must be disposed of somewhere, and it is impractical to prohibit wastewater discharges in every drain. This action may require some cities to construct wastewater transmission pipelines to reach the appointed sewers. The feasibility of this separation measure needs to be verified in detailed studies.

Industrial Wastewater Discharge Permit System The EPADP is currently responsible for issuing industrial wastewater discharge permits on drains. The activity needs to be enhanced on more consistent regulation bases through a closer corporation with the Environmental Protection Ministry and other relevant GOE agencies. It should be a parallel action with the on-going effort to control industrial wastewater discharge in the Nile river and irrigation canals.

By-pass Wastewater Explore the feasibility of transporting untreated or partially treated wastewater from selected cities to the Mediterranean Sea or some desert sites in the west and east of the Delta. There is a trade-off between the long-term environmental concerns and the immediate threat on the Delta residents. Sacrificing limited desert areas for wastewater dumping in exchange for sustaining agricultural production and human health on the Delta plain may not be an unrealistic choice for Egypt.

Low-cost Rural Wastewater Treatment Facility Development Encourage private investors to develop low-cost rural domestic wastewater treatment facilities. This will reduce the organic pollutant discharge in agricultural drains and contribute to the improvement of the drain system's sanitary condition, which represents the major reason for the closure of mixing pumping stations.

Drain Flushing Explore the feasibility of resuming a longer winter closure period in the Delta region so that the drain channels could receive stronger flushing flow at the end of the closure and obtain longer sunlight exposure for removing contamination.

Unofficial Reuse and Intermediate Reuse

Policy Visions

1. *There is potential for reducing pollution in drains by adopting intermediate reuse. Intermediate reuse will be supplementary to, but not a replacement for, the current main reuse system.*

The technical merits of intermediate reuse in capturing the good quality drain water before it gets mixed with poor quality drain water and replacing unofficial reuse at the canal tail where canal deliveries are in short supply should be recognized.

2. *Drainage reuse should be integrated in irrigation management both on farm level and main system level.*

Official reuse, unofficial reuse, and intermediate reuse all are means of reuse, making the system work at the current efficiency level. One may switch some unofficial reuse to official reuse but cannot eliminate one or the other or treat them as additional resources. To regulate (or administrate) all the unofficial reuse in the Delta would be impractical as well as unnecessary. An appropriate policy for the Ministry would be to start regulating unofficial reuse in selected but not all drain basins.

Recommended Policy Actions

1. *Restrict unofficial drainage pumping in the areas where major reuse projects exist.*

This is to secure the drain water availability for the Salaam canal and Kalapsho projects, which are already in operation. The action should be seen as an effort to reallocate water resources for a broader national development interest.

2. *Conduct a pilot intermediate reuse project in the Bahr Bagar drain.*

Factors Affecting Future Drainage Reuse

Policy Visions

1. *Over the next decades, the reuse of drain water may remain as the first supply augmentation measure with its easy handling and low cost. In the long-run, however, with less drain water volume and increasing salinity concentration, the potential for expanding reuse, or even continuing the current reuse level, will be limited.*

The drainage generation and reuse pattern will be altered in the future decades in the Delta by the extension of irrigation improvement projects, new irrigation technologies, and new water management policies such as the reduction of rice irrigation. The Toshka national water project will reduce freshwater supply by taking Nile water away from the Valley and the Delta and requiring reduced per-feddan irrigation supply. The general trend is a reduction of drainage volumes in both outflow and reuse, and an increase of drain water salinity.

2. *While short-term policies for promoting drainage reuse are absolutely necessary to combat the present irrigation demands, the long-term perspective of reduced drain water and the consequent policy changes should also be emphasized.*

A different viewpoint from the current concept of drain water management is to spend effort in reducing drainage generation rather than in reusing drain water. Each cubic meter of drainage water “consumes” more than one cubic meter of freshwater in the “production process”, and efforts to reduce drainage volume by improving irrigation management will increase the volume of available freshwater.

Future financial investment and technical/administrative efforts on drainage reuse should be cautiously reviewed so that the invested efforts in reuse will be synchronized with the changing pattern of drainage generation.

Institutional Aspects in Drainage Management

Policy Visions

1. *Promote cost recovery of drainage maintenance and operation and encourage the participation of stake-holders in drainage management.*

At present, drainage services are provided at no charge to farmers. As a result, farmers receive the benefits of drainage service without paying for the operation and maintenance

costs of the national drainage system. Similarly, municipalities and industries have little incentive to limit their discharges of wastewater, when the incremental cost of abatement exceeds the low price (or zero price) for discharging effluent into agricultural drainage system. This situation needs to be changed to transfer the direct cost of operating and maintaining the national agricultural drainage system from the MPWWR to the farmers who receive the benefits of drainage services.

2. *Encourage the involvement of private sector in drainage services.*

This should be the general direction for future drainage management. For implementation, studies and pilot privatization projects will be needed.

1 INTRODUCTION

1.1 Overview

Egypt's Nile River water resource is under increasing stress due to increasing competition for available water. Irrigation needs are expanding, as are domestic and industrial water needs due to population and industrial growth. An increasing load of pollutants is threatening Egypt's water quality, environment and the health of its citizens. The Ministry of Public Works and Water Resources (MPWWR) is the primary Egyptian governmental agency charged with the management of water resources. Keenly aware of the need to improve the utilization efficiency, productivity, and protection of water resources in Egypt, the MPWWR and the US Agency for International Development (USAID) in 1996-97 developed a "water resources results package" based upon years of earlier joint experience in water resources management projects.

The package had four major results: 1) improved irrigation policy assessment and planning process, 2) improved irrigation system management, 3) improved private sector participation in policy change, and 4) improved capacity to manage the policy process. The MPWWR and USAID designed the water resources results package aimed at policy analyses and adjustments leading to improved water use efficiency and productivity. Specific objectives are:

1. To increase MPWWR knowledge and capabilities to analyze and formulate strategies, policies and plans related to integrated water supply augmentation, conservation and utilization, and to the protection of the Nile water quality.
2. To improve water allocation and distribution management policies for conservation of water while maintaining farm income.
3. To recover the capital cost of mesqqa improvement, and to establish a policy for the recovery of operation and maintenance costs of the main system.
4. To increase users' involvement in system operation and management.
5. To introduce a decentralized planning and decision making process at the irrigation district level.

In early 1997, the water resources results package was folded into the USAID Mission's Agricultural Policy Reform Program (APRP). APRP is a broad-based policy reform program involving five Egyptian Ministries (Ministry of Agriculture and Land Reclamation (MALR), MPWWR, Ministry of Trade and Supply (MOTS), Ministry of Public Enterprise (MPE) and Ministry of International Cooperation). APRP has the goal of developing and implementing policy reform recommendations in support of private enterprise in agriculture and agribusiness.

USAID supports the MPWWR in five program activities under APRP. These five activities are: 1) water policy analyses, 2) water policy advisory unit, 3) water education and communication, 4) main systems management, and 5) Nile River monitoring, forecasting and simulation. USAID supports the Ministry's efforts through cash transfers (tranches) based on performance in achieving identified and agreed upon policy reform benchmarks and technical assistance.

Technical assistance for the water policy analysis activity is provided through a task order (Contract PCE-I-00-96-00002-00, Task Order 807) under the umbrella of the Environmental Policy and Institutional Strengthening Indefinite Quantity Contract (EPIQ) between USAID and a consortium headed by the International Resources Group (IRG) and Winrock International. Local technical assistance and administrative support is provided through a subcontract with Nile Consultants.

1.2 Purpose of the Report

One of the benchmark activities for APRP Tranche II (1/7/1997 – 30/6/1998) states that the “GOE will develop and approve new policies, regulations and criteria to promote drainage water reuse with appropriate incentives and technical support”. In support of this policy benchmark activity, a task to assess the drainage reuse development in Egypt was included in the EPIQ Water Policy Team project implementation plan.

Agricultural drain water reuse, as an important source of irrigation supply, is well developed in Egypt, particularly in the Nile Delta region. However, as the demand for reuse keeps on growing, the expansion or even the continuation of drainage reuse has been threatened by the deteriorating drain water quality due to municipal and industrial (M&I) wastewater pollution. The MPWWR faces multidimensional challenges in sustaining the current reuse and promoting more drainage reuse over the next decades. Meanwhile, in the long-run, the active economic reform in Egypt, the improvement of the irrigation system, and the changing water allocations among different regions and different water use sectors will alter the patterns of drainage generation and yield a different perspective in drain water management.

Under an objective to provide the best possible support to the Ministry in formulating new policies, the EPIQ team, under the direction of the Water Policy Advisory Unit (WPAU) and the Policy Advisory Group (PAG), has evaluated the short-term and long-term challenges in drainage management, and focused on a group of strategic drainage reuse topics listed below for new policy generation:

- What is the maximum drainage reuse potential and what are the minimum outflow requirements from the Delta to sustain the agricultural and fish production in the region?
- What are the current and long-term wastewater volumes and pollution loads in the Delta region, and what are the corresponding remedy policies?
- What is the fundamental evaluation of the drain water quality in the Delta, and what are the policies for effective water quality control?
- What are relationships between official reuse, unofficial reuse and intermediate reuse, and what are the policy implications?
- What would be the impact of extended irrigation improvement projects (IIP), application of new irrigation methods, reduction of rice areas, and Toshka project development on the drainage generation in the Delta, and what are the policy implications?
- What are the applicable institutional changes in drain water management?

This report summarizes EPIQ team’s technical analyses on these strategic issues, and the proposed policy recommendations based on these analyses. Limited by the execution time of the benchmark, the report concentrates on the Nile Delta region, the core part of Egypt’s agricultural drainage reuse development.

1.3 Organization of the Report

The following section in this chapter briefly describes the current status of the Delta region's drainage generation and reuse, from which, the needs for policy development in drain water management will be better understood.

The next five chapters of the report are organized in accordance with the above selected strategic issues. Each chapter starts with extensive and detailed technical analysis of the topic, and then presents policy recommendations resulting from the analysis. Each policy recommendation is intended to have its technical background in the analysis part of the chapter. Policy recommendations from chapters are also summarized in the Executive Summary at the beginning of the report.

The last chapter, Closing Remarks, introduces a long-term vision of the drainage water management in Egypt. The vision arises from a different approach to drainage management, and may represent a useful reference for long-term decision-making in Egypt's water development.

1.4 Drainage Water in the Nile Delta

The Trend of the Drainage Water Reuse

Since the large-scale installation of field sub-surface tile drainage was started in the late 1960s, a well-designed and well-constructed agricultural drainage system has been operating in the Delta (Abu Zeid, M. and S. Abdel-Dayem, 1991). Numbers of main drains and branch or lower-order drains collect and transport drainage flows from the south to the north on the Delta plain. More than forty lifting pump stations and twenty-two main reuse mixing stations are in operation in the 22 drain catchments of the Delta region. Each year, the drain network removes more than 30 million tons of salts from the Nile irrigation system. An annual amount of 4 bcm of drain water reuse is made available through the MPWWR's official drainage reuse program.

There is also an established monitoring network, providing daily measurements of drainage flow and bi-weekly salinity and other chemical components at 90 locations in the drainage system. Since the mid 1980s, the accuracy of field measurements and laboratory work have steadily improved, and monitoring results have been routinely published in annual data books. Recently, the monitoring program was extended to measure more water quality parameters at environmental quality sensitive locations.

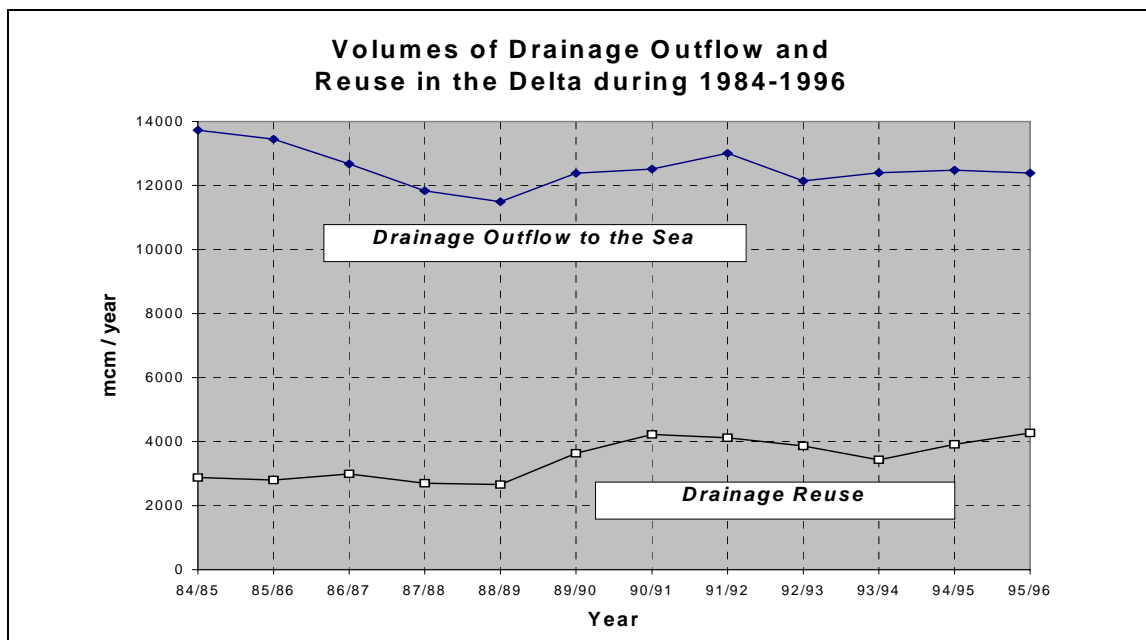
The magnitude of the Delta region's drainage system operation can be indicated by the volumes of the organized drain water reuse (official reuse) and the outflow drain water from the system. Tables 1-4-1 and 1-4-2 below give the annual drainage outflows to the Mediterranean Sea, the reused drain waters, and the corresponding salinity levels during the 12 year period of 1984-1996 (Drainage Task Force Committee, 1997). Figure 1-4-1 shows the volumes of the annual drain water reuse and outflow.

Table 1-4-1, Annual Drainage Reuse in the Delta during 1984-1996

Years	East		Middle		West		Whole Delta	
	Quantity (mcm)	Salinity (mmhos)	Quantity (mcm)	Salinity (mmhos)	Quantity (mcm)	Salinity (mmhos)	Quantity (mcm)	Salinity (mmhos)
1984/85	1301	1.28	763	1.29	814	1.53	2878	1.35
1985/86	1263	1.30	748	1.21	788	1.51	2799	1.34
1986/87	1420	1.34	766	1.24	807	1.53	2993	1.37
1987/88	1381	1.44	693	1.41	629	1.90	2703	1.54
1988/89	1400	1.53	704	1.46	555	1.62	2659	1.53
1989/90	1504	1.57	1506	2.24	626	1.49	3635	1.83
1990/91	1585	1.59	1999	1.70	639	1.57	4223	1.64
1991/92	1445	1.46	2058	1.8	617	1.46	4120	1.63
1992/93	1460	1.41	1841	1.69	561	1.28	3862	1.52
1993/94	1120	1.58	1691	1.76	619	1.12	3430	1.59
1994/95	1390	1.64	1843	1.86	685	1.24	3917	1.67
1995/96	1746	1.89	1815	1.79	706	1.20	4266	1.73
Avg 84/90	1378	1.41	863	1.48	703	1.60	2944	1.47
Avg 90/96	1458	1.60	1874	1.77	638	1.31	3970	1.63

Source: MPWWR Drainage Task Force Committee, 1997

Figure 1-4-1, Volumes of Drainage Outflow and Reuse in the Delta during 1984-1996



The average annual drainage reuse amount has increased from 3 bcm of 1984-1990 to 4 bcm of 1991-1996. The official reuse levels in the East and West Delta regions have almost remained constant in the past decade. It took about a decade to obtain 1 bcm reuse expansion in the Delta, mainly from the increased reuse in the Middle Delta region in the 1990s.

The volumes of drainage outflows from the Delta have remained nearly unchanged, 12.5 bcm each year, in the past 12 years. In comparison of the first and the second 6-year periods, the

decreased outflow from the Middle Delta can be explained by its increased reuse in the 1990s.

The volumes of reuse and outflow, as seen in Figure 1-4-1, were both relatively lower in the late 1980s due to the drought in the Nile River basin for that period. The sudden reuse reduction of 0.5 bcm in 1993-94 was due to the shut-down of several reuse mixing stations due to unacceptable drain water quality conditions. Some of those stations are still closed, resulting in the stagnant overall reuse level in the Delta.

Table 1-4-2, Annual Drainage Outflow to the Sea during 1984-1996

Years	East		Middle		West		Whole Delta	
	Quantity (mcm)	Salinity (mmhos)	Quantity (mcm)	Salinity (mmhos)	Quantity (mcm)	Salinity (mmhos)	Quantity (mcm)	Salinity (mmhos)
1984/85	4391	2.12	5013	3.35	4321	5.76	13726	3.72
1985/86	4219	2.35	4883	3.71	4339	5.02	13442	3.71
1986/87	3815	2.43	4900	3.72	3955	4.72	12670	3.64
1987/88	3514	2.64	4291	3.96	4030	5.65	11835	4.14
1988/89	3181	2.76	4142	3.88	4168	6.00	11491	4.34
1989/90	3651	2.85	4159	3.99	4573	5.75	12383	4.30
1990/91	3726	2.72	3674	4.06	5116	6.24	12515	4.55
1991/92	3795	2.40	4092	4.22	5118	5.46	13005	4.18
1992/93	4094	2.45	3740	4.09	4312	5.97	12146	4.20
1993/94	4219	2.71	3569	4.32	4613	5.50	12400	4.21
1994/95	4256	2.98	3966	4.18	4252	5.68	12474	4.28
1995/96	3790	3.20	4127	4.16	4469	5.67	12386	4.41
Avg 84/90	3795	2.53	4565	3.77	4231	5.48	12591	3.97
Avg 90/96	3980	2.74	3861	4.17	4646	5.75	12488	4.30

Source: MPWWR Drainage Task Force Committee, 1997.

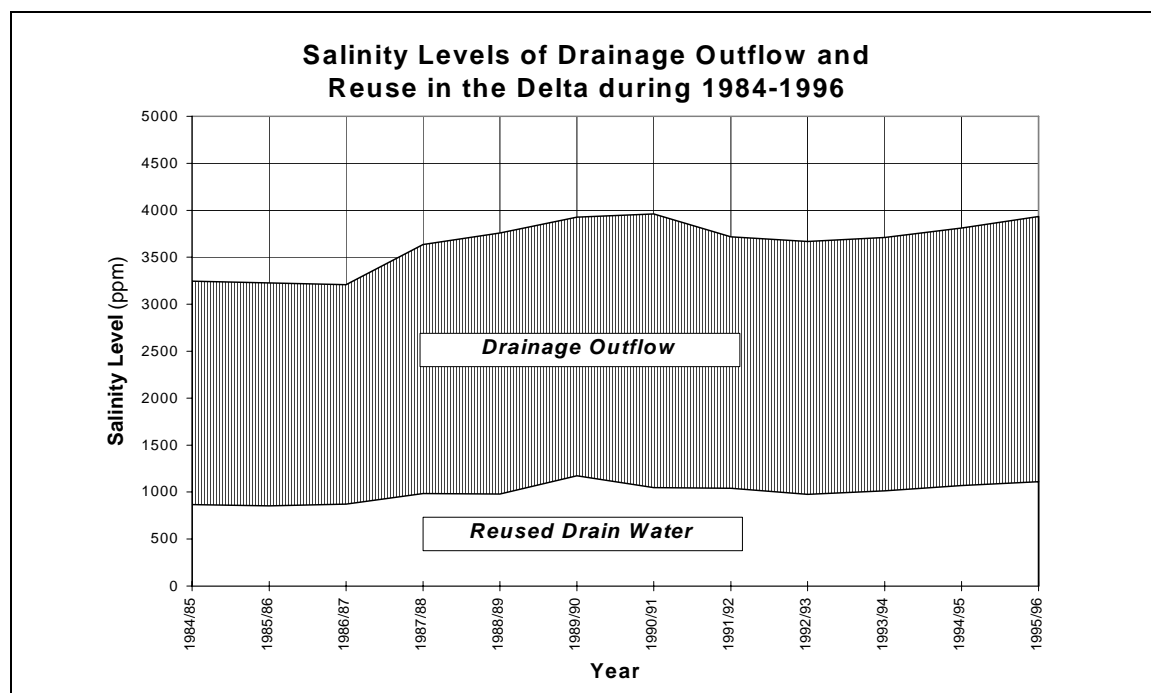
Figure 1-4-2 below shows the salinity levels in drainage outflow and reused drain water. Both lines demonstrate an upward trend. The outflow salinity has risen at a faster pace from 2,378 ppm in 1984 to 2,823 ppm in 1996 (or 3.72 mmhos/cm to 4.41 mmhos/cm as in Table 1-4-2), while the salinity level in reused drain water has increased from 866 ppm in 1984 to 1,109 ppm in 1996 (or 1.35 mmhos/cm to 1.73 mmhos/cm as in Table 1-4-1).

The increase of outflow salinity level in the past decade is a consequence of the expanded reuse, while the relatively low salinity in reused drain water indicates good potential for further intensifying the use of drain water in the Delta.

As shown in Table 1-4-2, the average salinity level in drainage outflows from the East Delta was only 2.53 mmhos/cm (1,619 ppm) and 2.74 mmhos/cm (1,754 ppm) in the two 6-year periods respectively, much lower than those in the other two Delta regions, 3.77-4.17 mmhos/cm in the Middle Delta and 5.48-5.75 mmhos/cm in the West Delta.

The significant differences are most likely caused by the saline groundwater upward flux in the northern part of the Middle Delta and the salts washed from the elevated Nubaria newlands in the West Delta. From the salt concentration viewpoint, the East Delta has larger potential than the other two regions for future reuse development.

Figure 1-4-2, Salinity Levels of Drainage Outflow and Reuse in the Delta during 1984-1996



The Government of Egypt (GOE) has used drain water as a main supply source for horizontal land expansion (Drainage Task Force Committee, 1997). Three major drainage reuse expansion projects have been planned since the late 1980s, and they are:

- *Salaam Canal Project* - to divert 2 bcm drain water of the Bahr Hadus and Lower Serw drain basins for 185,000 feddans irrigation in west Suez and 400,000 feddans reclamation in Sinai,
- *Umoum Drainage Project* - to reuse 1 bcm drain water of the Umoum drain basin for 500,000 feddans irrigation in Nubaria, and
- *Kalapsho Project* - to capture 1 bcm drain water of the Drain No1 and Drain No2 for 55,000 feddans new lands in Kalapsho.

This is, in total, a 4 bcm reuse expansion plan. Whether this will be achievable depends on the success of control measures to eliminate M&I wastewater pollution in agricultural drains, unofficial reuse management, intermediate reuse development, irrigation improvement project (IIP) extension, and several other factors which affect the generation of drain water in the Delta, as will be discussed more in later chapters.

Drainage Reuse in Egypt's Water Resources Management

Egypt almost entirely depends on the fixed 55.5 bcm of the Nile water released from the High Aswan Dam (HAD). Over the past two decades, the Ministry's basic policy has been to allow demands to increase on a more or less laissez-fair basis, resulting in a dramatic increase in both the intensity of irrigation and the extent of the irrigated areas. However, with the nation's growing population, industrialisation and urbanisation, this policy is no longer

sufficient, and conservation of water, mainly by recycling agricultural drain water, has become the core of Egypt's water management.

Egypt's water conservation has progressed in several stages. In the late 1980s, during the Nile drought period, the Ministry started giving HAD release allocation priority to the irrigation and M&I demands over the hydropower generation demand, which effectively reduced the effect of drought on agricultural production. Later in 1995-96, the Ministry implemented a policy for shorter winter closure period through staggering closure by regions. That has resulted in 2 bcm of Nile water savings each year.

The Ministry has intensified drainage reuse since the 1990s. As mentioned above, the drainage reuse was raised by 1 bcm in the Delta during 1991-96, and the Ministry plans to expand the reuse by another 4 bcm over the next decades.

Since the mid 1990s, however, many reuse mixing pump stations in the Delta have been under an increasing pressure of water quality deterioration by M&I pollution discharge, and some of them, were forced to stop operation. The drainage reuse in the Delta is entering a dilemma: on one hand, the expanding irrigation keeps on pressing for more drain water reuse, especially, after the Salaam canal operation; on the other hand, the official reuse system in the Delta seems to be stagnant and difficult to expand. Farmer implemented "unofficial" drainage reuse has been increasing in many drain basins. "Illegal" rice cultivation has been twice the officially sanctioned rice cultivation area, particularly due to this unofficial drainage reuse.

Agricultural drainage water is an economical supply source in irrigation. It has been and will continue to be a significant portion of the irrigation supply in the Delta region. The Ministry needs policy adjustments in the new stage of drainage water management.

2 MAXIMUM DRAINAGE REUSE POTENTIAL AND MINIMUM DRAINAGE OUTFLOW

Egypt is limited to 55.5 bcm of Nile freshwater. There is obviously a limit on the amount of drain water available for reuse. A central issue in Egypt's water resources management is how much more of the drain water currently being discharged to the Mediterranean Sea can be conserved by increasing reuse. This chapter addresses this issue by establishing a better understanding of the maximum reuse potential based on drain water salinity and the minimum drainage outflow requirements for the maintenance of freshwater fish production in the northern lakes.

2.1 Maximum Drainage Reuse Potential

Reuse Potential under Different Target Reuse Salinities

Key questions in this analysis are how much more drain water can be captured, and from what locations.

According to the 1993-94 drainage monitoring data (Drainage Research Institute, 1995), the average salinity of the reused drain water in the Delta region was 1,076 ppm. For more reuse, drain water pumping will need to be extended to drains containing higher salinity concentrations. Salinity levels of 1,500-3,000 ppm were used as reuse targets in our analysis to check the possible additional reuse pumping at each monitoring location. If one particular location's salinity measurement in 1993-94 was lower than a target salinity level, then the drainage outflow from the location (defined as the "to sea" outflow in the Drainage Research Institute's data book) is assumed to be recaptured in full and represent that location's reuse pumping potential under that reuse target. In our analysis, locations on every main drain in each Delta region were surveyed. Table 2-1-1 in the following page summarizes the results of this survey.

In Table 2-1-1, the first column categorizes the main drain basins in each of the three Delta regions. The second to fourth columns show the drainage flow rates to the sea, the salt loads transported by the outflows, and the reuse pumping volumes in each main drain basin during the period 1993-94. The next six columns illustrate the volumes of potential reuse pumping in each main drain basin using target reuse salinity levels of 1,500-3,000 ppm. The last column, indicated by row numbers, summarizes the results.

As an example, the Edko Drain in the West Delta provides a reuse pumping of 1,545 mcm if all the "to Sea" drain flows below 1,500 ppm in the basin are captured. This represents an additional reuse pumping of 1,038 mcm, compared to the reuse of 507 mcm in 1993-94 in the basin. As indicated in Row 1, under the 1,500 ppm reuse target, the entire West Delta could have an added reuse pumping of 1,855 mcm, compared with its 1993-94 reuse level.

Table 2-1-1, Summary Reuse Potential in the Delta

	1993/94 Annual Average			Reuse Pump at Higher Salinity Concentrations						
	To Sea Discharge (mcm)	To Sea Salt Load (10 ³ t)	Reuse Pump (mcm)	1500 ppm Reuse Pump (mcm)	2000 ppm Reuse Pump (mcm)	2250 ppm Reuse Pump (mcm)	2500 ppm Reuse Pump (mcm)	2750 ppm Reuse Pump (mcm)	3000 ppm Reuse Pump (mcm)	
West Delta										
Edko	1019	1285	507	1545	1545	1545	1712	1712	1712	
Alex Vicinity	1268	2459	54	870	870	870	870	870	1322	
Umoum	2326	12409	58	58	1218	1218	1218	1218	1218	
sum	4613	16154	619	2474	3633	3633	3800	3800	4252	
			added reuse pumping	1855	3014	3014	3182	3182	3633	Row 1
Middle Delta										
Drain no. 1	1136	2538	21	21	21	1157	1157	1157	1157	
Gharbia Drain	461	1900	1303	1366	1366	1366	1366	1366	1366	
Burullus Vicinity	944	3900	0	0	0	0	0	0	0	
Nashart Drain	497	813	57	289	449	449	449	554	554	
Other Drains	595	746	310	858	858	858	858	858	858	
sum	3632	9898	1691	2534	2694	3829	3829	3934	3934	
			added reuse pumping	842	1002	2138	2138	2243	2243	Row 2
East Delta										
Bahr Bagar	1157	1824	296	1265	1265	1265	1265	1265	1265	
Bahr Hadus	1578	3073	510	510	1806	1806	2088	2088	2088	
El Serw & Others	1484	2609	314	1277	1277	1277	1277	1798	1798	
To Red Sea & Suez										
sum	4219	7506	1120	3052	4348	4348	4630	5152	5152	
			added reuse pumping	1932	3228	3228	3510	4032	4032	Row 3
Whole Delta	12463	33558	3430	8059	10675	11810	12260	12886	13338	Row 4
		Reuse salinity	1076	1101	1265	1358	1384	1455	1505	Row 5
		Leaching fraction	0.13	0.13	0.15	0.16	0.17	0.18	0.19	Row 6
		Effective reuse	2997	7015	9055	9864	10195	10583	10858	Row 7
		Added reuse pumping		4629	7245	8380	8829	9456	9907	Row 8
		Added effective reuse		4018	6058	6867	7198	7586	7861	Row 9

Note: Leaching fractions (Row 6) are calculated based on the formula of $E_w / (5 \cdot EC_e - EC_w)$ as explained in the text

Row 4 in Table 2-1-1 summarizes the Delta region's reuse pumping potential under different reuse salinity targets. The reuse pumping potential starts at 8.1 bcm under the 1,500 ppm target, continues increasing with higher reuse targets, and reaches 13.3 bcm under the 3,000 ppm target. The 13.3 bcm reuse pumping level is near to the sum of the 1993-94 drainage outflow (12.5 bcm) and reuse (3.4 bcm). It is obvious that this would not be possible in implementation.

Leaching Requirements

Due to salt leaching requirements, the effective value of one cubic meter of drain water reuse pumping is, in fact, less than one cubic meter, and depends upon the salinity level of the reused drainage water.

For sandy loam to clay loam soils in low rainfall climate, leaching fraction (in unit of %) in surface irrigation can be calculated as $EC_w / (5 * EC_e - EC_w)$, where EC_w is the electrical conductivity of the irrigation water (mmhos/cm) and EC_e is the electrical conductivity of the soil saturation extract (mmhos/cm), for a given crop under a specific tolerance degree of yield reduction (Ayer, R. S. and D. W. Westcot, 1976). The Nile water exhibits an average electrical conductivity of 1.0 mmhos per 640 ppm, and a degree of 10% or less tolerable crop yield reduction was selected in leaching fraction calculations in Table-2-1-1.

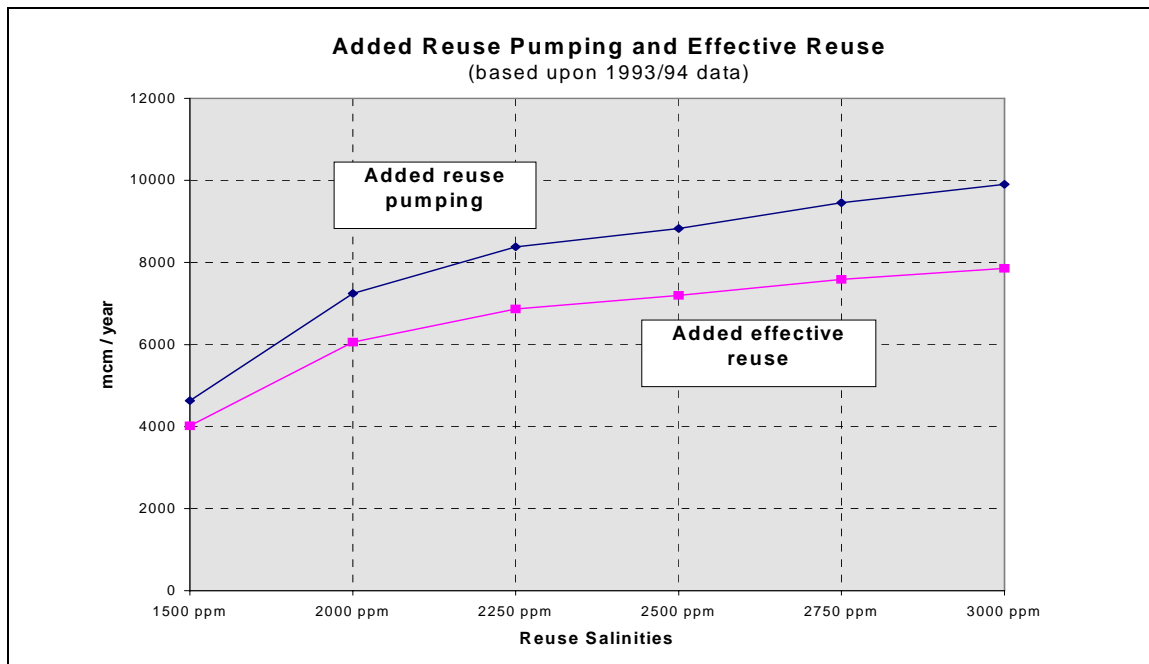
In 1993-94, the reuse pumping was recorded as 3.4 bcm, while the effective reuse value of the pumping was 3.0 bcm, due to the 13% leaching fraction from the average reuse salinity of 1,076 ppm. Leaching fractions and corresponding effective reuse values under different reuse targets are given in Row 6 and Row 7, respectively. Row 8 and Row 9 include the added reuse pumping and the added effective reuse under different targets over the 1993-94 reuse level. It is seen that under reuse targets of 1,500-3,000 ppm, the added reuse pumping will be 4.6-9.9 bcm, while the added effective reuse will be 4.0-7.7 bcm.

Figure 2-1-1 below depicts the increasing leaching requirements with the increase of reuse salinity levels. Leaching requirements increase from 0.6 bcm to 2.0 bcm with the expansion of drainage reuse from 1,500 ppm to 3,000 ppm. The higher the reuse target is, the higher will be the leaching requirements. Irrespective of how the reuse is practiced, i.e., mixed with freshwater or used directly, the effective value of the reuse will always be discounted by the leaching fraction.

Reuse Expansion Options

The reuse potential presented in Table 2-1-1 was estimated by only observing drainage salinity as the constraint. As discussed in Chapter III in this report, the deteriorating drain water quality due to M&I wastewater pollution is a more severe limiting factor than the salinity in drainage reuse. Since the 1980s, drainage reuse in the Delta has been relatively constant at a level of 4.2 bcm. In 1993-94, this was reduced by 0.7 bcm because of the suspended operation of several reuse mixing stations due to pollution. Table 2-1-1 suggests a promising potential but not an implementation rate of the reuse expansion.

Figure 2-1-1, Added Reuse Pumping and Effective Reuse



Two factors are emphasized below in proposing implementation of drainage reuse expansion:

- Drain water quality will not likely be improved in the near future. The potential additional reuse pumping estimated in Table 2-1-1 for many drain basins, such as the Alexandria vicinity, Umoum, Burullus vicinity, and Bahr Bagar, will not be possible for implementation until the pollution and water quality barricades are removed from those drain basins. A significant portion of the estimated reuse potential is likely to remain untapped as a result.
- The GOE has long planned expansion of drainage reuse in the Delta through construction of three main reuse projects: Salaam canal diversion, Kalapsho reclamation, and Umoum drainage reuse project. Reuse expansion efforts should be targeted at the point of the completion and effective operation of these projects.

Table 2-1-2 below presents three implementation options for the drainage reuse expansion in the Delta region.

- **Option I** Capture the drainage water with salinity below 1,500 ppm in Edko, Nashart, and El Serw drains, maintaining the 1993-94 reuse level in other drain basins (as illustrated in those shaded cells in Table 2-1-2). This will produce an additional reuse pumping of 1.0 bcm in the West Delta, 0.8 bcm in the Middle Delta, 1.0 bcm in the East Delta, totaling 2.8 bcm in the entire Delta. The total added effective reuse will be 2.4 bcm. The added 1.0 bcm of reuse in the East Delta could be used to serve 50% of the drainage diversion demand in the Salaam canal.
- **Option II** Capture the drainage water with salinity below 2,000 ppm in Edko, Umoum, Nashart, El Serw, and Bahr Hadus drains, and keep the 1993-94 reuse level in other drain basins. This option will bring in an additional 5.1 bcm reuse pumping (or 4.2 bcm of

effective reuse), as compared with the 1993-94 reuse level. The reuse expansion will require the full operation of the Umoum reuse project (about 1 bcm) in the West Delta, as well as the elimination of the current illegal rice irrigation in the Bahr Hadus basin (in the Sharhkia Governorate).

- **Option III** Capture the drainage water with salinity below 2,250 ppm in Edko, Umoum, Drain No. 1, Nashart, El Serw, and Bahr Hadus drains, and keep the 1993-94 reuse level constant in other drain basins. Compared with Option II, this option captures 1.1 bcm more from Drain No. 1, which allows the full operation of the Kalapsho reclamation project. The option will bring in an additional 6.2 bcm reuse pumping (or 5.0 bcm of effective reuse).

Table 2-1-2, Suggested Reuse Options in the Delta

	1993/94 Annual Average			Reuse Pump at Higher Salinities			
	To Sea Discharge (mcm)	To Sea Salt Load (10 ³ t)	Reuse Pump (mcm)	1500 ppm Reuse Pump (mcm)	2000 ppm Reuse Pump (mcm)	2250 ppm Reuse Pump (mcm)	
West Delta							
Edko	1019	1285	507	1545	1545	1545	
Alex Vicinity	1268	2459	54				
Umoum	2326	12409	58		1218	1218	
sum	4613	16154	619	1657	2817	2817	
		added reuse pumping		1039	2198	2198	Row 1
Middle Delta							
Drain no. 1	1136	2538	21			1157	
Gharbia Drain	461	1900	1303				
Burullus Vicinity	944	3900	0				
Nashart Drain	497	813	57	289	449	449	
Other Drains	595	746	310	858	858	858	
sum	3632	9898	1691	2471	2631	3766	
		added reuse pumping		779	939	2075	Row 2
East Delta							
Bahr Bager	1157	1824	296				
Bahr Hadus	1578	3073	510		1806	1806	
El Sewr & Others	1484	2609	314	1277	1277	1277	
To Red Sea & Suez							
sum	4219	7506	1120	2082	3083	3083	
		added reuse pumping		962	1963	1963	Row 3
Whole Delta	12463	33558	3430	6210	8530	9666	Row 4
		Reuse salinity	1076	1101	1265	1358	Row 5
		Leaching fraction	0.13	0.13	0.15	0.16	Row 6
		Effective reuse	2997	5406	7236	8073	Row 7
		Added reuse pumping		2780	5100	6236	Row 8
		Added effective reuse		2409	4239	5076	Row 9
		Reuse Expansion Options		I	II	III	

Note: shaded cells are assumed to have the same reuse volumes as 1993/94.

Summary Notes

- These options are categorized solely on the basis of the different target reuse salinity levels. In terms of practical application, they are inter-exchangeable, i.e., there is no time sequence for implementing them.

- The analysis results are consistent with the estimates of the Ministry (Drainage Task Force Committee, 1997), which does not include the smaller amount of reuse pumping potential in the Edko, Nashart, and several other small drains, and simplifies the potential statement as 1 bcm in the Umoum drain, 1 bcm in the Kalapsho reclamation (through the Drain No. 1), 2 bcm in the Salaam canal (through the Bahr Hadus and El Serw drains), and totaling 4 bcm in the Delta.
- If the reuse availability of the drain flows in Bahr Bagar and several other polluted drains is not diminished, the incremental reuse pumping after the 2,250 ppm reuse salinity target will be limited to 0.2-0.3 bcm. Therefore, it would not be meaningful to push for drainage reuse beyond the that salinity level, and the 9.6 bcm reuse pumping at the 2,250 ppm level defined in Option III can be considered as a practically achievable maximum reuse expansion in the Delta region.
- Since the prevailing reuse method in the Delta is to mix drainage with freshwater, there would not be an immediate threat to crop yields with the 2,250 ppm reuse expansion target.
- It should be noted that the above analysis is based upon a single assumption that the Nile inflow to the Delta would remain relatively unchanged from the 1993/94 level. Given the same system operation conditions, the drainage generation depends on the inflow, while the reuse, in consequence, will also be affected by the inflow.
- Furthermore, the drainage outflow under a reuse target will not be a simple subtraction of target reuse from the 1993-94 outflow. System inflow, ET consumption and other evaporative depletion, and system outflow are the three terms in a system's water balance equation. Drainage reuse and other recycling activities enter the water balance through the ET term. Given an inflow, the intensified reuse may increase ET, and the increased ET will result in a reduced outflow. In a large irrigation system like the Nile Delta, the effect of increased reuse on outflow reduction is relatively small and cannot be clearly seen on a large-scale curve. This explains why the reuse has been increased by 1 bcm since the 1990s in the Delta but the drainage outflow remains at 12.5 bcm as shown in Figure 1-4-2.

2.2 Minimum Drainage Outflow Requirements

Drainage outflow is an important component of the Mediterranean estuary ecosystem. After the HAD construction, drain water became the only source of water transporting nutrient and sediment deposits to the northern lakes and sea shores. Four northern lakes, Mariut, Edko, Burullus, and Manzala, are fed by drain water, which maintains their freshwater lake status. The volume and quality of the drain water is the key for preserving and protecting the northern Delta coastal area.

These lakes provide a huge aquatic environment for littoral lake fish production. During 1975-1993, lake fishery was one of Egypt's three main fishery categories (the other two are the marine fishery and Nile water fishery). Lake fisheries produced 52% (100 thousand tons) of the nation's total fish production, and provided an annual gross income of LE 340 million and an employment of 53,000 fishermen (WRSR Publication #20, 1996). The economic and

social value of northern lake fishery production should not be ignored in Egypt's water management.

To preserve sustainable production of safe, edible freshwater fish in the northern lakes requires a sufficient inflow of drain water. Principally, this means the inflows should provide adequate lake flushing and a net lake discharge to the Sea. The salts imported with the water and concentrated by evaporation need to be eliminated so that average lake salinity can be maintained below a maximum threshold.

The majority of drain water in the Delta discharges to the Mediterranean Sea through the northern lakes, while a smaller portion, goes directly to the Sea, as seen in Table 2-2-1.

Table 2-2-1, 1993-94 Drainage Outflows

	1993-94 Drainage Outflows		
	Volume (mcm)	Salinity (ppm)	Salt Load (10 ³ t)
To lakes	9391	2822	26498
to Manzala	4219	1779	7506
to Burullus	1828	2899	5298
to Edko	1019	1261	1285
to Mariout	2326	5335	12409
To Sea	3072	2298	7060
Total	12463	2693	33558

Source: Drainage Research Institute, 1995

Among the four lakes, Lake Mariout suffers from heavy pollution. Surviving fish species are limited in the lake and provide only a non-commercial food source to poor local residents. The lake's ecology may be salvageable, but it requires additional freshwater inflow and pollution reduction, which will be difficult to manage in the near future. As a general consensus, the lake will continue its salinization processes and eventually lose fish production. Therefore, Mariout is excluded in the following analysis.

The main lake parameters of Manzala, Burullus, and Edko are presented in Table 2-2-2. A mass balance was used to estimate the lake's outflow, flushing time and mixed salinity. Vertical water and salt exchanges were neglected by assuming equilibrium in these lakes. Once the lake has a net discharge flow to the sea, the lateral exchange between lake freshwater and sea water was also ignored.

Table 2-2-2, Parameters of Northern Lakes

	Area (ha)	Depth (m)	Volume (mcm)	Evap-Rain (mcm)
Manzala	80514	1.20	966	966
Burullus	48720	1.35	658	585
Edko	8800	1.00	88	106

Source: WRSR Publications #16 and #17, 1996

Table 2-2-3 below estimates the three lakes' status in 1993-94, including net discharges to sea, water flushing times, and average salinity levels. Each lake had a positive net discharge

to the sea. Burullus had the highest average lake salinity of 3,500 ppm and the longest water detention time (193 days in the year), which indicates a needs for additional inflow for flushing. Therefore, the potential for reducing drainage inflows should only be investigated for the Manzala lake and the Edko lake.

Table 2-2-3, Lake Status in 1993-94

	1993-94 Lake Status			
	Outflow from lake (mcm)	Flushing times (times/yr.)	Detention Time (days)	Mixed Lake Salinity (ppm)
Manzala	3253	3.4	108	2043
Burullus	1243	1.9	193	3581
Edko	913	10.4	35	1334

Using the Burullus lake as a base, a salinity of 3,500-4,000 ppm was selected as the threshold lake salinity for continued fish production. In other words, reduction of drainage inflows to Manzala and Edko were checked against the base salinity level to assure survival of freshwater fishes after drainage flow reductions. As seen in Table 2-2-4 below, we assumed that 2 bcm of the current drainage flow to Manzala will be cut for the Salaam canal, and that a 50% cut in the drain water to Edko and to the sea will be implemented. The 2 bcm drainage water diversion to the Salaam canal will not affect the salinity level of the drain water going to Manzala. It will remain at the 1993-94 level of 1,779 ppm. However, the salinity of the drain water to Edko will be doubled to 2,293 ppm, with an assumption that the outgoing salt loads remain unchanged.

Table 2-2-4, Drainage Outflow Reduction Scenario

	1993-94 Drainage Outflows		After Reductions	
	Volume (mcm)	Salinity (ppm)	Volume (mcm)	Salinity (ppm)
to Manzala	4219	1779	2219	1779
to Edko	1019	1261	560	2293
to Med. Sea	3072	2298	1536	4597
sum	8310		4315	

As shown in Table 2-2-5 below, the resulting average lake salinity in both lakes will be 3,800 ppm, which is in the range of the threshold salinity. However, the lake flushing time in Manzala drops down from 3.4 times in 1993-94 to 1.3 times per year, which may cause negative effect on fishery yield. For Edko, after the 50% drainage flow reduction, the lake will still be flushed 5.2 times per year.

Table 2-2-5, Lake Status After Drainage Reduction

	<i>with the Drainage Reductions</i>			
	Lake Outflow (mcm)	Flushing times (times/yr.)	Detention Time (days)	Lake Salinity (ppm)
Manzala	1253	1.3	282	3886
Edko	455	5.2	71	3715

Table 2-2-6 below presents the proposed drainage outflow volumes and salinity concentrations, and the consequent average lake salinity levels and flushing times for the northern lakes.

Table 2-2-6, Minimum Drainage Outflows

	<i>Minimum Drain Outflows</i>			<i>Lakes</i>	
	Reduced by	Volume (mcm)	Salinity (ppm)	Salinity (ppm)	Flushing (times/yr.)
<i>to lakes</i>					
Manzala	50%	2219	1779	3886	1.3
Burullus	0%	1828	2899	3581	1.9
Edko	50%	560	2293	3715	5.2
Mariout	0%	2326	5335	-	-
<i>the Sea</i>	50%	1536	4597		
	<i>sum</i>	8469			
<i>Reduced from 1993-94 level by</i>		3994			

Summary Notes

- As shown in Table 2-2-6, to preserve freshwater fisheries in the northern lakes requires a minimum drain water outflow of 8.5 bcm. This allows a reduction of about 4 bcm from the 1993-94 drainage outflow level, mainly to be accomplished by cutting 2 bcm of drainage flow currently going to the Manzala lake (e.g., drainage exporting to Sinai thorough the Salaam canal) and by reducing 50% of the current drain flow to the Edko lake.
- Why freshwater lakes? A fundamental argument is why not let these lakes become seawater lakes, which may provide seawater fish production with higher market values. Before a comprehensive ecological, environmental, and economic study is conducted, there is no convincing answer to this question. Even if the seawater-lake idea is proved to be more preferable, the physical transition will take decades to complete, and the fishermen may not accept the economic losses. There might be a trade-off, but it needs further study.

- Water quality indicators other than salt concentrations should be of concern. The abatement of pollution loading in drainage flows to the lakes should always be enhanced and continued.
- Furthermore, there are unregistered lands in the northern belt areas currently being irrigated by drain water beyond DRI monitoring points. The actual drainage outflow to the Sea would be less than the reported average amount of 12.5 bcm. Therefore, the real reduction of drainage outflow will even be smaller than 4 bcm.

2.3 Recommended Policy Visions and Actions

Egypt has entered a new stage in managing drainage water. Drainage reuse in the Delta is approaching a saturation level, and further expansion of reuse will be possible but only in a limited scope. The fish production in the northern lakes relies on the lakes' freshwater environment maintained by the entrance of drainage flows from the Delta.

Based upon the discussions in the chapter, the following *policy visions* are suggested for the Ministry to plan and implement its effort in drainage reuse and water conservation:

1. *Drainage reuse has been and will continue to be an important water conservation measure in the Delta region. Further expansion of drainage reuse in the Delta will be needed as well as possible over the next decades.*

The practically achievable reuse pumping potential in the Delta will be 9.6 bcm per year, which is 5.3 bcm more than the 1995-96 reuse level of 4.3 bcm. This 5.3 bcm additional reuse pumping potential can be achieved by capturing all the drain water with salinity concentration below 2,250 ppm, except for the unacceptably polluted drain water in the Bahr Bagar and several other drains. There will be no immediate threat on crop yields with this reuse target.

The reuse pumping potential includes 4 bcm of the three planned reuse expansion projects (Salaam canal, Kalapsho, and Umoum) and 1.3 bcm of the extra reuse pumping in the Edko drain in the West Delta and in the Nashart drain in the Middle Delta.

Efforts to recapture drain water with salinity levels higher than 2,250 ppm will not be efficient and meaningful, since the incremental capture after that salinity level will be limited to 0.2-0.3 bcm. The only way to obtain reuse beyond the 9.6 bcm reuse potential is to remove the M&I pollution and make the water available in the Bahr Bagar and several other polluted drains reusable.

2. *Minimum drainage outflow should be maintained to sustain freshwater fisheries and environment in the northern lakes.*

The freshwater fisheries in the northern lakes depend on the entrance of the drainage outflows of the Delta for nutrient supply and lake water flushing. The use of the drainage outflow in fish production is a beneficial water use, as valuable as land-based agricultural crop irrigation. The economic value of the fish production in the northern Delta needs to be recognized.

Given the freshwater lake-fish-production objective, the minimum required drainage outflow from the Delta would be 8.5 bcm per year. This allows an reduction of about 4 bcm from the current drainage outflow by exporting 2 bcm to Sinai and reusing 50% more of the Edko drain flow.

3 POLLUTION CONTROL IN THE DRAIN SYSTEM

With growing population and intensified industrial and agricultural activities, water pollution is spreading in the Delta region. Huge amounts of urban municipal and industrial (M&I) wastewater and rural domestic wastes discharge into agricultural drains without treatment. Because of the limited land source and the lower elevation of the topography of the Delta plain, agricultural drains have become easy dumping sites for all kinds of wastes. After the construction of the High Aswan Dam, the seasonal Nile floods, which used to flush Delta's lowlands periodically, no longer reach the Delta, and the pollutants brought by M&I wastewater are accumulated in the drain system year by year. There is an increasingly serious threat in the region's drainage reuse program.

This chapter discusses the effect of pollution of the M&I wastewater discharges, the resulting water quality status in the Delta region's drains, and the proposed policy actions.

3.1 M&I Wastewater Volume

Current Volume of Wastewater Discharge

The Delta region (including greater Cairo) has an estimated population of 44.6 million, among which 22.9 million (51%) live in cities and towns of different sizes, and 21.7 million (49%), in villages (WRSR Publication #15, 1996). In large cities like Cairo and Alexandria as well as many capital cities of governorates, public sewers and treatment plants are installed or partially installed, but for 90-95% of the small towns and villages, residents have no access to sewer system and treatment facilities (Welsh, J. and H. N. Khalil, 1991). Consequently, it is difficult to precisely estimate the amount of wastewater from those sources. At the present, most industries, except for a few large ones, have not yet installed effective wastewater treatment equipment. Industrial wastewater is often mixed with municipal wastewater in combined sewers, although it is illegal and prohibited by the Egyptian laws (Ramanda F. and S. Ahmed, 1995).

Table 3-1-1 below gives the current population distribution and M&I wastewater discharges in each Governorate in the Delta (WRSR Publications #15 and #17, 1996). Those discharges include most industrial wastewater discharges except a few direct discharges to the northern lakes and to the sea by large industries.

To facilitate discussion, an assumption was made that locations with sewage flows greater than or equal to 50,000 m³ per day be categorized as urban areas. The remaining areas are rural areas. The total sewage volume in the Delta region, either treated or untreated, is about 6.02 mcm/day, or 2.17 bcm /year. Seventy-two percent of which is from larger cities and towns, and 28%, from smaller towns and villages. Wastewater from Greater Cairo (including part of Giza), Alexandria, and Tanta (Gharbia) together account for 3.40 mcm/d, which is more than half of the total sewage volume in the Delta. This fact indicates the importance of controlling sewage flows from large cities.

Table 3-1-1, M&I Discharges in the Delta

	Population			Discharges		
	Total (10 ³ persons)	Urban (10 ³ persons)	Rural (10 ³ persons)	Total (10 ³ m ³ /d)	Urban (> 50*10 ³ m ³ /d)	Rural (< 50*10 ³ m ³ /d)
West Delta	15221	9931	5290	1840	1580	260
Alexandria	3801	3801	0	600	600	0
Beheira	4219	987	3232	250	50	200
Giza & west Cairo	7201	5143	2058	990	930	60
Middle Delta	12342	2339	10003	1214	330	884
Menoufia	2883	579	2304	252	60	192
Gharbia	3736	1226	2510	414	270	144
West Daqahlyia	3338	0	3338	388	0	388
Kafr El-Sheikh	2385	534	1851	160	0	160
East Delta	17056	10643	6413	2962	2440	522
East Cairo	5517	5517	0	1600	1600	0
Qalyoubia	3266	1432	1834	249	165	84
Sharkia	4434	934	3500	350	60	290
East Daqahlyia	1184	1184	0	135	135	0
Damietta	1002	284	718	196	110	86
Port Said	521	521	0	212	190	22
Ismailia	707	346	361	130	90	40
Suez	425	425	0	90	90	0
Sum	44.6	22.9	21.7	6.02	4.35	1.67
			<i>sum (bcm/y)</i>	2.17	1.57	0.60

Sources: WRSR Publications #15 and #17, 1996

Waste management in small towns and villages also represents an increasing pressure as the population grows. Farmers and residents in small towns dispose of wastes in casual ways, such as dumping wastes in leaching pits close to their houses, in nearby drains or even directly to irrigation canals. The urban wastes usually enter the main or larger drains as point pollution sources, while the rural wastes discharge into the smaller drains, spreading contamination over the entire Delta (Kelly, R. A. and J. Welsh, 1992).

Future Volume of Wastewater Generation

With population growth and economic development, the volume of M&I wastewater will continue to grow in the future. The current per capita per day wastewater generation rate is 190 liters in urban, 77 liters in rural, and 135 liters on average in the Delta (Table 3-1-2).

Table 3-1-2, Per Capita Values of Wastewater Flow

	Population		Sewage flow		
	Delta + Cairo (million)		total (mcm/d)		per capita (l/d)
Total	44.619		6.016		135
Urban	22.913	51%	4.350	72%	190
Rural	21.706	49%	1.666	28%	77

Using these per capita wastewater generation figures and assuming a very conservative estimate of 1.5% annual population growth rate (the current population growth rate is about 2.2%), wastewater volumes in the Delta are projected to 7.4, 8.2, and 9.1 mcm per day in year 2007, 2012, and 2017, respectively (Table 3-1-3). In other words, the sewage flow in the Delta will increase by 1.5 times in twenty years.

Table 3-1-3, Projected Wastewater Flow

	Population Delta + Cairo (million)	Sewage flow	
		total (mcm/d)	per capita (l/d)
Current	44.619	6.016	135
Urban	22.913	4.350	190
Rural	21.706	1.666	77
Year 2002	49.407	6.662	
Urban	25.372	4.817	
Rural	24.035	1.845	
Year 2007	54.709	7.376	
Urban	28.094	5.334	
Rural	26.615	2.043	
Year 2012	60.580	8.168	
Urban	31.109	5.906	
Rural	29.471	2.262	
Year 2017	67.081	9.045	
Urban	34.448	6.540	
Rural	32.633	2.505	

3.2 Pollution Loading from Wastewater

Current Loading of Pollution

Table 3-2-1 below indicates the values of major water quality parameters in typical municipal wastewater, based upon studies from the United Nations (WRSR Publication #15, 1996). These values are quite consistent with the monitoring data at the Zennin, Gabal Asfer and several other treatment plants (WRSR Publication #17, 1996), and therefore, can be generalized to the Delta case.

Table 3-2-1, Typical Municipal Wastewater Quality Parameters

Indicators	Strong (mg/l)	Medium (mg/l)	Weak (mg/l)
Total Solids	1200	700	350
Dissolved Solids (TDS)	850	500	250
Suspended Solids	350	200	100
Nitrogen (as N)	85	40	20
Phosphorus (as P)	20	10	6
Chloride	100	50	30
Alkalinity (as CaCO ₃)	200	100	50
Grease	150	100	50
BOD ₅	300	200	100

Source: UN study results cited in WRSR Publication #15.

Multiplying these figures by the estimated wastewater volumes yields current pollution loading (Table 3-2-2). For example, the current BOD loading in the Delta is estimated as 1,305 tons per day in the urban area and 500 tons per day in the rural area. Agricultural drains in many locations look dark, smell bad, and contain high fecal bacteria counts, confirming the high BOD loads in general characters.

Table 3-2-2, Current Sewage Pollution Loading in the Delta

<i>Indicators</i>	Strong		Medium		Weak	
	<i>urban</i> (ton/d)	<i>rural</i> (ton/d)	<i>urban</i> (ton/d)	<i>rural</i> (ton/d)	<i>urban</i> (ton/d)	<i>rural</i> (ton/d)
<i>Total Solids</i>	5220	1999	3045	1166	1523	583
<i>Dissolved Solids (TDS)</i>	3698	1416	2175	833	1088	417
<i>Suspended Solids</i>	1523	583	870	333	435	167
<i>Nitrogen (as N)</i>	370	142	174	67	87	33
<i>Phosphorus (as P)</i>	87	33	43.5	17	26	10
<i>Chloride</i>	435	167	218	83	131	50
<i>Alkalinity (as CaCO₃)</i>	870	333	435	167	218	83
<i>Grease</i>	653	250	435	167	218	83
<i>BOD₅</i>	1305	500	870	333	435	167

Future Loading of BOD

Table 3-2-3 below presents per capita BOD loads: 57 grams per day in the urban area, 23 grams per day in the rural area, and 40 grams per day on average in the Delta.

Using the above projected M&I wastewater volumes and assuming a moderate population annual growth rate of 1.5% with no essential changes in life style and technology, the BOD loading in the Delta region will be 2,213, 2,450, and 2,713 tons per day by year 2007, 2012, and 2017 respectively. In other words, by 2017 the BOD load in the Delta could be almost 1 million tons each year.

Table 3-2-3, Per Capita Values of BOD loading

	Population		BOD load		
	<i>Delta + Cairo</i> (million)		<i>total</i> (ton/d)	<i>Per capita</i> (g/d)	
Total	44.619		1805		40
<i>Urban</i>	22.913	51%	1305	72%	57
<i>Rural</i>	21.706	49%	500	28%	23

3.3 Wastewater Treatment Capacity

This section presents the limits to wastewater treatment with the current and near-future treatment facilities, and discusses the gap between treatment demand and capacity.

There are 38 existing wastewater treatment plants (either primary or secondary treatment plants), and 107 more under construction or planned for construction (Table 3-3-1). The existing treatment capacity in the Delta is 4.65 mcm per day, or 1.7 bcm each year. Plants under construction or in planning for construction will provide an additional capacity of 2.24 mcm/d.

Table 3-3-1, Wastewater Treatment Plants in the Delta

Governorates	Numbers of Plants		Capacities ($10^3 \text{ m}^3/\text{d}$)		Disposal Destinations
	Existing	in construction or in plan	Existing	in construction or planned	
1. Alexandria	2		700		Marouit lake
2. Kafr El-Sheikh		10		145	Dains
3. Daqahlyia	2	23	155	325	Drains
4. Damietta	18	6	110	270	Manzala lake and drains
5. Port Said	1	2	50	200	Manzala lake
6. Ismailia	1	1	40	110	Drains
7. Sharqya	2	15	100	210	Drains
8. Gharbia	1	13	60	270	Drains
9. Beheira	2	15	55	230	Drains
10. Menoufia	2	9	26	60	Drains
11. Qalyoubia		12		290	Drains
12. Cairo	4		2550		Land fields & drains
13. Suez	1	1	70	130	Suez gulf
14. Giza	2		730		Land fields & drains
Sum	38	107	4646	2240	(total capacity 6886)

Source: WRSR Publication #17

As a matter of fact, many existing treatment plants are not operating at the designed efficiency levels. Overloading and insufficient maintenance are not rare. Discharging incompletely treated flow or even raw sewage from treatment plants happens frequently. The actual available treatment capacity in existing plants would be less than that reported in the table.

Table 3-3-2 below presents the ambitious treatment capacity development plan of the National Organization of Potable Water and Sanitary Drainage (NOPWASD). The total capacity will be 6.95 mcm per day, the population served will be 41 million, and the costs will be 4.2 billion Egyptian pounds or 1.24 billion US dollars at the current exchange rate. However, the sources of the required investment and the timing of construction and operation of the planned plants are still uncertain. Evidently, the future picture of the development of treatment facility in the Delta region is not optimistic, and a broader pollution control options, including pollution abatement at sources and separation of M&I wastewater from agricultural drains will have to be considered.

Table 3-3-2, Expansion Plan on Wastewater Treatment Plants

Project	Capacity ($10^3 \text{ m}^3/\text{d}$)	Population Served (million)	Estimated Costs (10^6 LE)
Recent year status	4646	20.0	
Projects for 25 new cities	400	2.0	2612
Projects for 77 more cities/villag	600	6.0	563
Projects for 46 more cities/villag	1020	10.2	753
Projects for 34 more cities/villag	260	2.6	191
Projects for 20 more cities/villag	23	0.2	40
Sum	6949	41.0	4159

Sources: WRSR Publications #15 and #17.

3.4 General Status of Drain Water Quality

This section describes the general status of drain water quality in the Delta region and provides an overview of the potential remedies.

Pathogens, Pesticides and Heavy Metals

Three pollutant categories including *pathogen*, *pesticide*, and *heavy metal* are used to demonstrate the general drain water quality status.

Pathogens and parasites represent the most widespread and potentially damaging pollutants in the Delta. In rural areas, untreated human wastes and animal wastes discharge everywhere into the ground, the drains, and the canals. In many urban areas, there are no sewers to collect, treat, and disinfect human wastes. As the population grows more dense in the Delta, human (and animal) waste contamination of canal water, groundwater, and drain water will expand, raising infection rates and spreading diseases. The usual measure of pathogenic pollution is the most probable numbers (MPN) of bacteria per 100 ml of sampling water.

Heavy metals (trace elements) come from industrial wastewater discharge. The toxicity to humans and the long-term persistence of heavy metals in sediment are well known. The most critical heavy metals include mercury, lead, cadmium, chromium, nickel, copper, and zinc. The use of drain bottom sludge as fertilizer in traditional agriculture represents the most probable pathway for these heavy metals to enter the human food chain. Compared to pathogens, heavy metals are more rare and localized, posing less general threats in the Delta.

Pesticides have been widely overused in the Delta. Today's pesticide chemicals are less toxic and less persistent than those used decades ago (such as DDT). However, since they are designed to destroy living things, their toxicity to human and their persistence and tendency to accumulate in food chains are evident. Many pesticides are carcinogens in mammals.

1996 Reconnaissance Survey

The Drainage Research Institute conducted a reconnaissance survey to evaluate the present status of drainage water irrigation practice through the Monitoring and Analysis of Drainage Water Quality Project (Abdel-Gawad, S., 1998). Concentrations of pathogen, pesticide, heavy metal, and salinity in drain water, irrigation canal water, shallow groundwater, drain and canal sediments, soils, and crops were measured at 73 sites in the East Delta, 70 in the Middle Delta, and 70 in the West Delta (Louis Berger International and Pacer Consultants, 1997). The results of the survey are summarized as follows:

- Both drain water and mixed canal-drain water showed high average fecal coliform bacteria counts of 15,000/100ml. Fecal coliform bacteria counts in canal water were also as high as 6,000 MPN/100ml. Only 15% of the drain water sites, 17% of the mixed canal-drain water sites, and 22-42% of the canal water sites were in compliance with the sanitation requirements of the WHO irrigation water quality guidelines.
- Heavy metal concentrations in canal sediments, drain sediments, and soils were all high. At one particular site in East Delta, measurements showed 5 mg/l of cadmium, 47 mg/l of copper, 16 mg/l of lead, and 64 mg/l of zinc. Even in irrigation water, where trace

elements should not be detectable under normal conditions, the survey reported 0.12 mg/l of zinc, 0.04 mg/l of lead, 0.04 mg/l of copper, and 0.02 mg/l of cadmium in East Delta. Uptake of trace elements in crops was also found. For instance, on sites in Middle Delta, cadmium levels were 1.6 mg/kg in rice, 2.9 mg/kg in cotton seeds, and 1.8 mg/kg in maize. Without careful comparison against recognized standards of heavy metal residuals in crops, the seriousness of the contamination cannot be precisely evaluated. However, the possible impact of those trace elements in the food chain requires more attention..

- Concentrations of pesticide residuals were all low at non-detectable levels before pesticide applications in most monitoring sites. After applications, Atrazine and Lannet were detected in magnitudes of 10^{-3} ppm in soil, 10^{-1} ppm in canal or drain water, and 10^0 ppm in groundwater on some sites. Although no immediate conclusion can be drawn about the damaging effects of these residuals due to the scant availability of human toxicological data, pesticide residuals were detected, and chronic exposure to those residuals will pose danger to farmers' health. A substantial amount of a wide variety of pesticides (620,000 tons of 200 different types) were used on agricultural crops in Egypt in the 1960-70s, and they may still remain in the environmental media. There has been less use of pesticides in Egypt with the removal of price subsidy in the past decade, but the possible long-term contamination effect of pesticides should be emphasized.

No data are available to tell how long the current level of drain water quality contamination has taken to deteriorate in the Delta region. After construction of the High Aswan Dam, the seasonal Nile floods no longer flushed and "cleaned" the plain, and pollutants have stayed and accumulated in the drains. Without action, this trend will continue.

3.5 Regional Specifics of Drain Water Quality

The three Delta regions all exhibit increasingly deteriorated water quality, but with their own pollution distribution patterns and characteristics.

1. East Delta *A majority of the East Delta region is drained by two main drains, the Bahr Bagar and Bahr Hadus drains. Both of them flow from south to north and empty into Manzala Lake by gravity.*

Bahr Bagar Drain

Bahr Bagar starts in Kalubia Directorate with two branch drains, Kalubia and Bilbeis. The two branch drains currently receive 1.6 mcm/d of municipal and industrial wastewater from the Shoubra El Kheima area (Greater Cairo), part of Zagazig city (Sharkia), and other smaller neighboring towns. Wastewater discharge represents 75% of the total flow of the Bahr Bagar, making the drain into an open sewer which exhibits strong odors, dark color, and gas bubbles. Even at the end of Bahr Bagar, monitoring readings show TSS of 134 mg/l, COD of 108 mg/l, and MPN of 120,000/100 ml (Drainage Task Force Committee, 1997), all of which are far beyond acceptable levels according to Law 48 or any other recognized water quality standards. It was reported by the local engineers in the Kalubia directorate that the M&I discharge to Kalubia and Bilbeis drains will increase to 2.2 mcm/d by the year 2005.

Existing wastewater treatment plants in Zagazig city and other towns are overloaded and lacking of effluent quality assurance. The treatment plant in Shoubra El Kheima, currently under construction, will have a capacity of 0.5 mcm/d in phase I and a capacity of 2 mcm/d in phase II. With increasing population and industry expansion in that area, however, it is not sure whether adding this new treatment plant will resolve the problem of the Bahr Bagar and help resume its function as an agricultural drain in the near future.

The Wadi mixing station, one main reuse mixing station on Bahr Bagar, has been fully shut down due to the unacceptable sanitary conditions of the drain. This has resulted in a loss of 200 mcm of reuse opportunity each year. Along Bahr Bagar's 200 km route to Manzala Lake in the north, salinity measurements are all lower than 1000 ppm except for one single location (Bahr Bagar pump station). If not for pollution, the drain could provide more than 1 bcm reuse per year even without freshwater mixing, compared to the current official reuse record of 300 mcm.

Bahr Hadus Drain

At present, the pollution in the Bahr Hadus and the neighboring Lower Serw drain is not as serious as that in Bahr Bagar. The main problem in the basins is the conflicting needs on drainage water for rice irrigation and Salaam canal. The conflict may be mitigated if more drain water in Bahr Bagar could be released from the pollution burden and become available for Salaam canal.

Strategically, the drainage reuse potential in the entire East Delta region lies on the pollution control and recovery of the Bahr Bagar (El-Quosy, D., 1989).

Middle Delta The Middle Delta contains three main drains, Drain No. 1 in the northeast, Gharbia in the center, and Nashart in the west. Due to the region's low elevation, all drain waters are pumped to the Mediterranean Sea or to the Burullus Lake in the north.

Tanta City

Tanta city and its surrounding area (Mahalla El Kobra) are the main pollution source in the Middle Delta region. Both Gharbia and Drain No. 1 pass through the urbanized and industrialized areas surrounding the city and pick up large volumes of M&I wastes. Sewage flow gathered in the Gharbia Governorate accounts for about 400 mcm per day, making Tanta the 3rd largest sewage generation site in Egypt after Cairo and Alexandria.

Wastewater treatment plants in that area are frequently overloaded. The Tanta treatment plant was designed for 1 million population, but the present population is 2 million. Consequently, the treatment plant effluent to the Segaya drain is often a mixture of treated and untreated sewage. Industrial wastewater generated in the east Tanta region discharges into neighboring drains and irrigation canals. Regulations for environmental protection have never been implemented. All drains and irrigation canals in Tanta area are polluted.

For Tanta, the densely populated lowland area in the Delta, wastewater treatment is not seen as a short-term achievable solution. Preliminary proposals for separating and diverting sewage from the lowland to the west desert were studied but not advanced due to the expensive civil works needed to cross the Rosetta Branch, canals, and roads on the way of the diversion.

Gharbia Drain

The Gharbia drain passes through the heart of the Middle Delta. Both official and unofficial reuse can be found along the drain. Monitoring measurements at the Hamul mixing station can be used to represent the water quality status of the Gharbia drain: 164 mg/l of TSS, 114 mg/l of COD, and 11 million/100ml of MPN (Drainage Research Institute, 1995). Although salinity level remains low at 1,132 ppm, operation of the station and its 300 mcm/y reuse is threatened by the unsanitary drain flows. Another mixing station on the drain, the Potiata station, simply has not been operated since its construction for the same reason. To sustain the large volume of reuse on Gharbia, reduction of pollution is essential.

Drain No. 1

Water quality in Drain No. 1 is better than that in Gharbia drain in general, but not in each particular location on the drain. It receives sewage from the cities of Talkha and Sherbeen as well as a large volume of rural wastes in the northeast part of Middle Delta region. The drain provides source water for the direct drainage irrigation in the Kalapsho reclamation project. The success of the Kalapsho reclamation will depend on the pollution abatement and water quality assurance in Drain No.1.

Rural Waste Discharges

Another distinguishing feature of the Middle Delta is the region's big rural population and its huge rural waste volumes. As seen in Table 3-1-1, the region's average rural sewage flow reaches 884 mcm per day, much higher than those in the other two Delta regions. Obviously, this will be not changeable in the near future and poses a great hazard to the health of rural residents in the region.

West Delta The main drain systems in the West Delta include the Edko drain in the northeast, which empties into the Edko Lake, and the Umoum drain in the west, which empties in Mariout Lake. The Tabia pump station collects Alexandria's wastewater and pumps it to the Mediterranean Sea.

Edko Drain

The water quality in the Edko drain is similar to that of the Gharbia drain in Middle Delta. Mixed urban M&I sewage and village wastes, treated and untreated, continuously feed the drain as the only outlet in the lowland basin. The Edko pump station, as the main reuse mixing station in the drain, was shut down for short periods in the past years due to the unacceptable sanitary conditions. Unless the M&I sewage load from Damanhur city is effectively controlled, there is little hope to improve the drain water quality and expand reuse in the drain basin. Furthermore, a certain amount of Edko drainage flow is mixed into the Mahmoudia canal, the source for Alexandria city drinking water.

Alexandria Area

M&I wastewater in the east Alexandria, where a huge national chemical and petroleum industrial complex is located, is dumped into open drains and pumped to the sea through the

Tabia pump station. The local environment is highly deteriorated, and the area may represent the most polluted location in Egypt.

Most of Alexandria's M&I wastewater discharges into the Mariut Lake. The lake's environment is approaching "death". Monitoring measurements of the lake read unusually high: 2,000 mg/l of BOD, 2,000 mg/l of oil and grease, 30-90 mg/l of mercury, and 50-200 mg/l of chromium (Rady, M. A., 1996). With large volume of industrial wastewater discharge to the lake, part of the lake is red in color.

Mariut lake is also the destination of several agricultural drains. The Umoum drain disposes a large volume of drainage with water quality levels acceptable for irrigation use. The drain water becomes unusable after being mixed in the lake. There are various proposals for saving the lake's environment. However, implementation of these proposals has been slow.

Umoum Reuse Project

The Umoum mixing stations were constructed at the 46-km point of the Nubaria canal several years ago to lift 1 bcm of drain water to the Nubaria canal for reuse. However, the station has not been in operation now due to the bad quality of the drain water coming from the Abu Hommes and Shereshera areas, where large volumes of untreated M&I wastewater enter the drains. The fecal coliform count was recorded at $20 \times 10^6/100\text{ml}$ in the Umoum project design document. A wastewater treatment plant is under construction in Abu Hommes, and a proposal for relocating drinking water intakes on Nubaria canal has been discussed for years.

Moheit Drain

The Moheit drain is another problematic drain in West Delta. It carries the effluents from the Zenin and Aburawash wastewater treatment plants as well as significant amounts of solid wastes generated in the west Cairo area. The Moheit drain terminates in the Rosetta Branch, which eventually provides drinking water to Alexandria.

3.6 Drain Water Consumed by Pollution

Closed Reuse Mixing Stations

Most main canals in the Delta are multi-functional, delivering irrigation and municipal and industrial water. After being mixed with drain water, canal water quality is dominated by the quality of the drain water. When the drain water quality becomes unacceptably poor, the operation of mixing station has to be stopped. Many of the region's main drain mixing stations suffer from unacceptable degraded sanitary conditions. As shown in Figure 3-6-1 below, seven of the twenty-three main reuse mixing pump stations in the Delta have been entirely or periodically closed since 1992 (Drainage Research Institute, 1995).

1) Wadi mixing pump station

The Wadi mixing pump station (EB-3) is located at the intersect of the Wadi canal and two drains, the Kalubia and the Bilbeis. These two drains receive M&I wastewater from east Cairo and are heavily polluted. The station used to lift drainage from the Kalubia and the Bilbeis to Wadi canal for agricultural reuse. Because of the poor sanitary conditions of the drain water, operation of the station has been stopped since 1992.

2) Mahsama mixing pump station

The Mahsama mixing pump station (ET-2) is on the Mahsama drain, which flows by gravity into the Suez canal through Temsah Lake. The Mahsama drain receives neighboring rural area sewage and a certain portion of the Wadi drain water through El Qassasin pump station. The Mahsama station used to pump drainage water into Ismalia canal, the drinking water source for the cities of Ismalia, Suez and Port Said. To protect the drinking water source, the station has been closed since 1993.

3) Upper No 1 mixing pump station

The Upper No 1 pump station (M1-1) pumps Drain No 1 drain water to the Damietta Branch, which feeds Damietta City. Drain No 1 receives sewage from small towns (Talkha and Shirbin) and villages in the neighboring lowlands, and industrial wastewater discharged by the Talkha Fertilizer Company. The operation of the station was once stopped in 1993.

4) Hamul mixing pump station

The Hamul pump station (MG-8) is on the Gharbia drain. It diverts Gharbia drain water to the Bahr Tira in the north for reuse. Hamul station collects most of the M&I wastewater from the central part of the Middle Delta, including sewage from Elmahla Elkubra and Tanta, and the sugar industrial wastes from Hamul city. The station was closed for short periods in the recent past.

5) Potiata mixing pump station

Near the Hamul mixing station, the Potiata mixing station was constructed in the early 1990s. It has never been functioned because of the drain water pollution effect on a downstream sugar plant's water supply.

6) Edko mixing pump station

The Edko pump station (WE-4) pumps water from Edko drain to the Mahmoudia canal, the major water supply source to Alexandria City and neighboring rural areas. The Edko drain collects most of the pollution in the eastern part of the West Delta. The station was closed for a short period in the recent past.

7) Umoum mixing pump station

As mentioned above, the station has not been in operation since its construction in 1994.

Table 3-6-1 below presents selected water quality measurements at these mixing stations and the corresponding quality standards in Law 48 for irrigation drainage mixing. Except for salinity concentration (TDS), no measurements are in compliance with Law 48. The high COD/BOD ratios imply significant industrial pollutants; the TSS numbers indicate the need for at least primary treatment; and the large counts of fecal coliform (MPN) simply rule out any reason for using the water.

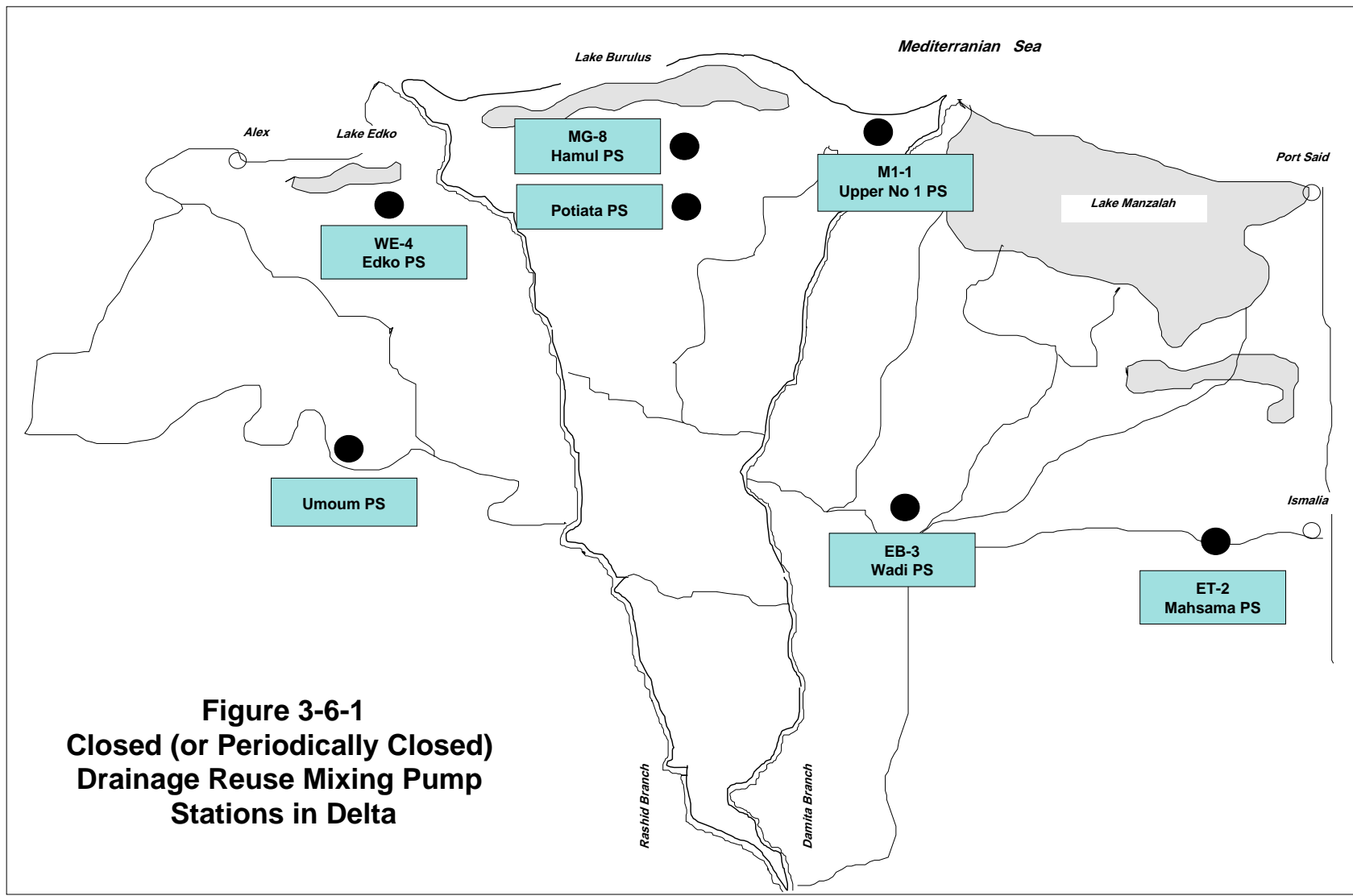


Figure 3-6-1
Closed (or Periodically Closed)
Drainage Reuse Mixing Pump
Stations in Delta

Drain water quality deterioration also occurs at other mixing pump stations. According to the Ministry (Rady, M. A., 1996), there are as many as 37 mixing or lift pump stations suffering from poor water quality. Monitoring measurements were also taken at the New Bahr Hadus Outfall (EH-17), Upper Serw (ES-1), and Drain No.1 (M1-2) mixing stations (Drainage Research Institute, 1996). The measurements showed similar levels of contamination, especially, fecal coliform counts all exceeded 100,000 /100 ml, or one hundred times higher than the standard set in Law 48.

Table 3-6-1, Selected Quality Indicators at Mixing Pump Stations ¹

		<i>Wadi</i>	<i>Mahsama</i>	<i>Upper No. 1</i>	<i>Hamul</i>	<i>Edko</i>	<i>Limits set in Law 48</i>
TDS	(mg/l)	900	846	733	1132	821	-
BOD	(mg/l)	79	19	10	13	15	< 10
COD	(mg/l)	224	108	138	114	98	< 15
NH₄	(mg/l)	2.36	0.24	1.95	1.98	0.41	< 0.5
MPN	(10 ⁶ /100ml)	37	0.1	1.8	11	0.3	< 0.005
TSS	(mg/l)	306	188	125	164	104	50-60 ²

Notes: 1) No data available for the Potiata and Umoum stations

2) It is the standard for M&I effluent in Law 48

When water quality monitoring is extended to more mixing reuse stations, a more precise evaluation will be obtainable. But it is clear that without control of the M&I wastewater discharges, more drains will become open sewers, more pump stations will be forced to close, and the entire official reuse system based upon centralized mixing stations is vulnerable and unsustainable. While the stations are closed, the contaminated waters may still be “unofficially” used by neighboring farmers, posing the probability of long-term health impact.

Drain Water Consumed by Pollution

Table 3-6-2 below presents an estimation of how much agricultural drain water is consumed by pollution. The six drains in the table are typical drains suffering from pollution in the Delta.

Table 3-6-2, Reuse Potential on Polluted Drains (based on 1993/94 data)

Name of Drain	Location on the Drain	Salinity ¹	To Sea 1993/94	Reuse 1993/94	Reuse with Target 2000 ppm	Reuse with Target 2250 ppm
		(ppm)	(mcm)	(mcm)	(mcm)	(mcm)
<i>Umoum</i>	<i>Qalaa PS</i>	1600	0	0	0	0
	<i>Truga PS</i>	1684	931	0	931	931
<i>Alex Vicinity</i>	<i>Tabia PS</i>	1449	617	0	617	617
<i>Drain No. 1</i>	<i>Lower PS #1</i>	2237	841	0	0	841
<i>Bahr El Bagar</i>	<i>Bahr Baqar bridge</i>	999	969	0	969	969
<i>El Serw</i>	<i>Lower Serw PS</i>	1272	962	0	962	962
		Sum	4321	0	3480	4321

1) Salinity readings at the representative locations

The Qalaa drain is heavily contaminated by the municipal wastewater from Alexandria, resulting in almost zero dissolved oxygen (DO) concentration in the drain. The Truga and Shereshera pump stations on the Umoum drain receive sewage flows from the Abu Hommes and Shereshera areas, where a very high fecal coliform bacteria count of 20 million/100 ml was detected in the 1980s, as reported in the design document for the Umoum reuse project.

The area surrounding the Tabia pump station is well known as the most severe industrial pollution dumping site. Drain No 1 and El Serw are not as seriously polluted as the other drains, but still, with poor quality indicators, such as 180,000/100ml of MPN, 1.95 mg/l of NH₄, and 138 mg/l of COD at the Upper PS #1 on Drain No 1, and 920,000/100ml of MPN and 120 mg/l of COD at the Upper Serw pump station on El Serw. The Bahr Bagar is the most problematic drain in terms of environmental quality.

As seen in Table 3-6-2, salinity levels in those drains are all acceptable for irrigation use. Without pollution, each year there would be an additional 3.5 bcm and 4.3 bcm of reusable drain water from those six drains, given the reuse targets of 2,000 ppm and 2,250 ppm, respectively. In other words, M&I pollution in the Delta consumed 3.5-4.3 bcm of good quality drain water in 1993/94.

As a matter of fact, despite the poor water quality, part of those drain flows are being used by farmers. The drain water that is difficult to recapture, due to poor water quality reasons, is the water in the Bahr Bagar and Alex vicinity drains, which accounts for about 1.5 bcm per year. In general, this 1.5 bcm can be considered as an estimate of the “non-renewable” drain water consumed by pollution.

3.7 A Costs Comparison of Tanta City’s Sewage Reduction Options

Below is a costs comparison of three reduction options of the Tanta City’s sewage flow. The options are 1) to treat the whole amount of sewage, 2) to treat part of the sewage through the existing treatment capacity and bypass the rest to the Mediterranean Sea, and 3) to bypass all the sewage to sea without treatment.

Tanta City has the highest population intensity in the Delta. It receives drinking water from El Kaased canal at a volume of 63,936 m³/day, from groundwater tapping at a volume of 149,870 m³/day, and in total, 213,806 m³/day. The sewage is discharged to the Seberbay drain, a branch drain of Gharbia drain. The existing treatment capacity in the city is 60,000 m³/day, inadequate to satisfy full treatment of the sewage flow, resulting in water quality contamination in Seberbay drain. According to the Tanta Council, sewage volume will increase further to 200,000 m³/day by year 2010.

Option 1 - Full Secondary Treatment of all the Sewage

This option means to expand the treatment capacity from the current level of 60,000 m³/day to 140,000 m³/day. Based upon the information in Alexandria wastewater treatment studies (Academy of Scientific Research and Technology, 1990), the average annual cost and the benefit of this option will be LE 37.5 million and LE 25.0 million, respectively. Accordingly, the annual net cost of this option will be L.E. 12.5 million.

Option II - Bypass Part of the Sewage to the Sea

This option is to continue the current treatment capacity under operation and bypass the remaining sewage flow without treatment to the Mediterranean Sea. This requires installation of a pipeline and series of pump stations to transport the sewage flow in a distance of about 100 km from Tanta to the Sea. The land topography in Delta region is flat, where there is only 5% a downward slope from the south to the north.

The design of the by-pass pipeline is summarized as follows:

- a reinforced concrete pipe line, at a diameter of 1.75 meter, with a capacity of 140,000 m³/day sewage and a flow velocity of 0.7 m/s,
- a hydraulic head of 17.5 meters to overcome friction losses, and
- 10 pump stations in series along the 100-km pipeline, each with 2 pumps at a head of 1.75 m and 54 hp to deliver the sewage flow for 10 km.

The annual costs of this option, including both capital and O&M costs, will be LE 4.0 million.

Option III - Transport All the Sewage to the Sea without Treatment

This option assumes that all the 200,000 m³/day of sewage will be transported to the Sea without treatment by using the similar pipeline and pump stations as in Option II with a larger flow capacity. The estimated annual costs will be LE 4.8 million. Clearly, Option II has the least annual cost of LE 4 million.

3.8 Recommended Policy Visions and Actions

As discussed in this chapter, pollution from the M&I wastewater discharge is threatening the sustainability of the reuse of agricultural drainage water in the Delta. The following **policy actions** are suggested regarding pollution control and protection of the agricultural drain water.

1. *Support the existing policies of constructing urban wastewater treatment plants and strengthening enforcement of Law 48 and other related environmental protection laws and regulations.*

Under this general and long-term policy, two specific policy actions are needed:

- Develop a closer cooperation with the Environmental Protection Ministry on drainage water quality management by creating a clearer division of each Ministry's administration responsibility and authority.
 - Strengthen the administrative responsibility and authority of the Egyptian Public Authority for Drainage Projects (EPADP) in drain water quality management.
2. *Promote public awareness of the M&I wastewater pollution in agricultural drains and its effect on the sustainability of agricultural production and the living environment for the Egyptian people.*

The awareness promotion should also be extended to the high-level officials so that an adequately firm political will can be created to accelerate the steps in pollution control and environmental protection.

Under this policy, the Ministry will need to use every possible communication channel at the national level to disseminate relevant information and educate the mass media on the environmental status of the drain system and the losses of the valuable water resources

caused by M&I wastewater discharge. The following contents of information would be useful in environmental education:

- Importance of drain water reuse in agricultural production in the Delta.
 - M&I wastewater and the associated pollutants discharged into agricultural drains. General and typical drain water quality status in the Delta.
 - Water consumed by M&I pollution.
 - Law 48 and treatment, separation and diversion of M&I wastewater.
3. *Declare a clear and firm policy against the disposal of large cities' untreated M&I wastes in agricultural drains.*

The misunderstanding of treating agricultural drains as a destination for human wastes must be removed, both from the mass public and the GOE sectors.

Agricultural drain water is reused as part of the irrigation supply in the Delta, and in principle, M&I wastewater disposal in agricultural drains should simply be prohibited. Considering the fact that the land space is limited in the Delta and it is almost impossible for every M&I wastewater source to find different means of disposal than agricultural drains, a realistic policy for the Ministry is to target at rejecting (or at least decreasing) the untreated wastewater discharges from large cities, which account for 70% of the region's total wastewater load.

The Ministry will need the approval and support from higher GOE level for this policy implementation.

4. *Promote the policy of "polluter pays".*
5. *Promote a policy to keep poor water away from good quality water and get good quality water out of poor quality water.*

This is a policy aiming at the separation of M&I wastewater from agricultural drains, as an immediate effort to accompany the general, long-term treatment policy in combating the increasing pollution problems. Under this policy, the Ministry may need testing the feasibility and effectiveness of the following separation measures:

Intermediate Drainage Reuse Assign one or two intermediate reuse pilot projects to evaluate the effectiveness and impact of this reuse approach, as will be discussed more in Chapter V.

Specified Drains as Sewers Test one or two agricultural drains as permissible wastewater carriers in exchange for the agreement and support from other water user sectors on reduced M&I discharge in other drains.

The huge volume of M&I wastewater in the Delta must be disposed of somewhere, and it is impractical to prohibit wastewater discharges in every drain. This action may require some cities to construct wastewater transmission pipelines to reach the appointed sewers. The feasibility of this separation measure needs to be verified in detailed studies.

Industrial Wastewater Discharge Permit System The EPADP is currently responsible for issuing industrial wastewater discharge permits on drains. The activity needs to be enhanced on more consistent regulation bases through a closer corporation with the Environmental Protection Ministry and other relevant GOE agencies. It should be a parallel action with the on-going effort to control industrial wastewater discharge in the Nile river and irrigation canals.

By-pass Wastewater Explore the feasibility of transporting untreated or partially treated wastewater from selected cities to the Mediterranean Sea or some desert sites in the west and east of the Delta. There is a trade-off between the long-term environmental concerns and the immediate threat on the Delta residents. Sacrificing limited desert areas for wastewater dumping in exchange for sustaining agricultural production and human health on the Delta plain may not be an unrealistic choice for Egypt.

Low-cost Rural Wastewater Treatment Facility Development Encourage private investors to develop low-cost rural domestic wastewater treatment facilities. This will reduce the organic pollutant discharge in agricultural drains and contribute to the improvement of the drain system's sanitary condition, which represents the major reason for the closure of mixing pumping stations.

Drain flushing Explore the feasibility of having a longer closure period each year for agricultural drains so that drain channels could receive stronger flushing flow at the end of the closure and obtain longer sunlight exposure for removing contamination.

4 UNOFFICIAL REUSE AND INTERMEDIATE REUSE

This chapter explains the multiple levels of drainage reuse, presents an estimate of the current unofficial drainage reuse, and describes the potential for intermediate reuse in the Delta.

4.1 Multiple Levels of Reuse

The agricultural drain system is well developed in the Nile Delta. Drain water is collected through farm tile-drains, branch drains, and main drains. There are more than a dozen main drains and numerous branch drains in the region, constituting a huge web of drainage transport and reuse. Drain water reuse in the Delta is practiced in three ways:

- Capturing drainage flows in main drains and mixing them with main canal water at centralized mixing pump stations is called the *official reuse*. The volume of this type of reuse is planned and managed by the Ministry with good records kept.
- Direct pumping of drainage water from a nearby drain (no matter what type of the drain) by individual farmers is called the *unofficial reuse*. Those individual farmers who receive inadequate freshwater for crop irrigation pump drain water without “permit”. It would be very difficult (or almost impossible) to measure this type of reuse due to its spontaneous and local nature. Unofficial reuse, particularly the unofficial drainage irrigation in the illegal rice fields in the Bahr Hadus, has competed with the Salaam canal drainage diversion and become an increasing concern of the Ministry.
- Between reuse at main drain mixing stations and reuse by individual farmers, there are other reuse opportunities, referred to as *intermediate reuse*. On branch drains, water can be captured when the water quality is appropriate. Intermediate reuse can help avoid unnecessary losses of branch drain water by using it before it enters a more polluted or saline main drain. Intermediate reuse has been applied in several drain basins in the Delta.

In addition to these three direct drain water reuse practices, there has been an increasing dependence on conjunctive use of “unofficial” shallow groundwater wells to meet irrigation and M&I demands in certain parts of the Delta.

All these water recycling practices are means to augment irrigation supplies. Main mixing pump stations centralize reuse on main drains; intermediate reuse helps capture water in branch drains before it gets mixed with polluted main drain water; and unofficial reuse, including unregistered shallow groundwater pumping, helps augment local supplies. Within the total reuse capacity of a system, they supplement each other and all contribute to the operation of the system.

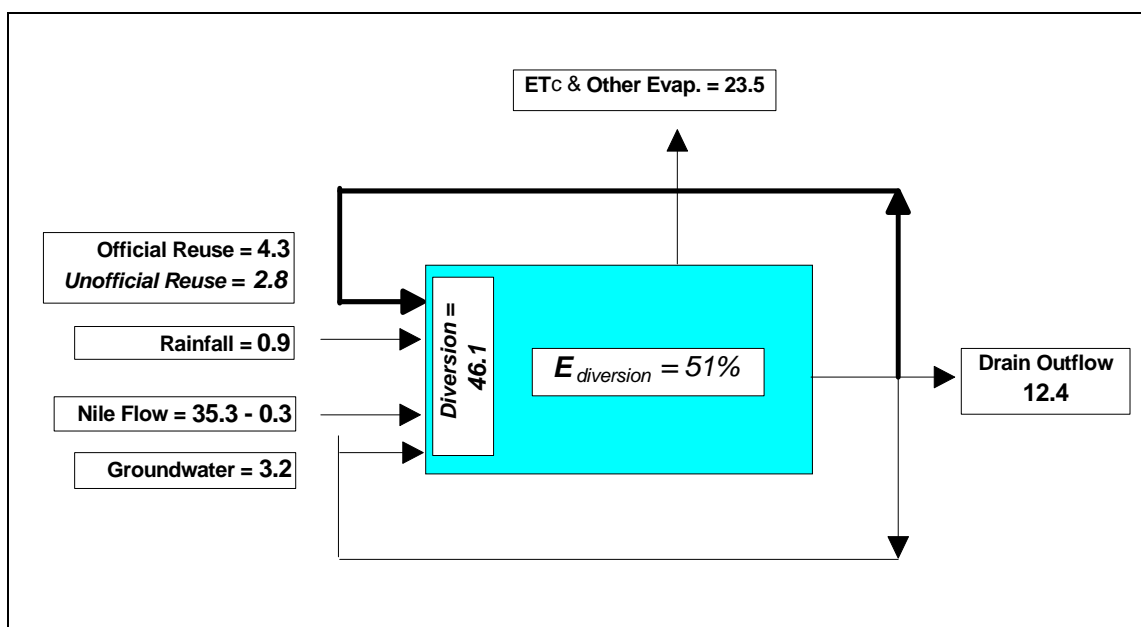
4.2 How Much Unofficial Reuse?

The *unofficial reuse* has been rapidly increasing since the end of last decade. Restricted canal water supplies, free crop patterns, increased rice irrigation, and land expansion could all have

contributed to the growth of unofficial reuse. The volume of each individual farmer's unofficial reuse is small, but the aggregated amount could be as large as the total official reuse, as will be explained below.

Figure 4-2-1 below illustrates the water diversions in the Delta in 1995-96. Assuming that the shallow groundwater aquifer in the region is stable, these inflow components (including the Nile freshwater passing Cairo minus the Nile water going to the sea, rainfall in the region, shallow groundwater withdrawal, and official and unofficial drainage reuse) must balance the ET production, other evaporative depletion, and drainage outflow to the sea in a linear equation with a system diversion efficiency. The total drainage recycling, or the sum of the official and the unofficial reuse, can be estimated by solving the equation. Given an official reuse, the unofficial reuse simply is the subtraction of the official reuse from the total reuse.

Figure 4-2-1, Water Diversion in the Delta Region



The diversion efficiency has the similar meaning as the classic irrigation efficiency when M&I water consumption is excluded. Given conservative estimates of 70% canal conveyance efficiency and 70% farm irrigation efficiency, the actual diversion efficiency in the Delta region should be no greater than 49%. A reasonable estimate of the actual diversion efficiency in the Delta region would be about 45 %.

An estimate of 2.8 bcm unofficial reuse in the Delta was reported (Drainage Task Force Committee, 1997). With this estimate, a 51% diversion efficiency is calculated from the above water balance equation, which is beyond the reasonable range mentioned above. In other words, the unofficial reuse should be larger than 2.8 bcm in the Delta region. The higher the system diversion efficiency is assumed, the smaller the estimated unofficial reuse will be. At a diversion efficiency of 54%, the unofficial reuse becomes zero in the balance equation. This indicates that the actual system diversion efficiency cannot be as high as 54%. There always exists a certain amount of unofficial reuse in irrigation practice, although with the currently available monitoring data, it is difficult to identify every component of the “unofficial reuse” term.

Table 4-2-1 below presents the calculated amounts of unofficial reuse at different system diversion efficiencies.

Table 4-2-1, Unofficial Reuse and System Diversion in the Delta

(based on 1995-96 data, unit=bcm)

	DRI Estimated 51%	At Efficiency 49%	At Efficiency 48%	At Efficiency 45%
Total Recycle	7.1	8.9	9.8	13.1
<i>Recorded Reuse</i>	4.3	4.3	4.3	4.3
<i>Unrecorded Reuse</i>	2.8	4.6	5.6	8.8
System Diversion	46.1	47.9	48.9	52.2

It can be seen from Table 4-2-1 that water circulation is active in the Delta. In 1995-96, the Nile River flow passing Cairo was 35.3 bcm, while the water diversions in the Delta were 48-52 bcm, or 1.5 times of the inflow at Cairo. Given system diversion efficiencies of 49%, 48%, and 45%, the unofficial reuse is calculated as 4.6 bcm, 5.6 bcm, and 8.8 bcm, respectively.

Note that the unofficial reuse term, as a residual from the water balance equation, may include unidentified shallow groundwater pumping in the southern Delta and displaced upward flow as seawater intrusion in the northern Delta besides individual farmer implemented reuse, unreported land expansion, and “illegal” rice drainage irrigation.

It is widely agreeable that the unregistered shallow groundwater pumping in the southern Delta would not be as large as in the magnitude of a billion cubic meters. The amount of the displaced upward flow as seawater intrusion is debatable, but still, it would be in the range of 1-2 bcm (WRSR Publication #25, 1996). Therefore, the magnitude of unofficial drainage reuse in the Delta would be 4-6 bcm. Obviously, to regulate (or administrate) all the unofficial reuse at such a large magnitude would be ambitious and impractical.

An important indication from the above analysis is that both official reuse and unofficial reuse are part of the system diversion. One may switch some unofficial reuse to official reuse but cannot eliminate one or the other or treat them as additional resources. As an example, to secure adequate drain water for the planned Salaam canal, the drainage irrigation in the “illegal” rice fields in the Bahr Hadus must be cut by regulating (or limiting) the unofficial reuse in the basin. From a water management point of view, regulating unofficial reuse is a reallocation of reuse potential but not a creation of reusable resource.

4.3 Why Intermediate Reuse?

As defined above, intermediate reuse means mixing branch drain water with branch canal water for irrigation use. The need for intermediate reuse development in the Delta region is derived from the following facts (Elwan, H., 1998):

- The philosophy of the current official reuse policy is to gather as much drain water as possible in main drains and redistribute it at centralized pump stations. This approach

emphasizes the global collection, transport and allocation of drain water and de-prioritizes local reuse on branch or lower-order drains. This was adequate in the 1970-80s when local reuse needs were not pressing. However, the centralized official reuse system has been extensively developed in the past two decades, and opportunities of more reuse on main drains has reduced. As revealed in the discussion of the maximum reuse potential (Table 2-1-1), most potential sites for reuse are on branch drains or lower-order drains, where salinity levels are still tolerable for irrigation.

- Pollution from M&I discharges are threatening the reuse capacities at main reuse mixing stations. As a result, 7 main reuse mixing stations are shut down. Using branch drain water before it is mixed with polluted water in main drains provides a viable short-term approach to the problem. In the long run, pollution from M&I wastewater discharges must be removed from the agricultural drain system, but the timing is unclear and uncertain. Intermediate reuse represents a means to keep good quality water away from poor quality water.
- With the poor conditions of the current delivery system, water shortages often occur at canal tails. This has generated a trend for farmers to augment their supplies with drain water in recent years. Organized intermediate reuse at the district level will mitigate the current reuse competition between official and unofficial reuse.

In addition, intermediate drainage reuse will lead to periodically lowered water levels in drains, which would allow increased sunlight penetration and better prevention of parasites and snails. Furthermore, the facilities required for intermediate drainage reuse are less sophisticated than those required in main drain mixing stations.

In the current water delivery system, a branch canal serves a number of mesqas. The intakes of mesqas located at the end of the canal are often higher than the operational water level at the canal during peak irrigation demand period. Farmers suffering from supply shortage have to pump drainage water from nearby drains to augment supplies for their crops. Because of the spontaneous nature of the unorganized use of drain water, farmers may pump more than what is actually needed or use drain water of a quality which should not be used. In this case, organized intermediate reuse could be applied to pump nearby drain water to raise the canal water level and deliver the properly mixed supply to the mesqas.

With intermediate reuse, unofficial reuse will be reduced. The Ministry will have more flexibility in implementing its strategic drain water allocation in the Delta.

Clearly, intermediate reuse will alter the drainage flows currently reaching the main mixing stations, both in quantities and qualities. Alternative drainage flow patterns after applications of intermediate reuse were not studied in detail due to the limited time and manpower. A likely consequence would be the reduction of drainage flow and increase of salinity in main drains. However, this should not be a threatening concern, since the reduction of reuse at main mixing stations does not mean the reduction of total drainage reuse as explained above.

Some directorates are practicing intermediate reuse as a means to mitigate water shortage at canal tails. For instance, in west Dakahlia, 5 intermediate reuse pump stations, each with a capacity of 36,000 m³/day, have been established in order to raise water levels at canal ends.

4.4 A Case Study of Intermediate Reuse

This case study investigates the feasibility of adding more intermediate reuse pump stations to capture the drain water lost at the closed Wadi mixing station due to pollution on the Bahr Bagar main drain.

There are both main level and intermediate level reuse practices on Bahr Bagar. The main level reuse, as shown in Table 4-4-1, used to mix 0.3 bcm per year of main drain water with canal freshwater for irrigation. However, the shut-down of the Wadi mixing station has caused a 0.2 bcm reduction of the main level reuse on the Bahr Bagar main drain.

Table 4-4-1, Main Level Reuse on the Bahr Bagar Drain

No.	Pump Stations	Canal Served by Reuse	Reuse in 1993/94 (mcm)
1	Wadi	East Wadi Canal	184
2	Blad Elayed	East Wadi Canal	101
3	Bahr Elbaqar	Batikh Canal	11
		Total	296

Intermediate drain water reuse is being practiced at two pump stations on Elazzazi and Elharami branch drains in the Abu Hammad district, as shown in Table 4-4-2. The average salinity in the two branch drains is 900 ppm. It is suggested that three more intermediate pump stations be added to the branch drains in the same district (45,000 feddans) so that more of the reuse lost at the closed Wadi station can be re-captured.

Table 4-4-2, Intermediate Reuse on Bahr Bagar Drain (in Abou Hammad District)

	Pump Stations	Drains	Served Canals	Areas (feddan)
Existing	1- Elazzazi, 0.75 m ³ /s	Elazzazi, 2 nd order	Om Hagar, 3 rd order	5,661
	2- Elharami, 0.5 m ³ /s	Elharami, 2 nd order	Om Hagar end, 3 rd order	5,661
Suggested	1- Mashaa, 0.5 m ³ /s	Elazzazi branch, 3 rd order	Mashaa, 3 rd order	544
	2- Haisamia, 0.75 m ³ /s	Elkhattara, 3 rd order	Saidia, 2 nd order	105,000
	3- Sharkia, 0.5 m ³ /s	Elazzazi, 2 nd order	Sharkia, 4 th order	880

The area of the involved drainage basins is 208000 feddans, and the recommended reuse rate in the area is 0.2 bcm per year. The required infrastructure for the suggested intermediate reuse will only be construction of pump stations and limited pipelines. It is recommended to use:

- movable diesel pumps on large mesqas of 100-300 feddans, with capacity of 20-80 liters per second, usable for both drainage pumping and possible future IIP use,
- simple civil works for pump stations, and
- a 1:1 blending ratio and an expected 700 ppm salinity after mixing.

Based upon the information of the irrigation improvement project (El Shinnawi and El Garnousy, 1996), the costs of the following three intermediate reuse schemes are calculated, as shown in Table 4-4-3:

- Scheme #1: reuse drain water along 3rd order canal

- Scheme #2: reuse drain water along 4th order canal
- Scheme #3: reuse drain water along large mesqas of 100-300 feddans.

Table 4-4-3, Summary of the Three Reuse Schemes

Schemes	Required Intermediate Reuse Stations				Total Costs* (million L.E.)	Per 1000 m ³ Costs (LE)
	No.	Reuse (bcm/y)	Discharge at One PS (m3/s)	No. of Units at Each PS		
#1	21	0.2	1.34	3 * 0.5 m3/s	4.05	20.24
#2	50	0.2	0.55	2 * 0.5 m3/s	2.26	11.28
#3	190	0.2	0.15	2 * 0.08 m3/s	1.43	7.13

*Total costs include capital and O&M costs.

As seen in the table, reuse along large mesqas (Scheme #3) bears the lowest cost but only provides very small reuse capacity, which is obviously not preferable in practice. A better choice is the combined intermediate reuse on branch canals and mesqas (Scheme #2), which captures adequate amount of drain water as well as increases canal operation flexibility in meeting water demands.

The estimated intermediate pumping cost for Scheme #2 is about LE 0.01/m³, which is consistent with the average drainage reuse cost in the main mixing reuse practice (WRSR Publication #1, 1996).

As shown in Table 4-5-1 below, the average per-cubic-meter cost of IIP activity is 20-25 times of the drainage reuse cost, and the average unit cost of wastewater treatment is even higher. Intermediate drainage reuse is much more economically attractive than wastewater treatment.

Table 4-5-1, Costs of Conservation / Augmentation Options

Options	LE / m3
Intermediate reuse	0.010-0.015
IIP activities	0.25
M&I wastewater treatment	>0.70
Desert aquifers	
Western deserts	< 0.05
Eastern deserts	0.12
Sinai	0.31
Desalination	
Brackish water	> 1.50
Sea water	> 4.50

Source: WRSR Publication #1, 1996.

4.5 Recommended Policy Visions and Actions

Based upon the discussions in this chapter, the following **policy visions** on unofficial drainage reuse and intermediate drainage reuse should be established:

1. *There is potential for reducing pollution in drains by adopting intermediate reuse. Intermediate reuse will be supplementary to, but not a replacement for, the current main reuse system.*

The technical merits of intermediate reuse in capturing the good quality drain water before it gets mixed with poor quality drain water and replacing unofficial reuse at the canal tail where canal deliveries are in short supply should be recognized.

2. *Drainage reuse should be integrated in irrigation management both on farm level and main system level.*

Official reuse, unofficial reuse, and intermediate reuse all are means of reuse, making the system work at the current efficiency level. One may switch some unofficial reuse to official reuse but cannot eliminate one or the other or treat them as additional resources. To regulate (or administrate) all the unofficial reuse in the Delta would be impractical as well as unnecessary. An appropriate policy for the Ministry would be to start regulating unofficial reuse in selected but not all drain basins.

The following three immediate ***policy actions*** are recommended:

1. *Restrict unofficial drainage pumping in the areas where major reuse projects exist.*

This is to secure the drain water availability for the Salaam canal and Kalapsho projects, which are already in operation. The action should be seen as an effort to reallocate water resources for a broader national development interest.

2. *Conduct a pilot intermediate reuse project in the Bahr Bagar drain.*

5 FACTORS AFFECTING FUTURE DRAINAGE REUSE

This chapter describes the other factors which potentially affect the drainage reuse in the Delta region, including IIP implementation, new irrigation technologies, rice area reduction, and the Toshka project.

5.1 IIP Effect

Agricultural drains collect various types of water losses from the irrigation system, including percolation losses, canal seepage losses, and canal tail losses (Abdel-Dayem, S., 1998). These losses are affected by the water management and the physical condition of the system.

Egypt has launched an ambitious irrigation improvement program (IIP), which includes the improvement of water delivery system, on farm-water management, irrigation methods and associated agronomic practices. The extension of the IIP programs in the Delta will affect the generation and distribution of drainage water in the region.

IIP programs improve land leveling in crop fields and distribute water more equitably along canals with the continuous flow, which helps decrease the deep percolation. Canal seepage losses on tertiary canal or mesqas will also be reduced through canal lining and automatic gate control in the IIP areas. Canal tail losses, which probably accounts for 25-50 % of the total water losses in irrigation, will be largely eliminated through the night-storage control in the IIP areas. The reduction of excess canal water released to the drains will likely increase the salinity concentration of the drainage water.

In the context of classic irrigation efficiency, the volumes of inflow, crop ET, non-beneficial depletion (evaporation and infiltration losses), and drainage outflow constitute a linear balance equation. Given the inflow, drainage outflow will be a linearly dependent variable of field efficiency in the equation. In a simplified case when non-beneficial depletion is negligibly small, the drainage outflow will be inversely proportional to efficiency. That is to say, every step of efficiency increase will result in a corresponding decrease of drain water volume and a corresponding increase of drain water salinity, depending upon the specific level of the efficiency.

In the Delta region, a 45-60% field irrigation efficiency is a reasonably acceptable estimate. As demonstrated in Table 5-1-1 below, within efficiency levels of 45-60%, every 1% efficiency increase will cause 2.2%-1.7% ET increase, 1.8%-2.4 % drainage volume reduction, and 1.9%-2.5 % drainage salinity increase. Both the ET increase and drainage decrease will be reflected in the reduction of the drain outflow to the Sea.

In the trend of responses in ET, drainage generation and drain water salinity, it is also seen from the table that the higher the efficiency, the less will be ET increase, the more drainage volume will be reduced, and the more drainage salinity will increase. At the efficiencies approaching 60%, ET responds in smaller steps, but drainage generation, both in quantity and in quality, responds in larger steps. This indicates that IIP effort should be first directed to those areas with lower irrigation efficiencies, i.e., areas having excessive irrigation losses.

Table 5-1-1, Drainage Generation on Fixed Inflow and Increased Efficiency

Inflow Q_{in}	Efficiency		Crop		Drainflow		
	E	Efficiency Increased	ET_c	ET_c Increased	Q_{out}	Volume Reduced	Salinity Increased
100	45%		45		55		
	46%	1%	46	2.2%	54	-1.8%	1.9%
	47%	1%	47	2.2%	53	-1.9%	1.9%
	48%	1%	48	2.1%	52	-1.9%	1.9%
	49%	1%	49	2.1%	51	-1.9%	2.0%
	50%	1%	50	2.0%	50	-2.0%	2.0%
	51%	1%	51	2.0%	49	-2.0%	2.0%
	52%	1%	52	2.0%	48	-2.0%	2.1%
	53%	1%	53	1.9%	47	-2.1%	2.1%
	54%	1%	54	1.9%	46	-2.1%	2.2%
	55%	1%	55	1.9%	45	-2.2%	2.2%
	56%	1%	56	1.8%	44	-2.2%	2.3%
	57%	1%	57	1.8%	43	-2.3%	2.3%
	58%	1%	58	1.8%	42	-2.3%	2.4%
	59%	1%	59	1.7%	41	-2.4%	2.4%
	60%	1%	60	1.7%	40	-2.4%	2.5%

As is widely agreeable, irrigation efficiency can be improved by 1-10% in IIP areas. During 1989-97, Egypt has implemented IIP on over 350,000 feddans. According to the GOE plan, IIP will be extended to an area of 3.5 million feddans in the Delta by the year 2017.

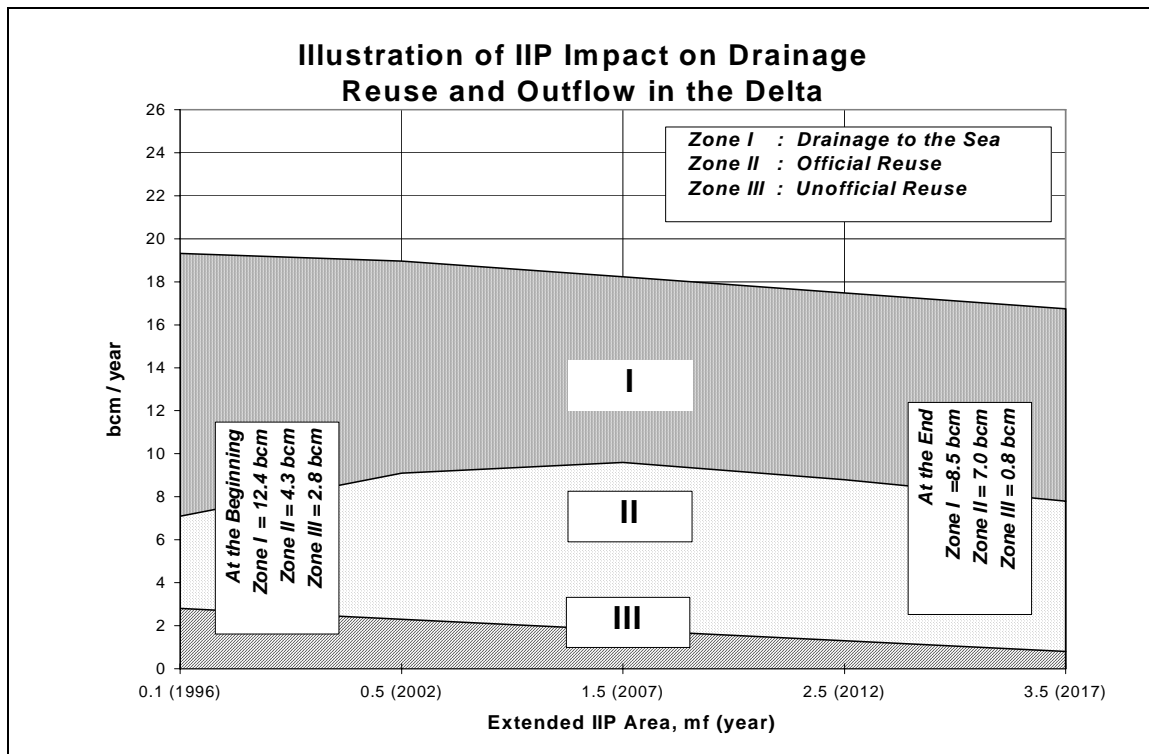
Based upon an average 2% drainage reduction sensitivity and 10% efficiency increase by IIP estimated above, the 3.5 million feddans IIP extension in the Delta will eventually result in a maximum reduction of 2.6 bcm drainage generation from the 1995-96 level of 19.5 bcm (12.4 bcm outflow, 4.3 bcm official reuse, and a Ministry's estimate of 2.8 bcm unofficial reuse).

This 2.6 bcm drainage reduction will affect the volumes of drainage outflow as well as official reuse and unofficial reuse. A precise prediction of the changes in future drainage outflow, official and unofficial reuse is beyond the scope of this report. Instead, Figure 5-1-1 below provides an illustrative picture of IIP impacts on drainage water generation.

As seen in Figure 5-1-1, the three zones represent drainage outflow, official reuse, and unofficial reuse, respectively. Given 2.6 bcm decrease of drainage generation in the future two decades, the drainage outflow would be shrinking from 12.4 bcm of 1995-96 to 8.5 bcm at the completion of IIP extension. The official reuse is assumed to expand from 4.3 bcm of 1995-96 to 7.8 bcm in the first decade, start declining in the second decade, and finally end at a level of 7.0 bcm. The unofficial reuse will continue shrinking, from 2.8 bcm of 1995-96 to an assumed small amount of 0.8 bcm. It is also assumed that part of the increased official reuse would come from the reduced unofficial reuse, like cutting illegal rice drainage irrigation in the Bahr Hadus basin for the official use in Salaam canal. From the beginning to the end of the two decades, there would be 2 bcm unofficial reuse to be re-allocated as

official reuse. The total reuse, including both the official and unofficial reuses, would expand for a while but finally shrink back to the similar scale as in 1995-96.

Figure 5-1-1, Illustration of IIP Impact on Drainage Reuse and Outflow in the Delta



The picture is illustrative only, but it indicates that if the ambitious IIP extension plan will really be implemented, then the currently scheduled drainage reuse expansion will become partially unnecessary, since there would not be so much drain water available for reuse (Abu Zeid, M, 1997). It should also be noted that with increased irrigation efficiency, the decreased drain water will be accompanied by increased availability of freshwater, although how much and where of this availability is not answered in this report.

5.2 Effect of New Irrigation Technologies

Horizontal Drainage and Vertical Drainage

There are two types of drainage system: horizontal (tile drainage) and vertical (tubewell). Horizontal drainage is indispensable for the removal of surface water, and it is effective for water table control and prevention of waterlogging and soil salinization. It has the advantage of low construction and operation costs, and is especially useful for areas with saline groundwater and clay soil without an underlying aquifer suitable for drainage. Its major drawback is the limited depth of water table attainable.

In areas where ground water is suitable for irrigation, vertical drainage by conjunctive use of groundwater for irrigation is an effective means for preventing waterlogging and salinization, and for water conservation (Ellassiouti, I., 1994, Attia, F. and A. Tunihof, 1989). The water

table can be controlled at an optimum depth by adjusting the ratio of water extracted from the irrigation system. Vertical drain systems are particularly useful in areas where shortage of water supply exists.

The selection of drainage type has a profound influence on the composition and layout of the irrigation and drainage system. Tubewell drainage depends on the geo-hydrological conditions of the area. Feasibility of tubewell drainage is limited to aquifers having relatively high transmissibility and to top soils with relatively low hydraulic resistance. Groundwater quality is also an important factor affecting the feasibility of the tubewell drainage. Brackish or saline groundwater, which cannot be used for irrigation, needs to be disposed off from the well field. Groundwater can be used either alone or mixed with surface water.

A vertical drainage system generates very little surface drainage flow and will most likely be free from pollution. The hydro-geological conditions of the fringe areas of the Nile make vertical drain system technically feasible and economically attractive, especially when large capacity wells are installed.

Sprinkler Irrigation and Drip Irrigation

Sprinkler irrigation, drip irrigation, surge irrigation, and automation of irrigation have the potential to provide higher water application efficiency and less drainage generation. At the present, applications of these advanced irrigation techniques remain in small-scale pilot areas in Egypt. However, extending application, first to the new lands and then to the whole of Egypt, may be a desirable trend. Modernization of the nation's irrigation system is the Ministry's main agenda for the coming decades. Its impact on the entire drainage system, particularly the drain system in the Delta, will be significant.

Sprinkler irrigation is effective in leaching excess salts. When properly designed and managed, it allows better water distribution and requires less irrigation supply, compared to surface irrigation. Sprinkler systems may produce a certain amount of surface runoff on relatively impermeable soils, and accordingly, may not be suitable in some cases.

Localized irrigation, such as drip irrigation, can potentially reduce deep percolation losses, permits very high water use efficiency, and results in limited drainage. However, it requires sophisticated maintenance, such as frequent and careful checking to ensure emitters are not plugged. Since drip irrigation only applies water in the area surrounding the plant, salts accumulate easily on the soil surface surrounding the wetted spot. Occasional use of sprinklers to provide salt leaching is commonly suggested for drip irrigation sites.

Application of these new irrigation methods will certainly affect the future drainage pattern. Drip irrigation is suggested for the orchards in Egypt. Currently, there are about 530,000 feddans of orchards under irrigation in the Delta. Surface irrigation delivery to orchards in the Delta is about 5,800 m³ / fed. On average, drip irrigation techniques may provide up to a 50% reduction of irrigation requirement, or a 2,900 m³ / fed canal water savings. Drip irrigation can be managed to produce little drainage. Using a conservative estimate of 20% drainage generation in drip irrigation, drainage generated on drip-irrigated orchard lands will be 580 m³ / fed, a reduction of 1,700 m³ / fed. On the entire 530,000 feddans of orchards, this totals a reduction of 0.9 bcm of drain water. However, it should be noted that to achieve this level of reduction means no intercropping on the orchard floor, which may not be socially acceptable in practice.

It should also be noted that both drip irrigation and sprinkler irrigation are higher frequency methods of irrigation, requiring continuous flow availability in the delivery system, which is not currently available yet in most of areas in the Delta.

Deficit Irrigation and Cyclic Irrigation

Currently, mixing drain water with fresh canal water is the dominant drainage reuse approach in Egypt. Drain water usually has a lower water quality than fresh water in canals, and the reuse mixing process reduces the value of the freshwater. Long-term practice of saline drain water irrigation also results in the reduction of soil permeability and causes top soil crusting. To reduce these negative effects of mixing drainage reuse, research studies have been conducted by the Drainage Research Institute to search alternative drainage management and reuse practices, and among them, the deficit and cyclic irrigation was tested and evaluated on selected sites (Kandil, H., 1998).

Deficit irrigation mainly means to deliberately allow certain degree of water deficit in crops by reducing irrigation amounts at carefully selected crop growing stages. In the Delta case, it means the reduction of drainage reuse in irrigation. Cyclic irrigation means the use of different kinds of irrigation waters in different crop production stages. In the cyclic irrigation pilot project conducted by the DRI, drainage water, without being mixed with canal water, was used in the last few irrigation applications when the crop had stronger salt-resistance capability.

Both the deficit and cyclic irrigation methods have the potential benefits of preserving the value of the limited Nile freshwater, reducing drain water pumping costs, and keeping field soils from M&I wastewater pollution. However, the management of these two irrigation methods is fundamentally very different from the current irrigation practice, and the question of whether these two methods should be immediately extended in the Delta is not fully answered yet.

Deficit irrigation and cyclic irrigation are not without controversy. Successful adaptation of these two methods without serious crop productivity losses will require a very strong technical assistance program. But still, these methods are practiced in many water shortage areas, such as India, Pakistan, and the Texas High Plains in the United States. It is worth exploring the applicability of these two methods in the Delta when water supplies in the region is limited and declining.

5.3 Effect of Rice Reduction

Rice is one of the most controversial crops in Egypt. Farmers favor the crop because of its high production yields and economic returns. Water engineers are more inclined to reduce the area under rice so that the large amount of rice irrigation water can be used for other demands such as expanding irrigation lands. In the context of the potential effect of rice irrigation on drainage generation and reuse, three aspects are of interest:

First, from a drain water reuse point of view, there is a difference between rice planted in the south of the Delta and that in the north of the Delta. In the south, rice irrigation water is consumed only by crop evapotranspiration (ET) and drainage outflow from rice ponding is available for downstream reuse, while in the north, a large portion of the irrigation water is

lost to a salt sink such as saline groundwater, and becomes valueless for reuse. Rice is a land reclamation crop in the north to prevent the seawater intrusion, and rice area reduction mainly applies to the south Delta region. Therefore, only the effect of south Delta rice reduction on drainage generation needs to be evaluated.

Secondly, on average, rice water requirements are about 3,000 m³ / fed more than other crops, and rice irrigation generates larger drainage volumes. The ET rate for rice is 3,738 m³ / fed, compared to 2,662 m³ / fed for maize in lower Egypt (WRSR Publication #26, 1996). In other words, on average, rice consumes 1,000 m³ more water per feddan than other common summer crops in ET production. Accordingly, the drainage reduction by rice area reduction would be about 2,000 m³ / fed. With a possible 500,000 feddans rice area reduction in the southern Delta, the expected decrease of drainage would be about 1 bcm.

Thirdly, rice irrigation, particularly the “unofficial” rice irrigation, uses large amount of drain water and reduces the availability of drain water for other planned national projects. For instance, in 1997 in Bahr Hadus drain basin, rice was the prime crop in an area of 320,000 feddans. This competed with the Salaam canal project on the allocation of the drain water in the drain basin. There is limited freshwater supply reaching that area and the rice plantation relies only on drainage irrigation. The planned drain water diversions to the Salaam canal include 7 mcm/day from Bahr Hadus and 2 mcm/day from Lower Serw. The currently actual flow is only 5 mcm/day in Bahr Hadus and 1 mcm/day in Lower Serw due to the drainage irrigation in rice fields. Since at the present there are only 3,000 feddans irrigated in Sinai, the competition for drain water is not serious yet. However, to accommodate the planned 400,000 feddans irrigation land in Sinai, the drainage water used in rice irrigation in Bahr Hadus must be reduced and re-allocated to the Salaam canal.

5.4 Effect of Toshka Project

The Toshka land reclamation is the largest irrigation project in Egypt after the High Aswan Dam construction. It will affect the Nile’s water allocations downstream to the Mediterranean Sea. This section focuses on the Toshka impact on future drainage patterns in the Delta.

The Toshka project is designed to develop 1 million feddans of arable land in the next 10 to 20 years (Shalaby, A., 1997). The project will be constructed in two phases. Each of them will bring 500,000 feddans under irrigation. At a designed annual irrigation requirement of 8,000 m³ / fed under the local climatic conditions, the project will withdraw 4 bcm of water from Nasser Lake and another 4 bcm from deep groundwater aquifers in the west desert (Advisory Group for the New Valley Pumping station Project, 1998).

For simplicity, the Toshka effect on Nile downstream water allocation is expressed as a 2-4 bcm reduction in current HAD release. To evaluate the Toshka effect on drainage reuse in the Delta, scenarios of 2-4 bcm reductions of HAD release were simulated in a Nile water balance calculation, as shown in Table 5-4-1 below.

With reduced HAD releases, the Nile water available for crop ET must decrease. In order to maintain the crop production at the decreased inflow, intensifying water recycling is the first available remedy option. If intensified drainage reuse cannot close the gap between inflow and ET requirements, then the total ET must be sacrificed to a certain degree by growing less

water-intensive crops. Or, irrigation efficiency must be improved, allowing a smaller per-feddan water delivery. In other words, an intensified reuse and a more restricted water supply scheme will be required. This emphasizes the dual needs for both a drainage reuse program and an irrigation improvement program.

Table 5-4-1, Scenarios of Drainage Reuse & Water Allocations after Toshka Project

	1995-96 Actual Toshka withdrawal = 0 bcml			Scenario #1 Toshka withdrawal = 2 bcml			Scenario #2 Toshka withdrawal = 4 bcml		
	Whole	Valley	Delta	Whole	Valley	Delta	Whole	Valley	Delta
Adjustment Measures									
1) Intensifying reuse									
Reuse in the Delta (bcm)			4.3			6.3			6.3
2) Reducing per-feddan supply									
Irrigated area (mf)	7.97	2.72	5.25						
Crop ET rate (m ³ /f)		5,792	4,132				5,502	3,925	
Irrigation supply rate (m ³ /f)		7,933	6,994				7,536	6,644	
Reduced supply rate by (%)					0%	0%		5%	5%
Water Balance									
System inflow									
HAD release / Nile at Cairo (bcm)	55.5	55.5	35.3	55.5	53.5	33.3	55.5	51.5	32.1
Rainfall (bcm)	1.0	0.2	0.9						
M&I & natural evaporation (bcm)	5.4	3.6	1.8						
Crop ET (bcm)	37.4	15.8	21.7				35.5	15.0	20.5
System outflows									
Drainage outflow (bcm)			12.4			10.4			10.3
Nile outflow (bcm)		35.3	0.3		33.3	0.3		32.1	0.3

Note: shaded cells are unchanged.

The Nile flow passing Cairo is a “bottle-neck” to the flow patterns in the Delta, and therefore, there is a compromise between the water allocated to the Valley and to the Delta. Reuse in the Delta region will have to be increased, but it will be bounded by the maximum reuse potential discussed in Chapter II. The following table summarizes the results.

Observations drawn from the Table 5-4-1 include:

- With a 2 bcm withdrawal for Toshka, if maintaining Valley’s 1996 water allocation (and consequently, its 1996 ET production level), the Nile flow passing Cairo would be reduced by 2 bcm from 35.3 bcm of 1996 to 33.3 bcm. To maintain the 1995-96 ET in the Delta, the official drainage reuse in the region would have to be raised from the 4.3 bcm of 1996 to 6.3 bcm, given the 2 bcm reduction of the Nile flow passing Cairo. The drainage outflow would be reduced from 12.4 bcm of 1996 to 10.4 bcm. Except for the intensified drain water reuse in the Delta, no extra effort would be required, and only the Delta region takes the pressure of the reduced HAD release.

It should be noted that the 2 bcm increase of drainage reuse would be a higher target to implement in a condition of a 2 bcm reduction of inflow. The effort would be as difficult as that of expanding 4 bcm reuse in constant Nile inflow condition.

- With a 4 bcm withdrawal for Toshka, the water delivered per feddan in the Valley would have to be decreased by 5% to maintain a 32.1 bcm of Nile flow passing Cairo (3.2 bcm

reduction from the 1995-96 level). Consequently, a 0.8 bcm of ET reduction would occur in the Valley. In the Delta, the official reuse would be impossible to expand past the level of 6.3 bcm, given another 1.2 bcm reduction of the Nile inflow. Therefore, a 5% decrease of per-feddan irrigation supply would have to be implemented in the Delta. The drainage outflow would be 10.3 bcm, slightly decreased from the previous scenario.

In this scenario, both the Valley and Delta would have to share the pressure of the reduced HAD release and “squeeze” 5% of their per-feddan irrigation supply. The Nile irrigation system would be under a situation more severe than that in the 1980s drought period.

- With the Toshka project, the reuse of drain water in the Delta will have to be maximized. Whether this will be realistically possible remains questionable. Fortunately, Toshka may take 5-20 years for full development, and the required drainage reuse expansion can be conducted in a series of steps, or may be partially replaced by other water management measures, in the course of the next decades.

5.5 Recommended Policy Visions and Actions

This chapter has explored several factors potentially affecting the future drainage generation and reuse in the Delta. Some factors were estimated quantitatively, while the others were only addressed in a descriptive way. And also, it was not possible to analyze the combined effects of these factors with the currently available knowledge and information, and therefore, estimates made in this chapter should be viewed as indicative outlooks only.

The following general *policy visions* on future drainage development in the Delta region are suggested:

1. *Over the next decades, the reuse of drain water may remain as the first supply augmentation measure with its easy handling and low cost. In the long-run, however, with less drain water volume and increasing salinity concentration, the potential for expanding reuse, or even continuing the current reuse level, will be limited.*

The drainage generation and reuse pattern will be altered in the future decades in the Delta by the extension of irrigation improvement projects, new irrigation technologies, and new water management policies such as the reduction of rice irrigation. The Toshka national water project will reduce freshwater supply by taking Nile water away from the Valley and the Delta and requiring reduced per-feddan irrigation supply. The general trend is a reduction of drainage volumes in both outflow and reuse, and an increase of drain water salinity.

2. *While short-term policies for promoting drainage reuse are absolutely necessary to combat the present irrigation demands, the long-term perspective of reduced drain water and the consequent policy changes should also be emphasized.*

A different viewpoint from the current concept of drain water management is to spend effort in reducing drainage generation rather than in reusing drain water. Each cubic meter of drainage water “consumes” more than one cubic meter of freshwater in the “production process”, and efforts to reduce drainage volume by improving irrigation management will increase the volume of available freshwater.

Future financial investment and technical/administrative efforts on drainage reuse should be cautiously reviewed so that the invested efforts in reuse will be synchronized with the changing pattern of drainage generation.

Eventually, there will be reduced drainage water reuse, as other water management options, e.g., IIP-type programs, take firm hold in Egypt. This will be a transforming process from traditional agriculture to modern agriculture.

6 INSTITUTIONAL ASPECTS

The fundamental limitation in planning of future reuse of drainage water for irrigation lies in the uncertainties of future changes in quantity and quality of drainage water as a result of changes in water management.

Drainage water with suitable quality is already diminishing. The fragile base is placed in further jeopardy as more restrictions are placed on drainage water reuse. Unfortunately, existing institutions are not sufficiently responsive to these critical conditions. In this respect, four key issues need to be addressed:

- Improving government institutional capabilities to plan and manage drainage water.
- Introducing sound economic principles and market forces into drainage management.
- Shifting management responsibilities from government to private sector users.
- Expanding private sector services.

This section describes and evaluates the present institutional framework, administrative and legislative, for drainage water management. The involvement of the private sector in drainage services is also addressed.

6.1 Present Institutions for Drainage Management

The land drainage system in Egypt consists of a collection sub-surface or tile drain system and a transport system of open drains and pumping stations. The sub-surface drainage system consists of several million kilometers of field laterals and collectors that are extended throughout the agriculture lands in Egypt. The drainage system has three main objectives: 1) to control groundwater levels in the irrigated field below the root zone and thus avoid water logging, 2) to facilitate the leaching of accumulated salts in the top soil and thus avoid land salinization and 3) to collect excess irrigation water either due to deep percolation or from canal spillage; thereby offering an opportunity for re-use of this water for irrigation purposes.

The development of the drainage sub-sector in Egypt involved several parties; the Egyptian Public Authority for Drainage Projects (EPADP), the Drainage Research Institute (DRI), the contractors, and the end-users or the farmers. EPADP was given the comprehensive responsibility for implementing drainage works. With the need to adapt international drainage technology to the Egyptian setting, the Drainage Research Institute (DRI) was established within the Water Research Center of the MPWWR. The DRI is responsible for carrying out all applied research in the area of drainage engineering and advising EPADP and other departments of the MPWWR.

Several Egyptian contracting companies have actively participated in the construction of both tile or sub-surface drains as well as the construction and renovation of open drains and pumping stations. Execution of tile drainage was started initially by large public sector companies, and gradually, several private sector companies have also evolved.

Although the Egyptian farmers at the beginning have had limited appreciation for the benefits and importance of sub-surface drainage systems, with time, farmers not yet served with the system are requesting installation of tile drains. This follows a plan developed by EPADP.

Egyptian Public Authority for Drainage Projects (EPADP)

In 1973, a Presidential Decree was issued to establish EPADP under the umbrella of the MPWWR to enable the implementation of a wider scope program. EPADP was given comprehensive responsibility for field drainage works including planning of projects, collection of data, preparation of designs, contracting and supervising the installation of subsurface drains, monitoring the impact of drainage, budgeting and operation of project accounts. In addition, EPADP was charged with any remodeling of open drains receiving collected drainage water from subsurface pipe drains and also new pumping stations which may be required on the open drains.

EPADP supports MPWWR's policies in construction, operation, maintenance and rehabilitation of the entire drainage system. The related policies include:

- Construction of sub-surface drainage systems for the remaining agricultural land in need of tile drainage;
- Operation and maintenance of the open drains and sub-surface drainage system already installed. Serious consideration is given to the involvement of farmers for operation and maintenance at the farm level through a drainage user's association;
- Rehabilitation of systems previously installed and where their function is impaired or maintenance is becoming excessively costly;
- Continue to search for optimum drainage means; e.g. vertical drainage of newly reclaimed and affected areas;
- Control of the execution of tile drains to keep construction cost to the minimum; yet ensure meeting the annual construction targets;
- Cost-benefit analysis of alternative ways of expanding the available drainage systems;
- Cost-recovery of the installed drainage systems by beneficiaries;
- Developing human resources in EPADP to be able to achieve the cited policies; and
- Enforcing laws and regulations related to agricultural drainage system and drain water quality.

Drainage Research Institute

The Drainage Research Institute (DRI) was established in 1976 to carry out all applied research in the area of drainage engineering to be able to advise EPADP and other departments of the MPWWR on issues related to the drainage system and drainage water. The DRI is one of the 12 member institutes of the National Water Research Center, the research arm of the MPWWR.

Most of the research activities of DRI relate to the establishment of pilot research areas where drainage design criteria, materials, and construction methods are tested under different conditions. In addition, performance of already installed systems is monitored and evaluated in a number of selected survey areas.

The DRI has also been heavily engaged on research related to the re-use of drainage water. The relationship between EPADP and DRI has been developed into a collaboration based on “mutual benefit”.

Contractors

At the start-up of EPADP, sub-surface drainage works were carried out on a limited scale mainly using manual methods. Mechanized construction methods were introduced to install PVC laterals and concrete collectors by several public sector companies. With time, more public sector and private sector contractors began working in the field. The private sector companies started work in this field as sub-contractors (for labor) to public sector main contractors and then later executed full projects on their own. To facilitate this, EPADP supplied contractors, when necessary, with drainage machinery to execute its projects. Contractors paid the machinery and negotiated with suppliers for better prices.

Contractors now have their own machinery and sometimes rent equipment to each other. Egyptian Contractors are now experienced in installing subsurface drainage systems using modern laser guided machinery. Because management style and efficiency varies among contractors, EPADP frequently holds meetings with contractors to solve problems. Contractors facing delays on a project are denied new contracts. Contractors are able to maintain technical staff to operate and maintain the drainage machinery. Occasionally ex-engineers and technicians from EPADP have gone to work with contractors because of better salaries or after retirement.

Farmers

The direct beneficiaries of the drainage works are the farmers. Under the Egyptian law farmers are to pay for the system costs over a 20-year period without interest starting one year from system completion. The costs include: 1) capital cost of subsurface drainage works, 2) 10% of administrative fee, and 3) crop damage compensation during drain installation. The mechanism for cost recovery is rather complex and three agencies are involved; namely, EPADP which implements the system and prepares statement of actual cost; the Survey Department of MPWWR which verifies the areas held by each beneficiary, and the Land Tax Directorate of the Ministry of Finance prepares bills. In fact, farmers are not yet charged for the maintenance costs of the field tile drains. The Government still pays for the de-weeding and de-silting costs on main open drains.

Farmers understand the problems of salinity and water logging, especially in Fayoum and the Delta regions. However, often they are not able to properly operate and maintain a system or prevent these problems. The field engineers of EPADP offer advisory service and visit farmer communities very often.

There hasn't been much effort in evaluating the effect of drainage advisory services on farmers' field behavior. And also, there has been little (if any) effort in public drainage management education on radio and/or TV.

No detailed information is available on individual small farmers. This makes it necessary to deal with groups of farmers, which may facilitate determining the responsibility of drainage system establishment and maintenance. At the present, farmers' associations and/or farmers groups for drainage management have not yet been established.

To improve cooperation between EPADP and farmers, farmers should be encouraged to participate in drainage construction. This is essential, especially in rice areas and areas with crops which need intensive irrigation. A procedure for farmers to officially complain to EPADP is established but does not function sufficiently yet.

6.2 Present Administrative Framework

In Egyptian Government, water management is organized in a way that each type of water use is handled by an individual ministry or agency. Water quantity issues and water quality issues (including health and environmental concerns) are managed in different governmental departments. This has aroused the needs for better coordination in decision-making.

Under Law 12/1984, the *Ministry of Public Works and Water Resources (MPWWR)* has the overall responsibility for appropriating and distributing water and for managing drainage, groundwater and the Mediterranean coastline. In addition, under Law 48/1982, the Ministry has the responsibility for controlling the inflow of pollutants into public waterways, and the EPADP implements and enforces these laws on drainage water.

The *Egyptian Environmental Affairs Agency (EEAA)* has a coordination role in all aspects of environmental protection, such as legislation, environmental impact assessment, monitoring and dissemination of information.

The *Ministry of Agriculture and Land Reclamation (MALR)* is responsible for policy development and implementation on farm production and cropping patterns. Within the MALR, the Executive Agency for Land Improvement Projects (EALIP) and the Public Authority for Land Reclamation in New Valley and other desert areas (PALR) are involved in water conservation. The General Authority for Rehabilitation Projects and Agricultural Developments (GARPAD) is responsible for the design and implementation of desert reclamation schemes which are subsequently transferred either to Public Sector Agricultural Companies or (during the last years) the private sector. The Agriculture Research Center (ARC) includes 16 research institutes, 5 laboratories, and 36 research stations. Among the institutes, the Soil and Water Institute has a research capability in land improvement by increasing drainage efficiency and optimizing water use.

The National Organization for Potable Water and Sanitary Drainage (NOPWASD) of the *Ministry of Housing, New Communities Construction and Public Utilities* is responsible for planning, design and construction of the drinking water and sanitation system, including water supply and sewage treatment. For greater Cairo, Alexandria and the Suez Canal Cities special organizations have been formed (semi-autonomous Authorities).

The *Ministry of Health* is responsible for setting standards for potable water sources, drain water that is mixed with other water and discharges from municipal and industrial treatment plants and from river vessels. It is also entrusted with the monitoring of municipal and industrial effluents.

Under the *Ministry of Industry*, the General Organization for Industry (GOFI) is responsible for planning the prevention or treatment of industrial effluent. Other ministries with an interest or role in water resources management are the *Ministry of Transport and*

Communications (navigation requirements, disposal of oil and waste from river vessels), the *General Authority for Fish Resources Development* (under the MALR), the *Ministry of Electricity and Power Production* (discharge of hydropower cooling water) and the *Ministry of Tourism* (floating hotels and tourist vessels).

To ensure proper coordination among the Ministries involved in the water sector, two committees have been established : the *Supreme Committee of the Nile* and the *Inter-Ministerial Water Planning Committee*. The first is supposed to meet on a monthly basis to direct and review different development plans as well as to resolve conflicts; but meetings are irregular and its effectiveness in maintaining coordination among concerned ministries is limited. The latter Committee supervised the work of the UNDP/WB financed Water Master Plan study. Policy is made in the MPWWR by upper level management, by Committees and by Boards of Directors of Authorities within the Ministry.

6.3 Present Laws and Decrees Controlling Water Quality

The legal framework for water quality management is established in a number of laws and decrees (Elassiouti, I., 1995), of which, the most important are:

- Law 93/1962 concerns drainage of liquid waste, implemented by ministerial decree 649/1962 and 9/1989 (Ministries of Housing and Utilities). These decrees regulate the discharge of wastewater into sewer systems. The part of decree 649/1962, that regulated drainage to watercourses, was replaced by law 48/1982. The ministerial decrees specify standards for liquid waste disposal to sewers, for use in irrigation, and in case of applications to the land;
- Law 48/1982 involves the protection of the River Nile and waterways for pollution, implemented by decree 8/1982 of MPWWR. This law defines various types of waterways and regulates the discharging of liquid wastes in waterways, MPWWR is made responsible for the licensing of wastewater discharge, whereas the Ministry of Health is responsible for monitoring. The decree specifies standards for the disposal of wastewater under different conditions and for receiving water;
- Law 12/1984 on irrigation and drainage regulates the use of water, including groundwater. It also regulates the operation of mesqas and drains and water lifting devices. It assigns water allocations by setting priorities between users, beneficial and harmful use of water, financial aspects and penalties; and
- Law 4/1994 on Environmental Protection describes the tasks of the EEAA, provides general rules for the protection of the environment and regulates air pollution and the use and protection of the marine environment.

Other laws are more specific, for example Law 27/1982 regulating public water resources used for drinking and domestic use and ministerial decree 2703/1966 of the Ministry of Health, establishing the Supreme Committee for Water. This committee has to set standards for drinking water, swimming, etc. and has to approve water treatment projects. Ministerial decree 380/1982 of the Ministry of Industry requires new industries to include equipment to prevent pollution in the technical specifications of the project.

6.4 Need for Institutional Changes in Drainage Management

The analysis of the specific features of drainage water management in the Nile Delta indicates that:

- Conflict of responsibilities. The Law 4/1994 stipulates that EEAA supervises and operates the national monitoring network, for which an environmental information center will be established within EEAA. The Law 48/1984 assigns the same responsibility to MPWWR. This also calls for the reliance on different institutions for basic data sampling, processing and storage.
- Lack of law enforcement. At present there is lack of capacity within the MPWWR to enforce the laws and regulations dealing with water quality. Government-owned enterprises, considered the main polluters, get special treatment on the basis that the government cannot fine them or force their closing.
- Unofficial reuse. The pressing need to increase the availability of irrigation water and to improve the efficiency of its use has resulted in more drainage water being mixed with freshwater from the Nile branches and irrigation canals. Currently, about 4.2 billion cubic meter per year of drainage water which was originally flowing from the Delta to the sea is mixed with fresh water through official pump stations operated by the Ministry of Public Works and Water Resources. The volume of drainage water officially reused will reach up to 7.0 bcm after the completion of the Salaam canal and the Umoum drainage projects. Another estimated 4.0 bcm is currently being used unofficially by farmers abstracting water directly from open drains close to their fields in order to satisfy water needs for different crops, especially rice. This unofficial use results in a shortage of drain water for existing and planned centralized reuse projects, and therefore, it is necessary to find proper means to regulate flows in main drains.

The Government of Egypt has already established some initiatives to improve the current drainage water management. This includes the establishment of:

- the High Committee for the Nile, chaired by the Minister of MPWWR and comprised by representatives of MOI, MALR, MHPU and MEE, is responsible for the protection of the Nile system in terms of its quality and quantity;
- the National Water Quality Conservation Unit (NWCU), which responds to the need of better information on water quality, is the focal point on water quality information in Egypt and aims to serve as a bridge between generators of data and users of information;
- the National Water Quality Conservation Program Advisory Committee, instituted to guide the program of NWCU and includes representatives of the several government bodies dealing with water quality matters, e.g. EEAA, DRI, RIGW, NRC agencies;
- an environmental impact assessment is now required for the operation of industrial and waste water treatment plants;
- a Central Directorate for Waterways Maintenance, under the Irrigation Sector of MPWWR, has the responsibility for issuing permits or licenses for municipal and industrial wastewater discharges according to Law 48 of 1982. This Directorate

supervises irrigation and drainage use to prevent unnecessary aggression from other parties and to carry out necessary follow-up legal actions; and

- a Water Awareness Unit, connected to the Minister of Public Works and Water Resources office, has responsibilities for raising public awareness about water scarcity and risks generated by polluting water resources.

6.5 Private Sector Participation in Drainage Service

Partnerships between private and public sectors have recently emerged as a promising way to improve the performance of the network, expand service coverage, raise the quality of service and increase operating efficiency. Private sector and farmer's organization involvement also provides alternative mechanisms of financing infrastructure investment and reducing the burden on public budgets.

For the Nile River system, the private sector's involvement in management will take time, probably a lengthy and slow process. Each party in the current management system will try to defend its ideas and interests. For this reason, the formulation of the expected institutional and financial interrelationships in the management of the irrigation and drainage system stands, at this stage, as one of the most important issues to be studied, investigated and discussed so that each party's role can be as clear as possible and won't contradict each other.

A middle road between continued government ownership and complete privatization might be possible. This could involve transfer of the current irrigation and drainage system to a self-sufficient but non-profit public authority. This approach

- develops responsibility for certain operational, maintenance and fee-collection tasks to farmers;
- increases corporate revenues by raising fees, improving collections, and generating secondary income from ancillary activities;
- reduces operating costs through a series of minor economies and through major cuts in the personnel budget; and
- provides financial incentives for superior performance to outstanding field units and to individuals in them.

A full privatization of the Egyptian irrigation and drainage system is hard to advocate. However, a general skepticism concerning the efficiency of large public bureaucracies suggests that consideration be given to the mechanisms (such as public authority) that will increase farmer share of expenses while improving agency responsiveness to actual farmer needs.

6.6 Incentives for Drainage Water Quality Management

There are two sets of instruments for water quality control: command and control instruments, and market-based incentives (Cestti, R. E., 1995). Although in the past the GOE has relied mainly on the former, it seems that now attention is being given to the latter

approach. Next paragraphs describe the set of instruments already in use under each approach.

Command and Control Instruments

They include any regulation that imposes constraint regarding water use, water using technologies, and effluent discharges. Among the instruments being used at present in Egypt, there are the following:

Regulations. The Law 48 of 1982 has formulated concentration-based water quality standards for effluents and fresh and saline water bodies. The standards established in the Law are as follows:

- Fresh water bodies receiving treated industrial effluent;
- Treated industrial effluent being discharged into fresh water bodies and groundwater reservoirs. There are different standards for the Nile river, its canal system, and groundwater sources.
- Treated industrial effluents for volumes less than one hundred cubic meter per day.
- Drainage water to be mixed with fresh water for irrigation purpose.
- Municipal and industrial effluents discharging into brackish or saline water bodies,
- Brackish or saline surface water bodies receiving treated municipal or industrial effluents.

Since the standards are concentration-based and not pollution load-based, many industrial firms have resorted to dilution as a means to comply with the law -- a solution which conforms to the Law without any beneficial impact on pollution levels.

Although water resources are used for different purposes (drinking, irrigation, and fishing), quality standards for receiving water bodies are similar across the border. As a result, some watercourses are subjected to looser standards, while others are subjected to stricter ones. Thus, some efforts should be directed to classify water bodies according to their potential use.

Penalty Fees. The Law 48 of 1982 stipulates penalty fines for non-compliance with the Law, which range between small monetary sums (LE 500 to LE 2,000) to imprisonment

Environmental Impact Assessment. The New EPL proposes the implementation of a new instrument for pollution abatement: requiring Environmental Impact Assessment (EIA). The EIA will be a prerequisite for all new establishments applying for licenses or for existing establishments looking for expansion. According to the New Environmental Protection Law, nine Ministries are responsible for the preparation of the EIA and upon completion they should be forwarded to EEAA for approval.

Market-Based Incentives

These include any measure that acts as an incentive for water users and polluters allowing them to determine the most efficient and effective means for water use and pollution abatement pattern. The 1994 Environmental Protection Law provides a number of financial incentives aiming to control pollution of water sources.

Environmental Fund. With the establishment of this fund, money from different sources will be made available for environmental protection projects. Regarding the water sector, the fund will provide soft-loans to industrial firms for pollution abatement projects such as recycling and reuse of treated effluents as well as for setting up small-scale pilot demonstration projects.

Effluent and Sewer Charges. EEAA is already in the process of studying other economic instruments, namely effluent and sewer charges, which are suitable for the Egyptian context.

6.7 Recommended Policy Visions and Actions

In the long-run, the following *policy visions* on institutional changes will be needed to improve the drainage water management in Egypt:

1̇ *Promote cost recovery of drainage maintenance and operation and encourage the participation of stake-holders in drainage management.*

The Ministry currently holds the responsibility for managing the national irrigation and drainage system, from Aswan to the Mediterranean Sea. Drainage services are provided at no charge to farmers, who may discharge unlimited volumes of surface runoff and subsurface drain water into regional drainage ditches. As a result, farmers receive the benefits of drainage service without paying for the operation and maintenance costs of the national drainage system. Similarly, municipalities and industries have little incentive to limit their discharges of wastewater, when the incremental cost of abatement exceeds the low price (or zero price) for discharging effluent into agricultural drainage system.

This entire situation needs to be changed to transfer the direct cost of operating and maintaining the national agricultural drainage system from the MPWWR to the farmers who receive the benefits of drainage services. A volumetric drain water pricing program would provide the most direct incentive for reducing drain water volume, but the cost of implementing such a program is prohibitive. An average cost program that includes a per feddan charge for drainage services is likely the most appropriate program to implement at this time. The charge may vary among regions as a function of differences in regional operation and maintenance costs.

2̇ *Encourage the involvement of private sector in drainage services.*

Privatization of local and regional drainage services can be encouraged by providing farmers and water user associations with the option of operating and maintaining local and regional drains, while paying reduced charges (or no charges) to the Ministry for provision of drainage services. It is likely that farmer organizations, or the contractors they employ, can operate and maintain drains at a lower average cost than the Ministry does for drainage services. It is also likely that markets for the provision of drainage services will arise when farmers are provided the opportunity to operate and maintain drains in return for reduced drainage charges.

The concept of privatization can be extended to include larger drains as private institutions for operating and maintaining. The appropriate role for the Ministry, regarding drainage management, is to establish and enforce appropriate water quality criteria that protect human and environmental resources. The operation and maintenance of drains and associated pumping stations should be conducted by farmers and their contractors, as they are most likely to perform those tasks at minimum cost.

7 CLOSING REMARKS

Drain water has been viewed in Egypt as a resource that can be used to augment the supply of fresh water from the Nile River system. Substantial capital and management resources have been invested in the construction and operation of reuse mixing pump stations for blending drainage water with canal freshwater deliveries at various locations.

In the long-run, will this be changed? As discussed in Chapter V, with improved water management, new irrigation methods, changed crop mix, horizontal land expansion in Sinai and Toshka, and other possible reasons, the current drainage generation and reuse pattern in the Delta will be gradually but substantially altered in the future. The general trend will be the decrease in drainage flow and the increase in drain water salinity.

A different viewpoint from the current concept of drain water management is to spend effort in reducing drainage generation rather than in reusing drain water. Each cubic meter of drainage water “consumes” more than one cubic meter of freshwater in the “production process”. Efforts to reduce drainage water volume by improving irrigation management will increase the volume of freshwater available for delivery and reduce the volume of the water that must be managed, recycled, or discharged to the Mediterranean Sea. And also, the smaller volume of drainage water will require smaller expenditures for operation and maintenance of the drainage system.

The efficiency and productivity of Egypt’s water resources may be enhanced by changing the perspective that drainage water is a resource for augmenting irrigation supply to a view that drainage water is an effluent causing negative environmental impacts and imposing direct and indirect costs to be borne by farmers, municipalities, industries and general public.

Drainage water volume can be reduced by providing farmers with correct incentives to improve water management. Appropriate policies include water pricing, institutional, and financial incentives for implementing improvements. It is essential that efforts to reduce drainage water volume are supported by policies that provide farmers with clear economic incentives regarding the relative scarcity of water resources and the direct and indirect costs of providing drainage services.

In the future decades Egyptian water engineers may go through a transition from the current drainage-reuse philosophy to a drainage-reduction philosophy. While short-term policies for promoting drainage reuse are absolutely necessary to combat the present irrigation demands, the long-term perspective of reduced drain water and the consequent policy changes should also be emphasized.

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