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ARAB REPUBLIC OF EGYPT
THE MINISTRY OF HOUSING AND RECONSTRUCTION

Alexandria Wastewater Master Plan Study

VOLUME II
TECHNICAL REPORT

Camp Dresser & McKee Inc.
International Division

with Chas. T. Main International Inc.
Arab Technical and Economical Consulting Office

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This Master Plan Consists of Four Volumes:

I SUMMARY REPORT

II TECHNICAL REPORT

III APPENDICES

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CHAPTER 1

INTRODUCTION

1.1 Purpose and Scope of Study

This study was undertaken to develop a Facilities Master Plan for the wastewater collection, treatment, and disposal system of Alexandria. The study addresses the absence of sewerage in developed and developing areas, problems in operation and maintenance of the existing system, pollution of major surface waters, and poor public health conditions in many sections of the city. Using the most recent planning techniques and the principles of environmental engineering, a program is proposed for the period extending from the present to the year 2000. The original scope of work included the following major elements:

- a detailed assessment of existing facilities and conditions in the urban Alexandria study area.
- determination of factors which affect the design of existing system improvements and the development of new facilities.
- determination of necessary oceanographic studies and conduct of other field studies.
- selection of a preferred plan after evaluation of each of the feasible alternative plans and interim plans, taking into account economic and functional constraints.
- selection of Top Priority Projects for immediate construction and selection of a feasible first stage construction program.
- preparation of conceptual designs and cost estimates for the recommended works.
- developemnt of a sound program for the implementation of the proposed plan.

The program was to be a compromise which would satisfy the requirements for improved wastewater disposal and, at the same time, avoid unacceptable economic, financial, social,and environmental impact. A major objective was the determination of an early construction program, which would provide maximum benefit to the study area and still be consistent with the long range planning goals.

1.2 Study Amendments

Four amendments to the original contract have been made. These amendments have provided:

1. Funding of this study by the United States Agency for International Development.
2. Procurement and installation of laboratory equipment and supplies for a project laboratory to become the property of GOSSD.
3. Extension of the study area to include the whole of the Alexandria Governorate; extention of the study scope to include economic and financial feasibility studies for the initial program; and extension of the study scope to include detailed marine studies.
4. Extension of the study scope to include an environmental impact statement according to the requirements of USAID; and extension of the study scope to include a program-defining survey of the disposal problem of waste solids and liquids that will be excluded from sewers under a new sewer use ordinance.

The Master Plan Report for Alexandria wastewater facilities is presented in four separate volumes.

Volume I - Summary
Volume II - Technical Report
Volume III - Appendices (to the Technical Report)
Volume IV - Marine Studies

Completion of the marine studies, the environmental impact statement, and the excluded waste survey will occur in mid 1978, at which time separate special report documents will be submitted.

1.3 Top Priority Projects

The Top Priority Projects (TPP) were defined during the Master Plan studies as immediate works needed to correct problems in operation, maintenance, and facility inadequacy, to improve the existing system and to provide sewer service in several developed areas where there are no sewers at present. The recommended TPP work was divided into four categories:

Category I - institutional changes
Category II - repairs and replacement in the existing system
Category III - new service in specified unsewered areas
Category IV - new construction needed to adapt the existing system to the Master Plan.

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The objective of the Top Priority Projects was to enable necessary sewerage work to begin before the completion of the Master Plan Report. Two TPP programs were developed: the first was a full program which included work in each of the four categories over the period 1977-1981. The estimated costs were beyond the short-term financial capabilities of the Ministry and the commitments of USAID, so a second reduced program was developed, tailored to a foreign exchange cost estimate of (US) $15 million. This program will complete all of the work outlined in Category IV, on the basis of item costs. Funds for the reduced TPP program have been committed and design, construction, and implementation commenced in March, 1978. Those items of work defined originally in TPP, but not included in the reduced program, have been included in the Facility Master Plan recommendations.

1.4 Previous Reports

In accord with the terms of the contract, reports on the progress of the study have been submitted, as described below:

- Special Report Number 1 (Oceanographic Studies), 28 February 1977, presented a recommended scope for a marine survey. An extensive oceanographic study has been undertaken, as a result of the report.
- Special Report Number 2 (Existing System Inventory), 26 April 1977, contained a compilation of information on the existing system of gravity sewers, pump stations, force mains, and treatment plants.
- Special Report Number 3 (Background Studies and Design Criteria), 1 May 1977, presented studies pertinent to the Master Plan work and the development of criteria for alternative facility plans.
- Interim Report (Top Priority Identification), 13 July 1977, tentatively defined and described the recommended immediate phase of work.
- Special Report Number 4 (Top Priority Projects), 15 August 1977, defined works for immediate implementation, comprising repair, reconstruction, and rehabilitation of parts of the existing system and provision of new sewers in a developed area where sewers do not exist. Included were cost estimates, financial feasibility evaluation, and management recommendations.
- Master Plan Status Report 1, 16 July 1977, described the progress of Master Plan studies up to date of issue and defined alternative plans being considered.

- Master Plan Status Number 2, 8 November 1977, included preview of the Facilities Master Plan recommendations and contained draft of several technical report chapters, preliminary evaluations of alternatives, and a description of the tentatively selected plan.

1.5 Acknowledgements

Grateful acknowledgement is expressed to the following agencies and especially to the personnel within those agencies for their help and assistance in this study effort:

Alexandria Governorate
Alexandria University, Faculty of Engineering
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Alexandria University, High Institute of Public Health
Alexandria Water General Authority
Central Agency for Public Mobilization and Statistics
Department of Housing, Alexandria Governorate
Food and Agricultural Organization
General Organization for Sewerage and Sanitary Drainage
International Bank for Reconstruction and Development
Ministry of Irrigation, Cairo, Alexandria and Damanhour
Ministry of Housing and Reconstruction
TAMS, Engineering Consultants to MOHR
United States Agency for International Development
World Health Organization

1.6 General Notes

No standard English spelling exists for many Arabic place names, as transliteration of Arabic sounds into English varies from one source to another. A standard spelling for each place name has been adopted to represent approximate Arabic sounds in current English and, where possible, to indicate common usage.

The standard international metric system of weights and measures is used throughout this report. An Egyptian unit of measurement, the feddan (0.42 ha) is also used. The Egyptian Pound is indicated by the abbreviation LE, taken at the tourist rate of LE 0.70 = US $1.00. All elevations are based on mean sea level at Alexandria (Western Harbor Tide Gauge).

Elevations below mean sea level are expressed as negative values.

Megalitres per day (ML/day) often replaces the more common term cubic metres per day (m^3/day) due to the magnitude of wastewater flow. One megalitre equals 10^6 litres, so that 1 ML is equivalent to 1000 m^3. Megalitres per day can be converted to the common US unit of flow, MGD, by dividing by 3.785.

A list of acronyms, metric units, and abbreviations used in this report follows.

Acronyms

ATECO - Arab Technical and Economical Consulting Office
AWGA - Alexandria Water General Authority
CAPMAS - General Agency for Public Mobilization of Statistics
CDM - Camp Dresser & McKee International Inc.
GOSSD - General Organization for Sewerage and Sanitary Drainage
MAIN - Charles T. Main International Inc.
MOHR - Ministry of Housing and Reconstruction
USAID - United States Agency for International Development

Metric Units

cm - centimetre
cm^2 - square centimetre
gm - gram
ha - hectare = 10 000 m^2
hr - hour
hp - horsepower
kg - kilogram
km - kilometre = 1000 m
km^2 - square kilometre = 100 ha
kt - knot
kW - kilowatt
kWh - kilowatt-hour (power)
L/c/d - litre per capita per day
mm - millimetre
m - metre = 1000 mm

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m^2	-	square metre
m^3	-	cubic metre = 1000 litres
m^3/sec	-	cubic metre per second
mg/L	-	milligram per litre
mmho/cm	-	micromho per centimetre
ML	-	megalitre = 10^6 litres = 1000 m^3
ppm	-	parts per million
tonne	-	metric ton = 1000 kg
sec	-	second

Abbreviations

ADWF	-	average dry weather flow
BOD_5	-	biochemical oxygen demand (5-day)
CIF	-	import price (dock delivery)
COD	-	chemical oxygen demand
DFEC	-	direct foreign exchange component (of cost)
DO	-	dissolved oxygen
DWF	-	dry weather flow
dwt	-	dry weight tonnage
FOB	-	export price
HWL	-	high water level
IFEC	-	indirect foreign exchange component (of cost)
LCC	-	local currency component (of cost)
LE	-	Egyptian Pound
MPN	-	most probable number (coliforms)
MSL	-	mean sea level
No	-	number
pH	-	logarithm of reciprocal of hydrogen ion concentration
PDWF	-	peak dry weather flow
pt	-	Egyptian Piaster = LE 0.01
SS	-	suspended solids
TDS	-	total dissolved solids
C	-	degrees celsius
%	-	percent
$	-	United States Dollar = LE 0.70 (at parallel or "tourist" rate)
Ø	-	nominal diameter (of pipe)

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CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

2.1 General

Provision of improved, adequate, and effective sewerage facilities for Alexandria to meet the needs of the area through the year 2000 poses challenging problems, both technical and financial. The task is of such magnitude as to necessitate a staged construction program for the many individual projects needed over the next 23 years. This report presents results of comprehensive study of the technical problems and practical solutions in the form of a Recommended Wastewater Facilities Master Plan. The plan constitutes the framework within which individual projects may be funded, scheduled, and constructed with confidence in the technical integrity, logic, and effectiveness of each toward attainment of the ultimate product: adequate sewerage facilities in Alexandria.

The recommended plan, if fully implemented, will provide the necessary collection, treatment and disposal facilities required to adequately handle sanitary wastewaters of the area through attainment of the following specific objectives:

1. Elimination of surface drainage of untreated sanitary and industrial wastewater by providing necessary sewers, collectors, pump stations, and appurtenances for underground collection and conveyance of the wastewaters to treatment facilities and points of disposal.
2. Elimination of overflow, or other discharge of untreated sanitary wastewater or combined runoff up to at least three times average dry weather flow to the beaches or near-shore waters of the Mediterranean Sea, Abu Kir Bay, and the harbors of Alexandria.
3. Treatment of collected sanitary and industrial wastewaters to a degree which will assure proper operation of disposal facilities and/or will allow discharge to receiving waters or land mass of the area without stressing natural purification processes, resulting thereby in maintenance of an acceptable steady state condition in the environment.

4. Elimination of troublesome flooding during wet weather of certain key areas of the city that are important to commerce and transportation.
5. Accomplishment of the above objectives with maximum use of existing facilities and processes of nature and with minimum adverse impact on the social, natural, and financial resources of Egypt.

2.2 Existing Conditions

The discharge of an estimated volume of 570 000 m^3/day of predominantly raw sewage (less than 15 percent of all wastewater flows receive any form of treatment) to Lake Maryut and along the shoreline of the city's Mediterranean beaches creates serious health problems, causes extensive pollution of the receiving waters, and results in considerable nuisance and noxious odors throughout Alexandria.

The existing sewer system, serving the central area of Alexandria from Maamoura in the east to Gabbary in the west, covers an area of approximately 4300 ha. The system comprises approximately 1500 km of street sewers, 150 km of interceptors, 30 km of force mains, and pump stations of varying capacities. Also included are the East Sewage Treatment Plant (limited secondary level) with a capacity of 65 ML/day and the West Sewage Treatment Plant, now under construction, at a projected capacity (primary level only) of 85 ML/day.

The system is divided into three zones: Central, East, and West. Sewage from the Central Zone is either pumped to the sea through a poorly functioning outfall at Kait Bey or overflows directly into the Eastern and Western Harbors. East Zone flows are conveyed by sewer or open drain to either the East Plant, located near the Hydrodrome for partial secondary treatment, or discharged as raw sewage to the Smouha Drain. Wastewaters from the eastern area,after passing through several kilometres of open drains, enter Lake Maryut and are subsequently discharged to the Western Harbor, with the exception that wet weather overflows occur at shoreline discharged points along the Mediterranean from Silsila to Montazah. In the West Zone, raw sewage from areas north of the main ridge flows directly into the Western Harbor, while to the south, the sewage drains to the main lagoon of Lake Maryut via sewers and open channels.

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The existing collection system is often overloaded during times of wet weather as it is essentially a combined (sanitary sewage and stormwater runoff) system. Extensive portions of the sewerage system are operated in surcharged condition much of the time even during dry weather. Overflows exist at many locations, discharging either to the sea or to nearby surface drains.

The strength of Alexandria sewage is unusually high in comparison to the normal range found in many urban wastewaters, as shown below:

Constituent	Wastewater Strength, mg/L Normal Range	Alexandria
Suspended solids, SS	180 - 240	300 - 1100
Oil and Grease	80 - 120	150 - 1400
Biochemical oxygen demand, BOD_5	175 - 250	340 - 1100
Chemical oxygen demand, COD	450 - 600	740 - 3280

The existing system is plagued by many operational problems, many of which could be alleviated by enforcement of the existing sewer use law. Large quantities of such materials as garbage, trash, mazout residue and other oils, toxic industrial wastes, cow manure and septage from holding tanks, are illegally dumped into the system which results in reduction in flow capacity, and ultimate blockage of the sewers, as well as difficult biological treatment conditions, fire hazard, and increased pollution loads on the receiving waters.

The existing collection and conveyance system is functional from a hydraulic standpoint and can be effectively utilized as an integral part of any future wastewater master plan program, if:

1. deficiencies of structure and capacity are corrected,
2. serious abuse of the system is mitigated through enforcement of a strong sewer use law, and
3. it is operated in the manner for which the system was designed.

Water quality along the Mediterranean shore at Alexandria, especially at the Western Harbor, eastern beaches, and Abu Kir Bay is poor due to the discharge of raw sewage, industrial wastes, and surface drainage of the area. Inland waters, primarily those of the Lake Maryut main lagoon, the lower reach of the Mahmoudia Canal, the full length of the Montazah Canal, and Kalaa and Abu Kir Drains are also polluted by wastewater discharges from domestic and industrial activities.

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The current state of public health in Alexandria is found to be very poor, due, in part, to lack of facilities for maintaining adequate sanitation. An expanded program for effective collection and disposal of the city's wastewaters must be implemented soon, as a basic step toward improvement in the status of public health.

2.3 Planning Projections

Population of Alexandria is increasing at an annual rate of approximately 2.8 percent due to natural growth rate and in-migration. It is expected that by the turn of the century about 5.3 million people will reside within the Governorate boundaries. This includes 600 000 temporary residents during the summer holiday season as well as 4.7 million permanent inhabitants.

By year 2000, total population within the area is expected to be distributed as follows:

	Population	
Area	Present	Year 2000
Central	1 400 000 (56%)	1 800 000 (34%)
Eastern	750 000 (30%)	2 300 000 (43%)
Western	350 000 (14%)	1 200 000 (23%)
TOTAL Population	2 500 000(100%)	5 300 000(100%)

Projections of average daily wastewater flow, which will require adequate collection and disposal are as follows:

	Flow, m^3/day	
	Present	Year 2000
Domestic & Commercial	280 000 (49%)	720 000 (49%)
Industrial wastes	230 000 (40%)	650 000 (45%)
Institutional & Other	60 000 (11%)	90 000 (6%)
TOTAL Flow	570 000(100%)	1 460 000(100%)

Constituent concentration of future domestic and industrial wastewater is expected to remain at much the same level as is present today with only slight increase in the strength of industrial wastes as a result of in-plant water conservation practices and new manufacturing processes. Indication of expected average waste load increase is given by five-day biochemical oxygen demand as follows:

	BOD_5 Load, kg/day	
	Present	Year 2000
Industrial wastes	145 000 (48%)	455 000 (55%)
Domestic & all other wastes	155 000 (52%)	365 000 (45%)
TOTAL Load	300 000(100%)	820 000(100%)

2.4 Engineering Considerations

Alexandria soils provide few constraints in consideration of normal methods of trench excavation and foundation design. Standard dewatering procedures will be necessary. In areas south of the main ridgeline, where very soft to soft clays are found to some depth, pile foundations are expected to be required for support of proposed pump stations and treatment plant structures. In these areas, special consideration for pipe bedding and support will also be required.

Groundwater, weather, traffic and availability of contractors and labor are not expected to represent any unusual or difficult constraints on standard construction practices for land-based pipeline and structural work. Congested land uses and difficult access in many developing portions of the city must be taken into account when determining construction procedures. The present limited availability of some basic materials (steels, cement, and pipe) is expected to be alleviated by the time of program implementation and should not represent a severe restriction on construction.

With adequate supervision, much of the construction work necessary for the proposed projects can be done by major local contractors, although some specialized installations, such as submarine outfalls, treatment process units and pumps will require foreign procurement and supervision, international construction contractors, and assistance in start-up.

In order to assure high standards of work in accordance with good construction practices, allowances for competent inspection, effective supervision, tender evaluation, and other quality control measures have been included in determining project cost. Such inclusions are necessary in order to correct problems inherent in present local practices.

All wastewater facility outline designs are based on established functional engineering design criteria developed in countries where wastewater collection and treatment have been practiced for many years. The facilities proposed for Alexandria will be modern, effective and reliable and are selected to minimize operation and maintenance problems and costs, to require less highly trained operators, and to minimize the requirements for foreign exchange.

Costs expressed for all future wastewater projects are based on mid-1977 price conditions in Egypt, without taking into account escalation. Total project costs include a 30 percent increase for engineering and contingencies as well as the costs of land acquisition. Unescalated annual operation and maintenance costs are estimated for various stages throughout the planning period.

2.5 Concept for Treatment and Disposal

The Recommended Wastewater Facilities Master Plan has been prepared to provide the guidance necessary for orderly and economic development of an expanded sewerage system in Alexandria. It is based on eliminating drainage of untreated sewage to local water bodies, reducing to a low level the magnitude and frequency of overflow from the sewage collection system, and adequately treating and disposing of collected wastewaters so that they do not have adverse impact on the people or environs of Alexandria.

There are three basic disposal options available for the future control of Alexandria's wastewaters: discharge to a receiving body of water, land application, and evaporation from holding ponds. Each approach dictates an alternative level of wastewater treatment in order to attain a comparable, desired level of quality in the environment.

At least a secondary level of treatment is necessary for discharge to inland fresh waters (Lake Maryut) or for subsequent reuse of effluent by crop irrigation on nearby agricultural lands. A preliminary level of treatment (screening and removal of solids/grit and floating materials) is necessary for submarine discharge well off the shores of the Mediterranean, whereas primary treatment (with adequate disinfection) is required for short outfalls near the coast. Apart from removal by screening of gross materials that might impair operation of pumps and force mains, treatment is not necessary for conveyance of raw sewage to remote evaporation ponds.

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There are two basic means by which toxic industrial wastewaters can be handled effectively: 1) exclusion from the municipal sewerage system by construction of a separate industrial collection /disposal system; 2) acceptance in the municipal sewers after specific toxicant materials have been neutralized or removed by in-plant treatment systems provided at each industry generating toxic wastewaters.

2.6 Evaluation of Alternatives

Three levels of system consolidation (entirely separate, partially combined, and completely consolidated) of sewerage zones were evaluated on a regional or "global" basis by comparing economic and functional aspects of each. Likewise two modes of wastewater collection were compared involving integrated versus separate systems for toxic industrial wastes and domestic sewage. Future comparisons were made in terms of costs and functional factors among three disposal schemes: a) sea discharge, b) reuse by crop irrigation, and c) desert evaporation.

Cost comparisons indicated that a partial level of consolidation involving an integrated collection system for the presently developed areas of the city and separate wastewater collection and disposal facilities in the outer developing areas is the most economical choice.

Economic comparison of alternative disposal schemes, as shown by the following comparative costs, indicates that a master plan program oriented toward sea discharge for a major portion of the city's wastewater is the preferable alternative by a significant margin.

	Comparative Costs, LE million		
	Scheme A Sea Discharge	Scheme B Crop Reuse	Scheme C Desert Evap.
Total Capital	310	380	410
Annual O & M	4	7	6
Relative Present Worth Cost	1.00	1.24	1.36

The discounted (present worth) value is the sum of annual operation and maintenance (O & M) costs plus total capital cost for conveyance, treatment and disposal, excluding connections and street sewers, through a staged program to the year 2000 at a discount rate of 10 percent.

Consideration of both the global alternatives and more detailed "hardware" alternatives within each sewerage zone, taking into account both costs and important functional factors (system effectiveness,reliability, flexibility, ease of implementation, and environmental impact) leads to selection of a preferred general plan consisting of the following principal elements by zone:

East	- a preliminary treatment facility and long submarine outfall.
West/Central	- two preliminary treatment facilities and a single long submarine outfall.
Abu Kir	- separation of systems; Peninsula flows (domestic) to the East system, the Bay (industrial) flows conveyed to a remote evaporation pond at Lake Idku.
Nouzha	- use of existing East Sewage Treatment Plant.
Mex/Dekheila	- waste stabilization ponds with discharge to the West Noubaria Main Drain
Ameria	- waste stabilization ponds with discharge to the West Noubaria Main Drain.

2.7 Recommended Wastewater Plan

The recommended wastewater plan is composed of six independent collection treatment-disposal systems, as follows:

1. Eastern - All flows from the Inner and Outer East Zones and Abu Kir Peninsula conveyed to a regional preliminary treatment facility 560 ML/day capacity) located in Ras El Soda for subsequent marine disposal through a 2200 mm diameter submarine outfall discharging 10 km off the sea coast at Sidi Bishr.
2. Abu Kir - Predominantly industrial wastewaters conveyed to a 4000 ha fully contained evaporation pond at Lake Idku for complete retention avoiding discharge to any receiving water.
3. Nouzha - All wastewaters conveyed to the existing East Sewage Treatment Plant (modified to adequate secondary level of biological treatment at 45 ML/day capacity) for subsequent discharge to the Kalaa Drain leading to Lake Maryut.
4. West/Central - All wastewater treated at preliminary levels within each zone , 175 ML/day capacity at new Kait Bey (Central Zone flows) Plant and 220 ML/day capacity at expanded West Plant, for combined disposal to the sea through a 1700 mm diameter submarine outfall discharging 10 km off Kait Bey Point.

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5. Mex/Dekheila - All Outer West Zone flows conveyed to a 370 ha waste stabilization pond (anaerobic/aerobic lagoons) at West Lake Maryut for 30-day detention prior to discharge to an open channel for conveyance 6 km to the West Noubaria Main Drain.
6. Ameria - All wastewater flows conveyed to a 315 ha waste stabilization pond (anaerobic/aerobic lagoons) east of the city for 30-day detention prior to effluent discharge into the nearby West Noubaria Main Drain.

The recommended plan includes provision of 92 800 new dwelling connections and 1040 km of additional lateral sewers (ranging in size between 200 mm and 800 mm diameter pipe), as well as principal wastewater conveyance , treatment, and disposal facilities. A doubling of present staff is estimated to be required in order to operate and maintain the expanded system by 1990.

The scope of the recommended plan will require, at minimum, staging of major construction projects over the planning period as follows:

Top Priority Projects (1978-1981)	- Immediate rehabilitation, repair, and improvement works in existing system.
Stage I Construction (1979-1983)	- Emphasis on expansion of collection system in the Outer East Zone along with new treatment and outfall facilities to serve the entire eastern area; also some additional collection in the West Zone and initiation of the Nouzha collection system.
Stage II Construction (1984-1988)	- Construction of the West/Central treatment and disposal system, as well as"outer area"projects in Mex/Dekheila, Ameria and Abu Kir.
Stages III and IV (1989-2000)	- Expansion of the entire collection system to meet additional service demands from domestic and industrial development as it occurs.

Costs associated with the recommended plan, as represented in Table 2-1 include a total capital investment for facilities of LE 447 million (at 1977 prices) over the next 23 year period and an annual cost for operation and maintenance of the system increasing from LE 1.8 million in the early 1980's to LE 2.7 million by year 2000.

It is estimated that direct and indirect benefits from the recommended master plan that can be quantified (primarily those related to increased land values

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and increased recreational activity result in a benefit-to-cost ratio of 1.15 at a discount rate of 10 percent.

The scale of investment for the entire plan may not yet be within the national level of expendituresfor fixed capital investment. The initial stages of construction (1979-1988) are financially feasible if international loans can be secured for the foreign exchange components of capital cost. Overall economic and financial feasibility of the recommended plan rests on considerations and priorities of the national government which should be resolved in the near future.

2.8 Plan Implementation

Implementation of the facilities plan will require strengthening of organization and management systems of GOSSD-Alexandria. Increasing organizational responsibilities should be met by establishing a Project Monitoring Unit, an Internal Audit Unit, and a position of Deputy General Director. Utilizing existing organizational structure, departmental responsibilities should be expanded to include training and staff development; sewer use regulation enforcement; central records and management information systems; collection services for mazout residue, manures, septage, and special industrial wastes; operation and maintenance of new sewage treatment facilities; and an industrial waste monitoring program.

Financing of the master plan program should utilize a number of sources. Local funds can be generated to recover operating costs of the expanded system as well as costs for property connections. Developers should pay a portion of the collection system costs in areas under their development. The foreign exchange component of capital investment costs should be financed through foreign investors while the local currency share of capital costs must be derived from national funds. Although local funding levels in the past have been well below those efforts needed in the future, placement of a higher national priority on capital investment in public utilities, and wastewater systems in particular, would improve the level of funding available. Delays or shortages in foreign or domestic capital development funds can, to an extent, be offset by segmenting the recommended master plan into independent staged wastewater system components for various geographical areas of Alexandria.

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TABLE 2.1

COST OF RECOMMENDED PLAN

	Capital, LE million Stage I (1979-1983)	Stage II (1984-1988)	Stage III&IV (1989-2000)	Total (1978-2000)
System				
East[a]	81.9	64.9	44.2	191.0
West/Central	7.8	83.7	7.6	99.1
Nouzha	1.9	8.0	0.7	10.6
Mex-Dekheila[b]	3.0	24.3	2.1	29.4
Abu Kir Bay Ind.	5.1	14.6	1.0	20.7
Ameria	2.3	32.5	25.0	59.8
TOTAL Master Plan	102.0	228.0	80.6	410.6
Top Priority Projects[c]	36.5	-	-	36.5
				447.1
	Component of Cost (percent)			
Direct Foreign Exchange	(48)	(26)	(0)	(26)
Indirect Foreign Exchange	(9)	(25)	(30)	(22)
Local Currency	(43)	(49)	(70)	(52)
	(100)	(100)	(100)	(100)
	Annual Operations & Maintenance, LE million			
By:	1983	1988	1994	2000
Activity				
Personnel (Payroll)	1.39	1.75	1.98	2.11
Energy[d]	0.20	0.24	0.28	0.29
Materials/Supplies	0.21	0.26	0.30	0.31
TOTAL	1.80	2.25	2.56	2.71

[a] Inner and Outer East Zones plus Abu Kir Peninsula.

[b] Outer West Zone.

[c] TPP costs occur between 1978 and 1981, LE 9.4 million is for new construction projects (Category III items) in the Ras el Soda area and of the East Zone, the remaining costs are for repair and general improvements (Category I & II items) of the existing sewerage system.

[d] Fuel and electrical power for vehicles, equipment and facility operation.

CHAPTER 3

EXISTING CONDITIONS

3.1 Historical Perspective

History of the Area

Alexandria, founded by Alexander the Great in 332 BC, is one of the oldest cities in the western world. It was the capital under the Ptolemaic pharaohs who ruled the country from 304 BC until Egypt became a part of the Roman Empire in 30 BC. Nearly seven centuries of Roman and Byzantine government followed, before Persia conquered Egypt in 616 AD. The Persian triumph lasted only a short time and the end of the Byzantine era occurred in 642, when the remains of the Byzantine fleet were driven from the harbor at Alexandria by invading Arab armies. Political absorption of the country by the Arabs proceeded rapidly. Arab rule, characterized by constant power struggles and lack of economic planning, continued until 1260, when power shifted to the Mamlukes, then to the Ottoman Turks, and back to the Mamlukes. From 1260 to 1798 the country was ruled both haphazardly and harshly by Mamluke sultans, with few lasting benefits to Egypt.

Napoleon's invasion in 1799 marked the beginning of the strong French influence on culture in modern Egypt. Following defeat of the French a short time later, Mohamed Ali was appointed Pasha by the Turks, and became, in time, absolute ruler. He ensured the continuing development of Alexandria by ordering construction of the Mahmoudia Canal. The canal provided a water supply which was necessary to support a growing population. After the Pasha's death in 1849, less capable successors, through personal extravagance and mismanagement, led Egypt to bankrupcy in 1876. The British took control of fiscal affairs and, after suppressing a nationalist movement in Alexandria in 1882, occupied the country for four decades. Considerable administrative reform, economic expansion, and improvement to public services occurred during this time. Alexandria's initial water and sewerage systems date from this period.

The time from World War I until 1952 was characterized by political unrest and rising nationalism. After the internal instability and economic difficulties which followed King Farouk's long reign, a group of military officers headed by Gamal Abdel Nasser took control of the country. The economic and social reforms of the new government brought order to Egypt. Nevertheless, unrest in the Middle East has required Egypt to commit funds for its national security which might have been used for economic development, such as expansion of industries, the building of cities, and provision of public utilities. Limited funds for improvements have caused serious lagging in important areas, one of which is construction of sewerage and drainage facilities.

Urbanization

Old Alexandria developed mainly around the natural harbors on either side of the Ras el Tin-Anfushi Peninsula (Figure 3-1). Residential and commercial use of this area has reached full development and expansion has occurred to the east, along high ground. In the eastern expansion area, the land available for development is being occupied rapidly. A large area between the Montazah Palace grounds and Abu Kir Point is now used for parks, reserves, and military purposes; it is not likely to be developed otherwise. Industrial development has taken place along the Western Harbor west of the dock area in Mex, along the railroad and Mahmoudia Canal south of the central city and, more recently, along Abu Kir Bay between Abu Kir and Maadeya. Low income housing and commercial development, in dense configurations, have also occurred in industrial areas.

Population densities range from 400 persons per hectare in higher income areas to 1350 persons/ha in low income areas. The present maximum of 1350 persons/ha for low income areas is considered to be near saturation, although several small areas within the city contain densities in excess of 1700 persons/ha. Values shown in Table 3-1 indicate that current increase in Alexandria population is nearly 60 thousand persons annually. Alexandria is a rapidly growing, commercial, industrial, and recreational seaport that links the Middle East with Europe.

Sewerage System Development

Until late in the nineteenth century all wastewaters in Alexandria were discharged to local drainage ditches. A sewerage system report was prepared in 1893 advising construction of two sea outfalls and an Eastern Harbor collector sewer. The latter was then built. In 1902 a report prepared by the Alexandria Water Company proposed construction of a separate wastewater collection

TABLE 3-1

ALEXANDRIA POPULATION DATA

Census Year	Number of People[a]	Average Annual Increase	Percent Annual Increase
1882	232 636	-	1.76
1897	315 844	5 547	1.07
1907	353 807	3 795	2.04
1917	444 617	9 081	2.04
1927	573 063	12 845	2.24
1937	685 136	11 267	1.64
1947	919 024	23 329	2.54
1960	1 516 234	45 939	3.03
1966	1 801 057	47 470	2.64
1976	2 382 000	58 094	2.44

[a] Permanent population only.

system without sea discharge. Several other reports were then prepared criticizing such proposals and advising pursuit of the previous sea disposal approach.

In 1908, Mr. Lloyd Davis, member of the civil engineering committee and chief engineer of the Alexandria Municipality, prepared the first detailed report on the problem of sewerage. The service area at that time extended from Sporting on the east to Gabbary and Mex on the west (refer to Figure 3-3) and from the Mahmoudia Canal on the south to the sea on the north, an area of 1257 hectares. The population of the city was estimated to be 360 000. The report recommended use of a combined system for wastewater and runoff, except in the zone adjacent to the Mahmoudia Canal. In this zone, a separate system was proposed for wastewater discharge by pumping to a Kait Bey outfall, while runoff would be drained into Lake Maryut. An 800 metre sea outfall was proposed at Kait Bey to discharge wastewater from the northern portion of the city into the open sea, with overflow in excess of three times average dry weather flow (ADWF) to be discharged to the sea directly through weir outfalls at Silsila and Kait Bey. Construction of main collectors was advised for Wardian and Mex. These two collectors were to end at the Kait Bey Pump Station. If the beaches continued to be polluted after construction of the outfall, the report provided for the construction of "purification tanks", to treat the dry weather flow, before discharge to the sea.

Implementation of the "Davis Plan" was carried out over a long period with interruptions due to the First World War and a long period of turmoil in Egypt. While its recommendations were generally followed, the municipality also constructed a combined system of sewers in the southern portion of the city, so that during wet weather periods, raw sewage mixed with rain water was discharged to Lake Maryut. Kait Bey sea outfall was subject to considerable controversy and was not constructed until 1954.

In 1935 Mr. Taylor, Consulting Engineer, was commissioned to prepare a report on the Alexandria sewerage system. Mr. Taylor's report, submitted in 1936, was similar to the Davis report, except that it did not reject the idea of a combined sewer system, even for the southern part of the city. The work proposed by Mr. Taylor was not accomplished before the Second World War. In the interim period construction costs had increased substantially, so that by 1945 the Alexandria Committee rejected the idea of building a sea outfall and pump station. Another committee was appointed to study the matter. Recommendations of this committee included discharge of treated effluent into the sea through a Kait Bey outfall. Wastewaters from the eastern and western areas of the city would also receive treatment before discharge to local drains.

Recommendations were agreed upon by the Committee and in January, 1947, the municipality invited bids for the original project, consisting of the construction of the sea outfall, the new main collector, and the new Kait Bey pump station. In March, 1947, another technical committee was formed to study the Alexandria on-going sewerage project and comment. This committee reviewed the proposed construction projects, all previous reports, medical and technical notes, and discussed matters with those engineers who proposed different plans. It also studied all complaints, the inefficiency of the pump stations, the problems of capacity in collectors, the pollution of Lake Maryut and the sea, and the areas not served by sewers.

The committee recommended that maximum use be made of topography by dividing the city into three zones. The eastern zone included the area east of Sidi Gaber, between the sea and the Mahmoudia Canal. Collectors in this zone were to convey wastewaters to a point southeast of the city, where complete treatment would be provided before discharge to Lake Maryut through drainage canals. The central zone extended west and north of the Mahmoudia Canal to Sidi Gaber on the east. Collectors would convey wastewaters to a Kait Bey pump station, where treatment "according to need" would be provided, before discharge to the sea. Sludge would be conveyed to the southern side of the city, where it would be treated and disposed. The third or western zone extended along the Mahmoudia Canal south and west to the city limits. This zone would be served by a complete treatment plant and discharge would be to the drainage canal for final disposal to the sea through the Mex Pump Station.

In view of the agreement by previous committees in 1945 and 1947 on disposal of wastewater from the central zone of Alexandria by sea outfall at Kait Bey, and treatment of wastewaters from eastern and western zones, the Alexandria Municipality ordered, in 1948, construction of the following facilities:

1. A sea outfall at Kait Bey (735 m of 1.25 m diameter pipe to discharge 16 m below the water surface).
2. A new shoreline collector from Kait Bey to Avirof Street (1.55 m diameter).
3. A Kait Bey pump station containing six pumps each having capacity of 50 m^3/minute.

In 1954, the Alexandria Municipality engaged Mr. Abbas Helmy, consulting engineer, to make the necessary studies and designs for provision of sewerage service to the high priority areas in the eastern and western zones. Following preparation of designs and specifications, the Municipality asked two West German experts to review and report on the work. After this review, the Municipality then invited international contractors to submit tenders for the whole or parts of the project. Contracts were awarded and construction was started in 1961, to be completed by 1965. Economic problems have forced the extension of the construction and it appears that completion of the work is still several years away (as of 1978).

Additions and extensions to the Alexandria sewerage system during the past two decades have generally followed the recommendations of Eng. Abbas Helmy and earlier committees. The eastern zone system has been extended to include Montazah Palace, Maamoura, and the Hospitals area. Changes in the central zone have been largely to increase the capacity of the existing system. Collectors and sewers have been constructed in the western zone in anticipation of the West Plant project. Treatment facilities at the East Plant were placed in operation in late 1974. The West Plant is still under construction. Raw sewage from the central zone is being pumped to the sea from the Kait Bey pump station.

3.2 Geographical Features

Physical Features

The dominating physical features of the Alexandria area are the Mediterranean Sea, the lower Nile Delta lands, and the vast Western Desert. Also of major importance are the manmade canals which convey Nile River water to the area. If Alexandria had to rely upon local fresh water resources, it would long ago have reached its limit of development. The Mahmoudia Canal, which was built in 1820, has figured strongly in the development of Alexandria and the

the northwest Delta region, and it has also become a dominating physical feature as shown on Figure 3-1. The location of drainage and transportation facilities have been influenced by its alignment.

The study area contains several different geological and topographic features which affect the character of development. The basic geological features which have caused the linear development of Alexandria are a ridge and a marine lagoon, both of which parallel the seashore. The ridge of calcareous rock and sand occurs 500 to 1500 m inland from the seashore and extends from Abu Kir Point in the east to beyond the western limits of the study area. The height of the ridge varies from 5 to 22 m.

The marine lagoon, which varies in width up to 6 km, lies behind the ridge and extends beyond the principle urban areas in both directions. The width of the high ground dominated by the ridge varies from about 1.3 to 4.4 km. The high ground affords good foundation conditions and groundwater only at or slightly above sea level. On the other hand, the marine lagoon soils are silt and clay, offering very poor foundation conditions and groundwater saturation to the surface, which is commonly a metre or two below sea level. Much of the original marine lagoon area has been recovered for cropland by filling and construction of a drainage canal network. The water body that remains on the west side is called Lake Maryut and to the east of the Mahmoudia Canal, Lake Idku.

West of the Noubaria Canal and south of the marine lagoon, the desert land rises to a rolling plateau with elevation of 30 to 50 m. The soil is sandy clay and has excellent foundation properties. It is generally suitable for irrigated agriculture with use of water from the Noubaria Canal and provision of adequate drainage. Local domestic water supplies in this area are extremely limited or non-existent, so that there is complete reliance on the Alexandria water supply system.

The Mahmoudia Canal extends from the Rosetta Branch of the River Nile at Mahmoudia, about 40 km upstream of Rosetta, to Alexandria. Water level in the canal is above the level of adjacent land surface for much of this distance, particularly where it crosses the marine lagoon. This makes the Canal an effective drainage barrier throughout its entire length.

A newer canal, the Noubaria, originates at the Reiha Behera Canal about halfway between Alexandria and Cairo. Its course follows closely the edge of the

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desert until it reaches the marine lagoon near Alexandria where, through locks, its level is dropped to that of the marine lagoon. The canal continues to the Western Harbor, where there is another set of locks to raise the waterway to sea level. This canal supplies irrigation water to the developing Western Desert, is important to barge traffic between Alexandria and Cairo, and supplies water in relatively small amounts for municipal uses near Ameria.

The Anfushi Peninsula, which dominates the coast of the Mediterranean Sea at Alexandria, forms the protected Eastern and Western Harbors. Added protection is afforded by manmade breakwaters which enclose the harbors and reduce circulation of currents. The Western Harbor Port, Egypt's principal commercial shipping center, is always full to capacity with ships waiting outside the harbor for unloading. The Eastern Harbor is primarily used for small boats. Two other prominant peninsulas, Agamy on the west and Abu Kir on the east, give the shoreline its unusual character. West of Agamy the shoreline is a wide sandy beach, very attractive for summer living. Near future plans indicate the wide, U-shaped indentation between Agamy and Anfushi will become an expanded Western Harbor, probably semi-closed by harbor protection structures. The shoreline from Anfushi to Abu Kir consists of a series of small, rocky projections into the sea, which separate sandy beaches. East of Abu Kir is another wide U-shaped indentation, Abu Kir Bay. A submerged rocky ridge extends across the open part of the bay and effectively cuts off the normal shoreline currents to decrease significantly their flushing effects.

The near shore sea bottom, to about 8 km offshore, is characterized by a series of rocky ridges parallel to the shoreline with flat or slightly upgrade (sloping upward away from the shore) sandy areas between them. Farther away from shore, the bottom is sandy with a flatter and more uniform down slope.

Climate

Climate in the study area is arid. There are essentially two seasons; summer extends from May through October, and winter runs from November through April. Summer is characterized by hot days and cooler nights, with no rainfall; winds are generally off the sea from the northwest. Winter is the rainy season with storms bearing variable amounts of rainfall and occurring in cycles during the period between late November and mid-March.

The short (3-5 day) storms are usually accompanied by fresh to strong winds from the northwest. Between storms the winds may shift to other directions for two or three days. Tropical storms, such as typhoons or hurricanes do not occur, nor are there violent cyclonic storms associated with large masses of circulating air. The breeze from the Mediterranean Sea during the summer is one of Alexandria's major attractions.

Information extracted from Climatological Normals published by the Ministry of Military Production, Meteorological Department for the Alexandria weather station is described on Figure 3-2. The numerical data presented on meteorological conditions are applicable to the principal portions of the study area that are directly influenced by the Mediterranean Sea. For remote desert portions of the study area, there is more variability in temperatures with higher maximums, somewhat lower humidity, greater evaporation rates, and more variable winds.

Alexandria mean maximum temperature readings vary between 18°C and 30°C with the annual average a comfortable 25°C. The mean minimum temperature readings vary between 9.3°C in January and 22.9°C in August with an annual mean of 15.9°C. The recorded maximum and minimum temperatures for Alexandria are 42.1°C and 2.4°C, respectively.

Relative humidity values near 70 percent result in a pleasant climate. However, there are times when the relative humidity is uncomfortably high. The humidity in Alexandria plus the salty spray from the sea have a particularly corrosive effect on structures near the shore. Inadequately protected metal corrodes quickly. Concrete and wood also are affected.

A relatively small amount of rainfall occurs primarily during four winter months, November through February, with only trace amounts ever recorded from April through September. The mean annual rainfall is 192 mm (7.6 inches). Data on the variability of annual totals are not available. Rainfall over the area is extremely variable for any given storm. Instances of steady rain in appreciable amounts over several hours are few, most of the rainfall being derived from small squalls of limited extent which, under the influence of strong winds, pass quickly over the city from the sea.

Evaporation exceeds annual rainfall by an order of magnitude, averaging more than 1900 mm per year. The large excess of evaporation over rainfall makes attractive the disposal of wastewater by evaporation and the drying of sludge on open beds. However, for waste stabilization ponds, evaporation tends to increase dissolved salt concentration and make effluent less attractive for agricultural and other potential reuses.

Available wind data indicate that the prevailing wind during much of the year is from the northwest quadrant. The least windy month is October, during which light northeast winds predominate. Wind speeds are generally less than 16 knots and only very infrequently do wind speeds exceed 34 knots (gale force). Wind speeds are generally greatest during the January to March period.

Hydrology

Hydrology in the Alexandria area is relatively simple because several features occur that limit hydrologic processes. Alexandria and the eastern Mediterranean Sea are under the influence of tropical zone circulation of air masses. Air currents rise to high altitudes near the equator, flow north to latitude 30°, and descend to flow south near the land surface. This circulation tends to concentrate rainfall near the equator, where rising air currents are cooled and precipitation takes place. Thus, the high and descending air masses carry little moisture.

During the winter, when the northern hemisphere is tilted away from the sun, lower latitude circulation becomes weaker and local hydrologic processes become influential. This results in alternating southwest and northwest winds, and rainfall which is brought by the northwest winds. The moisture source of this rainfall is the Mediterranean Sea, with help periodically from air masses originating north of latitude 30°. The consequence of these circulation patterns is that Egypt has very limited rainfall, concentrated mostly on the coastline over a few winter months.

Much of the rain falling on developed areas in Alexandria flows directly to the nearest water course. Much of that falling on sandy surfaces outside the urban area infiltrates. The sandy soils which allow high infiltration rates also allow good air circulation in the pore space and the high evapoation rates tend to remove soil moisture before much of it accumulates. Therefore, in sandy soils of the study area hydrologic processes tend to deter significant accumulation of groundwater. The common "lens" of fresh groundwater floating on brackish water often found in humid coastal regions does not occur in Alexandria. This results in little or no fresh groundwater in the area. Proximity to the sea, maintenance of the marine lagoon below sea level, and discharge of surface runoff waters directly to the sea exacerbate the situation further. The relatively high elevation of the sea surface with respect to the surface in the marine lagoon creates a potential flow through the porous ground from the sea to the lagoon. The method of drainage and pumping water from the marine lagoon limits the accumulation of any fresh water drainage and runoff on the heavier saltwater.

Drainage

Except for the Mediterranean Sea, water resources for Alexandria are closely associated with the area's canal and drainage system as shown in Figure 3-1. The northwestern corner of the Nile Delta is largely farm land irrigated with water supplied from the Nile River. This water is conveyed from El Mahmoudia on the Nile by the Mahmoudia Canal, and from the Cairo Barrage by the Reiha Behara Canal. The two canals intersect near Damanhour and flow continues to Alexandria and the Mediterranean Sea. Flow in this system, except for low-lift pumping at the Nile, is entirely by gravity. The surface slopes of the canals are very flat, however, in order to preserve available elevation for distribution of irrigation water without general pumping. The water surface in the Mahmoudia Canal at Alexandria is maintained at +1.5 metres above sea level for barge traffic, for irrigation head, and for the discharge of excess water to the sea.

Much of the northwestern delta farm land varies in elevation from -1.5 m to 4 m above sea level. In order to drain this land, the collection system must be below sea level and pumps are required to lift the drainage water into the sea. Near Alexandria, there are two extensive drainage areas as mentioned which are divided by the Mahmoudia Canal.

The drainage area north and east of the canal is served by the Abu Kir drainage system and the Tabia Pump Station, which lifts drainage water from an elevation of about -5.5 m and discharges into nearby Abu Kir Bay at the shoreline. The drainage consists of not only agricultural return water, but also significant amounts of chemical and organic wastes from several textile mills near Kafr el Dawar and two large paper mills near Tabia.

The drainage area south and west of the Mahmoudia Canal discharges return water through several drain systems, the principal one being the Umoum Drain. The level of Lake Maryut is maintained at approximately -2.5 m by the Mex Pump Station, which lifts excess waters into the Western Harbor.

The area of Alexandria south of the ridge, which parallels the seashore, drains either to the Abu Kir Drain system or to Lake Maryut. This drainage is complicated by the Mahmoudia Canal because runoff from north of the Canal must be conveyed under the canal by inverted siphons. The siphon discharges add to the surface runoff south of the Canal and flow continues to Lake Maryut. East of the Nouzha Airport, this runoff combines with effluent from the East Treatment Plant, raw sewage that bypasses the plant, Smouha Drain discharges (runoff and urban wastewater), and a discharge of untreated wastewater from the Nouzha area. The flows pass through a system of drains and discharge into Kalaa Drain, where flows are mixed with a significant amount of irrigation return water. The drain is an open ditch about 6 km long which conveys flows to Lake Maryut.

West of the Drinking Water Canal, runoff mixes with urban sewage from an area which drains via three channels into lake Maryut along its northern shore, and one channel near its southeast corner. These drains, from developed areas both east and west of Nouzha Airport, contain very strong domestic and industrial wastewater.

North of the shoreline ridge, an area which varies from 0.5 to about 1.5 km in width drains to the Mediterranean Sea. In the developed portion of this area, stormwater runoff is collected in sewers to be discharged either with sanitary sewage (up to the capacity of the downstream system) or overflow to the sea at the shoreline.

Lake Maryut extends from near the Nouzha Airport westward for a considerable distance beyond the developed area of Alexandria. The lake is divided into

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two parts by the Mersa Matrouh Railroad causeway, which has no openings for interchange of flow. The eastern portion of the lake which has a mean depth of 0.8 metres contains fresh water. It is traversed by three barriers, Umoum Drain, Noubaria Canal and the Alexandria-Cairo Desert Highway. Although the several segments of the lake are interconnected, the portion of the lake west of the causeway is salty and is used as an evaporation pond for the production of industrial salt. The areal extent and depth of this portion is variable, depending mainly on the net evaporation rate.

Much of original Lake Maryut east of the railroad causeway has been reclaimed for agricultural uses. The land use plan of the Governorate shows that there will be, when reclamation is complete, a main lagoon of about 2000 hectares, an experimental fishery lagoon of about 500 ha and a pond, presumably for cooling water for the refinery and for commerical fishing of about 1200 ha. A portion of the existing lake adjacent to the Noubaria Canal is to be reclaimed for industrial uses. Drainage carried by the Kalaa Drain enters directly into the lake. Other local drains in the area enter the fishery lagoon, pass into the southern portion of the main lagoon, and traverse the lake to the Mex Pumping Station. A local control gate at Mex regulates the withdrawal of water from the lake to the pumps. The Umoum Drain does not discharge into Lake Maryut, except as an overflow. However, the excess water in the Noubaria Canal resulting from the operation of the locks at kilometre post 100 and at Western Harbor is discharged by overflowing into the main lagoon.

Southwest of Lake Maryut the land rises to a level of 30 to 50 m; the desert plateau. Much of this land is composed of sandy clay soils suitable, if irrigated and drained, for agriculture. Development of this area is progressing rapidly. The drainage of this area at present is incomplete. The West Noubaria Main Drain is intended to drain the agricultural areas in Ameria to the sea. The lower portion of the drain, between the ridge and the sea (see Figure 3-1), is presently under construction. The drain will follow the south shore of the western portion of the lake to a point west of the Ameria-Agamy road, where it is to cross the lake and discharge by gravity into the Mediterranean Sea between Agamy and Sidi Krier. At present some drainage is discharged to the Noubaria Canal and passes on to Lake Maryut.

North of the western portion of Lake Maryut is a coastal strip one to four kilometres wide, consisting of a limestone ridge and sandy area north of the ridge. This area is largely undeveloped, except for a strip of resort properties at Agamy and to the west. There has been mining of limestone along the ridge. Drainage south of the ridge is to Lake Maryut while run-off north of the ridge seldom occurs because of percolation into the sand.

Drinking Water Canal

The Drinking Water Canal, constructed in 1943, forms a drainage barrier for an area of about 6000 ha, located between the canal and the Mahmoudia Canal. The Kalaa Irrigation Drainage Pump Station lifts water from this area through a siphon under the Drinking Water Canal to a drain that discharges into Lake Maryut.

Hydrodrome

The Hydrodrome was built in 1945 in the Nouzha area to provide an international marine airport and to ensure an emergency water supply in the event of an interruption in the Mahmoudia Canal. This 570 ha manmade lake has a design water surface elevation at sea level and a depth of about three metres. Water is supplied through a connecting conduit from the Mahmoudia Canal and there are overflow and outlet structures on the south side that provide for discharge to the Kalaa Drain. The open canal connection from the Hydrodrome to the Drinking Water Canal is not operable in its present condition.

3.3 Present Sewerage System

General Description

Drainage and sewerage systems have been constructed to serve the developed areas from Maamoura on the east, to the industrial highway on the south, Gabbary on the west, and the Mediterranean Sea on the north. Important and developing areas of Abu Kir, Ras el Soda, Siouf Keblia, Nouzha, Mex, Dekheila, Agamy, and Ameria have limited formal drainage and no sanitary sewerage system.

The existing sewerage system serves an area of about 4300 ha and has a connected population which varies from about 2 million in the winter months to about 2.4 million in the summer. In addition, there is a considerable industrial wastewater flow, estimated to amount to 870 000 m^3/day.

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This flow is considered 25 percent contaminated, the greater portion being single-pass cooling water. Alexandria industries in total produce wastewater equivalent to a population of 1 760 000; nearly equal to Alexandria's present population.

The existing system includes about 150 km of main interceptor sewers, 1500 km of secondary collectors and street sewers, 30 km of force mains and 34 pump stations of varying capacities. There are, in addition, some privately operated pump stations, force mains, and sewers. There are 11 km of force mains which have never been used. The system also includes the East Treatment Plant (65 ML/day capacity) which was placed in operation in 1974 and the West Treatment Plant (design capacity 85 ML/day) presently under construction. Except for wastewaters influent to the East Plant, all collected wastewaters of the area discharge untreated to local water bodies. Major discharges occur into Abu Kir Bay through the Tabia Pump Station, into the Mediterranean Sea through the existing Kait Bey outfall, into the Western Harbor through local drains and into Lake Maryut through a number of sewer outfalls and drains. Wastewaters discharged to Lake Maryut are conveyed after a short lake residence time into the Western Harbor through Mex Pump Station. There are, in addition, many local points of discharge to the Mediterreanean Sea through shoreline overflows and local drains. These discharges are primarily wastewater except during wet weather when sewage is diluted with storm runoff.

The existing sewerage system is divided into three zones: the Central, Western, and Eastern. The tributary limits of each zone and the principal features of the system are shown in Figure 3-3. Complete inventory of gravity collectors, pump stations, and force mains, as well as description of present treatment works are contained in Special Report Number 2, submitted 26 April 1977.

Results of the sewer inventory indicate that the main sewers and collectors were designed to provide slopes that will insure self-cleaning velocity when the pipes are flowing full. However, when sewers are operated in a surcharged condition, solids settle out. GOSSD design procedures indicate that self-cleaning velocities are provided in the lateral system. The collection systems in the Central, West, and the older portions of the

Eastern Zone consist of combined sewers designed to handle stormwater as well as sewage. Sewer pipes of the combined systems were initially designed to handle three times DWF. Many of the major sewers, however, were found to have capacities slightly less than three times DWF for storms in excess of fifteen minutes duration. Rainfall intensity-frequency-duration curves used by GOSSD in design of sewers were found to yield low runoff values for storms of more than 15 minutes duration.

The present sewer system has operated satisfactorily for many years according to most observers and it would appear that the collection system is adequate (except at several locations identified herein as troubled by frequent flooding) for near-term future flows expected.

A partially separate collection system has been constructed since 1964 in areas of the East Zone. Dual pipelines were constructed, one for sanitary wastewater and one for stormwater. Manholes were designed to enable either system to overflow into the other at times of high flow. Sanitary wastes are conveyed to the East Treatment Plant. Stormwater is lifted to the sea for shoreline discharge by several pump stations and force mains. As the system is continuously operated in a surcharged condition, the advantage of the dual overflow design feature is entirely lost.

There is groundwater infiltration into portions of the Alexandria sewer system through defective pipe joints, cracked pipes and manhole walls, and, in some instances, perforations designed to lower the local water table. Much of the collection system has been constructed of cast-in-place concrete, brick masonry, and stoneware pipe. Although it has been standard practice to encase sewer pipes in concrete envelopes, flexible water-tight joints have not been widely used. Extensive lengths of the more recently constructed sewer system are located below the groundwater table, although the older more deteriorated sewer pipes of the inner-city area are in soils where the water table is relatively deep.

Central Zone

Within the Central Zone wastewaters are collected primarily by gravity to Kait Bey Point where they are pumped without treatment through a short outfall into the sea. The Central Zone collection system operates largely by gravity. The Sporting, Mohsen Pasha, and Smouha Pump Stations lift into

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the system but do not have adequate capacities for tributary flows. The several parallel, interconnected Main Collectors pass along the Eastern Harbor Corniche and intercept sewers at the shore. The Kait Bey Outfall Pump Station, which was built in 1953, contains six axial flow horizontal centrifugal pumps and has sufficient capacity to handle the projected tributary area (1160 ha) wastewater flows. The station does not have screening facilities and pumps must be opened to remove rags and trash after every two to three hours of operation. The pumps operate under negative suction head, causing cavitation, which has contributed to the damage of inlet casing castings. The existing outfall is 735 m long and was designed for open-end discharge into 16 m of water without use of diffusers. However, it is ruptured in several places so that much of the sewage is discharged close to the shore.

The western portion (60 ha) of the Central Zone that naturally drains to the sea is served by local sewers which discharge directly to the Western Harbor along the shoreline. This has created a condition of gross local pollution within the confines of the busy and commercially important Western Harbor. Trouble spots in this collection system have been identified and corrective measures included in the ongoing Top Priority Project construction program.

West Zone

The existing Western Zone system is in an interim state of operation because construction of the West Treatment Plant is not yet completed. Raw wastewater is now being discharged to the Western Harbor from three tributary areas comprising 175 ha and to Lake Maryut from four tributary areas (665 ha) which are shown on Figure 3-3.

At present, Pump Station No. 2 West pumps to the sea through a temporary force main and shoreline outfall. Sewage flows to Pump Station No. 3 West either overflow at the station or are pumped through a force main that is intended to enter the West Treatment Plant but which, at present, empties into a ditch which discharges to Lake Maryut. Until such time as the West Treatment Plant is completed, sewage flows in the Gabbary Collector bypass Pump Station No. 1 West and discharge directly to the lake. This system also receives sewage overflows from the Old and New Forn el Garaya Pump Station.

There is a collector system which serves Karmouz and Mohsen Pasha, two districts located along the north side of the Mahmoudia Canal, and which discharges to an open ditch south of the railroad to the lake. Wastewater flows from the Gheit el Enab area also discharge to the Mohsen Pasha system either through the Old Forn el Garaya Pump Station, the Gheit el Enab Auxiliary Pump Station or the Gheit el Enab Main Pump Station. The Mohsen Pasha Pump Station discharges flow north to the Central Zone through the Salah el Din collector; however, because of the limited capacity of the intake sewers, most of the flows by-pass the station and discharge to Lake Maryut. Operation of Mohsen Pasha Pump Station improves drainage of the Moharrem Bey area by discharging flows to the Mahmoudia East Collector. Drainage of the area is severely hindered by the limited capacity of the siphon under the Mahmoudia Canal. Construction of a larger siphon would enable the Mohsen Pasha Pump Station to be abandoned. The industrial area south of Mahmoudia Canal lying on both sides of Suez Street is served by the Industrial Pump Station which lifts flows to Lake Maryut. There is also a by-pass directly from the gravity sewer system in this area into the lake. Flows have been witnessed entering the by-pass from the lake during operation of the Industrial and Gheit el Enab Main Pump Stations.

The West Treatment Plant, which has been under construction for a number of years, is still several years from completion. Construction is limited to the funds made available each year. The plant has several design deficiencies which, unless corrected, will seriously affect its future operation. These include: gravity conveyance of raw sludge and scum in very mildly sloping open channels; limited slope on sludge hoppers; and use of travelling bridge sludge mechanisms that require movement from one tank to another. The hydraulic capacity of the plant is based on a design flow of only 85 ML/day while it is estimated that the average dry weather sewage flow from the area will be 132 ML/day within the next four years. Peak flows are estimated at 210 ML/day by 1980.

East Zone

The Eastern Zone has two sewer systems, one tributary to Smouha Drain, the other to Pump Station No. 11. The Smouha Drain, as shown on Figure 3-3, is a large open channel located south of the Mahmoudia Canal. The drain receives gravity flows from two large East Zone collectors that discharge under the Mahmoudia Canal through a siphon. The Hagar el Nawatia Collector serves an area (110 ha) to the east of the Smouha Club, while the Mohammed Aly collectors serve an extensive area (870 ha) west of the Club. Three pump stations at Sidi Bishr, Sarwat and Glym serve a large coastal area (360 ha) and lift in series into the Mohamed Aly collectors. There are two other pump stations in the area tributary to Smouha Drain, namely Sidi Gaber and Smouha. The Sidi Gaber pump station is presently under reconstruction and does not operate. The Smouha pump station primarily serves to lift stormwater into the Central Zone system in order to relieve local flooding at the railroad underpass.

Areas of the Eastern Zone located between Smouha Club and the Alexandria-Rosetta railroad (to the north), as well as lands southwest of the Club, are low-lying and flat, so flooding is a frequent problem. Main sewers of the area were constructed with perforations, in order to lower the groundwater table. These sewers have flat bottoms and arched crowns; many are more than 40 years old, and the perforations may be sealed up by now. Investigations during design phase will determine whether these sewers might be incorporated into the improved drainage system needed in this area. The Municipality now operates portable engine driven pumps at the Moustafa Pasha, Ibrahimia, and Cleopatra railroad underpasses. Each underpass has two pumps which draw from suction hoses located in drain manholes for discharge through hoses or buried steel pipe force mains to nearby higher sewers. Present flooding in the low areas could be eliminated by construction of an improved drainage system to the Smouha Drain south of the Mahmoudia Canal. An improved drainage system would also enable the Smouha Pump Station to be abandoned.

The other sewer system within the Eastern Zone is tributary to the East Treatment Plant. Pump Station No. 11, shown on Figure 3-3, receives wastewater from an area of about 1000 ha. The collection system is composed of a series of local sub-systems, each with its own pump station and force main which discharges into the next sub-system. There are, in all, eleven such stations. At the final Pump Station No. 11 wastewaters are conveyed through a 48-inch force main to the East Treatment Plant. When a single pump of this station is operated at high speed without bypassing a portion of the flow, the downstream treatment plant inlet works are completely flooded. When the pump is not operating, wastewaters overflow at the site, creating local flooding prior to drainage to the surface system. Surface drainage is a part of the extensive Abu Kir Drain system that ultimately discharges at Abu Kir Bay through the Tabia Pump Station. Sewage overflows thus pass through extensively developed areas in the southeastern portion of the city that include the Siouf Water Treatment Plant.

In the Eastern Zone, seven additional pump stations discharge stormwater through separate force mains to the sea. When the pumps are in operation, discharge is usually mixed stormwater and wastewater because the system normally operates in a surcharged condition. In addition, there are also numerous overflows that discharge from the sewer system either to the sea or to the Abu Kir Drain system.

The East Treatment Plant, constructed between 1964 and 1974, has a rated capacity of 65 ML/day. A Czechoslovakian firm designed the plant and supplied the equipment. Construction was carried out by an Egyptian contractor. The plant employs an activated sludge process for secondary treatment of half of the flow while the other half receives primary settling only. Raw sludge from the plant is dried on adjacent sand-drying beds for ultimate disposal to farm land. Secondary treatment afforded by the plant is of significantly lower quality than normally expected from an activated sludge process, due to intermittent flows, toxic wastes, excessively high BOD loadings, and limited air supply. The lack of any operating flow meters further precludes satisfactory operation of the facilities. The considerable trash and grit received at the plant are an additional source of operational problems. They are also a primary source of excessive odor and fly nuisance problems.

3.4 Wastewater Flows and Characteristics

Collected Wastewaters

Prior Data. Very few flow and strength measurements were made in the past in Alexandria. The sewer system has no operating flow recorders. Pump station flow rates were crudely estimated on the basis of power usage. In an attempt to adequately quantify present flows and their properties, field investigations were carried out as part of this Master Plan study during the summer months of 1977.

Field Studies. The field measurement and sampling program was undertaken in late May and was completed by mid-July 1977. Six principal wastewater discharge sites were selected and monitored. Flow measurements were taken at half-hour intervals throughout a 24-hour period and samples collected (proportionally to flow) for compositing on a 6-hour basis. Each week two sites were monitored on a single day. The six sites were:

1. Inlet to the East Treatment Plant
2. Smouha Drain
3. Industries Pump Station (wet well)
4. Gheit el Enab Drain
5. Gabbary Drain
6. Kait Bey Pump Station (discharge chamber to outfall)

The locations of these sites and their approximate tributary areas, assuming normal pump station operations were in effect, are shown in Figure 3-4.

Flow measurement determinations were made with use of a current meter at three of the six sites: Smouha Drain, Kait Bey and Gabbary Drain; whereas calibrated weirs or pump performance curves were used at the remaining three sites. Refrigerated 6-hour composite samples (12 half-hour proportional grab samples) were analyzed at the Laboratory of Sanitary Chemistry, Faculty of Engineering, Alexandria University.

A summary of the results is shown in Table 3-2. In most cases, measurements agreed well with either empirically estimated flow rates based on tributary populations, measurements taken several years ago (at one site), or with rough estimates made by velocity-area approximations. The East Treatment Plant influent field measurements are believed to be too low because of sand deposits behind the weir. A combined average day instantaneous flow of 3.2 m^3/sec, accounting for an estimated 80 percent of total Alexandria wastewater flow, was gauged during the period of field study.

Flow-weighted average values of 585 mg/L BOD_5 and 1245 mg/L COD were obtained from the sampling study. These are indicative of highly concentrated wastewater. Large industrial waste loads, in combination with low domestic water use, are the principal contributing factors to this high strength which is two to three times that found in sewage from many other comparably sized cities.

Domestic and Commercial Sewage

Water Consumption. Collection and evaluation of water sales data pertaining to the Alexandria Water General Authority supply system led to the following

TABLE 3-2

SUMMARY OF WASTEWATER GAUGING AND SAMPLING PROGRAM

	East Plant[a]	Smouha Drain	Ind. P.S.	Gheit el Enab	Gabbary Drain	Kait Bey	Flow Weighted Average
Flow, m^3/sec							
Average[b]	0.33	0.57	0.45	0.54	0.15	1.17	-
Range (high)	0.64	0.69	0.45	0.68	0.22	1.71	-
(low)	0.16	0.44	0.45	0.34	0.08	0.63	-
Quality[c], mg/L (with exception of pH)							
pH	7.0	7.5	7.0	7.0	7.0	7.0	7
BOD_5	498	343	1100	536	445	570	585
COD	1313	738	3281	1257	1075	705	1245
Oil & Grease	167	163	1436	186	153	304	396
Alkalinity ($CaCO_3$)	344	362	441	472	430	358	390
Total Solids	1850	1300	776	1843	1610	1295	1216
Volatile	596	332	1435	760	465	436	530
Suspended	658	282	1107	645	412	416	552
Vol-Susp.	423	183	737	486	290	313	390
Ammonia (as N)	36	27	9	30	35	34	29
Albummoid Nitrogen	5	5	3	7	12	11	8
Chloride	407	317	2848	388	274	425	730
Phosphate	9	7	2	14	13	12	10

(a) Flow measurements are known to be less than actually occur at intake to plant.

(b) Over a 24-hour period.

(c) Average quality based on four 6-hour composited and flow weighted samples at each site.

estimates of unit domestic water consumption (litres/capita/day) for 1976:

	Range	Average
Lower Income Areas	69-93	80
Middle Income Areas	128-165	154
Higher Income Areas	229-237	230
Area-Wide Average	(115-125)	121

Evaluation of all available data on the AWGA system led to the following estimates of water consumption for 1976:

	Use, 1 000 m^3/day	Percent
Domestic	281.3	50
Industrial	106.9	19
Government	72.3	13
Other Users	19.1	3
System Losses	81.4	15
Average Day Demand	561.0	100

The above figures do not include areas outside Alexandria in the Western Desert (Mersa Matruh Governorate) and portions of Beheira Governorate which are also served by the AWGA supply system. System losses (leakage, waste, theft, and unidentifiable use) are taken as the difference between estimated total supply and identifiable water use.

Sewage Production. Taking into consideration all water supply losses, including evaporation, direct leakage to groundwater, the sea and Lake Maryut, as well as consumptive uses, a wastewater return to water use ratio of 83 percent was calculated. This results in an average non-industrial (domestic plus commercial) per capita wastewater flow rate of approximately 100 L/day. It is estimated that nearly 2.38 million persons (permanent and seasonal) presently reside within sewered areas; thus present domestic wastewater flow is estimated to average 238 000 m^3/day. The corresponding BOD_5 contribution, at an estimated 50 gm/c/day, is approximately 120 000 kg/day.

Industrial Wastes

Industries in the Study Area. The existing industries are widely varied, ranging from iron and steel fabricating and petroleum refining to light manufacturing. Major water users include pulp and paper producers, textile manufacturers, dyeing, chemicals, and leather tanning operations. There are, in addition, a significant number of food processing firms that consume large amounts of water. Industrial waters are taken from several sources; the public (AWGA) supply, the Mahmoudia, Noubaria and Rakta Canals; and from local groundwater wells. Wastewater from these industries is presently discharged into the public sewers, principal agricultural drains, the lower reaches of the Mahmoudia Canal, the waters of Lake Maryut, and the Mediterranean Sea.

Industrial Waste Survey. A comprehensive industrial waste survey was performed in order to gather basic data on water use and wastewater generation from all major industrial plants in Alexandria. Of approximately 200 water-using industrial plants located within the study area, 145 were visited and data were obtained from 129 different operations. These included all plants of a heavy industrial nature and those smaller operations (less than 25 m^3/day) where process wastes might contain toxic constituents. Those industries not surveyed were small plants using less than 25 m^3/day of water and generating non-toxic wastewaters.

Data on plant processes, annual production, raw material needs, water consumption, volume of waste discharge, and general chemical characteristics of the wastewater were collected by questionnaire, interview, and by effluent sampling. Additional flow measurements and chemical analyses were carried out for a number of major industries where existing information was sparse or open to doubt. Detailed findings of the survey were presented in a separate background document "Report on Industrial Wastewater" in July 1977, and are reproduced in Appendix C of Volume III.

A summary of findings is presented in Table 3-3. Of an estimated 870 ML/day of industrial wastewater discharge, approximately 226 ML/day is contaminated, the rest if primarily single-pass cooling water. Industrial process wastes constitute the major flow (92 percent) of contaminated wastewaters. Nearly 40 percent of contaminated industrial flow enters the public sewers; another 40 percent flows to local drains; the remaining 20 percent is discharged directly to canals or the sea. A more detailed breakdown of flow by type of industry is presented in Appendix C.

Based on quantitative information provided by some industries during the survey, a number of samples analyzed in the laboratory, and by extrapolations of chemical wastewater characteristics from knowledge of the plant processes involved, total waste loads of BOD_5 and COD were estimated.

TABLE 3-3

PRESENT INDUSTRIAL WATER USE AND WASTEWATER GENERATION

Water Use, ML/day		Industries Served	All Industries	Cooling Water	Net Water Use[a]
Public System AWGA		88.9	97	-	97
Private Supply		612.6	684	572	112
TOTAL		701.5	781	572	209
Wastewater Flow, ML/day				**Uncontaminated[b]**	**Contaminated**
From:	Sanitary[c]	4.6	8 (1%)	-	8 (3%)
	Process	251.0	275 (32%)	68 (11%)	207 (92%)
	Cooling	538.1	587 (67%)	576 (89%)	11 (5%)
To:	Public sewers	84.1	92	3	89
	Drains	279.0	306	218	88
	Canals	340.5	377	363	14
	Sea	91.4	95	60	35
TOTAL		795.0	870	644	226

(a) Estimated total industrial water use less cooling waters.

(b) Cooling water, AWGA treatment plant wastewater and other identifiable uncontaminated industrial plant process wastewaters.

(c) In-plant sewage flows, numbers in parentheses, represent percentage of total wastewater flow.

The 870 000 m^3/day of total industrial wastewater flow (contaminated and process-cooling waters) is estimated to carry 160 000 kg/day of BOD_5 and 315 000 kg/day of COD. Approximately 90 percent of these loads are associated with contaminated wastewater flow and represent an average value, for BOD_5 of 640 mg/L and for COD of 1240 mg/L. Contaminated industrial wastewater flows discharged to drains, canals, or other open water bodies, instead of the public sewers, are often diluted with process-cooling wastewater.

Overall Flows

Combining domestic (including commercial) and industrial discharges with estimated infiltration results in a current average dry weather wastewater flow of 383 000 m^3/day in sewered areas. Details are presented in Table 3-4 for both sewered and unsewered areas. A resultant overall (sewered and unsewered area) wastewater average dry weather flow value of 562 000 m^3/day is estimated to represent the 1977 condition in Alexandria. This value is equivalent to an overall per capita wastewater generation rate of 236 L/day.

3.5 Management and Finance

System Operation

Alexandria's sewerage system is plagued by many problems, many of which could be alleviated by improvement and enforcement of the existing Sewer Use Law. The dumping of solid wastes and trash, mazout (fuel oil residues) and used lubricating oil, toxic and low pH wastes from industry, septage from the pumping of septic tanks, and manure from cow barns located within the city into the sewer system has resulted in partial blockage and accumulations of solids that would normally be carried through the system by flow in the sewers. Mazout and waste oils float on the sewage, accumulating at high points in the collection system. These materials make sewer cleaning difficult, represent a potential fire hazard, and upon discharge, degrade water quality. Low pH industrial wastes attack sewer structures and metal manhole components. These and toxic wastes make operation of biological treatment processes nearly impossible. Several toxic materials found in industrial wastewaters are taken up by and accumulated in plants and animals which may result in potentially dangerous concentrations of toxicants being passed along the food chain to affect the health of higher animals and humans.

TABLE 3-4

ESTIMATED PRESENT WASTEWATER FLOWS

	1977
Population	
Total in Alexandria (permanent plus seasonal peak)	2 800 000[a]
Within presently sewered areas	2 380 000
(percent sewered = 85%)	
Domestic Sewage Generation, litres/person/day	100
Wastewater Flows, ML/day	
Domestic:	
Sewered area	238
Unsewered areas	42
TOTAL	280
Contaminated Industrial:	
To sewers	89
To drains, canals, and the sea	137
TOTAL	226
Infiltration (4300 ha x 0.15 L/sec/ha)	56
Average Dry Weather Flow:	
In sewered areas	383
In unsewered areas	179
TOTAL	562

(a) 1976 permanent population (2.382 million) times annual growth rate (2.7%) plus a seasonal population peak of 358 thousand temporary residents.

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These materials must be excluded if the sewerage system is to operate properly. The present Sewer Use Law prohibits dumping of such materials into the system, but the law is not enforced. Before it can be enforced, alternative means of collection and disposal of these wastes must be established. The people who generate the problem wastes need to be instructed in proper use of the new collection procedures and facilities. For the benefit of the sewer system, as well as for public health and for logistic reasons, all cow barns within the city should be moved to rural locations.

Another barrier to proper operation of the sewerage system is the policy of surcharging the gravity collection system. The principal reason for the policy is to allow for system deficiencies. A few pumps, for example, are mismatched to the head conditions and will not discharge at the required rates unless the head is decreased by surcharging the pump suction. In other cases wet wells have not been provided with adequate capacity between the levels where pumps are stopped and started. Several older pump stations have no wet wells at all. Operating in a surcharged condition, however, has allowed fewer pump starts and stops, which is desirable for operability of pumps and electrical gear.

Surcharging renders useless the nominal separation of stormwater from wastewater in new portions of the East Zone system. Operating the system in a surcharged condition increases the number of raw sewage overflows along the shoreline, when electrical failures interrupt pumping. If the system were not operated in a surcharged condition, power outages of an hour or two could be adequately handled without overflow, by using storage available in the existing system. Similarly, during periods of runoff, storage available in the system (until it fills) is useful in eliminating flooding due to short duration rainfalls and reducing the extent of flooding for longer rainfall periods. Surcharging also causes contamination of groundwater in the vicinity of sewers, due to exfiltration from pipeline joints. For proper operation, the system must be kept pumped down in order to result in open-channel flow within the gravity lines. Modification of existing pump stations will be necessary to allow this mode of operation. The program of construction set forth in this report includes such work.

Organization and Administration

Wastewater System Management. Management is provided by a national organization, the General Organization for Sewerage and Sanitary Drainage (GOSSD), a branch of the Ministry of Housing and Reconstruction (MOHR). Overall policy-making, budgeting, and financial control, as well as design, tendering, and contract-award for major projects, are the responsibility of GOSSD. GOSSD maintains staff, offices, and other facilities in Alexandria (GOSSD-Alexandria) to operate and maintain the wastewater collection and disposal systems within the city.

A chart of the organization of GOSSD-Alexandria is shown on Figure 3-5. The General Director's duties are presently being performed on a part-time basis by an official of the GOSSD offices in Cairo. As shown in the chart, there are four staff departments, five line departments, and two technical departments, each headed by an Assistant General Director.

Administrative Functions. Four departments provide personnel, legal, financial, and general services for GOSSD-Alexandria.

The Personnel Department follows the standard government employment policy in hiring GOSSD-Alexandria personnel. There are weaknesses in the compensation system which limit their ability to attract and retain competent personnel. Among these weaknesses are low salary scales, lack of provision for merit pay increases, and limited opportunities for promotion. There are no incentives for achievement or performance. Planning for staff needs (number and skills) is not performed adequately.

The Budget and Finance Department is responsible for local budgeting, accounting, purchasing, storekeeping, and disbursing funds. Basic accounting techniques are prescribed in the Egyptian Standardized Accounting System. No asset accounts are maintained. Further, since the standard system does not prescribe depreciation accounting for wastewater facilities, no depreciation is recorded. An internal audit acitvty does not exist. Purchasing activities conform to nationally established procedures which require competitive bidding for purchases costing in excess of LE 500. Inventory is maintained in a number of locations to serve the needs of various operating and maintenance units. Although a great deal of statistical information is gathered throughout the organization, such data are generally not collected, summarized, or evaluated for the use of top level management.

The Legal Department provides a range of legal services. The lack of an effective industrial waste monitoring program has hindered any efforts to secure compliance with the Sewer Use Law.

The Public Services Department is responsible for community relations and receives and processes complaints. It also supervises security services. Its Assistant General Director also assists the Project Execution Department in the capital development planning process.

Operations and Maintenance Functions. Three departments are responsible for the operation and maintenance of the Alexandria sewerage system.

The Sewer Maintenance Department, responsible for cleaning and repairing sewer lines throughout the city, has a highly decentralized approach to its tasks. There are seven districts, each with assigned crews and a basic allotment of tools. Some have permanently assigned mobile equipment. Additional equipment is obtained from a central pool. The districts vary widely in size and operational complexity. Severe problems have been created through the misuse of the wastewater system. As a consequence, most of the Department's work is corrective, rather than preventative, in nature.

The Water Pollution Control Department is responsible for operation and maintenance of the East Treatment Plant and for monitoring water quality in Lake Maryut and along the beaches of the Mediterranean Sea within the city limits. The East Plant is not functioning properly due to a variety of circumstances including faulty design, heavy loading of industrial wastes, and lack of training and motivation of plant staff, as has been discussed previously.

The Mechanical and Electrical Department operates and maintains pump stations, provides auxiliary pumping services as needed, and operates and maintains the vehicle fleet of GOSSD-Alexandria. In addition, the staff of this department provides mechanical and electrical design services, when required, for the design of small pumping facilities. Pump stations are staffed on a 24-hour basis and the city is divided into two zones for operational control purposes. Emergency pumping services are provided by an auxiliary unit when needed to alleviate flooding or for dewatering pump stations that are under repair. The equipment shop is capable of repairing or rebuilding virtually any pump or vehicle included in its inventory.

Project Development. Two departments in GOSSD-Alexandria are responsible for new projects.

The Design Department's duties include design of small extensions and pump stations, collection of field data for designs to be prepared in Cairo, placement of grade stakes for construction, and estimating project completion for contractors' payments. It is handicapped in performing these functions by its small staff and limited equipment.

The Project Execution Department represents GOSSD-Alexandria on all construction projects. Department representatives participate first in the bid opening and evaluation processes. A team of inspectors and engineers is then assigned during construction to assure compliance on site with project plans and specifications. Applications for connections and extensions are received and processed by this department. Applicants for new connections are required to deposit with the Department the amount of the estimated cost of the connection. The Department also collects developer payments for the cost of designing and building collection systems and connections to new developments. The Department includes a drafting team to meet both its needs and those of the Design Department.

Financing Arrangements. The funding requirements of GOSSD-Alexandria are met through national budget allocations. Although charges are made for new connections, the total amount of revenue generated is reduced by subsidizing these costs for lower-income families. Operations, maintenance, and capital development expenditures in excess of revenues received from new connections and contractor developments are met by quarterly allotments deposited in the bank account of GOSSD-Alexandria by the Ministry of Finance. Authorization to spend such funds expires at the end of the fiscal year, and any funds remaining are used to reduce the allotment for the first quarter of the succeeding year.

A summary of expenditures from 1973 to 1976 is shown in Table 3-5 along with 1977 budget estimates. Annual wastewater expenditures fall into two major categories--operating costs and capital costs. The annual budget for these expenditures is prepared by GOSSD-Alexandria and submitted for review to the Ministry of Housing and Reconstruction and the Ministry of Finance. The section of the budget dealing with projects must also be approved by the Ministry of Planning. A five-year capital improvement program is developed annually by GOSSD-Alexandria and GOSSD-Cairo as a planning tool.

The approved budget is allocated by GOSSD-Cairo. Moderate increases in operation and maintenance costs occur annually, due to regulated increases in government wages as well as increases in unit cost and required quantity of materials and supplies. Budget amounts for capital improvement projects fluctuate according to the availability of funds and project priorities. When expenditures exceed budgeted funds, GOSSD-Alexandria must have additional costs approved by the Ministry of Finance.

The Budget and Finance Department has the authority to disburse all funds. The Ministry of Finance audits some of the financial documents of GOSSD-Cairo at year-end and a second review is made by the Central Agency for Auditing under the authority of the Parliament. Detailed internal and on-site checks of transactions pertaining specifically to GOSSD-Alexandria are not made.

Conclusions. The organization of GOSSD-Alexandria could be made more effective and the level of public service could be improved. Among the present weaknesses are:

- lack of full-time General Director;
- low levels of compensation for employees;
- a high turnover rate among employees;
- a shortage of personnel in certain departments;
- lack of a preventive maintenance program;
- lack of asset records and an absence of depreciation schedules;
- lack of an internal audit unit, and
- inability to enforce the sewer use law.

Correcting these weaknesses will not necessitate a restructuring of the present GOSSD-Alexandria organization but will result in a more effective organization.

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TABLE 3-5

GOSSD-ALEXANDRIA FIVE-YEAR FINANCIAL SUMMARY, 1973-1977

Annual Expenditures, LE[a]	1973	1974	1975	1976	1977[b]
Operating Costs					
Salaries and Allowances	398 482	437 150	497 074	544 442	549 984
Employee Benefits	68 618	73 822	97 921	141 640	165 800
Fuel	24 215	23 413	24 024	25 412	33 900
Utilities	33 485	34 266	30 683	84 755	89 050
Spare Parts and Materials	67 495	63 898	50 253	58 277	100 000
Major Repairs	15 499	16 241	13 088	13 647	24 400
Other Expenditures	23 049	26 725	28 437	29 734	32 510
TOTAL	630 843	675 515	741 480	897 907	995 644
Capital Costs					
Master Plan Sewers	111 155	163 763	99 248	484 903	600 000
Master Plan Pumping Stations	48 041	40 105	34 036	-	300 000
Master Plan Treatment Facilities	203 859	175 270	303 423	399 940	500 000
Other Projects	181 795	120 862	100 951	144 809	200 000
TOTAL	544 850	500 000	537 658	1 029 652	1 600 000
Debt Payments	-	-	9 312	3 508	3 508
Total Annual Expenditures	1 175 693	1 175 515	1 288 450	1 931 067	2 599 152
Revenues					
Service charges, fees[c]	87 870	127 015	79 262	96 993	not available
Government contribution	1 087 823	1 048 500	1 209 188	1 834 074	not available

(a) Based on financial records of the Budget and Finance Department, GOSSD-Alexandria.

(b) Operating costs based on budget approved by GOSSD-Cairo. Capital costs based on annual needs estimated by the Project Execution Department on 1 July 1977. Debt Payments based on information from Budget and Finance Department on existing commitments.

(c) Customer contributions for extensions and connections.

3.6 Water Quality

Mediterranean Sea

General Condition. Outside of locally polluted zones, the Mediterranean waters in the vicinity of Alexandria are beautifully clear with low turbidity and low counts of marine organisms. The sea is generally nutrient-poor, especially in the eastern portion, due to the lack of major discharges into it. The significant reduction in the Nile discharge, due to the Aswan High Dam, has taken away a considerable source of nutrients, reduced turbidity, and affected flora and fauna to a yet undetermined extent. Urban pollution along the shoreline of the sea has, on the other hand, stressed local, natural self-purification resources to a considerable degree, resulting in unacceptable degradation along some portions where circulation and dispersion are weak or non-existent. The entire shoreline of Alexandria, as far as two kilometres offshore, is being stressed and degraded.

Western Harbor. Large quantities of untreated domestic and commercial wastewaters, as well as urban runoff, are discharged at the shoreline in several locations near the Central Dock area of the Western Harbor. These flows, coupled with the usual wastewater discharges from berthed ships and other harbor activities have created too great a demand on oxygen resources along shore, resulting in summertime anerobic conditions and attendant nuisances. Along the shoreline further west, discharge of untreated wastewaters from an abattoir and several tanneries, as well as domestic sewage from an extensive residential area, causes a similar problem situation. Even further to the west, there are additional discharges of industrial and domestic wastewaters, also untreated. A large chemical manufacturing plant discharges, through its own sea outfall, caustic wastes and wastes from the manufacture of chlorine; the discharge is presumed to contain significant concentrations of mercury. Fortunately, natural circulation and dispersion in the extreme western portion of the harbor have held visible effects of this pollution to a minimum.

Another pollutional load discharging to Western Harbor is the drainage from an area of about 200 000 ha of irrigated farm land. A relatively small quantity of this drainage discharge is from and through Lake Maryut, which receives a considerable portion of Alexandria's untreated wastewater. This drainage discharge into the Western Harbor is of relatively good quality, except that it contains both nutrients and pesticide residues associated with agricultural runoff. Pollutants are usually well mixed and dispersed by turbulence of waves and wind-generated local circulation.

Kait Bey Point. The outfall at Kait Bey Point discharges untreated wastewater from the central portion of the city into the surf zone at the end of the Anfushi Peninsula. At present, average dry weather flow in excess of 100 000 m^3/day is discharged through this facility. The outfall pipeline is laid on the bottom through the surf zone with a minimum of concrete encasement, affording inadequate protection against wave action. Consequently, the pipeline has been broken in several places and wastewaters are unintentionally discharged along its 735 m length. Outfall design provided for a single open-end discharge thus affording minimum dispersion. A major portion of the wastewater passes close to land as there is usually a current parallel to the shoreline predominantly in the northeasterly direction, although sometimes to the southwest. The current carries poorly diluted wastewater for several hundred metres before the plume becomes visibly undetectable through sufficient mixing. Odors are noticeable near the plume several hundred metres from the outfall. Bacterial contamination of the beaches several kilometres in either direction is caused by this discharge, when there are onshore winds.

Eastern Shoreline. Between the Eastern Harbor and Montazah there are more than twenty sewer overflows which, at various times, discharge raw or runoff-diluted wastewater to the sea at shoreline. Considerable volumes of wastewater are discharged through those outfalls from pump stations during the non-bathing season. It is a common operating procedure to shut off pumps during the winter and allow wastewaters to discharge to the sea. When overflows and intentional discharges occur at these outfall points, wastewater plumes are visible with associated characteristic septic sewage odors and attendant large flocks of sea birds in the vicinity. During periods of offshore winds an oily slick can be seen from the point of discharge extending several hundred metres from the shore. During onshore winds, the polluted, warmer and less saline wastewaters discharged from these overflows float on the denser sea water and are held close to the shore by the winds, thereby not reaching dispersing currents and causing a concentrated polluting effect along the beaches.

Studies made at Alexandria University[1] have developed circumstantial but convincing evidence of a direct correlation between the incidence of typhoid fever and persons who have been swimming at beaches near known sewage overflows. Occurrence of dense marine plant growths on shoreline rocks and structures is ample evidence of the existence of organic pollution in shoreline waters. These plant growths are removed by the truckload from bathing areas both before and during the summer season.

Near shore pollution is also evident due to urban runoff that flows directly to the sea at the shoreline from areas north of the ridge. The extent of this pollution is relatively small, however, and the considerable cost involved in correcting this problem makes it impracticable, in view of the many more pressing problems. Certain of the local storm drainage system manholes are used by haulers of septage for discharge of septic tank sludges removed from nearby unsewered areas. This very strong, noxious, septic sludge flows a short distance in the drain before entering the sea at shoreline. One common location for this clandestine dumping of sludge is near Montazah Garden at the eastern end of the Corniche; this point is 100-300 m from beaches in either direction.

Abu Kir Bay. The considerable pollution of Abu Kir Bay is mainly of industrial origin. The point of discharge to the bay is at the Tabia Pump Station. The major sources of pollution are several textile mills located northwest of Kafr el Dawar and the two paper mills located on either side of the Tabia Pump Station (refer to Figure 3-3). While the Abu Kir Drain system carries considerable agricultural drainage, the magnitude of the industrial wastes discharges and their waste loads are such that the Tabia discharge to the bay is highly polluted. These flows contain small amounts of heavy metals from the paper mills, dyes from both the textile and paper mills, and often very low pH wastes from the textile mills. Fibre from the paper mills is also evident.

Abu Kir Bay is well sheltered from the main body of the Mediterranean by Abu Kir Peninsula and shallow underwater rocky shoals or ridges that lie

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[1] Sharkawy, Fahmy, "Study of the Effects of Swimming in the Sea on Health", Sanitary Survey of Alexandria Beaches, 1976.

across the open portion of the bay. This results in very limited movement of water into or out of the bay and little circulation or turbulence within the bay waters compared to the open sea. The particular location of the Tabia discharge point is at a most sheltered point in the bay. As a result, discharged wastewater at Tabia is poorly dispersed and tends to remain in the vicinity. A report[1] of the pollution conditions in the bay indicates that during a 1976 study period, the sea water BOD_5 near the Tabia discharge point had a mean value of 650 mg/L and a range of from 500 to more than 1000 mg/L, well in excess of the strength of normal domestic raw sewage. Samples taken at a point 3.4 km east of Tabia and 0.3 km offshore in Abu Kir Bay had a mean BOD_5 value of more than 300 mg/L. At Maadeya, 8.7 km east of Tabia, shoreline observation showed evidence of organic pollution, but at a significantly lower level. This indicates that there are considerable pollutional loads being discharged at Tabia that are not being dispersed or mixed. Continued discharges are likely to exacerbate problem conditions in the bay, the likely consequence of which would be loss of the anadromous fishery in Lake Idku.

Inland Waters

General Conditions. All surface waters in the immediate vicinity of Alexandria, with the exception of the Drinking Water Canal and the Hydrodrome, receive pollutional loads of one sort or another. The Drinking Water Canal branches from the Mahmoudia Canal upstream of any significant Alexandria development and, although it contains pollutants carried by the Mahmoudia flows, there are no downstream uses to add more pollutants. The various canals, drains, and channels of the region all receive stormwater runoff and are otherwise used as receptors for wastewaters of various sorts.

Mahmoudia Canal. Although the Mahmoudia Canal is primarily a water supply canal, it receives considerable agricultural drainage by pumping. There are also upstream uses which introduce pollutants. The quality of the water becomes continually poorer as it flows through the developed areas of Alexandria. At the point of discharge to Western Harbor, the canal water is septic and has the appearance of ordinary sewage.

Montazah Canal. The Montazah Canal is supplied by the Mahmoudia Canal at

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1 Mitwally, H., et al., "Pollutional Status of Abu Kir Bay", Department of Environmental Health, Alexandria University, May 1977.

a point downstream from the Siouf Water Treatment Plant intake. The canal passes through densely populated areas where it receives pollutants from many sources, including sewer overflows, industrial waste discharges, stock watering, laundry, urban runoff, and agricultural drainage. The canal supplies water, near its end, to the Maamoura Water Treatment Works. Water quality in all portions of the canal is very poor and certainly not fit for its many present uses, including drinking water supply, dishwashing, bathing, and laundry.

Noubaria Canal. The quality of water in the Noubaria is quite good in comparison to waters of other canals in the area. The canal has limited traffic and passes through areas which are undeveloped. It does, however, receive some agricultural drainage and its salinity approaches the limit of suitability for high value crop irrigation. The salinity of the canal water near the Western Harbor is very high, due to inflow of seawater when the locks are operated.

Umoum Drain. Umoum Drain water quality is also reasonably good. The drain carries agricultural drainage from a substantial area that contains almost no urban development. Consequently, there are no concentrations of organic pollutants to cause environmental stress of significance.

Hydrodrome-Kalaa Drain. The Hydrodrome-Kalaa system drains the area primarily south of the Mahmoudia Canal and east of Lake Maryut, as shown on Figure 3-1. It is also an agricultural drain. A portion of the drain, formed by depressions resulting from the construction of the Hydrodrome, extends around the Hydrodrome and consists of two separate channels, one northeast of the Hydrodrome, and the other southwest. The latter carries small amounts of clear, clean water, primarily seepage from the Hydrodrome reservoir. The other channel, however, receives wastewater flows and runoff from the East Sewerage Zone of Alexandria, including the area of Nouzha which lies south of the Mahmoudia Canal. These wastewaters are largely untreated, although a small portion of the flow receives processing at the East Treatment Plant, the effluent of which also discharges into this channel. The channel is about 40 m wide, about 5 m deep, and about 5 km long. It is covered along most of its length with a thick layer of floating sludge, which in some places supports lush weed growth. Anaerobic conditions exist throughout. Discharge from this channel is controlled in order to maintain a water level higher than that of the Kalaa

Drain. This decreases the differential head between the Hydrodrome and the channel, and minimizes seepage. A large natural open sludge digester is created in the channel which affords a significant degree of treatment for the wastewater. Overflow from the channel leads to the Kalaa Drain upstream of the Kalaa Pump Station. Throughout the year water overflowing the channel is black, septic, and highly turbid. BOD_5 reductions in the channel are found to be on the order of 60 percent, as determined by analysis of samples. The BOD_5 values of channel overflow are in the range of 110 to 200 mg/L. During wet weather, considerable pollutional loads normally retained in the channel are flushed out to the Kalaa Drain.

Overflow from the channel mixes with drainage from a small agricultural area and is lifted by the Kalaa Pump Station to the Kalaa Drain where it is further diluted by additional agricultural drainage. Water in the Kalaa Drain downstream of the pump station discharge is turbid, has a characteristic sewage odor, and supports the growth of weeds, hyacinths and algae. It has a BOD_5 of about 60 mg/L. Six kilometres downstream, the Kalaa Drain discharges into Lake Maryut. At that point, the BOD_5 has been reduced to about 50 mg/L. The entire length of the Kalaa Drain, downstream of the pump station discharge, was choked with hyacinths during the summer of 1977.

The Hydrodrome is now used an an emergency reservoir for water supply and does not affect the wastewater or water quality considerations of this study.

Lake Maryut. The eastern fresh water portion of Lake Maryut is of major interest in this study. The waters of the western portion of the lake are highly saline and are utilized for industrial salt production. The amount of pollution entering the western portion is small. The nutrient level is such as to produce intermittent blooms of unusual pink-colored algal species. It is important that the west part of the lake be protected against major fresh water (including raw sewage or treated effluent) influx in order to safeguard the salt production.

The eastern portion, however, is a major receptor of Alexandria's wastewater, most of which is untreated. The lake discharge to the sea is of relatively good quality indicating that its self-purification properties are considerable. The lake has some serious environmental problems, however, and is suffering heavily from eutrophication.

The several lagoons comprising the eastern portion of Lake Maryut have different uses and different water quality conditions. The main lagoon, which receives the heaviest organic pollutional load, is in a relatively advanced stage of eutrophication. Waters in the open part of the lagoon are highly turbid and support dense algal blooms. Dissolved oxygen values are variable, depending upon wind-generated turbulence and photosynthesis to maintain suitable levels against the demands of a considerable organic load. Dissolved oxygen values are sufficiently high and consistent to support a fishery. Around the northern and eastern ends of the main lagoon where the wastewaters enter, dissolved oxygen is absent. These local waters are virtually raw sewage. Considerable areas of floating sludge exist along the north shore of the lagoon. On the opposite shores, the growth of marsh grass is extensive. In these areas dissolved oxygen is also low due to poor circulation and high organic loads.

In other lagoons of Lake Maryut which do not receive such gross pollutional loads, water quality is reasonably good. These lagoons, are, however, highly eutrophied and support considerable growths of aquatic and emergent plants and algae. Fish catches in these lagoons are far better than in the main lagoon.

Because Lake Maryut figures so prominantly in the present wastewater system and as one of the possible Master Plan alternatives includes the lake as an interim disposal medium, considerable study has been given to the water body. Details of this study are covered more explicitly in Section 6.2.

Abu Kir Drain. Water quality in Abu Kir Drain is very poor because of the presence of agricultural drainage and industrial wastes, as indicated above in the discussion of conditions in Abu Kir Bay.

3.7 Environmental Health

Statistical Health Data

The state of public health in Alexandria and Egypt is very poor as a result of lack of adequate environmental sanitation and health facilities. Provision in the near future of suitable sanitation facilities for Alexandria will require not only a tremendous "catch-up" effort to correct past and present deficiencies but also a continuing program to provide for a population increase of 50 000 to 100 000 persons per year.

Statistical data available for Egypt and Alexandria are presented in Tables 3-6, 3-7, and 3-8. Values indicate alarming health conditions, even though they are suspected to be under-reported.

A good overall measure of the status of sanitation is the infant mortality rate. Egypt was reported in 1973 to have 98 infant deaths per 1000 live births, a reduction from 119 per 1000 in 1963. Only six nations in the world are known to have higher infant mortality rates. Comparative infant mortality rates in selected Middle Eastern and Asian countries reported from 1968 to 1973 are: Egypt 98, Libya 80, Iraq 28, Kuwait 44, Jordan 23, Syria 22, Pakistan 124, and India 61.

The infant mortality rates (Table 3-6) for Cairo and Alexandria exceed those of the country as a whole. This undoubtedly reflects better reporting from urban centers but also a serious urban environmental health situation.

Typhoid, paratyphoid, infectious hepatitis, dysentery, and other major gastro-enteritic diseases are endemic to Egypt and especially in the major urban centers, Cairo and Alexandria, as is indicated by the data in Table 3-7. These data indicate that typhoid, infectious hepatitis, and dysentery rates have been substantially higher in Alexandria than in Cairo or the country as a whole. This is in spite of the fact that Cairo is more crowded and has extensive areas where public services, such as water and sewerage, are inadequate.

A good basis for assessing the potential for the spread of waterborne disease in Egypt is the detailed epidemiological study that was carried out during the 1970 cholera outbreak. Because of the intensity of investigation and household follow-up, reporting is believed to have been good. The severity of the outbreak in the governorates hardest hit, in the order that the disease was first identified, is shown in Table 3-8. It is evident that the epidemic was most severe in Alexandria where the attack rate was four times that experienced in Cairo.

Relationship to Sanitary Conditions

The environmental health conditions indicated by the above data bear a clear relationship to a number of obvious sanitation problems in Alexandria: the absence of sewers in extensive, densely inhabited residential areas; the

TABLE 3-6

VITAL STATISTICS IN EGYPT, 1972-1973

	Cairo	Alexandria	Egypt
Population, middle 1972	4 765 100	2 066 506	34 501 500
Births, 1972	143 617	60 088	-
Deaths, 1972	61 925	23 192	-
Infant deaths, 1972	21 790	7 530	-
Infant mortality [(a)]	152	125	116
Deaths, 1972			
Typhoid	109	30	-
Enteritis	308	167	-
Recent Infant mortality [(a)]			
1963	152	133	119
1964	157	134	117
1965	154	150	113
1966	157	144	127
1967	139	120	116
1968	161	139	131
1969	143	132	119
1970	144	128	116
1971	125	106	103
1972	152	125	116
Average 1963 - 1972	148	131	118

[(a)] Per 1000 live births.

TABLE 3-7

WATER-RELATED DISEASES IN EGYPT

	Cairo	Alexandria Governorate	Egypt
Population, 1974	5 640 600	2 250 300	36 254 100
Typhoid & Paratyphoid cases			
Average, per year (1970-74)	5585	2486	12 621
Average, per 100 000 per year	99	110	35
Infectious Hepatitis			
Average, per year (1970-74)	2325	2647	22 053
Average, per 100 000 per year	50	118	61
Dysentery			
Average, per year (1970-74)	30	208	331
Average, per 100 000 per year	0.5	9.2	0.9

Source: Ministry of Health as reported in WHO/World Bank Water Supply and Sewerage Section Study, June 1977.

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TABLE 3-8

CHOLERA IN EGYPT - 1970[a]

Governorate[b]	Date of Onset	Attack Rate per 100,000 persons
Kalyoubia	31 May	27.4
Alexandria	3 June	100.3
Cairo	14 June	25.2
Giza	27 June	21.7
Matrouh	4 July	75.8
Red Sea	5 September	56.1
All Egypt		16.5

[a] From "Report on the Epidemic Situation in Alexandria (1970-1971)", by Dr. M.H. Wahdan of the High Institute of Public Health and M. El Nomrousy, Ministry of Health, Department of Statistics.

[b] All governorates not mentioned had attack rates lower than 20 per 100 000 population.

failure of sewers in other areas because of their use as receptacles for refuse; the absence of a proper refuse collection system and consequent high prevalence of flies; and the combined effect of the above with Alexandria's low elevation and high water table create many sewage-filled pools and ditches throughout the city. Many of these accumulations of sewage are close to food vending establishments and household kitchens. Some market places are located within basins of combined sewage and runoff. The pools are used as play areas by children. In many places, sanitary drainage flows along and across city streets, where passing vehicles splash through and pedestrians wade to cross. The pollution of the heavily used bathing waters by wastewater overflows at the shoreline is probably a lower level of direct health significance.

Pollution of the water of the Nile and of the canals supplying water to Alexandria's water treatment plants, together with intermittent difficulties in the water distribution system, probably contribute to the overall very serious environmental health situation in Alexandria. Accumulation of solid waste and consequent disease transmission by flies is also undoubtedly an important factor. Nevertheless, observation of the potential for human contact, and contamination of food with sewage in parts of the city lacking sewer service strongly suggest that lack of a suitable means for disposal of human wastes is a very important, and possibly the single most important, factor responsible for the present conditions.

There is a very great potential for an explosive outbreak of waterborne diseases of greater seriousness than that of 1970. If this should occur, it would have tremendous social and economic effects. The economic effects would include not only the cost of dealing with the outbreak itself, but also the resulting loss of tourist income.

Improvement of human waste disposal conditions, not only close to dwellings and markets but also in the waters which receive collected wastewaters, should be given very high priority for the future of Alexandria.

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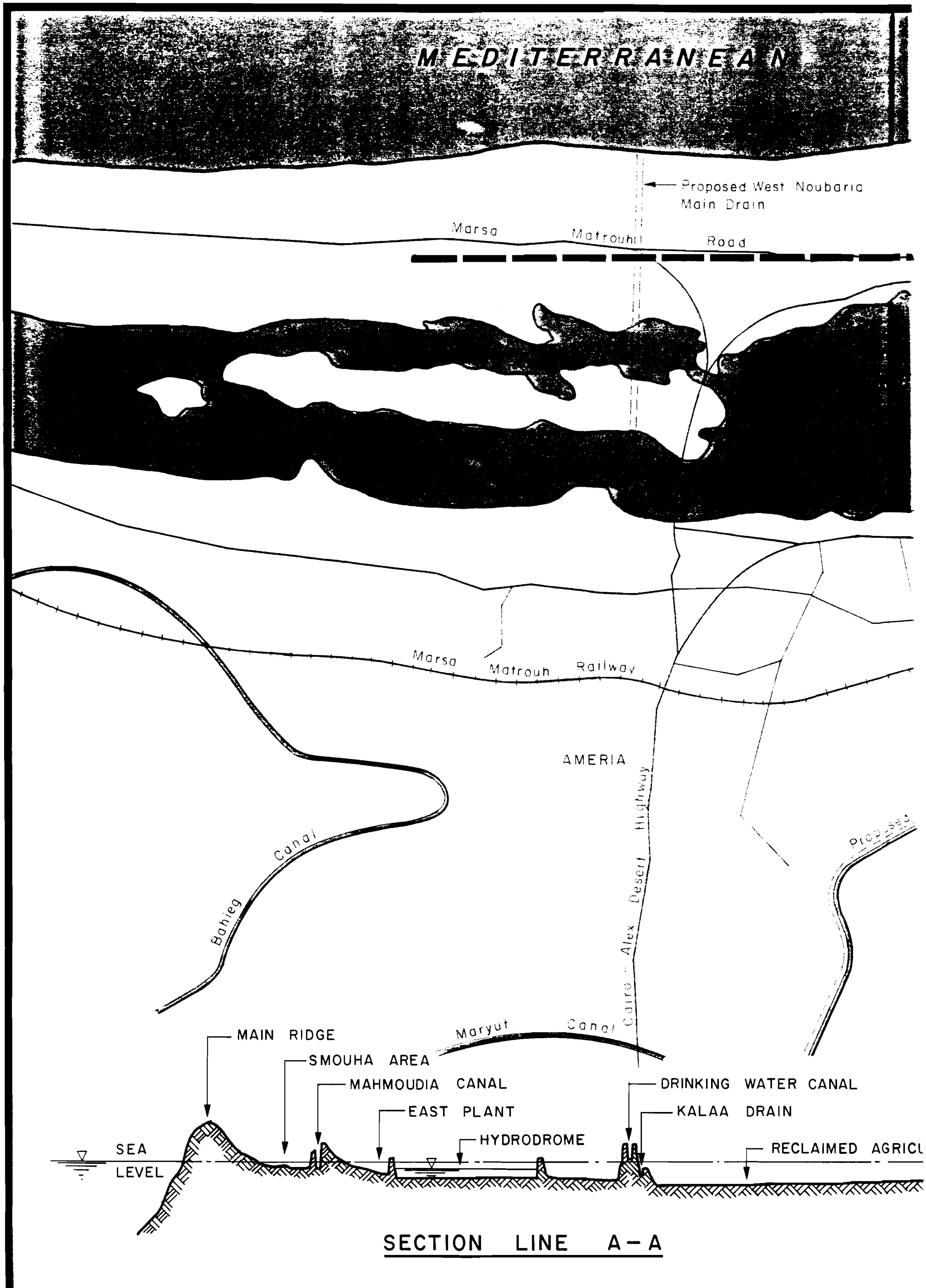

SECTION LINE A-A

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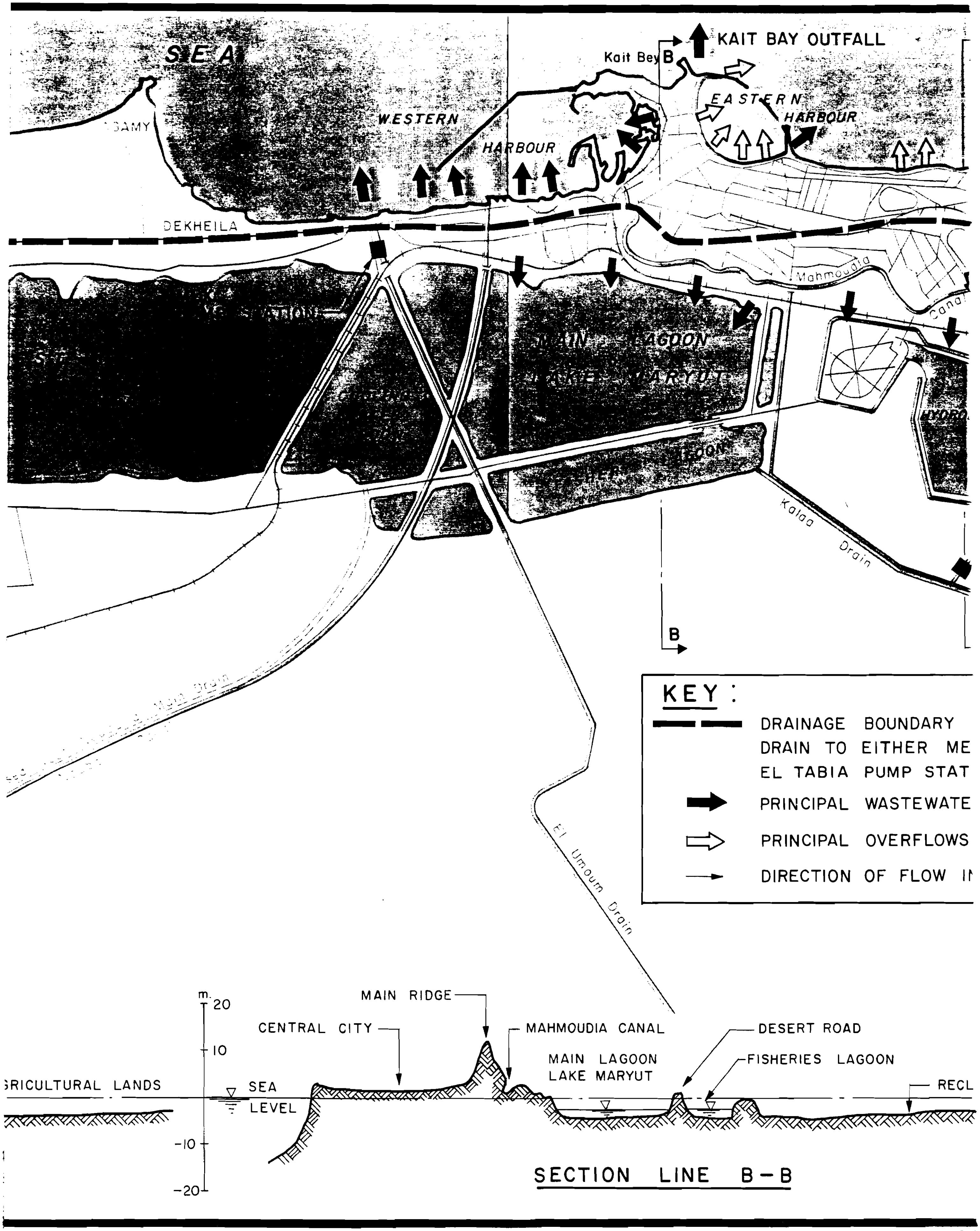
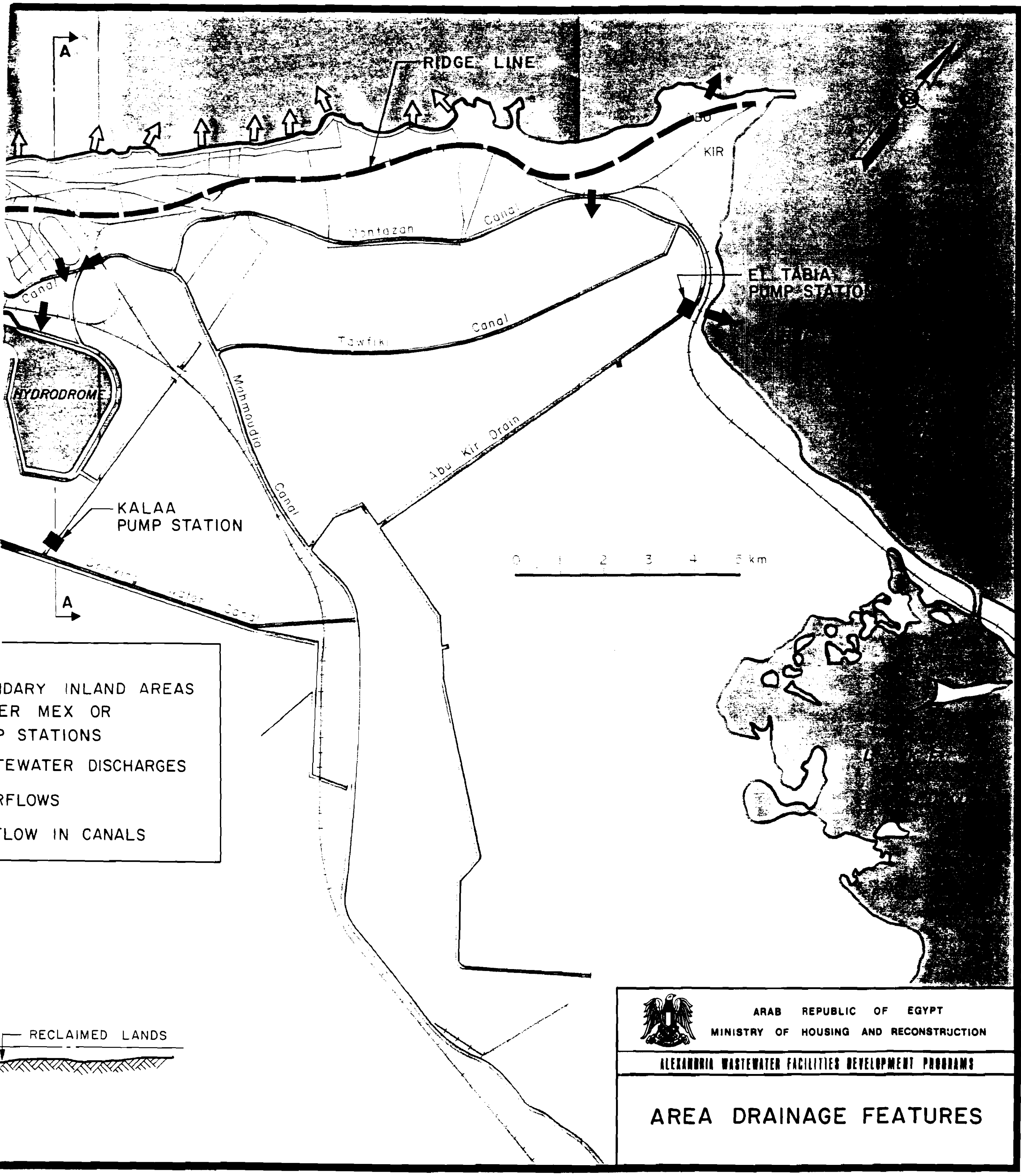


SECTION LINE B-B

63A

BEST AVAILABLE

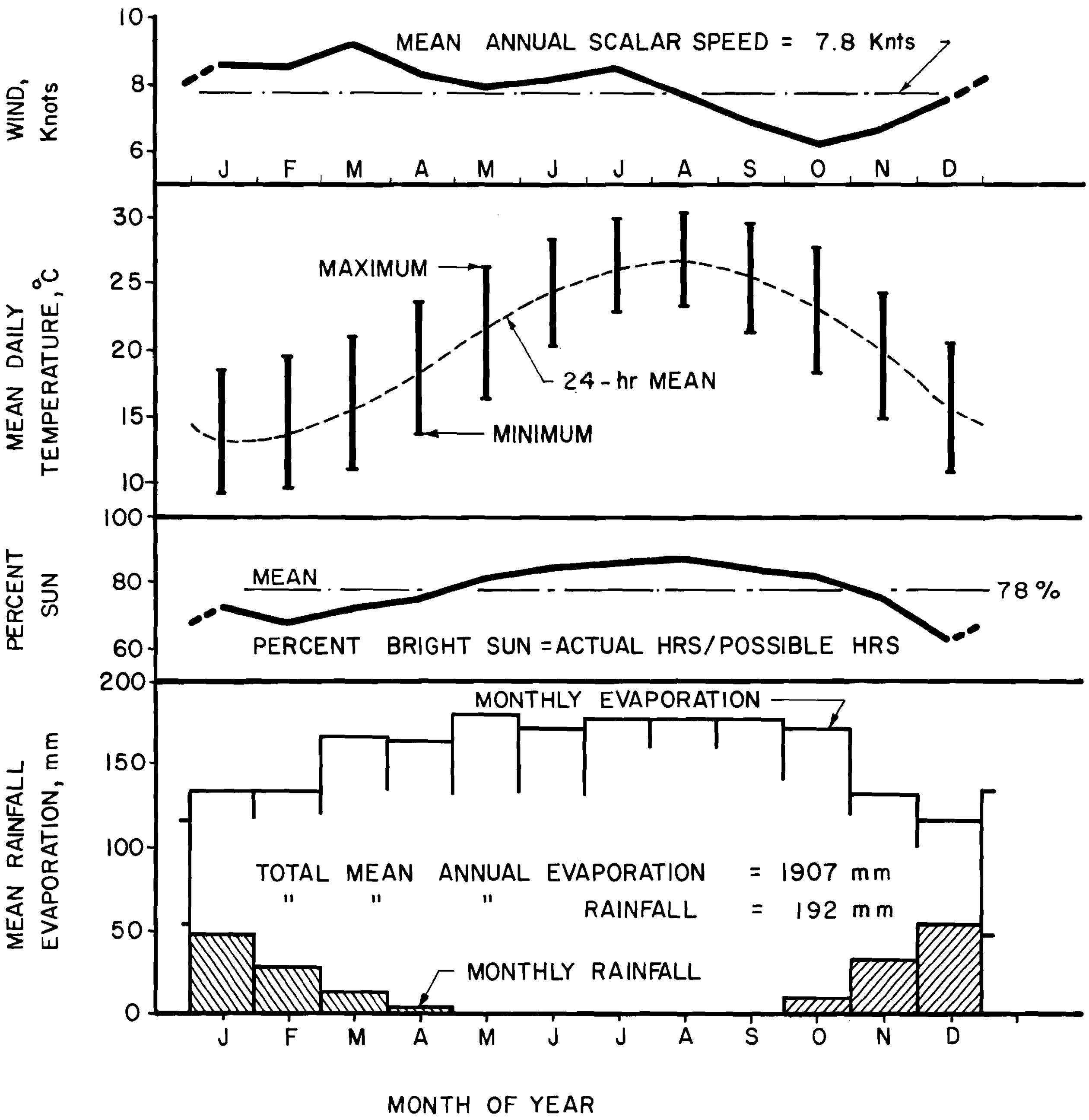


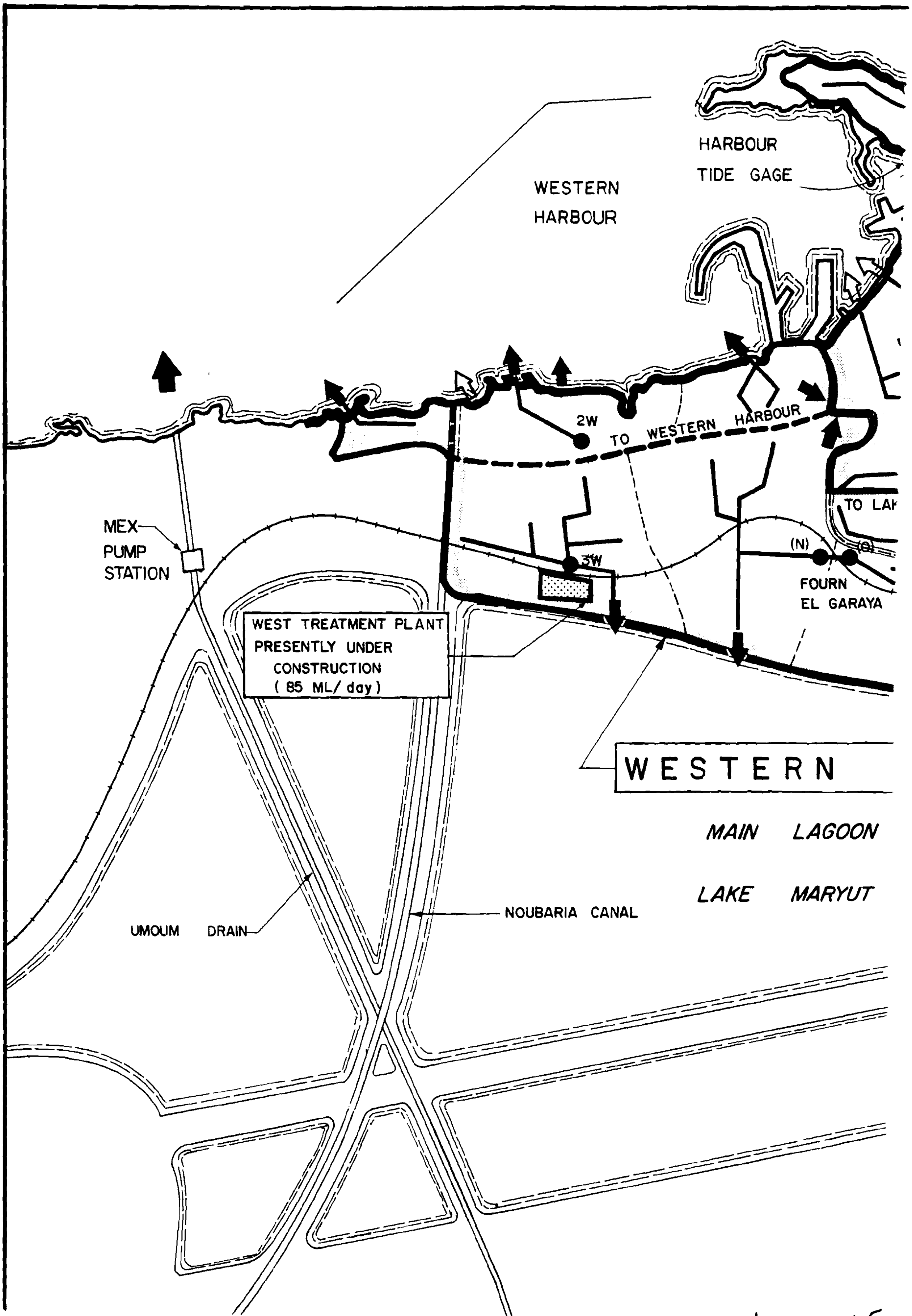
63B

FIGURE 3-2 SUMMARY OF SEASONAL VARIATIONS IN ALEXANDRIA CLIMATE

NUMBER OF DAYS OF OCCURANCE

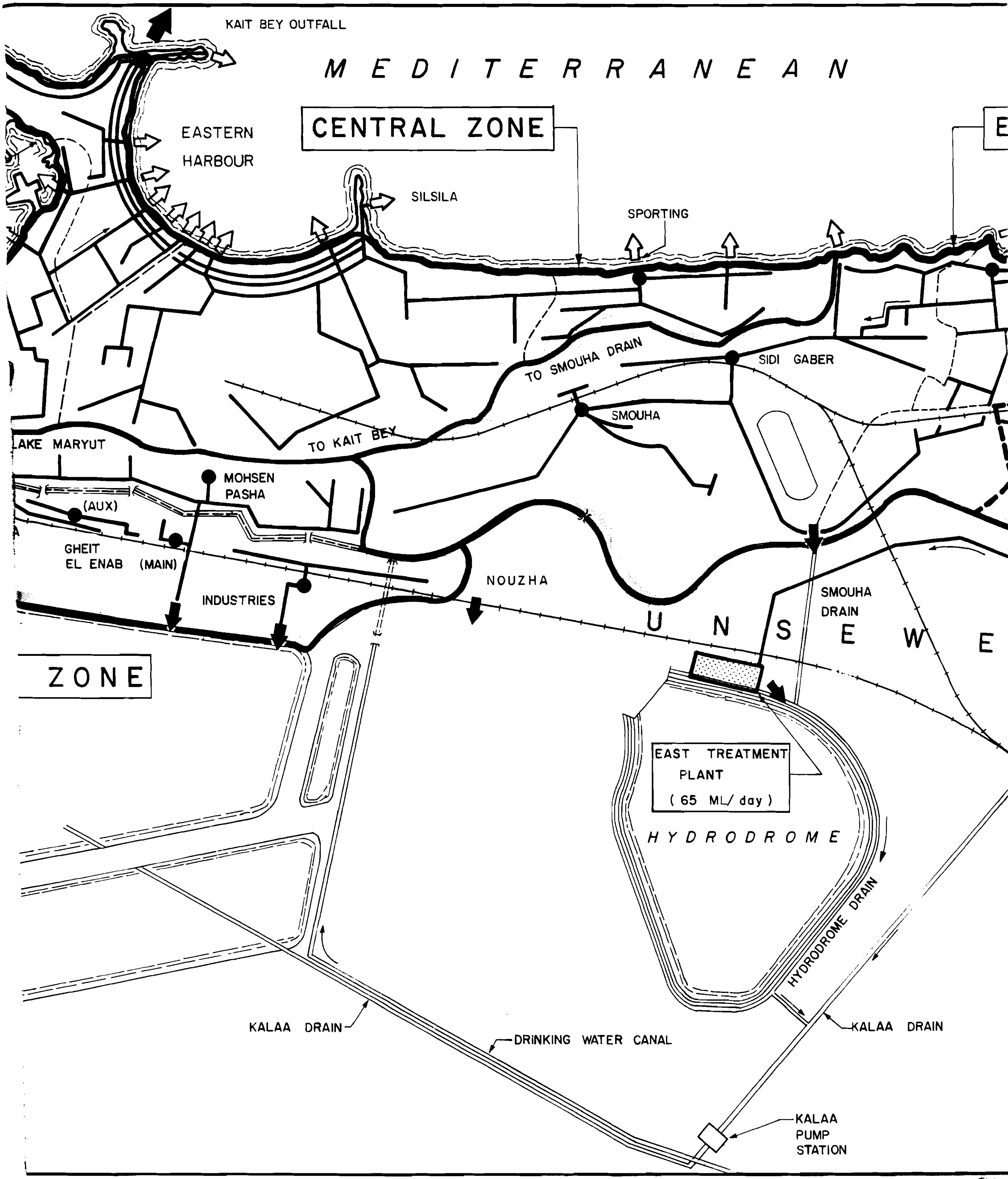
MONTH →	J	F	M	A	M	J	J	A	S	O	N	D	
GAIL FORCE	0.2	0.2	0.3	0.1	0	0	0	0	0	0	0	0.2	-WINDS (≥34 Knots)
HAIL	0.5	0.6	0.4	0.1	0.1	0	0	0	0	0.2	0.1	0.4	
FOG	2.7	1.8	1.0	2.1	1.6	0.7	0.3	0.7	0.6	2.6	2.6	3.4	VISIBILITY (≤ 1000 m)
THUNDER	1.1	0.5	0.7	0.1	0.4	0	0	0.1	0	0.4	1.3	1.2	STORMS

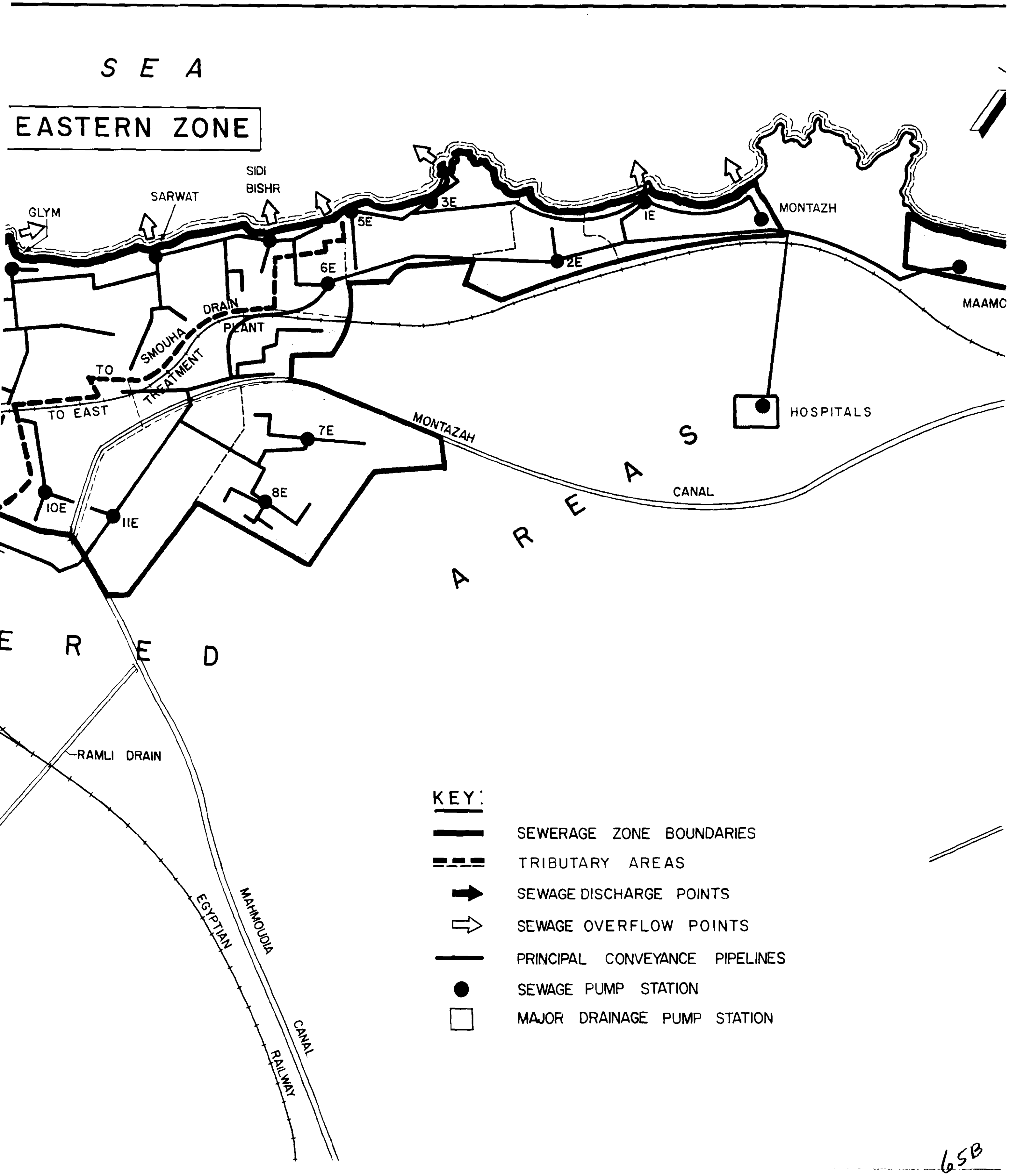




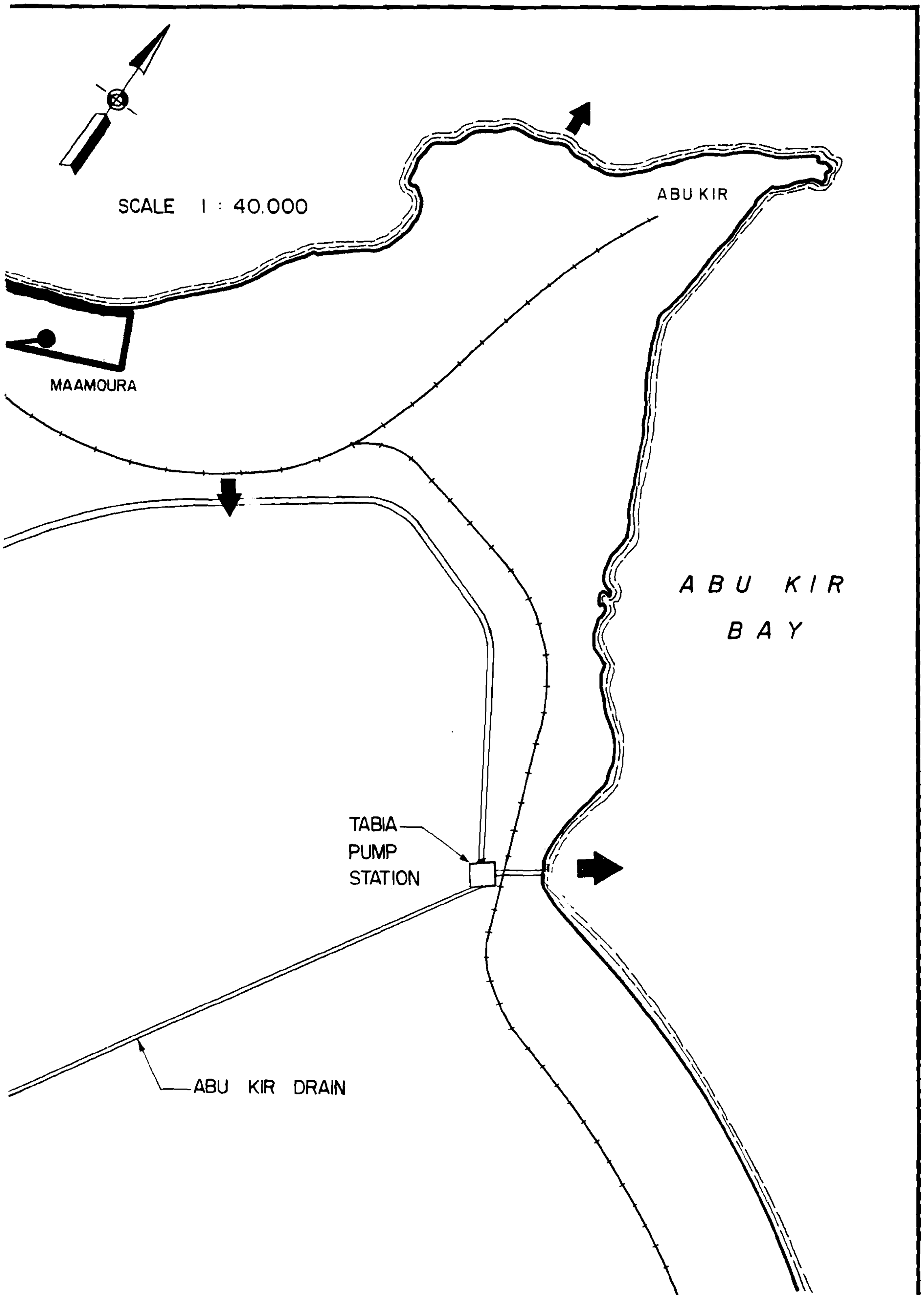
HARBOUR
TIDE GAGE
WESTERN
HARBOUR
2W
TO WESTERN HARBOUR
TO LAK
MEX
PUMP
STATION
(N)
3W
FOURN
EL GARAYA
WEST TREATMENT PLANT
PRESENTLY UNDER
CONSTRUCTION
(85 ML/ day)
WESTERN
MAIN LAGOON
LAKE MARYUT
NOUBARIA CANAL
UMOUM DRAIN

15-


KAIT BEY OUTFALL
MEDITERRANEAN
CENTRAL ZONE
E
EASTERN
HARBOUR
SILSILA
SPORTING
TO SMOUHA DRAIN
SIDI GABER
SMOUHA
TO KAIT BEY
LAKE MARYUT
MOHSEN
PASHA
(AUX)
GHEIT
EL ENAB (MAIN)
INDUSTRIES
NOUZHA
SMOUHA
DRAIN
UNSEWE
ZONE
EAST TREATMENT
PLANT
(65 ML/ day)
HYDRODROME
HYDRODROME DRAIN
KALAA DRAIN
DRINKING WATER CANAL
KALAA DRAIN
KALAA
PUMP
STATION



SEA
EASTERN ZONE
GLYM
SARWAT
SIDI
BISHR
5E
3E
1E
MONTAZH
6E
2E
MAAMO
DRAIN
PLANT
TO
SMOUHA
TREATMENT
TO EAST
7E
8E
10E
11E
MONTAZAH
CANAL
HOSPITALS
S
A
E
R
A
E R E D
RAMLI DRAIN
EGYPTIAN
RAILWAY
MAHMOUDIA
CANAL
KEY:
SEWERAGE ZONE BOUNDARIES
TRIBUTARY AREAS
SEWAGE DISCHARGE POINTS
SEWAGE OVERFLOW POINTS
PRINCIPAL CONVEYANCE PIPELINES
SEWAGE PUMP STATION
MAJOR DRAINAGE PUMP STATION



ARAB REPUBLIC OF EGYPT

MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

EXISTING SEWERAGE SYSTEM

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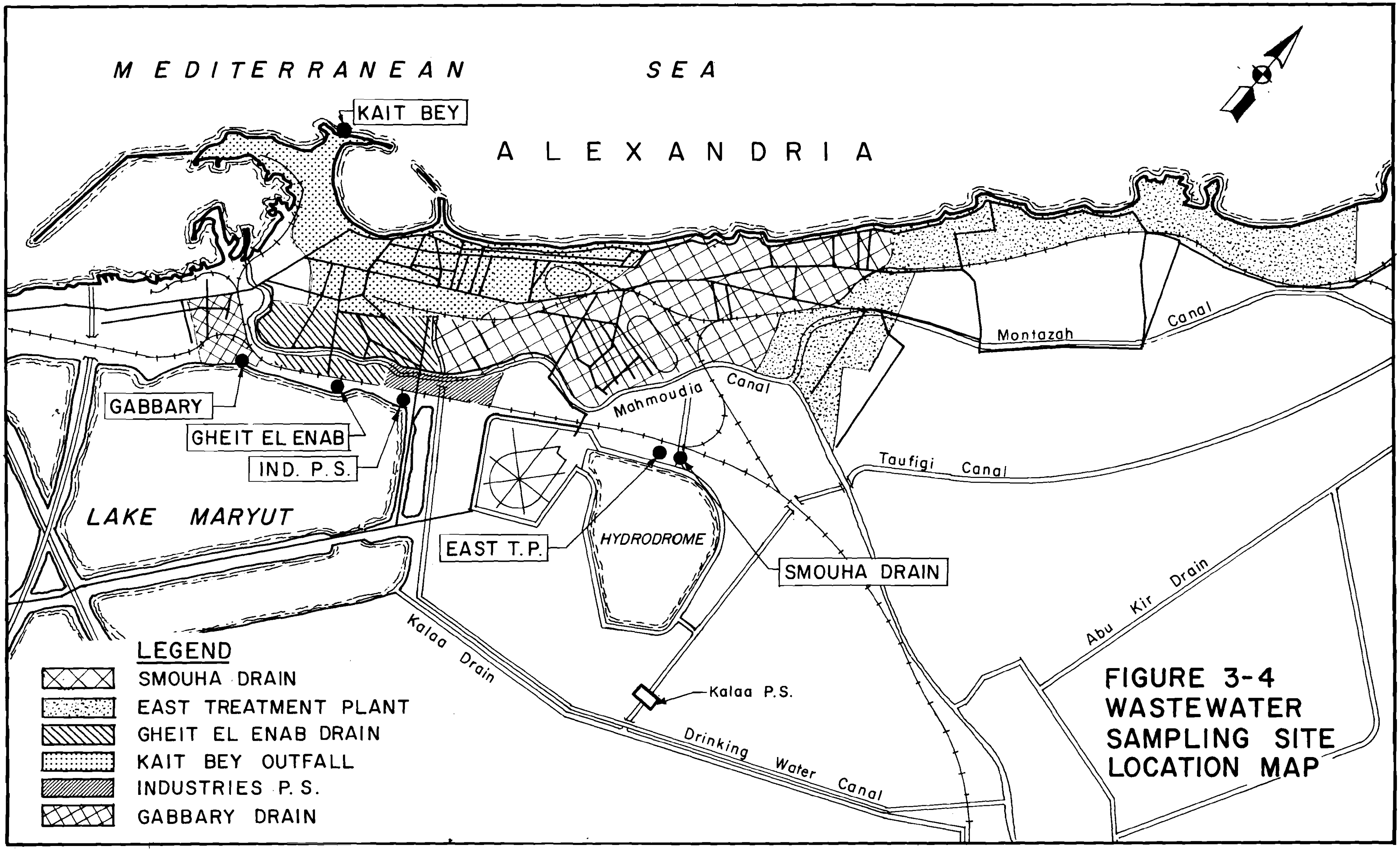

FIGURE 3-4
WASTEWATER
SAMPLING SITE
LOCATION MAP

FIGURE 3-4

FIGURE 3-5 EXISTING ORGANIZATION GOSSD - ALEXANDRIA

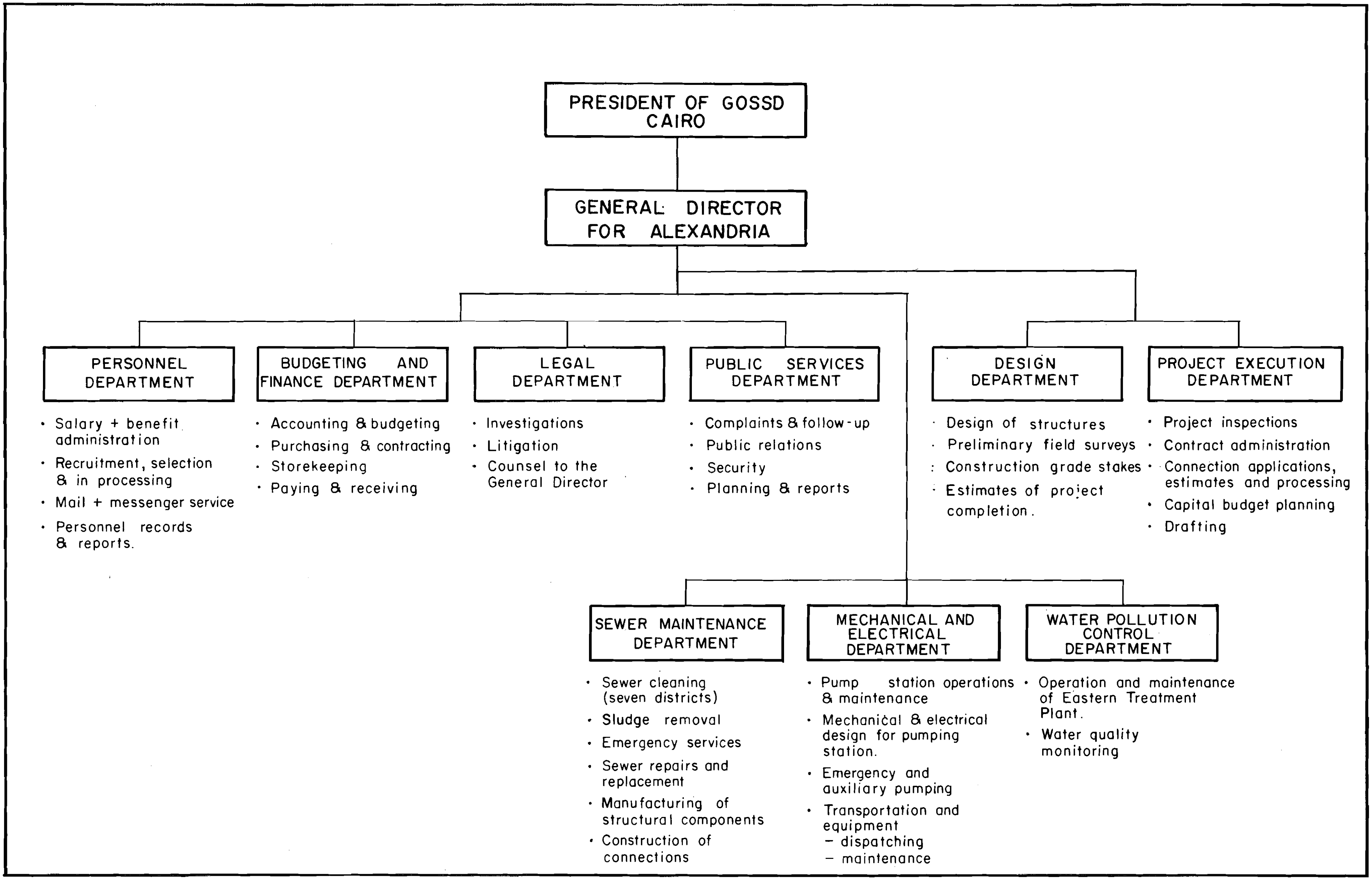

FIGURE 3-5

CHAPTER 4

PLANNING PROJECTIONS

4.1 Population and Land Use

Demographic Setting

Alexandria, the second largest city in Egypt, has developed in recent years from a commercial resort city into a major Middle Eastern seaport. Rapid population expansion, in conjunction with substantial industrialization, has resulted in serious stress on many of the existing public services. Future residential and industrial growth may be severely affected by limitations on available land and general development policies of the Government.

Population records, presented in Table 3-1, indicate an historic trend in urban settlement within the Alexandria area. Population of the city has increased from 300 000 at the turn of the century to well over two million at present. The current population growth rate of Alexandria is estimated to be in excess of 2.8 percent per year, based on census information collected since 1966. A considerable portion of the growth is due to the rapid increase in number of people drawn to the city from agricultural regions of Egypt. Prior to World War II less than 30 percent of the total population of Egypt resided in urban areas. The figure now lies at nearly 45 percent and is expected to reach 65 percent within two decades.

In the past several decades the expanding population of Alexandria has tended to spread eastward toward the Abu Kir peninsula out of the old, inner residential areas of the city. Public services such as water, sewerage, transportation, and electrification have not kept up with the rapid pace of expansion. Inner areas of the city have become so densely inhabited that existing public services are overloaded. Present gross area urban densities range from less than 200 persons/ha in some higher income districts to greater than 1800 persons/ha in parts of some low income neighborhoods.

Population and land use within Alexandria have been expressed on a district level for both wastewater and the water supply system planning efforts. District names, present population, and general income level classifications are presented in Table 4-1. District boundaries are defined in Appendix A.

Population Forecasts

Alexandria's permanent population has been projected to the year 2000 on the basis of: (1) the city's population growth relative to Egypt as a whole, taken together with official projections for Egypt; and (2) the trends of natural increase and rate of net migration within the study area. An average of the two forecast methods yields the population projection values used in developing the Wastewater Master Plan.

Straight-line projection of the continuously increasing ratio of the population of Alexandria to that of Egypt yields a value of 7.2 percent by the year 2000. However, several factors may affect the future relative rate of increase in population of Alexandria. These include: government planning and development emphasis on other provincial governorate cities; continued rural-to-urban migration trends; attempted demographic stabilization in Cairo with attendant new industrial development in Alexandria and Port Said; and construction of new planned urban centers to relieve demographic pressure on existing cities. Considering all these factors, Alexandria's share of the total population of Egypt was projected to rise steadily from approximately 6.2 percent in 1976 to 7.0 percent by the year 2000.

Applying Alexandria/Egypt population ratios to government (CAPMAS) country-wide forecasts (an expected increase from 38 million to 66 million people by 2000) results in Alexandria's share of Egypt's total population being 4.62 million people as shown in column 4 of Table 4-2.

Review of crude birth, death, and resultant natural increase rates for Alexandria, as detailed in Appendix A, indicates a current rate of natural increase between 1.8 and 2.2 percent per annum. The past rate of net migration for Alexandria has been assumed as the difference between compound population growth rate (for various intercensal periods) and estimated rate of natural increase. Net migration, using this approach, is found to be about 0.6 percent per year currently, having decreased slightly over the last several years due to slower economic growth within the city than previously experienced and resettlement of refugees in the Suez Canal Zone.

TABLE 4-1

PRESENT DISTRICT POPULATION - 1976

District Name	Permanent Population[a]	General Economic Classification[b]
Gomrok	166 000	low to middle
Manshia	48 000	middle to low
Labban	91 000	low to middle
Attarine	80 000	middle to low
Karmouz	235 000	low
Moharrem Bey	371 000	low to middle
Bab Sharky	354 000	middle to low
Ramleh	454 000	middle
Montazah	249 000	middle to high
Minet el Bassal	260 000	low
Dekheila	54 000	low
Ameria	20 000[c]	low
TOTAL	2 382 000	

[a]Based on CAPMAS mid-76 census information rounded to nearest thousand persons.

[b]Based on estimation of average family income level, the initial classification being predominant while the latter is secondary (e.g., low to middle = lower incomes in general although ranging to middle income level in some neighborhoods within the district).

[c]Population is roughly approximated in this district due to the transient nature of many inhabitants (i.e., there are significant numbers of nomadic Bedouin and yet unsettled recent arrivals).

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TABLE 4-2

POPULATION FORECASTS

Year	Total Population Egypt 1	Percent Population Alexandria 2	Percent Total Annual Increase 3	Alexandria Population Forecasts, million: Ratio Method 4[a]	Rate Inc. Method 5[b]	Average 6[c]	High 7[d]	Low 8[e]
1976	31.8	6.3	2.7	2.38	2.38	2.38	2.38	2.38
1980	41.7	6.4	2.7	2.61	2.69	2.65	2.74	2.60
1985	47.1	6.5	2.9	3.08	3.07	3.07	3.23	2.90
1990	53.0	6.7	2.9	3.54	3.54	3.54	3.78	3.23
1995	59.3	6.8	2.9	4.06	4.08	4.07	4.40	3.60
2000	66.0	7.0		4.62	4.71	4.66	5.08	4.02

[a] Egyptian population (Col. 1) multiplied by percent in Alexandria (Col. 2).

[b] Based on total annual rate of increase, r, (Col. 3) where $P_y = P_o + P_o r^y$, y = year.

[c] Average of two methods, (Col. 4 + Col. 5)/2.

[d] Based on year 2000 Alexandria share of population equal to 7.7% proportionate increase between 1976 and 2000.

[e] Based on total annual increase equal to 2.2%, $P_y = P_o (1.022)^y$.

The rate of natural increase is expected to remain reasonably constant during the next quarter century, due to compensating effects of anticipated projections of population-age dynamics, public health improvements and minor changes in expected per capita real income. The migration rate, however, is expected to increase as major new industrial projects envisioned for Alexandria begin to influence the labor market and as port facilities continue to expand. Combining an estimated future steady-state annual rate of natural increase of 2.2 percent with an annual net migration rate of 0.5 percent between 1976 and 1985 and 0.7 percent thereafter, results in an Alexandria population forecast of 4.71 million persons by the year 2000, as shown in column 5 of Table 4-2.

For master planning purposes, an average of the two forecasting methods was used for projection of Alexandria permanent populations between 1976 and the year 2000, as shown in column 6 of Table 4-2. Both high and low projections were also made in order to define a range in results. Maximum proportionment of total Egyptian population to Alexandria (7.7 percent by year 2000) constitutes the upper limit shown in column 7, whereas zero net migration to the city (2.2 percent natural growth increase only) represents the lower limit shown in column 8. These population forecasts are illustrated on Figure 4-1.

Seasonal Visitors

The large influx of summer-season residents and holiday visitors to Alexandria must be taken into account in projecting future total population and geographical distributions within the study area. On the basis of review of current water consumption in the city, the number of visitors is estimated to be within the range of 250 000 to 500 000 at the peak of the season. It is further estimated that more than one million persons visit the city at some time during the summer season.

It is estimated that peak seasonal population will reach nearly 600 000 persons by the year 2000, assuming doubling of the number of temporary residents over a somewhat longer tourist period of the year. Total peak population for Alexandria is, therefore, forecast to be in the neighborhood of 5.3 million (permanent plus seasonal) by the year 2000.

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Residential and Industrial Development

The location of industry in Alexandria has had and will continue to have a significant effect on the overall development of the city, including the geographical distribution of its inhabitants. A tabulation of present and anticipated potential increases in the extent of land use for major industrial pursuits within various districts of Alexandria is presented in Table 4-3. The figures are based on current Alexandria Housing and Reconstruction Directorate information. Expected future major industrial areas and residential development are illustrated by the land use map shown in Figure 4-2. New population centers outside present residential sections of the city are expected to develop near new major industrial operations. This is in part because Alexandria's public transportation system is not adequate for transporting large numbers of additional workers.

The Abu Kir peninsula is expected to develop primarily as a residential area with few new industrial sites being designated. The Abu Kir Bay area, however, is currently prime industrial development land, due to its accessibility to natural gas deposits, the sea, freshwater and drainage systems, and rail transport, as well as its remoteness from congested high density urban developments. Future expansion of existing paper and food industries, as well as fertilizer and other plants, is anticipated. There are plans for a major labor housing development and other public housing in the vicinity of these industrial developments along Abu Kir Bay.

In the eastern districts of Montazah and Ramleh, industrial developments have access to water and rail transportation and are relatively close to current large concentrations of workers. Labor intensive industries are expected to continue with future developments, but sufficient open space exists, principally south of the Montazah Canal, to accommodate future industrial employment and residential development . Very little additional land is available in the inner-central districts, and no additional land is available to undergo industrial development in the inner-west districts of Karmouz and Minet el Bassal.

Significant industrial development is expected to the west and south in Dekheila and Ameria districts. This includes a 600 ha duty-free zone, an Institute for Rural Development, several major assembly factories, and a possible petro-chemical facility. In addition, an iron and steel complex,

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TABLE 4-3

EXTENT OF INDUSTRIAL DEVELOPMENT

District	Industrial Development, ha Present	Additional	Total	Range in New Jobs Generated, thousand
Eastern:				
Abu Kir[(a)]	289	256	545	65 - 130
Montazah	95	482	577	50 - 60
Ramleh	146	358	504	40 - 50
Central:[(b)]				
Moharrem Bey	115	64	179	5 - 10
Bab Sharky	115	233	348	25 - 35
Western:				
Karmouz	71	-	71	-
Minet el Bassal	17	-	17	-
Dekheila	83	3890	3973	50 - 150
Southern:				
Ameria	19	2081	2100	100 - 300
TOTAL	950	7364	8314	335 - 735

(a) Although Abu Kir is part of Montazah District it is listed separately because of its significant industrial development.

(b) There is negligible industrial development either at present or expected in the central districts of Gomrok, Manshia, Labban and Attarine.

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an oil refinery, and several chemical plants are planned, as well as extensive agricultural projects. Industrial employment will necessitate the development of major new urban sub-centers within reasonable distances. An economic base for an additional population of approximately 750 000 (although figures as high as two million have been discussed) is expected in the combined Ameria and Dekheila districts.

In all, an estimated additional 7360 ha of land, more than 80 percent of which is located in Dekheila and Ameria, may be allocated to industrial development. Such development, which is expected to occur between now and year 2000, could generate from 335 000 to 735 000 new jobs in Alexandria. One-half million new industrial jobs might, in turn, create secondary employment of 500 000 to one million persons in service and support operations within the study area. The forecasted population estimates are in accord with these industrial development projections. It is expected that the new inhabitants of the city will locate in areas nearby these industrial developments.

Distribution by Land Use

The factors studied in distributing future population throughout the Alexandria area included: industrial development, available land for housing, public transportation, subsoil conditions, the predominant socio-economic character of existing urban areas, and government policies regarding future development and expansion. In addition, access to beaches, resorts, and public transportation were considered in distributing non-permanent seasonal inhabitants.

Permanent population distribution was established in conjunction with density of habitation for various levels of family income, after detailed assessment of probable land use and study of socio-economic development for each subdistrict of Alexandria. This information is presented in Appendix A. In general, low income gross area densities were found to range between 1 200 and 1 800 persons/ha, whereas lower middle income areas were characterized with a range between 900 and 1300 persons/ha. Middle income area densities were between 600 and 800 persons/ha, while upper income areas ranged between 190-450 persons/ha.

Seasonal population distribution was based primarily on a combination of anticipated new resort developments and existing areas of summer habitation.

Two-thirds of the additional seasonal residents projected for Alexandria are expected to locate in the outer west area of Agamy. Distribution of the remainder is anticipated throughout the eastern coastal districts to Abu Kir peninsula.

A summary of projected population (permanent and seasonal) by district is presented in Table 4-4. More detailed projections in terms of density, land use classifications, and economic category for each sub-district within the city are tabulated in Appendix A. Although availability of land for both residential and commercial development north of Lake Maryut is limited, it is expected that some increase in population will continue to occur in presently urbanized areas through increased density of habitation. In addition, well over one million people are expected to locate in the presently rural areas of Alexandria to the east, west, and south of present urban limits.

4.2 Domestic and Commercial Water Use and Wastewater Production

Water Use

Background. Details of the review of historic water use trends in Alexandria, analysis of present conditions, and projection of future water demand have been presented in both Wastewater Special Report Number 3 (May 1977) and the Part I Immediate Phase Waterworks Master Plan Preliminary Report (August, 1977). The following information is a brief summary of study findings that are most pertinent to wastewater master planning. Additional information is presented in Appendix B (Volume III) regarding present and projected water use for industrial and domestic needs.

Data on total annual water production for Alexandria have been kept by the Water General Authority (AWGA) since the last century, when supply to the city was less than 8 million m^3 per year (average flow - 250 L/sec). Annual rate of growth in supply remained less than 4 percent per annum until the early 1950's when nearly 70 million m^3/year were distributed to inhabitants and industrial operations of Alexandria. By 1976 an estimated 250 million m^3/year (8 000 L/sec) were being produced, representing a rate of increase greater than 6 percent per annum.

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TABLE 4-4

PROJECTED POPULATION DISTRIBUTION

District	Population, thousand 1980	1990	2000
Gomrok	168	169	170
Manshia	51	55	56
Labban	95	103	112
Attarine	82	88	93
Karmouz	238	244	252
Moharrem Bey	375	380	385
Bab Sharky	390 (135)	514 (165)	526 (172)[a]
Ramleh	530 (40)	656 (50)	706 (54)
Montazah	336 (200)	723 (205)	1345 (214)
Minet el Bassal	272	327	370
Dekheila[b]	63 (25)	106 (80)	145 (160)
Ameria	50	175	500
Permanent	2650	3540	4660
Seasonal[a]	(400)	(500)	(600)
TOTAL	3050	4040	5260

[a] Values in parentheses are peak seasonal population projections.
[b] Includes the summer resort area of Agamy.

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Although water consumption has been difficult to determine because of irregularities in metering, billing, and accounting operations, a reasonable estimate was derived from a study of AWGA revenue records. During recent years, increases in water production have been well in excess of Alexandria's population and industrial growth rate, due primarily to rising per capita water demands and greater system losses. Although annual rate of growth in water use during the past decade has averaged nearly 5 percent, accountable water use has increased at an annual rate nearly double this percentage, primarily due to reductions in unmetered domestic and industrial subscriptions.

Projected Water Use. Projection of future water needs in Alexandria was based on served population multiplied by expected unit water demands. It was assumed that AWGA will continue to provide water to nearly all persons residing in the city (more than 93 percent of inhabitants are estimated to be served at present), including both permanent and seasonal residents. Future unit water demand was estimated for each major type of user (domestic, industrial, government, and others), on the basis of anticipated combined effects of identifiable socio-economic influences including changes in family income, increasing utility rates, suppressed current demand for water, changes in domestic life-style, and new industrial processes. System losses were also projected in order to arrive at the overall estimates of water use for the Alexandria area shown in Table 4-5. Detailed projections are found in Special Report Number 3, and the Preliminary Waterworks Master Plan Report, and are also included in Appendix B of Volume III.

The expected amounts and locations of future water consumption in Alexandria are used as primary factors in projecting domestic wastewater volumes. A summary of water use for each district of the city is presented in Table 4-6. The quantity of water required to meet expected needs is projected to increase from a present level of approximately 560 000 m^3/day to 1 470 000 m^3/day by year 2000--a 250 percent increase or about 4 percent per annum.

Wastewater Production

Wastewater flows have been projected on the basis of an assumed increase in domestic (residential plus commercial) per capita flow from the present 100 L/c/d (based on water use) to 125 L/c/d in the year 2000. Multiplying forecast population (presented in Table 4-2) by domestic unit generation

TABLE 4-5

UNIT AND OVERALL
WATER USE PROJECTIONS

Year	1976	1980	1990	2000
Population, thousand				
Permanent residents	2380	2650	3540	4660
Equivalent served[(a)]	2450	2780	3700	4850
Unit Demand, L/c/day				
Domestic	115	130	146	158
Industrial	44	65	68	69
Governmental and Others[(b)]	37	40	40	40
Losses	33	40	38	36
TOTAL	229	275	292	303
Water Requirements, million m^3/year				
Alexandria	205	280	394	537
Total System[(c)]	220	296	416	571
Water Use, m^3/sec				
Average Day (AD)	6.5	8.9	12.5	17.0
Maximum Day (1.3 AD)	8.5	11.5	16.3	22.0
Peak Hour (1.7 AD)	11.0	15.0	21.2	29.0

[(a)] Based on determination of equivalent seasonal residents and percentage of total inhabitants served within Alexandria Governorate.

[(b)] Includes harbor facilities, public gardens, fire fighting, etc.

[(c)] Includes water service to Western Desert (Mersa Matrouh) and to areas within Beheira Governorate which are beyond the limits of the Wastewater Study.

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TABLE 4-6

WATER USE PROJECTIONS BY DISTRICT

District	Average Water Demand, 1000 m^3/day 1976	1980	1990	2000
Gomrok	21.5	28.0	33.0	36.0
Manshia	8.3	9.0	10.0	11.0
Labban	11.0	16.0	18.0	21.0
Attarine	15.5	17.0	18.0	20.0
Karmouz	33.0	38.0	45.0	50.0
Moharrem Bey	59.6	78.0	87.0	96.0
Bab Sharky	111.1	137.0	170.0	190.0
Ramleh	217.6	170.0	235.0	277.0
Montazah	90.2	130.0	250.0	418.0
Minet el Bassal	36.3	48.0	54.0	63.0
Dekheila	40.3	62.0	86.0	124.0
Ameria	6.6	32.0	74.0	164.0
Alexandria-TOTAL	651.0	765.0	1080.0	1470.0

[a] Includes water service to the Western Desert and to AWGA areas within the Beheira Governorate which are beyond the limits of the Wastewater Study.

rates results in domestic wastewater flow values for each district of Alexandria. The results are presented in detail in Appendix D. The total domestic sewage flows are expected to be 322 000 m^3/day in 1980, 488 000 m^3/day in 1990 and 658 000 m^3/day by year 2000.

Domestic waste concentrations in Alexandria are found to be higher than occur in many other cities of the world, because of the low per capita water use. This condition is expected to continue.

Based upon measurements made during the study and summarized in Appendix D, the projected domestic waste loadings for planning purposes are estimated to be as follows:

	1980	1990	2000
BOD_5, kg/day	183 000	269 000	367 000
BOD_5, gm/C/day	65.8	72.7	74.6
COD, kg/day	350 000	513 000	690 000

4.3 Industrial Water Use and Wastewater Generation

Industrial Development

Development of major industry in Alexandria has been increasing at a steady pace. In general, the industrialized area forms a long, narrow crescent around the southern side of the city with termini at Abu Kir Bay and Dekheila. Expansion is presently occurring both in eastern and western portions and is expected to continue. In addition, future industrial expansions are also anticipated beyond Lake Maryut in the Ameria district and along the Mahmoudia Canal southeast of Alexandria. There are an estimated 210 000 people directly employed by major industry at present while future projections range from 335 000 to 735 000 persons by the turn of the century.

Projected Industrial Flows and Loads

Forecasts of future industrial wastewater quantity and quality have been based on two principal considerations: (1) five-year expansion intentions expressed by industries interviewed in the field survey; and (2) projected demographic growth trends (e.g. an approximated doubling of population by the year 2000), as indicators of probable overall industrial development and wastewater production.

Wastewater flow projections are tabulated in Appendix C for various types of industrial operations and are summarized by area in Table 4-7. Contaminated wastewater production in the principal industrial areas is expected to increase from 226 000 m^3/day at present to 647 000 m^3/day by year 2000, an average annual increase of 18 ML/day. It has been assumed that near-term industrial expansions will imply average annual increases of 25-30 ML/day in wastewater flow, whereas later annual growth will be limited to 12-15 ML/day as a result of water conservation measures, improved industrial reuse operations, and increased segregation of non-contaminated industrial process waters.

Projected industrial waste loadings for BOD_5 and COD are based on an assumption that present average wastewater concentrations will undergo gradual and slight change in the future. Average concentrations of BOD_5 are projected to increase from 640 mg/L to 700 mg/L while COD would increase from 1 240 mg/L to 1 500 mg/L at the planning horizon. Area-wide industrial waste load projections are shown in Table 4-7; more detailed tabulations are presented in Appendix C. Future loads of 453 000 kg/day BOD_5 and 970 000 kg/day COD, (about three times current industrial waste loads) are expected by the year 2000.

4.4 Overall Wastewater Quantity and Quality

Infiltration

There exists no reliable quantified information from which to determine the magnitude of infiltration throughout the sewer system. Some field measurements have been attempted in the past, but due to the nature and surcharged condition of the collection system, definitive data cannot be developed.

Several numerical methods have been used by GOSSD to estimate infiltration for the design of new sewers. One is to allow for 0.006 gallons/hr/ft of sewer for each inch of pipe diameter (equivalent to approximately 35 L/hr/km of pipe per centimetre of diameter). The other method, by formula, allows for consideration of pipe depth below water table and type of pipe material. For concrete pipe and a 25 cm depth of water above sewer centerline, the resulting infiltration rate by formula is 10 L/hr/km per cm of diameter.

TABLE 4-7

PROJECTED INDUSTRIAL WASTE DISCHARGES

Industrial Area	Contaminated Wastewater Flow, 1000 m^3/day 1977	1980	1990	2000
Dekheila	35	59	104	140
Mex	2	2	3	4
Gabbary	1	1	2	5
Karmouz & Gheit el Enab	8	19	33	40
Moharrem Bey	1	2	3	5
Industries Pump Station	32	37	49	60
Hadara	12	14	20	27
Nouzha	2	2	10	20
Smouha	12	16	30	45
Siouf	14	19	39	60
Abbis	3	4	6	8
Ras el Soda	5	7	18	30
Maamoura	2	6	8	8
Abu Kir	84	110	133	140
Ibrahimia	1	1	2	3
Ameria	12	20	38	52
TOTAL	226	319	498	647
	Waste Loadings, 1000 kg/day			
BOD_5 (a)	145	207	336	453
COD (b)	280	440	722	970

(a) Based on 640 mg/L in 1977, 650 mg/L in 1980, 675 mg/L in 1990 and 700 mg/L by year 2000.

(b) Based on 1240 mg/L in 1977, 1380 mg/L in 1980, 1450 mg/L in 1990, and 1500 mg/L by year 2000.

On the basis of existing average length of sewer per hectare of area within various districts of the city, average infiltration rates range from 0.03 to 0.25 L/sec/ha; lower rates are associated with well constructed sewers above water table and higher values apply to collection systems below water table. This range in infiltration rate was used for evaluation of existing sewer system problems as set out in Special Wastewater Reports Numbers 2 and 4.

For purposes of determining size of future sewer pipes needed for the Wastewater Master Plan, an infiltration rate of 0.1 L/sec/ha was assumed, in expectation of improved utilization of local materials, better construction, and refined design. Where new sewers are needed for specialized purposes or constructed in abnormally difficult areas, higher design infiltration rates are advisable.

Projected Total Flow and Strength

Total wastewater flows have been estimated by combining domestic and contaminated industrial wastewater flows and adding an allowance for infiltration. Present and future waste loads were similarly determined, on the basis of estimated average concentrations of specific constituents.

Resulting area-wide wastewater flow projections by category are shown in Figure 4-3. Table 4-8 presents a summary of these projections for future sewerage zones in the study area. Conversion tables from district level to sewerage zone are presented in Volume III, Appendix D of this report.

A year 2000 total average dry weather daily volume of 1.47 million m^3 of wastewater, 44 percent of which is expected to be contributed by industrial activities, is projected for the Alexandria area. A total BOD_5 load of 820 000 kg/day, suspended solids load of 735 000 kg/day and a COD load of 1 660 000 kg/day are projected for the year 2000.

TABLE 4-8

SUMMARY PROJECTED WASTEWATER FLOWS AND LOADS

Sewerage Zones	Dry Weather Flows, 1000 m^3/day Average Day 1980	1990	2000	Peak Day 1980	1990	2000
Abu Kir	119	147	173	181	225	268
Outer East[a]	42	124	205	73	206	331
Inner East	203	268	332	288	377	464
Central	127	150	173	191	223	253
Inner West	136	178	219	210	269	324
Outer West	66	113	161	103	176	249
Ameria	32	85	137	51	131	209
Nouzha	17	31	45	30	52	74
TOTAL	742	1096	1445	1127	1659	2172
Unsewered Areas[b]	13	14	25	22	26	43
Alexandria TOTAL	755	1110	1470	1149	1685	2215

	Wastewater Loads, 1000 kg/day 1980	1990	2000
BOD_5	390	605	820
COD	790	1235	1660
SS	380	555	735

(a) Includes Ras el Soda, Siouf Keblia and Sadat City areas.

(b) Those remote areas of Alexandria; principally Agamy and small villages south of Siouf, where sewers are not expected to be required until beyond the planning horizon, year 2000.

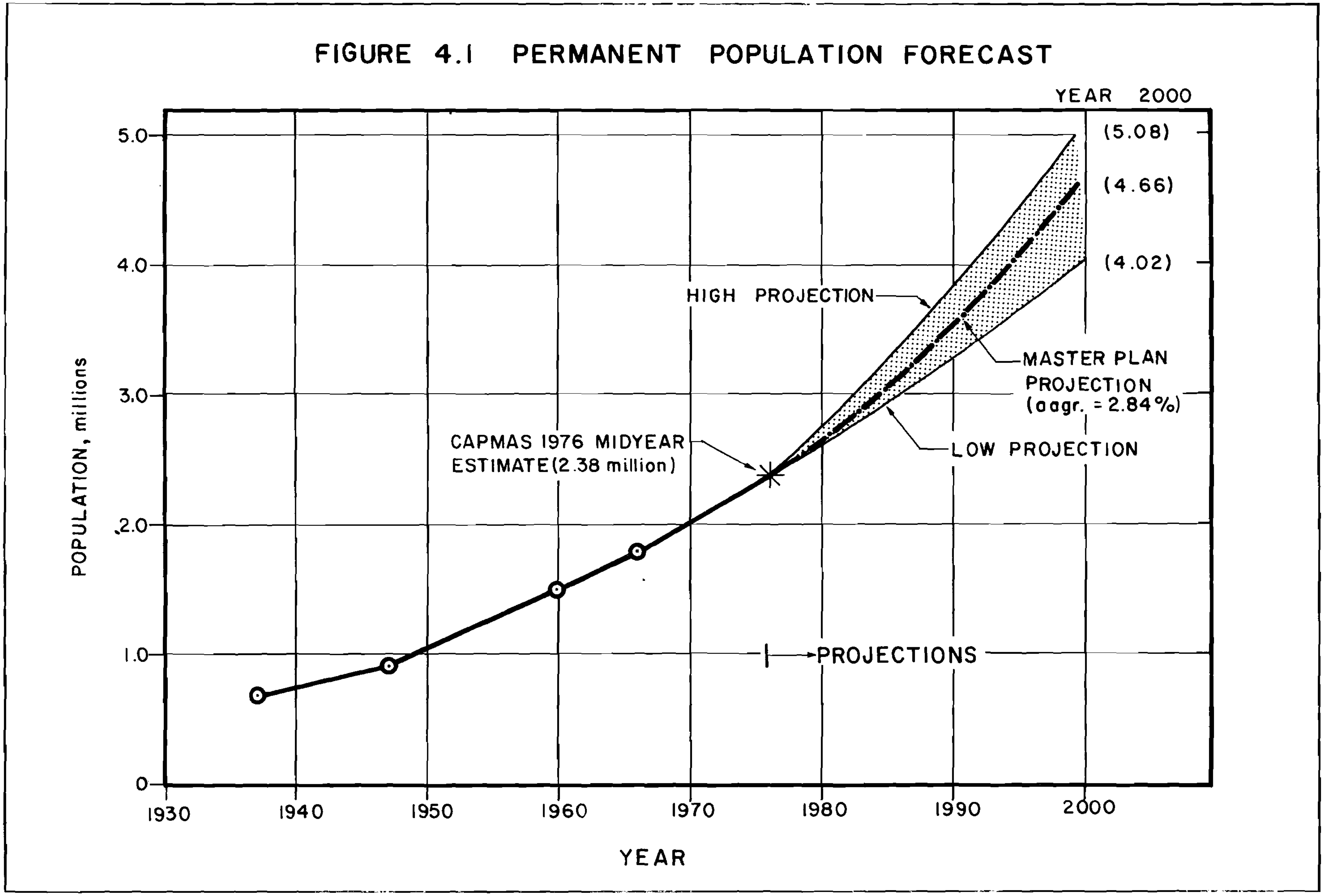
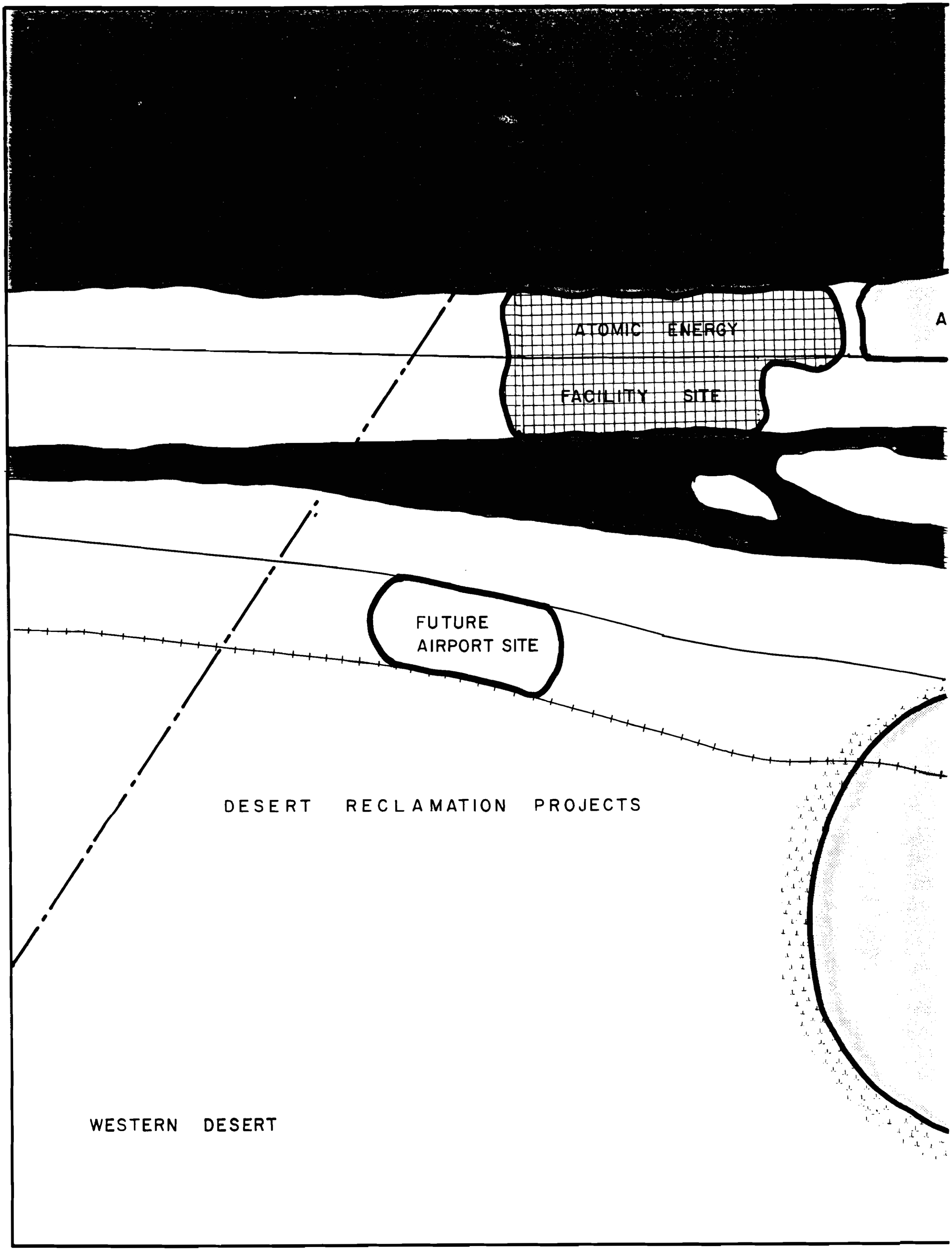


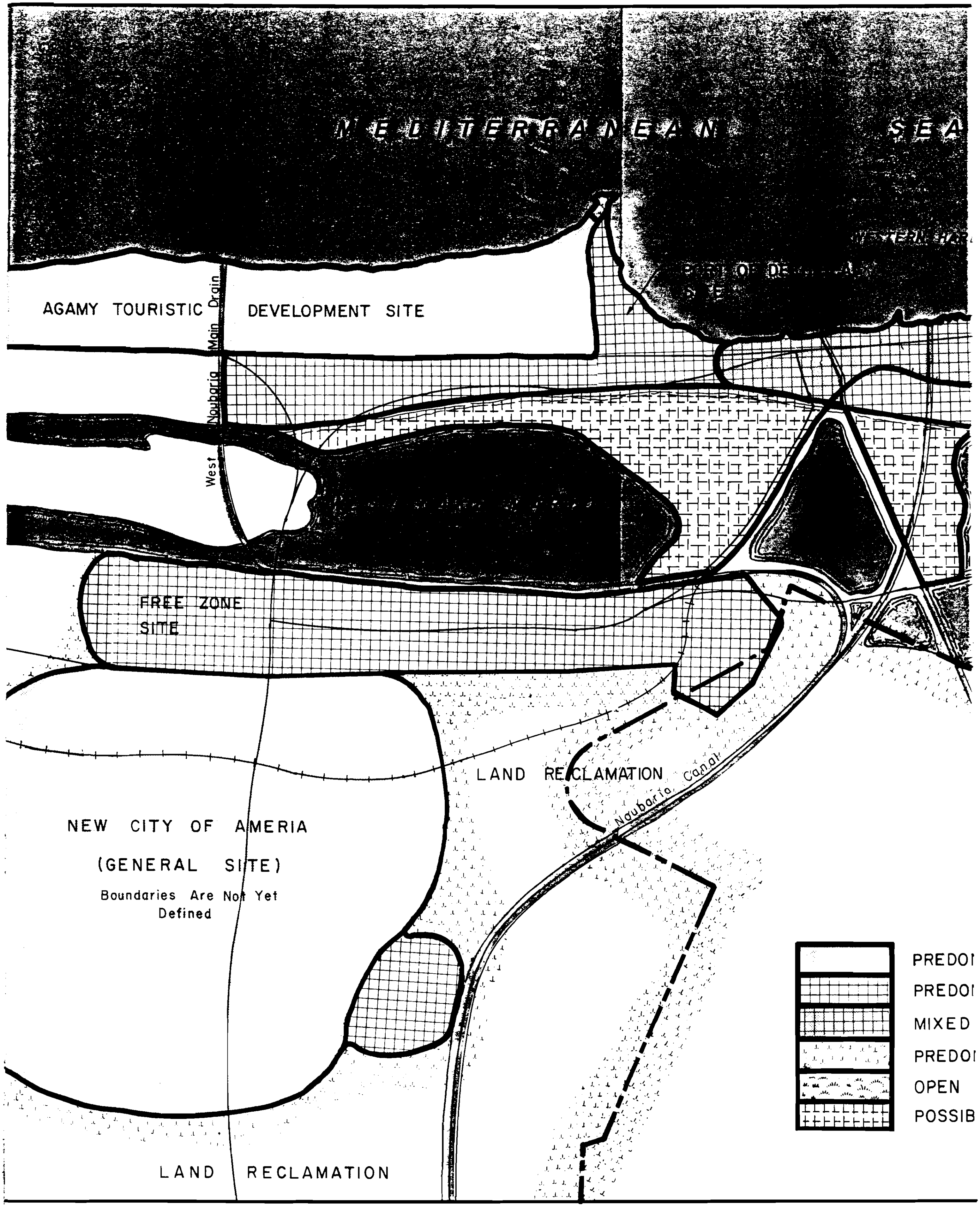
FIGURE 4.1 PERMANENT POPULATION FORECAST
YEAR 2000
(5.08)
(4.66)
(4.02)
HIGH PROJECTION
MASTER PLAN PROJECTION (aagr. = 2.84%)
LOW PROJECTION
CAPMAS 1976 MIDYEAR ESTIMATE (2.38 million)
PROJECTIONS
POPULATION, millions
5.0
4.0
3.0
2.0
1.0
0
1930
1940
1950
1960
1970
1980
1990
2000
YEAR

FIGURE 4-1



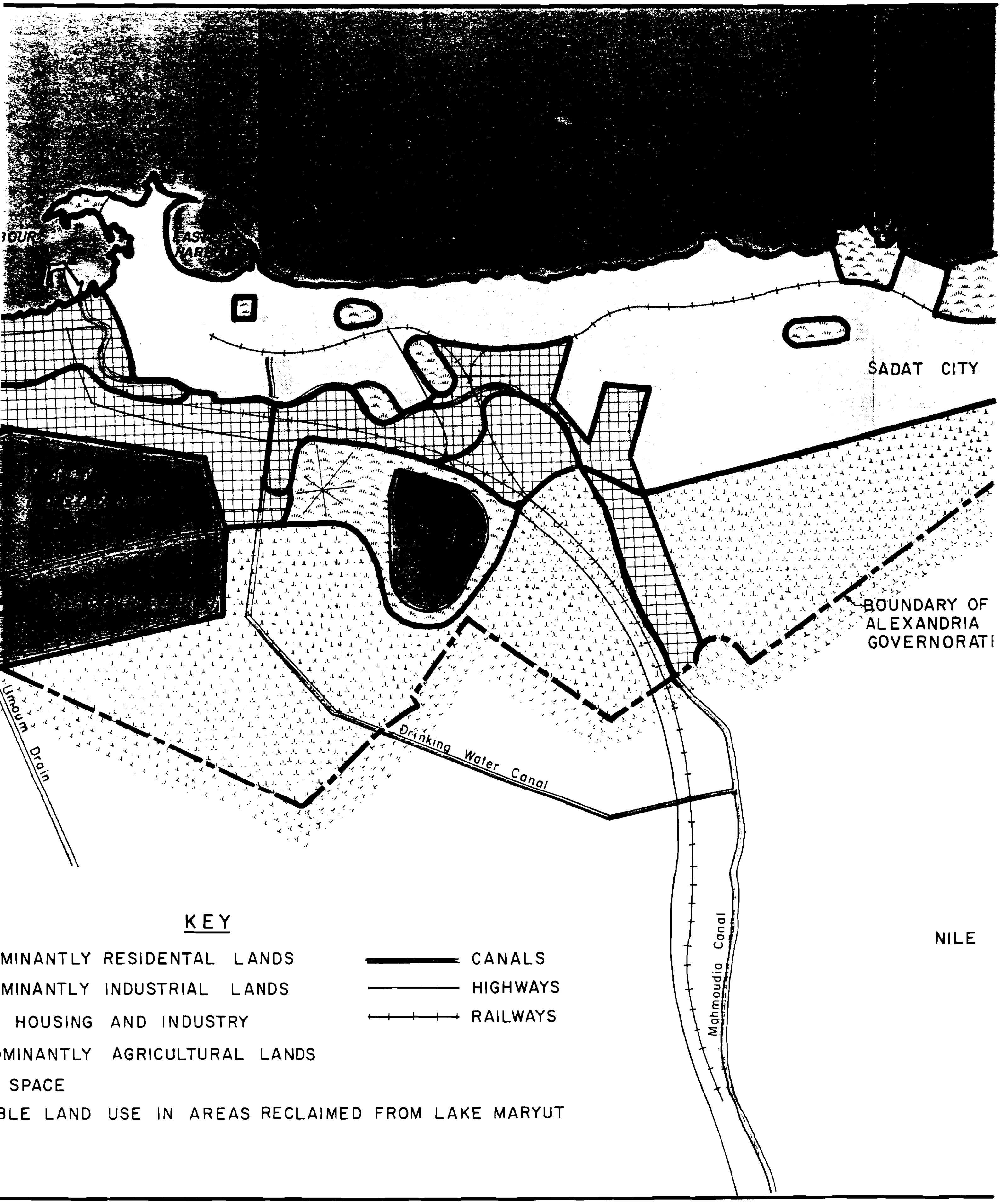
CAMP DRESSER & McKEE INTERNATIONAL INC.
CONSULTING ENGINEERS
CHAS. T. MAIN INTERNATIONAL INC.

BEST AVAILABLE



BEST AVAILABLE

870



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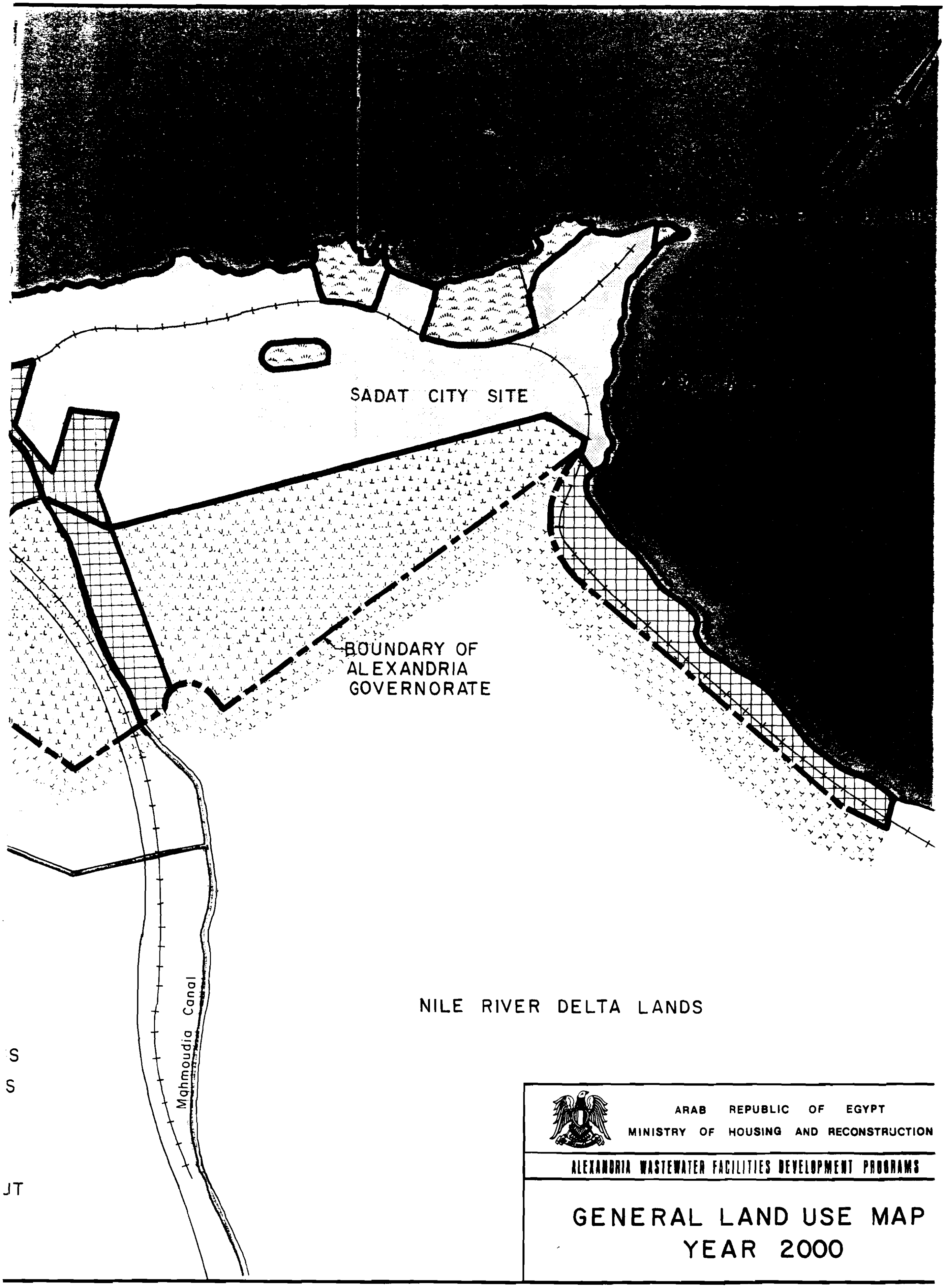

ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

GENERAL LAND USE MAP
YEAR 2000

FIGURE 4-2

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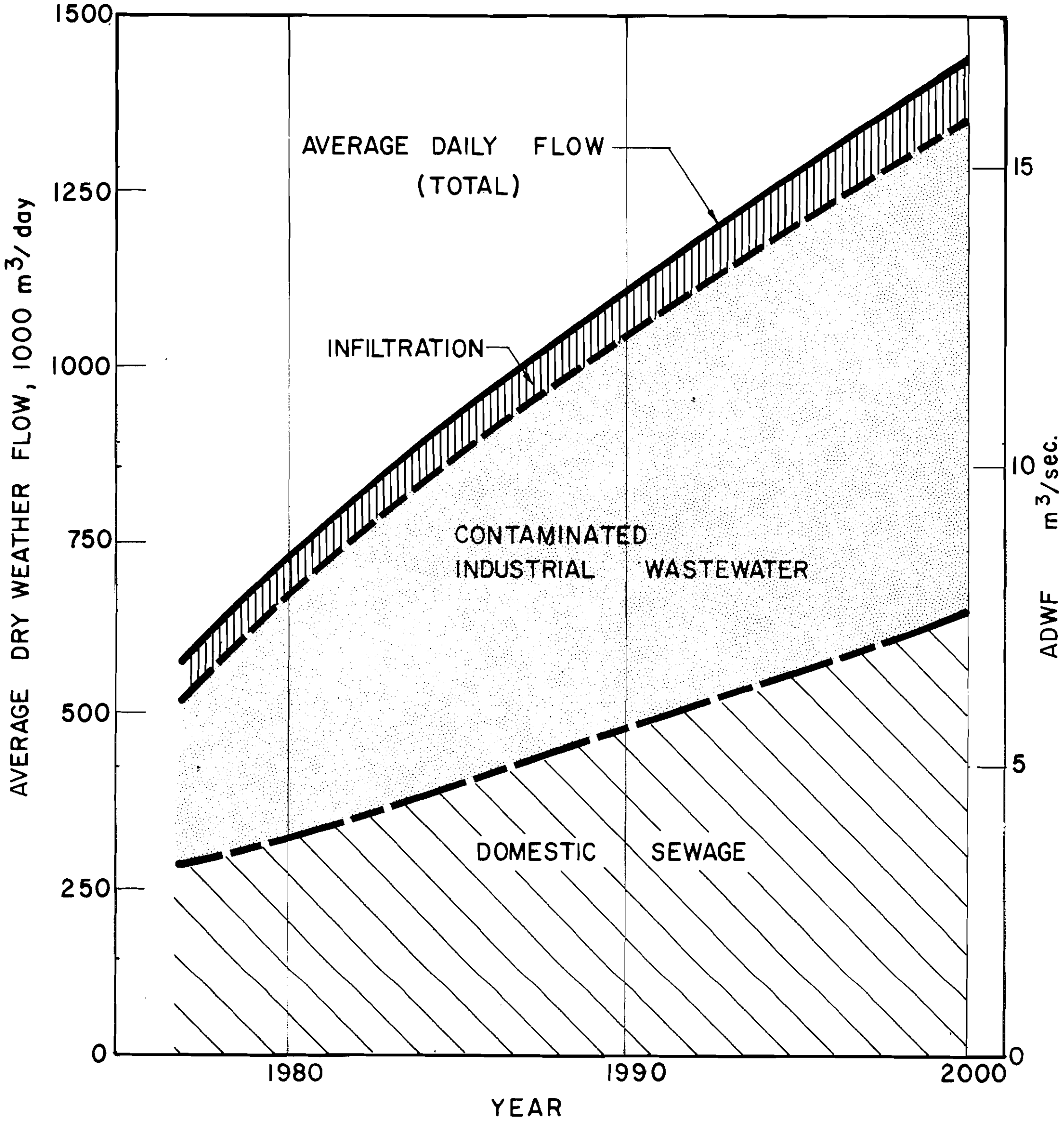
FIGURE 4-3 PROJECTED WASTEWATER FLOWS



ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

PROJECTED WASTEWATER FLOW

FIGURE 4-3

CHAPTER 5

ENGINEERING CONSIDERATIONS

5.1 Soils and Subsurface Geology

Regional Site Conditions

Alexandria, situated on a narrow strip of land running in a northeast-southwest direction between the Mediterranean Sea and Lake Maryut, lies at the northwestern edge of the Nile River Delta. The strip of land forms a low ridge, rising little more than 10 m above sea level and consisting of stratified limestone. The ridge divides the city in a north/south direction and also separates the surficial soils. To the north of the ridge exist beach deposits that are sandy in nature; to the south are lagoonal deposits, consisting principally of marine clays.

Based on existing information, the area can be divided by subsoil type into five general zones, although differing and intermixed strata occur within each roughly defined zone. The soil zones are described in Figure 5-1 and can be characterized in general as follows:

- Zone 1, which includes most of the older portion of the city, has subsoils that consist of debris and fill underlain by sands which contain pockets of clays and shells. Natural solution cavities are found in the limestone which underlies the sand at varying depths. In addition, manmade caves, holes, and conduits dating from the Roman era have also been discovered.
- Zone 2, which covers the high ground east of the old city (Zone 1) and extends to Abu Kir Point, has sandy subsoils which are cemented or partially cemented in some areas. Lenses of silt also occur in the sands, which are hard when dry but lose strength when wet. Shallow limestone rock outcrops occur randomly.
- Zone 3, which encompasses the area west of the old city (Zone 1) and north of Lake Maryut, is characterized by shallow deposits of sand (2 to 3 m in depth) covering weathered limestone which, in turn, is underlain by unweathered limestone. Further to the west, beyond Dekheila, the limestone grades into calcareous sandstone. There are frequent rock outcroppings.

- Zone 4 includes the entire area south of the ridge behind Zones 1 and 2. Subsoils consist of fill over very soft to soft clays which in places contain layers of shells. The clay (4 to 10 m deep) is underlain by cemented sand, varying in thickness from a few centimetres to 4 or 5 m, below which is a stiff clay about 2 m thick. These clays rest on sand. To the east of the Mahmoudia Canal, the very soft and soft clays extend in places to depths in excess of 30 m.
- Zone 5 covers the high Western Desert ground southwest of Lake Maryut in the Ameria area. This is the edge of the desert plain, where soils are predominantly sandy with a surface cover of silty material in low-lying flat portions. Further to the west, soils are entirely clayey sands.

Due to the nature of subsoils in Zones 1, 2, and 3, the groundwater table occurs at or near sea level elevation. Groundwater problems in excavations are not likely to occur in these zones except along the shoreline or in deep trenches extending below sea level. In the low lying Zone 4, however, where groundwater occurs at or near the surface, additional construction problems are anticipated for subsurface work. Many below ground structures in Zone 4 will require controlled dewatering during excavation and construction. Within Zone 5, the deep groundwater table will be well below any normal construction except in the immediate vicinity of irrigated fields. There have been local instances of waterlogging in some irrigated areas of Zone 5 where drainage has been inadequate.

All wastewater structures to be located below groundwater table in any soil zone of Alexandria must be designed in the future to withstand the effect of hydraulic uplift. Swelling soils, common in Cairo and in several other areas of Egypt, have not been identified in any of the soil zones of Alexandria.

Foundations and Sewer Excavation

Foundations for wastewater structures considered for construction in every area but Zone 4 will be, in all probability, concrete footing and mat type, without piling, bearing on natural inorganic soils. Pile foundations, however, are likely to be necessary within Zone 4. Any filling to raise grade site in this zone must be thoroughly and carefully evaluated, as weight of fill can cause consolidation of clay subsoil with attendant soil column settlement. Differential settlement can result in breakage by shear between soil-supported pipelines and pile supported pump stations or treatment plants.

Sewers can be constructed with direct earth support below normal pipe bedding in almost all areas with exception of Zone 4, where pile support for some principal collectors may be necessary. Pipe bedding in Zone 4 should include a 15 cm thick layer of coarse sand placed directly on the clay subsoil to serve as a working mat and, in addition, prevent bedding material from being forced into the clay.

Excavation can be effectively accomplished with standard machinery, as well as manual labor, in all but Zone 3. Due to the presence of shallow rock, excavations in excess of 2 m deep may encounter difficulty in the western area. Where sewer pipe inverts would be considerably lower than 5 m in order to achieve gravity flow, pumping alternatives need to be considered. Except where there are surface obstructions, sewer trenches can be built by open excavation, but lateral support should be used where trenches in excess of 4 to 5 m in depth and below groundwater table are required. Current construction practice is normally limited to excavations less than 7 m in depth, but several proposed collectors will require 10 m deep trenches.

In some cases the use of steel sheeting will be essential. In soft clays care must be taken to drive sheeting well below invert elevations to avoid underslippage and subsequent base failures. The caisson construction method is worthy of consideration for most pump station substructures due to existing subsoil and groundwater conditions, particularly in Zone 4.

Little experience in constructing major pipelines by use of jacking methods is yet evident in Alexandria, although one project now underway entails jacking two 3200 mm diameter concrete conduits under the Mahmoudia Canal in Smouha. Future installation of sewers under existing railroads, main thoroughfares, and canals by jacking methods will become more frequent as the economic advantages of such procedures are recognized.

The sandy and soft clay subsoils in many areas of Alexandria, in combination with high groundwater table, will render soft ground tunneling a difficult and expensive method of construction. Where unweathered, good quality bedrock occurs at reasonably shallow depth, rock tunnels might offer some possibility of economical construction, in lieu of pumping through force mains.

Although very mild earthquakes are known to have occurred in Egypt, the local engineering practice is not to consider seismic forces in design. Seismic effects are not expected to represent an important construction consideration in preliminary structural or foundation design for the recommended facilities.

5.2 Construction Methods and Materials

Conditions Affecting Construction

Installation of new wastewater collection, treatment, and disposal facilities for Alexandria will in general require use of construction methods, materials, and labor best suited to local conditions but will necessitate introduction of certain specialized construction procedures for specific projects. Such procedures must not only be practical, but also the most economical for situations encountered in this region of the Mediterranean.

Principal factors which will affect construction practices in Alexandria can be categorized as either environmental or economic. The environmental factors include soils, groundwater, weather, and land use. Economic factors involve availability of contractors, labor, material, and equipment.

Local environmental factors are not expected to pose severe restrictions on any of the anticipated construction operations. Soils have been discussed in Section 5.1; in general, the subsurface conditions do not present unusual problems for excavation or structural foundations. Likewise, groundwater levels will not impose severe constraints on construction of sewer trenches, pump stations, or treatment plant foundations, as long as standard dewatering and excavation support procedures are maintained. Furthermore, the moderate climate of the area, in conjunction with an extensive annual dry-weather period, does not place significant limitation on standard land-based construction operations. During the winter months, storms can be expected to cause interruptions in marine construction. Short-term construction projects that require taking existing facilities out of service and thereby leading to increased or continuous overflow of sewage near bathing beaches, should preferrably be undertaken in the winter.

Narrow streets and traffic congestion in several of the more densely developed areas of Alexandria will require attention to precautions or special procedures such as modification in route selection, traffic control, public safety protection, and shoring to protect the integrity of main roadways or adjacent buildings. Considerable bracing and sheeting of trenches even for shallow sewers will be necessary to avoid damage to nearby dwellings. Further restriction may be caused by the Governorate's prohibition on trenching and other construction along several principal urban thoroughfares during the summer season. It may become necessary to relax this prohibition in certain instances where timely completion of the work is essential.

Many streets and access roads in low to middle income neighborhoods of the eastern and western districts are not yet paved, although some are sewered. Vehicular access, with the exception of donkey carts, is limited due to stormwater flooding and wastewater overflows onto low areas underlain by silty clay soils. Raised earthen pathways and doorway step stones are maintained by local residents to allow building access in these areas. Where sewers have not been installed, it is common practice for residents to construct holding tanks and leaching pits in the middle of the unpaved streets. The roof slabs of such underground structures are in most cases weak as they are fashioned locally out of odd lengths of pipe, wire, and poorly mixed concrete. Many streets are lower than surrounding lands due to the extensive removal of sandy topsoils prior to constructing dwelling units. The dwelling units have been erected in irregular patterns which result in large numbers of narrow, dead-end streets, and the obstruction of many rights-of-way.

Extensive dewatering operations will be necessary in some low lying areas. Materials and equipment delivery will require specialized transport arrangements in some situations. Standard construction practices will suffice in most instances but it is expected that somewhat greater cost for excavation and installation will be required in congested areas than is usual in urban areas where streets have been properly constructed to grade as well as paved.

Economic factors are expected to impose greater constraint on future construction operations. Lack of readily available skilled and semi-skilled labor, as well as some basic construction materials and special equipment in Alexandria can limit selection of construction methods and dictate, in key situations, reliance on imported sources.

The present shortage of skilled and semi-skilled labor has been caused in part by a labor drain to the Suez and construction projects in other Arab countries. The lack of adequate training programs, limited skill transfer by inheritance and insufficient laws governing the quality of labor have also contributed to the shortage. As a result of these factors it is anticipated that construction costs may be above those experienced in the recent past. Higher wages will need to be paid to attract skilled labor and the additional supervisory personnel who will be necessary to maintain quality construction, especially for important major facilities proposed.

The continuous and ready supply of unskilled labor available in Alexandria presents little problem for future wastewater construction programs. Likewise, the availability of competent, experienced, and qualified major Egyptian contractors in electrical, mechanical, and civil engineering who have access to most equipment necessary for construction of sewers, plant structures (civil works), and other wastewater control facilities does not present a major limitation to the consideration of construction methods. International tendering, now allowed by the Egyptian Government, is expected to be necessary for some of the more specialized construction projects. Technology transfer should remain a requirement for all foreign or joint Egyptian and foreign construction contracts.

Construction Materials

Basic materials, such as sand and aggregate, are quarried from the Western Desert near Alexandria and transported by truck and barge to construction sites within the city. Timber and plywood must be imported into the country. Good quality facing brick is available locally and can be used for lining and construction of superstructures.

Manufacture of cement, an ancient Egyptian industry, occurs locally but does not meet current demands of the building industry. During the last several years, over one million tons of cement have been imported annually in order to meet requirements. Projects have now been initiated to repair and expand existing cement production facilities. In addition, studies are underway for new cement plants. It is expected that the larger national contractors most capable of performing the civil works envisioned in the Wastewater Master Plan will have priority in obtaining cement.

Reinforced concrete components which are to be in contact with sewage, are subject to attack by sulphides. Sulphide attack can result in rapid deterioration of concrete and lead to structural failure. In order to protect against such deterioration all concrete must utilize a Type II cement which exhibits higher resistance to sulphide attack. This will be particularly true for reinforced concrete pipes, manhole structures and basins holding sewage. It is good practice, furthermore, to avoid use of different grades of cement in construction of wastewater facilities. Therefore, all cement used should be of Type II. Some components of the system may require greater protection against deterioration. Type V cement which is generally difficult to obtain is not expected to be available in Egypt. Use of special coatings over the concrete will offer the only solution in these severe situations.

Special consideration must also be given to selection of materials which are exposed to salt spray. Use of plastics and special coatings will be necessary to avoid the rapid deterioration of more commonly used materials which is prevalent along the coastal environs of Alexandria.

Various types of sewer pipe are manufactured in Egypt, including: clay pipe up to 1200 mm Ø; reinforced concrete pipe up to 2000 mm Ø; asbestos cement pipe up to 1000 mm Ø; spiral welded steel pipe up to 600 mm Ø; and longitudinally welded steel pipe up to 1400 mm Ø. In addition, cast iron pipe up to 400 mm Ø is locally manufactured and there are plans to produce ductile iron pipe up to 1500 mm Ø within five years. All ductile iron pipe is at present imported. Small (less than 150 mm Ø) plastic pipe is locally manufactured (with plans to increase to 200 mm Ø). Fiberglass reinforced plastic pipe up to 2000 mm Ø may soon be manufactured in Egypt but is now imported. Lead and cement joints for various types of pipe are manufactured locally. Rubber ring seals are imported. Bitumen coating and cement lining of various pipe types has not been part of plant operations in the past, but will be necessary for quality construction in the near future.

The quality and quantity of locally manufactured valves is not expected to be adequate for the needs of the proposed construction projects. A similar inadequacy applies to locally manufactured sewage pumps. These items, together with all other plant equipment, metering, and controls, are expected to be imported.

Most standard structural and architectural components for building construction, such as prestressed concrete beams, structural steel shapes, and materials and equipment for furnishing, forming, and placing reinforced concrete are available in Alexandria. Architectural items are also available, such as roofing, doors, windows, glass, wall and ceiling tiles, and floor tiles. Factory-made cast iron manhole covers, and frames, as well as other appurtenant structures related to sewers, are manufactured in Egypt and in quantities adequate for future construction requirements.

Construction Methods

The recommended Wastewater Master Plan applies basic, well recognized methods of construction for excavation (gravity sewers, force mains, and structures such as pump stations and treatment facilities), bedding, dewatering and backfilling on pipelines, and foundations of major structures.

Excavation for most wastewater facilities in Egypt has been carried out in the past by hand labor using simple and basic tools. The practice of removal of materials (with exception of hard rock requiring blasting) using picks, spikes, and sledge hammers is expected to continue throughout the planning period for this study. Where groundwater levels permit, excavations are made using an open method where sheeting and shoring are seldom used, and side slopes stand nearly vertical. Such practice is not expected to change but, where subsurface conditions (poor soils and/or high groundwater levels) require or deep trenches are necessary, special excavation methods will need to be employed. These will include provision for standard lateral bracing with wood or steel sheeting, as illustrated in Appendix H. Wherever wood sheeting is utilized for pipeline trenches, the sheeting must remain in place up to the crown of the installed pipe. This will necessitate cutting the sheeting at that level. Removal of sheeting below will impose additional structural loads on the pipe due to loss of lateral support along the pipe barrel. Design of pipe wall thickness can compensate for this loss in support, however, extra heavy pipe wall thickness results.

Excavations have generally been dewatered, where necessary, by open pumping methods, as groundwater conditions and the small quantity of surface runoff seldom merits well points or deeper surrounding wells for the shallow trenches used to date. In many areas of the city, sewer trenches and structural excavations will require operational sumps at the lowest point in which pipes or appurtenant structures are being placed, until sufficient backfill or loading is in place to prevent floatation. Well pointing will be necessary for some deep excavations.

Bedding of pipe is of major importance in consideration of future sewer construction projects. It is recommended that a granular bed of crushed stone or screened gravel be employed, in lieu of concrete encasement; this will permit use of more flexible, watertight joints and a better quality pipeline which can result in overall construction and operational economies. Special cases where backfill or surcharge load exceed pipe support strength will necessitate concrete cradles, arches, and encasement. Selected well compacted materials should be used above the gravel bedding to a recommended height of 30 cm over the crown of the pipe.

Methods of backfilling will vary according to bearing strength of pipes, width of trenches, character of material excavated, method of excavation, and necessary degree of compaction. Backfilling should occur as expeditiously as possible in order to prevent trenches from being used as refuse receptacles. In general, granular materials should be used because silts or clays and other fine materials are not amenable to adequate compaction. For costing purposes it is assumed that, following backfill and adequate compaction, cover surface will be restored to a condition equal to, or better than, that found prior to excavation.

Foundations for all major wastewater structures (treatment plants, pump stations, outfalls, etc.) must, in the future, meet the following two requirements:

1. the foundation, including underlying soil, must be safe from structural failure.
2. settlement must be held within limits which will not damage the structure or impair its useful function.

In most areas of Alexandria, the recommended facilities can be supported on concrete footing and mat foundations bearing on natural inorganic soils, which are placed just above the groundwater table. In areas of soft clay (Zone 4) pile foundations may be necessary as discussed in Section 5.1.

Construction of the major recommended facilities will require a number of skilled trades, such as mechanical work (pumps, motors, chemical feed and other process equipment), electrical work (wiring, power supply, installational controls and instrumentation), plumbing work (installing piping and drainage), and general civil work such as carpentry, formwork, stone facing, masonry, equipment operation and repair, steel placement, plastering, concrete finishing and other trades required for construction of the structures. With effective supervision, a considerable portion of the construction can be done by major local contractors, although specialized installations, such as plant machinery, aeration units, major pumps and motors, submarine outfalls, sludge handling equipment, and electrical controls will require additional foreign supervision and advisory assistance from equipment suppliers, foreign contractors and others.

The quality of construction of the recommended facilities will depend on the quality of design, workmanship, materials and equipment, and on the inspection provided. Best results cannot be achieved unless workmanship is performed well, irrespective of optimum use of materials and good design practices. Correspondingly, use of inferior equipment or materials cannot result in quality construction. Development of the Wastewater Master Plan has been predicated on quality workmanship, equipment and materials. It has been repeatedly demonstrated that projects constructed under these criteria are the least expensive when subsequent operation, maintenance and replacement are considered.

In order to assure a high standard of work, in accordance with good construction practices used elsewhere in the world, values used in determining future project costs include allowances for competent inspection, tender evaluations, and other quality control measures. Such inclusions which imply increases in unit costs above present levels are essential, in order to improve the low standards of construction now present.

5.3 Functional Criteria

Introduction

In order to establish recommended plan facilities, an initial set of simplified design criteria was developed. These criteria were applied to all elements utilized in the alternative "planning level" studies. As such criteria are, in-part, inadequate for use in final design, a second, more detailed and specific, set was developed for "feasibility level" studies. Recognition was made of existing GOSSD design standards and, wherever compatible, they were included in the design criteria presented herein.

Sewers and Appurtenances

Sewer pipe size selection has been based on peak instantaneous flow for the design year using Manning's formula with pipes flowing full. Minimum sewer slopes were determined, as shown in Appendix F, for pipe-full velocities of not less than 0.6 m/sec, thereby providing for self-cleansing.

Peak sewer design flow has been determined by the average daily domestic wastewater flow rate, multiplied by a peaking factor, to which is added an appropriate industrial flow rate and a nominal allowance of 0.1 litres/sec/ha for infiltration. The latter value is based on an assumption that new sewer systems will be structurally sound and will have water-tight flexible joints. Unless reasonably strict administrative controls or the admittance of extraneous flows to new sewers is enforced, greater allowance will be necessary.

A minimum depth of one metre to crown of the street sewer (laterals) will in most instances permit gravity collection. Where this is not the case, and sewers cannot be laid deeper, pumping facilities will be required in basements or below grade vaults. This should be avoided, if at all possible. Minimum diameters of 200 mm for street sewers and 150 mm for house connections have been adopted in order to minimize risk of blockage.

Force mains are sized for provision of velocities between 1.0 and 3.5 m/sec, over the full range of pump station capacities. Force main alignment is selected on the basis of minimizing total dynamic pumping head (static plus friction). Continued use of flow dampening chambers at the discharge end of force mains, the current GOSSD practice, will not be necessary as all future sewers are sized to convey peak discharge rates. Air relief valves will be provided at high points, blowoffs at low points and joints will be restrained at all bends as required to eliminate thrust blocks. Force mains would be built of ductile iron or asbestos cement pipe of adequate pressure rating for the design conditions.

Use of inverted siphons (sewers depressed to pass under obstructions) has been avoided wherever possible as they are difficult to maintain. Where unavoidable, inverted siphons are designed to provide minimum velocities of 1.0 m/sec in the primary barrel at least once per day. Additional barrels are provided as required for peak flows.

Manholes are to be provided at all sewer junctions and at all changes in pipe size, slope, and direction. The recommended maximum spacing of manholes for future Alexandria wastewater collection systems is:

Pipe Size, mm	Maximum Spacing, m
less than 200	30
200-250	40
250-450	50
450-600	60
600-1200	100
1200 and larger	150 (special structure)

The manholes are to be of adequate size to facilitate sewer maintenance (commonly 120 cm inside diameter with 60 cm clear access openings). Each is to be water-tight and constructed of durable quality materials. The current practice of using butted joints in vertical sections of manholes must be discontinued. Either a water-stopped joint or tongue and groove with a rubber gasket will be utilized.

Appurtenant structures, such as drop connections, building connection cleanouts, drain inlets, storm water diversion structures, and other devices of special design are also considered, based on standard design criteria. Illustrations of common layout design for such structures, as well as typical manhole and sewer construction, are presented in Appendix H.

Four major factors specific to the situation of Alexandria as regards stormwater flows have led to the recommendation not to provide for stormwater drainage in the sewerage system. These are:

- the limited rainfall, less than 200 mm annually, that falls December through March (normally about six storms causing runoff) which is the time of least tourist and economic activity in Alexandria and of lowest sanitary sewage flows;
- the design of existing sewers provides for capacity up to about 3 times average dry weather flow, leaving considerable capacity, in view of the seasonally low sanitary flows, for stormwater;
- the shape of Alexandria, i.e., long and narrow, makes separate drainage of stormwater flows either to the sea or to inland drainage systems easy and economical as pipelines or open drains can be short;
- the considerable additional expense that will be incurred in providing much larger Master Plan conveyance, treatment, and disposal facilities sized to handle stormwater flows for only a few hours use each year.

Therefore, the Master Plan recommends facilities designed to handle peak sanitary wastewater flows, and limited facilities for stormwater drainage of known problem areas. The new system, if operated properly, will handle much of the stormwater runoff, but it may be necessary to add limited stormwater drainage facilities later, when the proposed sewerage system is in operation, as determined by observed needs. It is inappropriate to increase the funding requirements significantly for a sorely needed sanitary wastewater system and run the risk of jeopardizing implementation of such works.

Pump Stations

Preliminary design of wastewater pump stations has been based on provision of sufficient capacity to pump peak instantaneous flows. At least two pumps would be initially provided, the total number being sufficient to meet peak demand with the largest pump on standby. Centrifugal, radial flow pumps, with two speed drives capable of pumping screened raw sewage, are deemed appropriate for most stations. Pump suction and discharge openings would be at least 100 mm in diameter. Consideration should be given to use of variable speed drives for the larger pump stations

Provision for emergency auxiliary power by connection to two independent power sources, where available, or by on-site generation are included in design.

Two compartment, interconnected wet wells, with sufficient capacity to eliminate surcharging, are used as a design basis. Provision for controls, ventilation, flow measurement, and screening is also included in preliminary functional design.

Submarine Outfalls

Effluent may be safely dispersed into the waters of the Mediterranean if an adequate degree of treatment is matched with a proper distance offshore and adequate dilution by discharge through multiple port outlets. For purposes of developing the Wastewater Master Plan, preliminary functional outfall design was based on sufficient water depth to afford adequate initial dilution and sufficient distance from shore to allow for secondary dispersal and bacterial die-off. Initial dilutions in the range of 100-200 to 1 and secondary dispersal providing a ten-fold increase (1000-2000 to 1) are required for disposal to the sea with minimum preliminary treatment.

Onshore facilities would consist of influent pumping (where necessary), screening of sewage, grit extraction, and skimming by air flotation to remove scums, grease, and other flotables. These processes would be followed by effluent pumping to a submarine outfall pipeline. The preliminary plants will be designed to accommodate future addition of primary sedimentation if such should be deemed necessary.

Functional design criteria on dilution ratios, outfall capacities and capabilities, pumping requirements, and treatment are further discussed in Volume IV, Marine Studies.

Treatment Facilities

The degree of treatment necessary for Alexandria wastewater disposal is influenced by several factors other than basic economics. These include consideration of desirable receiving water quality, public tolerance to local pollution, and both national and international concern for pollution control measures. In most instances conventional engineering criteria, as used elsewhere in the world, for maximum loadings, detention times, hydraulic capacities, etc., have been used. In general, treatment capacity is based on average daily flow rates entering the plant; units within the facility being designed to avoid process shutdown when any one unit is out of operation. Hydraulic designs are to provide for peak instantaneous flows.

Emergency bypass channels are also provided. Preliminary (for submarine discharge), primary, and secondary (waste stabilization ponds and conventional activated sludge) treatment systems are each considered.

Design Criteria

Final design of the facilities recommended in this report must be based on the most modern practices, modified to suit the peculiarities of the Alexandria situation. The standards must be rigidly and consistently applied, in order to construct the new works and upgrade existing facilities proposed in this report.

The current design standards utilized by GOSSD were found to be generally in accord with current worldwide engineering practice. However, major deficiencies for certain details, such as pump station wet well design have been noted.

Appendix F presents the design criteria that were used in developing the "feasibility level" engineering layouts and that are recommended for use in preparing final designs of the proposed facilities.

5.4 Basis of Project Costs

Introduction

In order to develop project cost estimates, information from many sources, including local construction contractors, governmental agencies, representatives of Egyptian engineering firms, material and equipment manufacturers, and suppliers was collected. In cases involving imported goods, cost estimates from the United States, Europe, and from major wastewater facility construction projects in several other areas of the world were assessed, with values adjusted to reflect transportation to and conditions affecting installation in Alexandria. All values have been based on mid-1977 prices in Egypt at the parallel conversion rate of US $1 = LE 0.70.

Unit Prices

Wages for unskilled and skilled construction workers tend to be lower in Egypt than in most Middle Eastern countries. Common laborers in Alexandria presently earn from LE 1.25 to 2.00 per day (8 hours work) including some social benefits. Most unskilled construction laborers work a 48-hour, 6-day week and are paid according to the quantity of production. Semi-skilled workers earn from LE 2.50 to 3.50 daily, while skilled workers in the construction industry (e.g., electricians, plumbers, and carpenters) earn from LE 4.00 to 4.50 per day including social benefits. A detailed list of average daily wages (mid-1977) for construction workers by classification is presented in Appendix G.

Unit prices of both local building materials and imported construction materials have been gathered. These are also tabulated in Appendix G. To determine import costs it was assumed that GOSSD will continue to import major items required, turning them over to contractors for installation. Local customs, duties, and taxes (to be paid in local currencies) have not been estimated in developing program costs as they are considered an internal and redundant cost.

Unit prices for various basic construction items, such as excavation, backfilling, sheeting or shoring, and pavement removal/replacement were gathered based on review of recent contracts, discussions with construction contractors and application of labor productivity and material needs to specific work items. Detailed values, including the contractor's overhead and profit, are tabulated in Appendix G.

Construction Costs of Project Components

Major components of future construction projects envisioned in the Wastewater Master Plan include sewers, pump stations, force mains, treatment facilities and submarine outfalls. Construction cost curves for the various components have been prepared in order to enable "planning level" cost estimation for economic comparison of alternative plans. "Feasibility level" determination of costs for the recommended wastewater system involved more detailed estimates for major structural elements on the basis of actual facility capacities and design layouts.

Gravity collector sewer construction costs were based on earthwork, material costs, handling, laying, and jointing of pipes, restoration of pavement, manholes, and contractor's overhead and profit. The cost curves shown in Figure 5-2 are representative of costs to install pipelines in paved streets where the degree of difficulty for traffic maintenance, accessibility, soil excavation, dewatering, and interference with existing utilities is at a level normally encountered in Alexandria. Costs of pipelines constructed in open country and/or dry areas will be less, whereas within densely urbanized portions of the city or in difficult terrain, they can be expected to be greater. The curves do not include provision for engineering or contingencies. These curves were built up from sufficiently detailed information that they are valid for feasibility level as well as planning level estimates.

Construction costs for force mains, tunnels, and submarine outfalls were also developed, based on planning experience with comparable systems found elsewhere in the Mediterranean area, as well as major construction experience in the United States, taking into account local conditions in Alexandria. The resulting curves are shown in Figure 5-3. The curves are valid for planning level comparisons only. They do not include provision for engineering or contingencies. For feasibility level costs new estimates were prepared from basic unit costs taking into account actual proposed dimensions, obstructions, etc.

Construction cost curves for sewage pump stations, as shown in Figure 5-4, include provision for costs of pumps, fittings, electrical and other equipment, and structures. It was assumed that dual power sources would be provided so that the cost of standby power generation capacity was not included. Installation costs of all equipment, electrical controls and wiring, as well as contractor overhead and profit, were included. No allowance was made for engineering or contingencies. These curves are sufficiently accurate and the impact of the pump station construction costs on the total project cost is sufficiently small that these curves are suitable for feasibility level as well as planning level cost estimation.

Sewage treatment plant construction costs are shown in Figure 5-5 for four types of treatment including: preliminary, primary, secondary activated sludge and anaerobic/aerobic lagoons. The cost curves include provision for all civil works, equipment supply and installation, and controls. The curves are based on costs of similar facilities that have been planned or designed in many other countries, with unit costs adjusted to reflect mid-1977 conditions in Egypt. Due to the particular importance of waste stabilization pond treatment, in the form of anaerobic/aerobic lagoons, for future wastewater management in the Alexandria area, the curve was based on local costs

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for excavation, earth movement including grading and diking, as well as installation of control structures and piping. Unit construction cost is found to decrease only minimally with increased pond capacity as there is little "economy of scale" associated with expanding lagoon size. The curves do not include provision for engineering or contingencies; they are valid for planning level cost comparisons only. For feasibility level purposes, quantities and costs were developed from more detailed outline designs.

Operational Costs

Estimated costs of operating and maintaining envisioned wastewater facilities were based on unit prices in Alexandria for labor, materials, equipment renewal, and energy. Current experience of GOSSD and conditions found in well-operated systems elsewhere in the world were reviewed prior to establishing the curves. Operational costs have been developed on a capacity basis for pump stations (refer to Figure 5-6) and for various types of sewage treatment operations as shown in Figure 5-7.

Overall operating cost, expressed on an annual basis, for future conveyance systems (including laterals, collectors, force mains, and submarine outfalls) was taken as one-half of one percent of pipeline construction cost for comparison of alternatives at the "planning level". For "feasibility level" studies more detailed operational costs were determined based on extent of system, equipment, and staffing considerations.

Land Costs

Land is relatively costly in Alexandria and, due to high priority uses, is often not readily available for new projects. In addition, there are significant constraints on locating major new collectors, pump stations or treatment facilities, based on suitable outfall conditions and existing trunk sewer lines. Several sites may well be in crowded areas or on sites previously dedicated to other uses. Land costs for proposed sites were thus specifically estimated, using the best information currently available for the areas under consideration. This information was gathered from consultation with various governmental agencies and representatives of private organizations.

Present land costs, under ruling market rates as of July 1977, indicate a range from LE 100-200/m^2 in prime commercial areas of central Alexandria to less than LE 1.0/m^2 in outlying regions. Average residential land costs run from LE 20/m^2 in the western districts to LE 60/m^2 in eastern districts. Where GOSSD has not been able to agree to a purchase price with an existing land owner in the past, a value for compulsory purchase has been established by government committee, normally at the prevailing market rate.

Total Cost and Foreign Exchange

Planning Level Comparisons. Costs used for comparison of alternative schemes and hardware plans were developed from construction curve costs for various facilities, with addition of 30 percent for engineering and contingencies. Annual operation and maintenance costs of treatment plants and pump stations were also estimated directly from the cost curves. The annual addition of 0.5 percent of the cost of pipeline (sewers, force mains, and outfalls) construction was used to estimate operational costs for conveyance. Land cost estimates were also included in determining total program costs.

Feasibility Level Estimates. Feasibility level capital cost estimates were based on values from the cost curves (for collectors and pump stations) or, for treatment and disposal facilties, from outline designs, quantity estimates of major material items, basic unit costs and generally more detailed estimates of equipment (including installation) costs. In all cases the addition of 30 percent for engineering costs and contingencies, plus estimated land costs were included.

Feasibility level operation and maintenance costs were estimated on the basis of proposed cleaning and maintenance programs, estimated operations personnel and equipment requirements plus estimates of the cost of electricity and supplies, including provision for annual increases through the duration of the Master Plan program.

Foreign Exchange. The foreign exchange component (FEC) of construction costs for principal project facility components (i.e., treatment plants, pump stations, force mains, sewers, and outfalls) was determined by estimating the percentages of foreign currency costs for the elements (excavation, reinforcement, cement, aggregate, formwork, pipes, trenching, etc.) comprising the principal components, weighted by the estimated proportions of the respective elements comprising the total cost of each facility component.

Direct and indirect FEC's were estimated separately. Direct FEC was taken as the foreign component of the cost of labor (including engineering), materials, and equipment to be imported specifically for and to be incorporated in, or consumed during construction of, the recommended projects, e.g., major pumping units, sewage treatment equipment, and foreign engineering costs. Indirect FEC was taken to be the foreign currency cost associated with the project that represents:

1. Materials and equipment to be incorporated in, or consumed during construction of, the project which:
   a. are made in Egypt by industries having, or expected to have, foreign currency investment, e.g., flexible-jointed clay sewer pipes;
   b. include some (but less than 100 percent) imported materials, components, or labor (such as reinforced concrete pipe);
   c. are both made in and also imported into the country and are to be purchased for the project within Egypt (e.g., cement);
   d. are wholly imported, not specifically for this project, but would be purchased for the project within Egypt (e.g., trench sheeting, and lumber); and
2. Depreciation on imported equipment to be used for construction in the wastewater facility projects.

The results of these FEC estimates expressed as percentages of capital cost, including engineering and contingencies but excluding land costs, are:

	Cost Component, percent		
	Direct FEC	Indirect FEC	Local Currency
Sewage Treatment Plants	42.0	13.0	45.0
Stabilization Ponds	1.5	55.0	43.5
Evaporation Ponds	1.0	56.0	43.0
Pump Stations	43.0	10.0	47.0
Force Mains	51.0	1.5	47.5
Submarine Outfalls	61.0	1.5	37.5
Lateral (Street) Sewers	-	23.0	77.0
Interceptor Sewers (Collectors)	2.0	23.0	75.0

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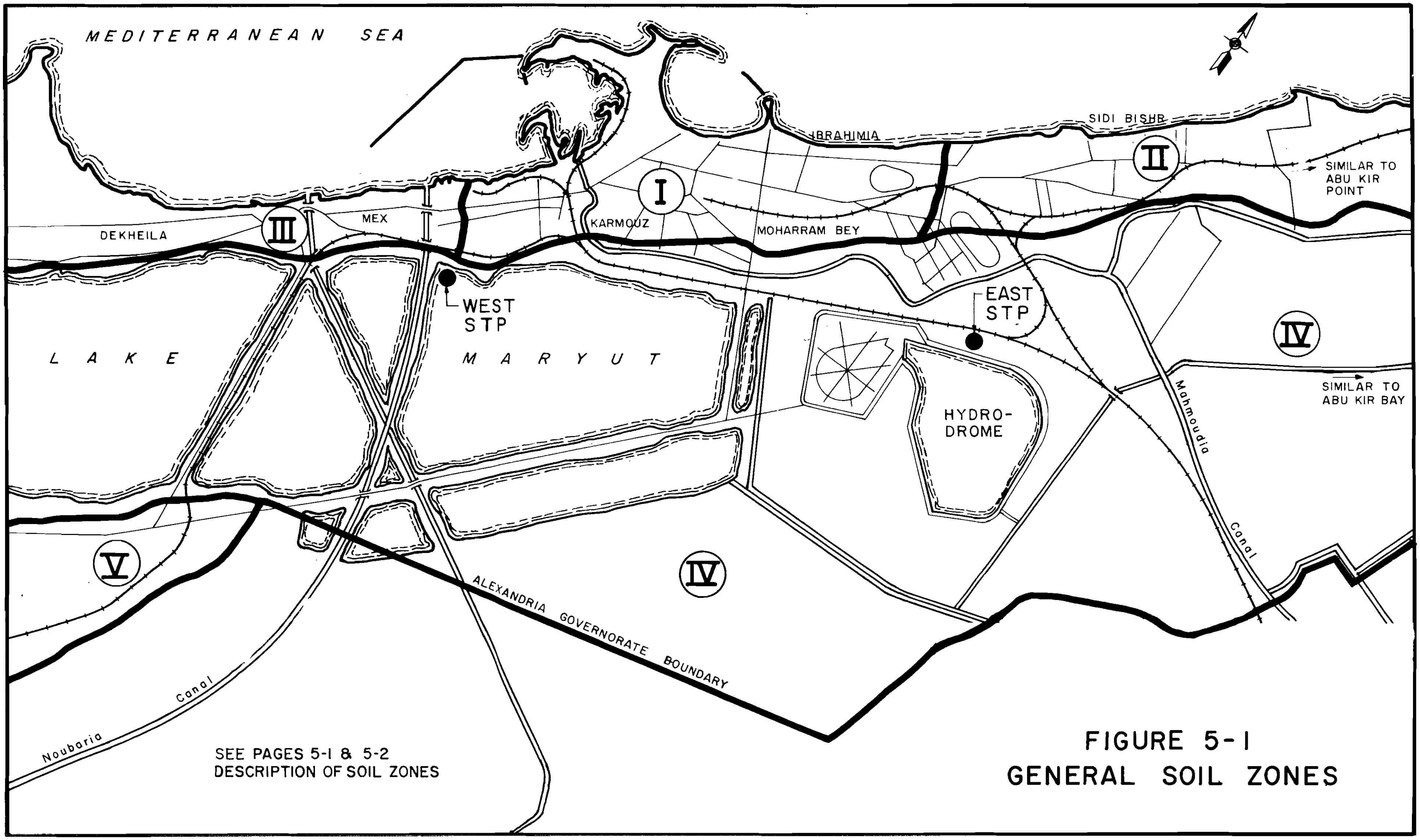

FIGURE 5-1
GENERAL SOIL ZONES

FIGURE 5-1

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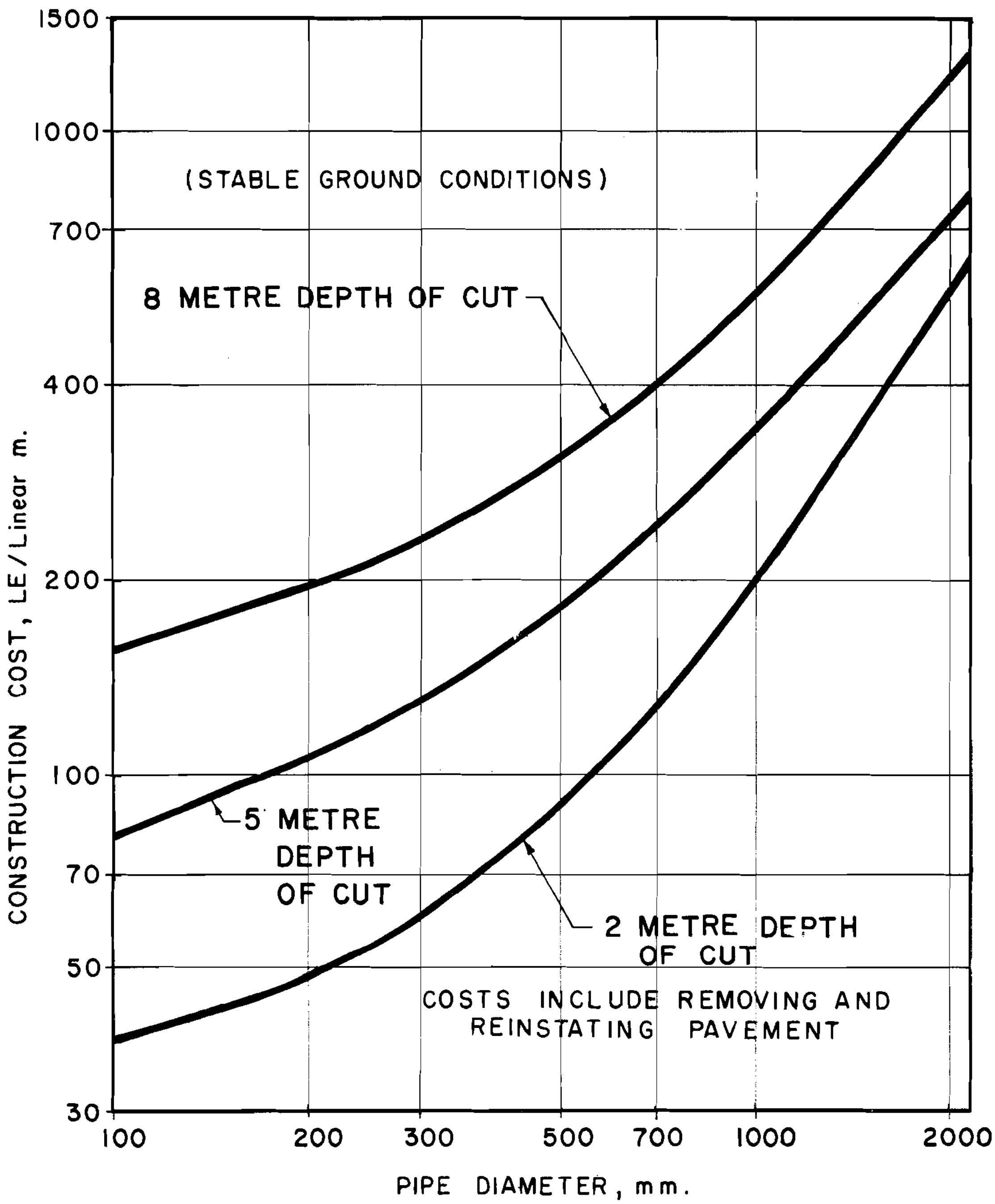
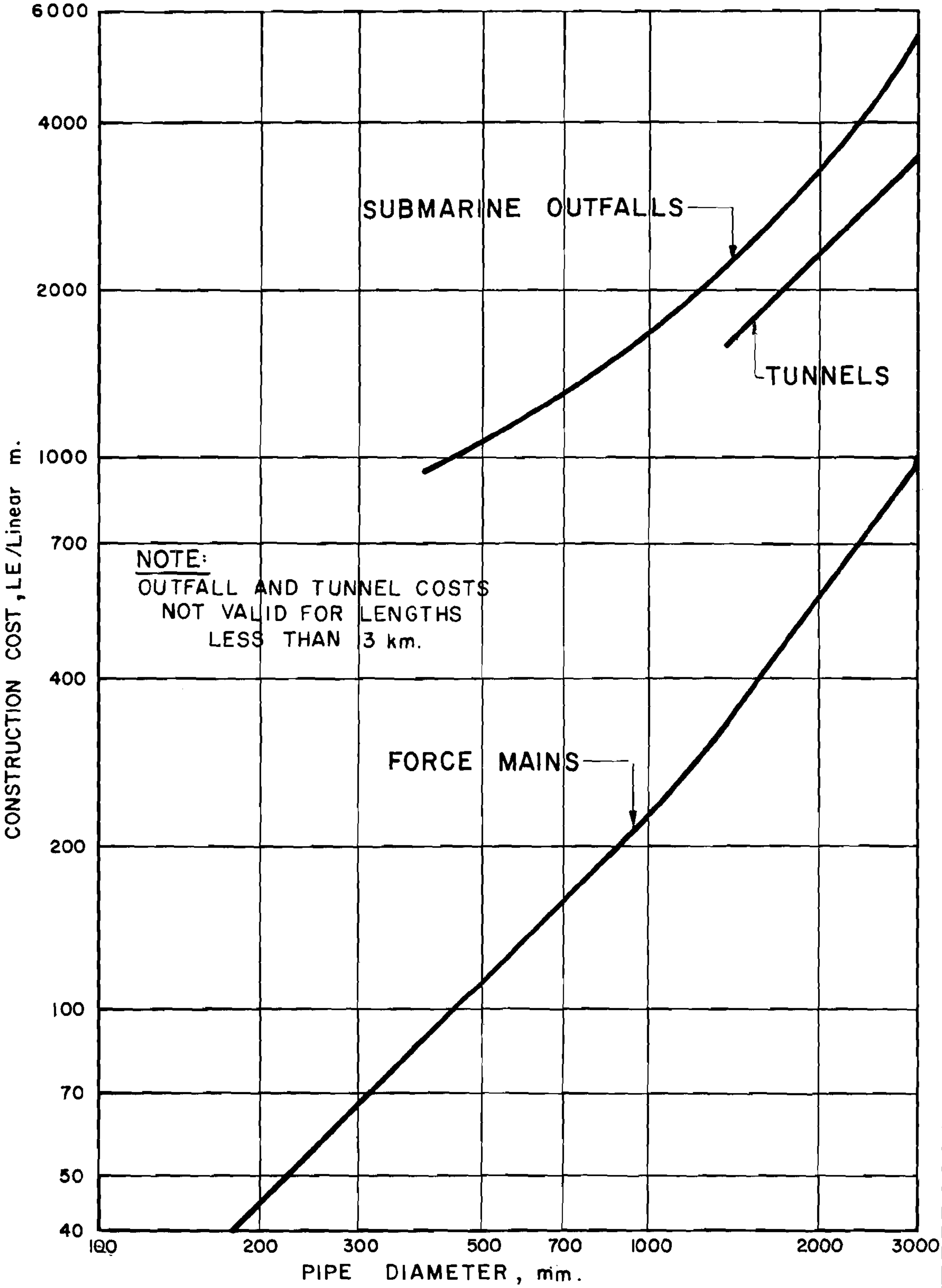


ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

CONSTRUCTION GRAVITY SEWER COSTS

FIGURE 5 - 2

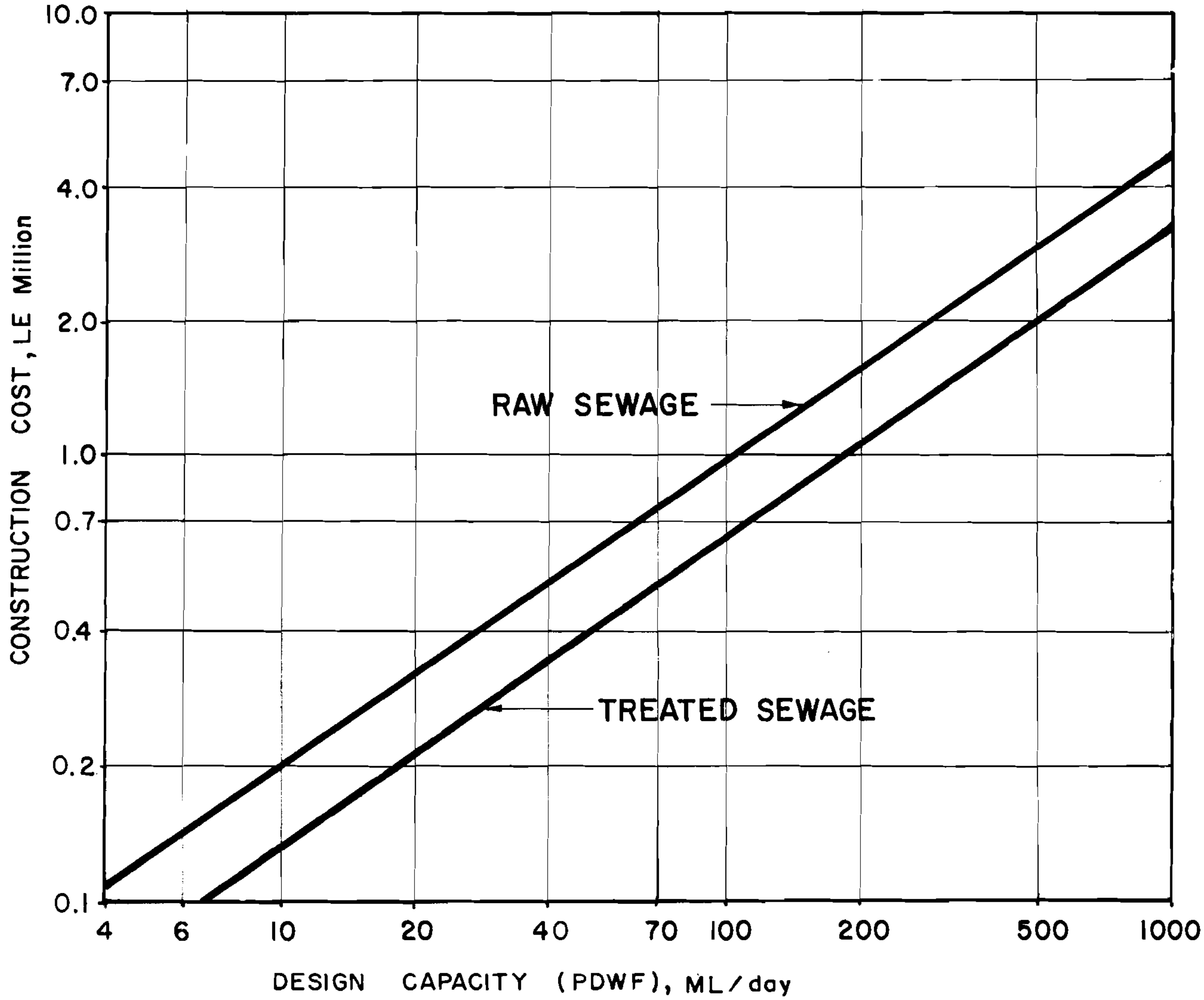


ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

CONVEYANCE
CONSTRUCTION COSTS

FIGURE 5-3

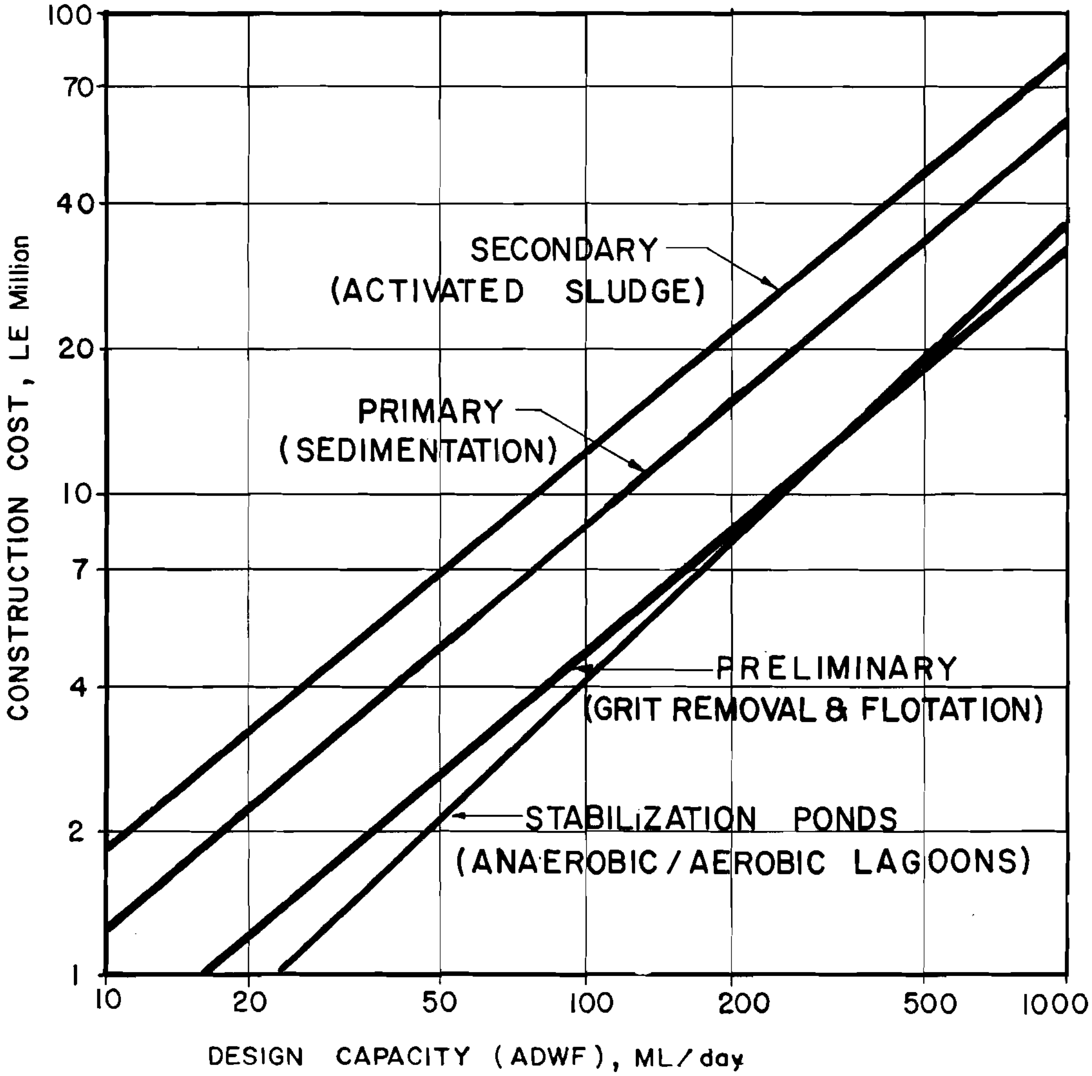


ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

PUMP STATION
CONSTRUCTION COSTS

FIGURE 5-4

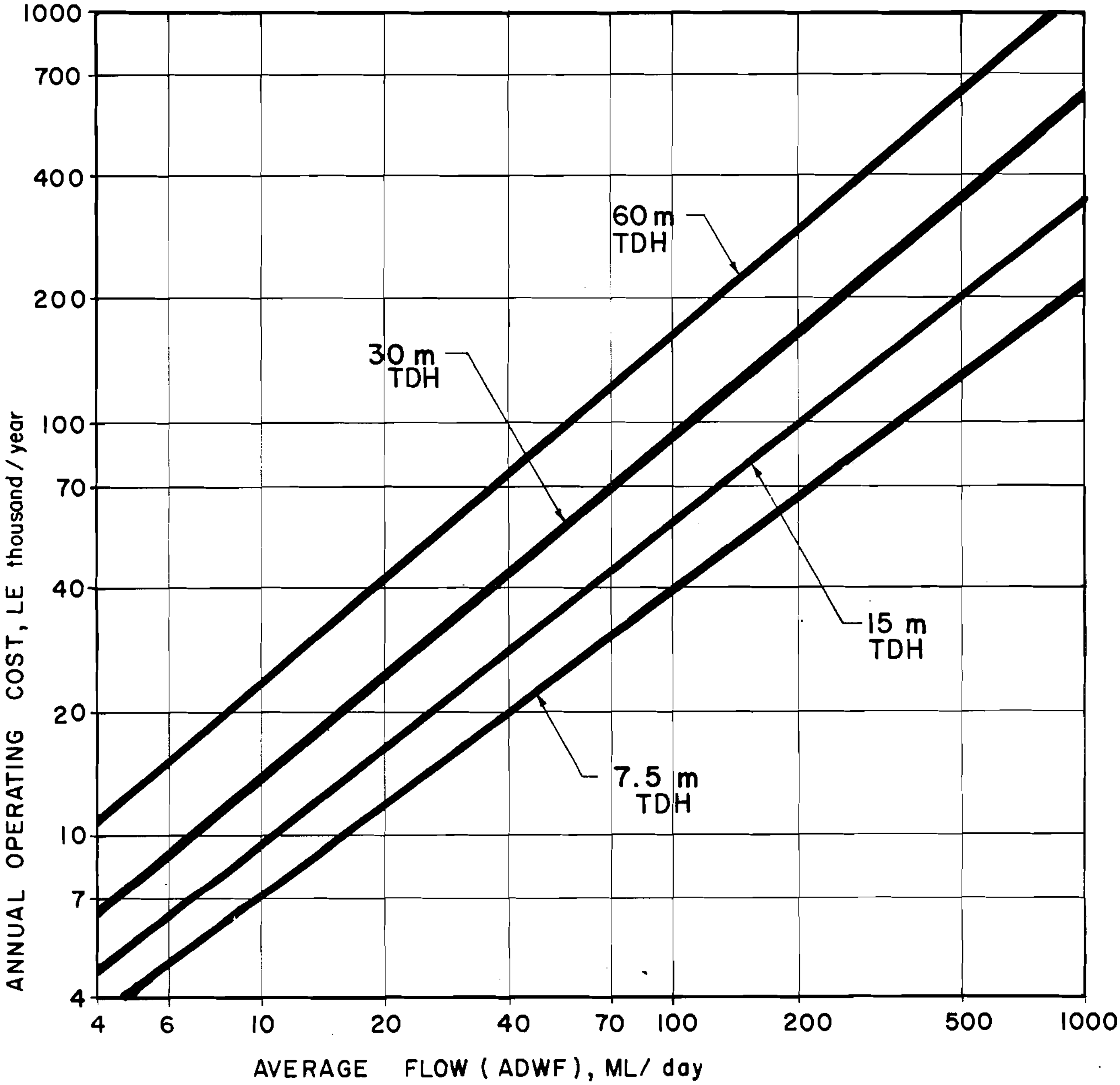


ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

TREATMENT FACILITY CONSTRUCTION COSTS

FIGURE 5 – 5



TDH - TOTAL DYNAMIC HEAD IN METRES

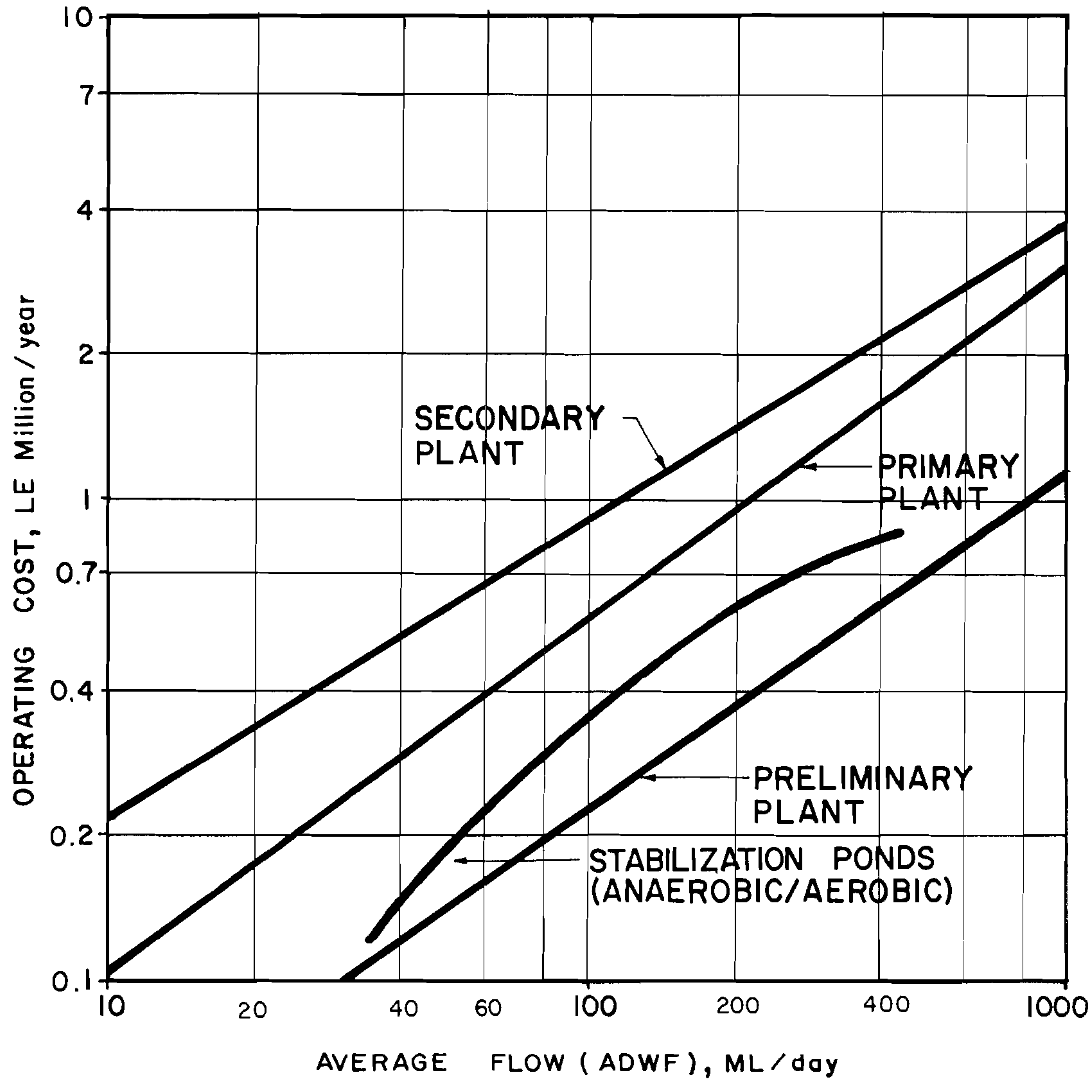
ARAB REPUBLIC OF EGYPT

MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

PUMP STATION
OPERATING COSTS

FIGURE 5—6



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MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

TREATMENT PLANT OPERATING COSTS

FIGURE 5 — 7

CHAPTER 6

CONCEPTS FOR TREATMENT AND DISPOSAL

6.1 Scope of the Master Plan

Objectives

The Wastewater Facilities Master Plan for Alexandria will provide guidance for the orderly and economic development of a sewerage system to meet the needs of the city through the year 2000. The planned program will satisfy specific objectives. These are:

1. Elimination of surface drainage of untreated sanitary and industrial wastewater by providing necessary sewers, collectors, pump stations, and appurtenances for underground collection and conveyance of the wastewaters to treatment facilities and points of disposal.
2. Elimination of overflow, or other discharge of untreated sanitary wastewater or combined runoff up to at least three times average dry weather flow to the beaches or near-shore waters of the Mediterranean Sea, Abu Kir Bay, and the harbors of Alexandria.
3. Treatment of collected sanitary and industrial wastewaters to a degree which will assure proper operation of disposal facilities and/or will allow discharge to receiving waters or land mass of the area without stressing natural purification processes, resulting thereby in maintenance of an acceptable steady state condition in the environment.
4. Elimination of troublesome flooding during wet weather of certain key areas of the city that are important to commerce and transportation.
5. Accomplishment of the above objectives with maximum use of existing facilities and processes of nature and with minimum adverse impact on the social, natural, and financial resources of Egypt.

Level of Quality and Compromise

Attainment of the above objectives will provide for a wastewater management system with a level of quality comparable to that found in more advanced countries of the world. Accomplishment of a plan to meet the objectives will require considerable financial resources and significant commitment of both local and foreign construction capability.

Selection of lower levels of quality or extension of time for project completion will mean compromise of one or more of the objectives. Such compromise is found to have adverse economic impact. Cost reduction either by the construction of inferior treatment and disposal systems or by the delay of completion will curtail program benefits significantly. A review of the current state of public health and sanitary conditions in Alexandria, together with an assessment of the funds needed to maintain the existing wastewater system, indicates that there is little room for compromise in attainment of objectives without severely jeopardizing the health and welfare of Alexandria's population. Furthermore, the economic base of the city, both in terms of tourism and industrial development, is closely tied to the attainment of at least minimial standards of public sanitation and urban wastewater control, as they are understood throughout the world.

6.2 Wastewater Disposal

General Options

A fundamental consideration in the Master Plan study is the effective disposal of nearly 1.5 million cubic metres of wastewater a day (by the year 2000), which will contain substantial amounts of organic and chemical pollutants that must be properly treated and/or dispersed in order not to cause unacceptable environmental degradation within the area. Three basic options are available: disposal by application to land, disposal by discharge to a receiving water, and disposal by evaporation. In reality, application of wastewater to land results in disposal of part of the flow to the air through evapotranspiration, and part to receiving water, through infiltration and runoff.

Reuse (Land Disposal). Two concepts exist for land disposal. One concept is to optimize disposal of wastewater by applying to the land as much wastewater as it can assimilate without creating significant drainage, runoff, and environmental problems. According to this concept, crops that can be grown and harvested are considered of secondary importance and are usuallt of limited economic value. The other concept is to optimize crop production and

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its value by application of wastewater (and its nutrients) when plants require irrigation. Both concepts have been considered at a preliminary stage in the development of the Master Plan. A detailed report is included in Volume III, Appendix E on Reuse of Wastewater for Irrigation.

A secondary level of treatment has been adopted as a necessary requirement for the disposal of wastewater through crop irrigation. Protection of public health is the principal reason for this requirement. Significant advantages such as the need for less land area, less extensive distribution systems, and considerably less maintenance of the soil surface from clogging also accrue if secondary treatment effluent is involved. Unless a reasonably stable effluent is applied to the land, a significant odor nuisance can result. Several thousand hectares of land would be necessary for land application for all of Alexandria's wastewater.

Optimization for Disposal. Land application of wastewater at rates in excess of crop needs is not considered a viable approach for the following reason. The degree of treatment for such a method of disposal is equivalent to the degree needed for crop maximization or for interim discharge into Lake Maryut. If there is found to be economic value to treated wastewater sufficient to allow expenditure of funds for distribution facilities, then it will be prudent to maximize the return by optimizing crop growth. There is no advantage to be gained, therefore, in considering optimization for sewage disposal.

Optimization for Crop Production. Factors that must be evaluated when considering reuse of treated wastewater for irrigating crops are primarily economic. If the net cost to convey, treat, and distribute wastewater, assuming that the value of wastewater equals that of canal water, is more than the return produced from the use of the replaced canal water, then reuse of wastewater is not economic. The net cost to convey, treat, and distribute wastewater for reuse by crop irrigation is the sum of capital and operating costs for: (1) conveyance to a treatment plant site; (2) provision of secondary treatment; and (3) an extensive system of distribution; less the capital and operating costs of a least-cost alternative. If continued disposal of wastewaters to Lake Maryut is considered least costly, then the net cost for land application is only the cost of transport and distribution from a secondary treatment facility to the irrigated croplands. The return from uses to which replaced canal water is put is the value of additional reclaimed land made possible by the replaced canal water, the crops produced on such land, the value of industry and/or housing the replaced water might support, and revenues derived therefrom. There are several modifying factors, however, which must also be considered. The present and potential supply of water from other sources, its cost, and the relative efficiency of present water irrigation use affect the economic assessment. The major use of water in the Nile Delta is for irrigated agriculture. It is understood that present irrigation practice is about 50 percent efficient in terms of water use.

Water for irrigation is provided by the Egyptian Government without cost to the user. Cost to the government for irrigation water in the lower Delta region is reported[1] to be about LE $0.002/m^3$, based upon Egypt's share of the development cost for the High Aswan Dam waters allocated to irrigation, plus added allowance for cost of control and distribution. There are two opportunities for appreciable economic extension of the Nile Delta water supply system. The obvious one is to improve efficiency of use, i.e., to "tighten up" present irrigation practices in order to better utilize water supply resources already developed. The second approach is to increase water supply by construction of new dams, canals, and regulating facilities in the Upper Nile River Valley. Such development might provide an estimated nine billion cubic metres of water annually for Egypt[2]. Development of groundwater resources has also been mentioned but no net increase in water supply would be realized unless aquifer recharge was by water that otherwise would be wasted. Although costs have not been expressed for these developments, the unit cost of supply capacity for resources of this type is typically much less than the unit cost of secondary treatment. It is calculated that reuse of Alexandria's entire wastewater flow in the year 2000 would release for other uses about one-half of one percent (0.5%) of Egypt's present average annual water supply.

Another factor which must be considered is the quality of treated wastewater. A key parameter of water quality for irrigation is the concentration of total dissolved solids (TDS). In general, decreased crop yields can be

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[1] Personal communication, Mr. Saleh Shihab, Undersecretary, Ministry of Irrigation, Damanhour on April, 1977..

[2] "Water Resources Development in the ARE", Lecture by Mr. Farid Nicola, then Undersecretary of State, Ministry of Irrigation, Karlsruhe, West Germany, 6 July 1971.

expected when TDS concentrations exceed 500 to 800 mg/L. While some crops are more salt-tolerant than this, higher value crops are likely to be most affected. The level of salinity affecting less tolerant crops depends upon several factors which include the concentration of dissolved salts, the soil type, drainage characteristics, depth to water table, and the relative concentration of sodium salts in relation to total salinity. Crops grown on clay soils of the type found in the Delta are usually more sensitive to salinity than the same plant species grown on sandy soils. Another problem may be the concentration of nutrients in wastewater. Many plants which are important commercially, grow luxuriantly with enlarged stalks and leaves in the presence of more nitrogen than they really need, but bear small and immature fruit.

The TDS of waters in the Mahmoudia Canal (used for irrigation and water supply) is normally about 250 to 400 mg/L. Measured TDS of Alexandria wastewater varies from about 1080 to 1600 mg/L. The increment of TDS added through overall use is, therefore, on the order of 1000 mg/L with possible variations of plus or minus 350 mg/L. In order to maintain a TDS of 800 mg/L in a mixed canal--treated wastewater irrigation supply, the average proportions needed are 55 percent canal water and 45 percent wastewater. It is highly uneconomical to treat wastewater for reduction in total dissolved solids.

TDS of Noubaria Canal water (at the Maryut Water Treatment Plant) has been between 900 and 985 mg/L during the summer of 1977, although upstream values at Kafr Boline ranged between 260-300 mg/L during the same period. It is assumed that, in time, the problems causing TDS increase between these two locations will be corrected. The requirement for mixing wastewater in desert canals is expected to be equally as important as in the Delta. It is certain that reuse without mixing will decrease the value of farm products, when compared to reuse after mixing with canal water.

Alexandria wastewater also contains greater than normal concentrations of nitrogen and phosphate nutrients. An analysis of 24-hour composited wastewater samples indicates a mean nitrogen concentration of 33.0 mg/L and a mean phosphate concentration of 10.3 mg/L (as P). With a normal irrigation application of 7000 m^3 of water per feddan per year and a ratio of canal water to wastewater of 55:45, the annual application of nitrogen through wastewater reuse would be 102 kg/feddan. Similarly, the annual application of P_2O_5 would be 24 kg/feddan. Alexandria's wastewater would provide two to three times the nutrients typically required, if applied without even greater dilution ratios.

From consideration of both TDS and nutrient loads, it would be best to mix canal water and wastewater on about a 70:30 or even a 75:25 ratio. A major conveyance pipeline system would be required to distribute wastewaters to the extent necessary for attaining such a mix.

Based upon the above considerations, a system to reuse 80 percent of Alexandria's year 2000 wastewater flow for agricultural irrigation on Delta lands would require an area of 173 800 feddans or about 700 km^2. This would comprise the entire present extent of agricultural land east of the Umoun Drain and northwest of the village of Abu Hummus (35 km southeast of Alexandria) on the Alexandria-Cairo Delta road. A realization of the scope and extent of any future distribution system can be obtained from this calculation. Costs of such a system will place a high price on wastewater reuse, one that is not expected to be economical in the foreseeable future. Nevertheless, reuse by crop irrigation has been maintained as a candidate alternative throughout evaluation of plans in the following chapter.

Reuse of wastewater for crop optimization results in periods when a portion of the wastewater flow is not needed, i.e., during both the harvest season and those times when crop requirements are satisfied wholly or partially by rainfall. During these periods of the year, wastewater must be stored or discharged elsewhere. Storage is expensive and requires additional commitment and significant land area. The only reasonable alternative is discharge elsewhere, in this case, to Lake Maryut. In evaluating alternatives, the reuse concept cannot be rated fully effective as a solution to Alexandria's wastewater problems because of the necessity of discharging excess wastewater to Lake Maryut. An additional reduction in effectiveness is found as the discharge of excess wastewater nutrients, mainly nitrogen, not taken up by plants or absorbed in the soil, can readily find their way into Lake Maryut and the Western Harbor via agricultural drains

Feasible locations in considering agricultural reuse of secondary treated wastewaters from Alexandria include:

- <u>Abu Kir and/or Abbis Area(s)</u>. Urban wastewaters could receive secondary treatment in a plant located southeast of the city. Use would be by mixing canal water and wastewater at points where irrigation water is presently diverted from irrigation supply canals, with the mix not less than 55 percent and preferably 70 or 75 percent canal water. Conveyance facilities would be provided to serve an appropriate area for maximizing reuse. Surplus wastewater would be discharged to local drains and to Lake Maryut.

- Maryut Sector Area. After secondary treatment, wastewater from Ameria, Mex-Dekheila, and the Central/West Zones might be pumped south of Ameria and discharged into the branches of the Noubaria Canal for mixing and conveyance to irrigation sites. The point of discharge would be downstream of any future domestic water intake. Surplus waters would be wasted to local ditches and to Lake Maryut from one or more treatment plants located to the west of the city.
- Ameria Northwest Area. Treated wastewater from Ameria, Mex-Dekheila, and the Central/West Zones might also be conveyed to and used, without mixing with canal water, on croplands not yet developed northwest of Ameria. Such land would first need to be levelled, provided with irrigation canals or other distribution systems, and adequately drained to assure no salt build-up.

Evaporation

In a region where annual evaporation greatly exceeds annual rainfall, and where there exist extensive areas of land of marginal value, the possibility of disposal of wastewaters by evaporation becomes feasible. The concept requires commitment of an adequate amount of remote land as a "salt sink", where waste residues left when sewage evaporates will remain and accumulate. In the Alexandria area the conditions of evaporation exceeding rainfall are certainly applicable and there is considerable remote area in the desert southwest of the city. Wastewater disposal by evaporation must be considered as a viable alternative.

The amount of land required is dependent on the amount of excess evaporation over rainfall. The annual average excess for the coastal area of Dekheila is 2.1 m, while far inland at Wadi el Natrun excess evaporation is 3 m. Data are not available for the area southwest of Ameria, but if an assumption is made of 2.5 m net evaporation, the required area for Alexandria's entire average dry weather sewage flow in year 2000 would be 18 367 ha (184 km^2) of land. If disposal of Central Zone wastewaters were to the sea and Ameria

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wastewaters were reused by crop irrigation, the required area for the balance of Alexandria's projected sewage flow would be 15 300 ha.

The conceptual approach would be to select an appropriate site, one which offers, if possible, a natural shallow depression, or one which can be levelled economically, and convey wastewater by pumping and pipeline to the site. The disposal piping arrangement would require many points of discharge in order to distribute wastewater over the area. No treatment would be involved, except as needed to protect conveyance facilities. The average BOD loading, based on 600 mg/L in raw wastewater, would be on the order of 48 kg/ha per day, which is a relatively low loading rate and assimilation could be expected with only localized nuisance. Waste residues would quickly plug soil pores so there would be little or no resulting groundwater to cause drainage problems. Operational costs would involve pumping, pipeline maintenance, and patrol of the site. The considerable area involved might have a "small weather" effect on local environs, especially downwind, where relative humidity may be increased. An appreciable climatic change to the area would be expected, but the area should remain isolated for obvious reasons of public health by controlling access.

Field reconnaissance of areas within feasible conveyance distance from Alexandria has been made in search of suitable sites. It has been found that with localized exceptions, the dry plateau area immediately southwest of Alexandria represents potential agricultural land. Soils in this area contain a significant amount of clay and, if irrigated and drained, will be of considerable value for many agricultural purposes. Work is presently underway to reclaim some of this land, and plans for a much more extensive program have now been developed. It is likely that the nearest available site for a large evaporation pond would be southwest of the proposed El Nasr Canal, the location of which is more than 75 km from central Alexandria.

The availability of smaller areas as possible evaporation disposal sites suggests consideration of such "salt sinks" for separate disposal of toxic and more intractable industrial wastes. Two sites have been considered for this use, one in the western portion of the Lake Maryut depression, and the other along the western edge of Lake Idku near Abu Kir. Further discussion of these sites is contained in Section 6.4.

Receiving Waters

Sewage may be discharged to the open waters of the Mediterranean Sea, the Western Harbor, Abu Kir Bay, and Lake Maryut. Although all represent sufficient volume to be able to receive the quantity of wastewater projected for discharge, none is capable of assimilating satisfactorily the pollutants carried in the wastewater without some degree of technological assistance. In order to maintain an acceptable quality in any of these receiving waters, treatment and dispersing facilities must be provided and adequate natural dispersing currents must occur.

Discharge to the Sea. The principal objective of marine disposal of wastewater is to disperse waste effluent into seawater so that the resulting low concentration of pollutants can be handled by the natural processes of organic decomposition and oxidation without exceeding acceptable limits of environmental degradation. It is possible, when favorable natural conditions of current, depth, salinity profile and winds are present, to dilute discharged sewage to as much as 2000 parts of seawater to one part of wastewater with proper attention to design of diffusers. Dilution at this magnitude will disperse wastewaters to such an extent that, with the exception of bacteriological monitoring, it becomes difficult to detect any effect on receiving waters. For example, if the discharging wastewater has a biochemical oxygen demand (BOD_5) of 600 mg/L, dilution to 1 : 2000 will result in a concentration of about 0.3 mg/L, which even with modern laboratory techniques is barely detectable. The decomposition or oxidation of waste matter will occur quickly and readily by natural biological and biochemical forces already present in seawater and without undue stress on the environment. In fact, the resulting minor increase in nutrients could be of benefit to fish and other aquatic life in the offshore marine environment, which is known to be nutrient-poor.

Thus, if constituents such as grit and floatable materials, which occur in relatively small amounts in municipal sewage, are removed by preliminary treatment, wastewater could be discharged to the sea without visible degradation of the marine environment. Grit must be removed because of its tendency to wear pumps and reduce pipeline capacity. Floatables must be removed because, regardless of how well dispersed, they will rise to the surface and can be conveyed by surface wind currents back to shore where they will be seen and be recognized as having a wastewater origin. They also tend to clog diffuser ports. Treatment facilities to remove grit and floatablesare relatively simple to construct and operate, as well as being low in overall cost. Travelling screens are usually installed at the plant to protect equipment from damage due to gross solids. The reasonably small amounts of screenings, grit, and floating debris removed can be trucked to solid wastes disposal areas or used for land fill.

Discharge of wastewater containing heavy metal toxicants to the sea poses a problem in that such pollutants are accumulative i.e., they do not degrade biochemically to form innocuous substances. Heavy metals are taken up by plants and animals in the receiving water and accumulate in their bodies. If they are ingested by principal links in the food chain, the effects of toxicants are transferred along the chain. Heavy metals toxicants also inhibit growth of organisms which carry out the carbonaceous oxidation process in secondary wastewater treatment plants, by accumulating in biological slimes and sludges until concentrations become great enough to affect the health of the organisms. Heavy metals occur in relatively low concentrations in most municipal and industrial wastewaters, but a few industries are known to discharge them in significant amounts. Fortunately, it is relatively easy and inexpensive to remove most heavy metals before discharge to the sewer, if industrial wastewater streams are separated and treated in-plant where the volume is small. Even if this does not occur, their dilution in wastewater results in low concentrations and, with further substantial dillution upon discharge to the sea, resultant concentrations of toxicants are not likely to pose environmental problems. However, if heavy metals removal is not required, potential accumulation could take place which might result in unacceptable concentrations over the long term. Therefore, it will be necessary to limit or eliminate heavy metals discharges as soon as practicable for wastewater disposal to either the sea or inland waters.

Sufficient marine information, not available at the start of the Master Plan study, was necessary to determine whether or not sea disposal is a feasible approach for future wastewater management. As a result, a comprehensive marine studies program was undertaken to obtain the necessary information. This study, presented as Volume IV of this report, was started in July, 1977 and ran for one year duration. It includes physical, chemical, and biological investigations needed to assess the possibility of sea disposal, to provide preliminary design information, to determine the existing or baseline conditions for future assessment of environmental impacts, and to afford a confident estimate of construction difficulties and costs if an outfall system is found to be preferable. Sufficient information is now available from the marine study to conclude that submarine discharge off Alexandria is not only a practical means of disposal, but also most attractive from the standpoint of costs and functional considerations.

For an initial consideration of sea disposal, varying outfall lengths were identified and analyzed. Ten km outfalls discharging to 50 m or more depth entailed preliminary level of pretreatment (grit and floatables removal) only. Outfalls of lesser length, 4 to 6 km, involving primary sedimentation and chlorination pretreatment, would be adopted if adequate dispersing currents could not be found. Early comparative evaluation between outfall lengths showed significant cost and environmental advantages for the longer outfalls. Therefore, in establishing alternative plans, the shorter outfall-primary treatment approach was eliminated as being less cost effective. However, future international agreements may someday establish the need for additional treatment. When selecting sites, adequate space for further treatment processes was provided in the outline designs and estimates of land costs for a sea disposal program.

Facilities associated with submarine outfalls include, after preliminary treatment works, an effluent pump station and a pipeline fitted with a diffuser section along the last few hundred metres of length. An effluent pump station is required to provide the lift needed to overcome friction head in the pipeline, discharge head against heavier sea water, wave set-up which occurs during periods of onshore winds, and energy for the passage of wastewater through the ports. The pipeline would be constructed to cross the shoreline and surf zone below the surface of the ground/sea bottom for protection against wave action or other damage and to conceal its presence. Beyond the surf zone, at a depth of greater than 10 m, the pipeline would be laid on the bottom or in a shallow trench, as permitted by bottom profile conditions, and adequately protected from anchors and nets. The diffuser section would also be laid on the bottom and adequately protected. It is likely that anchoring and trawling in the vicinity must be prohibited. The pipeline, including diffuser section, is expected to be from 8 to 10 km in length, measured from the shore.

For conditions 10 km from shore, where the water depth is 50 to 55 m and current speeds in excess of 0.10 m/sec are common, a multiple port diffuser can be designed to give the effluent an initial dilution of approximately

100 to 1. This initial dilution occurs when the discharged effluent rises from the numerous ports and mixes with the surrounding seawater. After the buoyant plumes complete their rise from the sea bed, the initial dilution relies on the processes of diffusion and dispersion, as the plume is carried away from the discharge site by currents. The rate of secondary dilution depends on the intensity of turbulence and on velocity gradients, but it is safe to estimate that an additional twenty-fold secondary dilution will be attained within 10 km of the discharge point. It is, therefore, conservatively estimated that sewage discharged from a well-designed multiport diffuser 10 km from shore will receive 2000-to-1 dilution before reaching any point along the shoreline.

A principal concern for sea discharge is the rapidity of bacterial die-off. Bacterial die-off rates, expressed as T_{90} values, or the time in hours for a 90 percent reduction in a bacterial population, vary greatly depending on sunlight or darkness. T_{90} values at night may be as high as 40 to 60 hours compared to 1 to 8 hours during the day. Measured values of T_{90} off the coast of Alexandria are about one hour. Similar values have been observed elsewhere in the Eastern Mediterranean. The estimated time for return travel to the beach of waters discharged 10 km offshore during periods of onshore winds is 14 hours. A 10 km outfall length will assure that all wastewater discharged is exposed to sunlight before it reaches the beach. An alternative would be to provide chlorination facilities to decrease bacterial populations by disinfection and thereby allow a shorter outfall. Disinfection requires costly facilities, continuing operational costs, a need for monitoring results, and may, in the future, as more becomes known about the subtle effects chlorine has on the newer organic chemicals, require a change in methods to eliminate possible chlorine toxicity in the marine environment. Furthermore, chlorination is of doubtful value for effective disinfection of raw sewage.

An additional advantage of long outfalls and depths thus afforded is the possibility during early summer months of continual submergence of the wastewater plume. Under conditions of considerable difference in surface and bottom temperature in the sea, it is possible with good mixing and dispersion to produce a seawater-wastewater mix the density of which is somewhat greater than the surface seawater. When this happens the seawater-wastewater mix does not rise to the surface but reaches a terminal height about 10 to 15 m below. If this occurs, excellent protection is afforded to beaches because no wastewater then reaches the shore. Observed conditions off Alexandria do not ensure that a wastewater plume can be submerged, particularly in late summer and fall. Heating of surface waters in spring and summer creates the proper condition for a strong density gradient, but a mixing effect from almost continuous northwest winds increases thickness of the heated surface layer until, by autumn, density gradients of strength and depth to maintain submergence may no longer exist. Therefore, it will be necessary to design the outfall and diffuser to afford adequate dilution and bacterial disappearance without allowing for the benefit of continuous plume submergence.

Marine study has revealed the existence of a lower-density surface band or layer of water which often occurs near the coast. This may be the result of a large freshwater discharge from the Mex Canal and other fresh water discharges along the shoreline. When this band is present, a sewage plume discharged more than four km offshore will be kept away from the beaches. However, the occasional occurrence of this band is not reliable for continued protection.

A further advantage to an outfall of about 10 km length at Alexandria is the smoothness of the bottom at such distance from shore. At 8 km or less the bottom contains several ridges which tend to permit shoaling and accumulation of solids. The smooth bottom and stronger currents at 10 km distance tend to minimize this effect.

Consideration of outfall location has been based on assessment of four possible sites. They were as follows:

- Kait Bey. Replacement of the existing outfall in order to handle flows from the Central and West Zones. The existing outfall has inadequate capacity and is much too short to provide adequate dispersion for beach protection.
- Sidi Bishr. For discharge of flows from the Eastern Zones of Alexandria as far east as Montazah.
- Abu Kir. For discharge of flows from Maamoura, Abu Kir Peninsula, and Abu Kir Bay industrial areas.
- Agamy. For discharge of flows from Agamy, Mex-Dekheila, the future industrial and tourist areas further west and, ultimately, the Ameria area.

Considerable study was given to the location and number of outfalls. Analysis of present flows and expected development of the outlying areas indicate that the relatively small wastewater flows now present may increase significantly by the year 2000. In a growth-dependent situation of this kind, construction of a major outfall within the next several years is not economically practical. It is far less costly to defer the expense of an outfall until flows are of great enough magnitude to warrant a major construction project. Furthermore, it is difficult to operate satisfactorily an outfall at low initial flows and impractical to build a small pipeline now and duplicate it later. Interim measures, in the form of treatment and inland disposal are preferable. An outfall at Agamy is thus not considered a viable approach until after year 2000.

It was found to be more economical to convey Abu Kir Peninsula wastewaters to an outfall system serving the Eastern area. This is primarily because of the relatively low flows projected for the Abu Kir area and the sharp economy of scale relationship for outfalls in which a considerable portion of incremental cost is not dependent on pipe size.

It was decided, after thorough assessment of conditions, that two outfalls would be necessary, one located at Kait Bey to maximize use of the existing Central Zone system and the other to be located to the east in the Ras el Soda area. The latter location is near the center of the eastern sewer service zones where land is available for preliminary treatment facilities. It was found less economical and very disruptive in fully developed areas of the city during construction to convey wastewater from either Kait Bey or Eastern areas to a central location for a single submarine outfall. Thus a sea disposal alternative was established on the basis of two outfalls.

If, in a matter of three or four decades, economics of wastewater reuse undergo significant change and international political pressures require cessation of wastewater discharge to the Mediterranean Sea, conveyance and treatment facilities needed now for sea disposal can be utilized to good advantage in a future inland discharge system. Pipelines, treatment plants, and pump station facilities would all be incorporated into a system for conveyance inland. The submarine outfall facilities would then serve as a backup or standby disposal system. Excess flows not utilized inland would also be discharged effectively by the outfall system.

Discharge to the Western Harbor. The disposal of Alexandria's wastewater to the Western Harbor, west of the Port of Alexandria breakwater structure, was considered during the initial formulation of alternatives. Suitable criteria involved at least secondary treatment and a short outfall for dispersion. The cost of wastewater conveyance to a plant site near the open part of the Harbor at the west end of the Mex-Dekheila area was found prohibitive. Land in the area is, or soon will be, high in value. The general land use plan of the Governorate shows that the entire area will be developed as part of the Western Harbor extension, a use of the land more valuable both to Alexandria and to Egypt than allocation of a significant portion of it for wastewater treatment. Further consideration of this approach as a viable alternative was ruled out.

Discharge to Abu Kir Bay. Similarly, the disposal of wastewater to Abu Kir Bay was given preliminary consideration. The bay is now grossly polluted by industrial discharges from the Abu Kir Drain through the Tabia Pump Station. Bay waters have poor circulation due to shallow depth and a submerged rocky ridge which crosses the open part of the bay. A high degree of treatment, secondary or even tertiary, would be needed and facilities for dispersion would be required for adequate disposal. Long conveyance facilities to the extreme end of the service area make system costs excessively high. Abu Kir Bay discharge was thus also ruled a non-viable approach.

Discharge to Lake Maryut. An initially attractive approach to the disposal of Alexandria wastewater is the discharge of treated effluent into Lake Maryut. The lake now affords a measure of effluent dilution and several days detention time for further polishing treatment prior to final discharge to the sea near the Western Harbor through the Mex Pump Station. A possible benefit, although subject to considerable question and argument, is the supply of nutrients in wastewater for support of the local Lake Maryut fresh water fishery.

The present fresh waters of Lake Maryut are only a portion of a shallow marine lagoon which extends laterally along the coast for a considerable distance behind the ridge upon which Alexandria has been established. Over the years major portions of this lagoon have been reclaimed for agricultural land and industrial use. The salty portion west of the Mersa Matruh Railroad causeway is now used as an evaporation pond for the production of salt for industrial uses. The lake remaining, shown on Figure 3-1, consists of a main lagoon of about 2000 ha, a cooling water lagoon for El Nasr Refinery, and a smaller fisheries lagoon of about 500 ha south of the Alexandria-

Cairo desert access road. The mean depth of the lake is about 0.8 m. The elevation of the water surface is maintained at about -2.5 m to -3 m (below sea level) by the Mex Pump Station.

The Noubaria Canal and Umoum Drain cross the westerly end of the main lagoon. General land use plans for Alexandria indicate that, at some unspecified future date, areas between the Umoum Drain and the Noubaria Canal, as well as areas along the eastern side of the Noubaria Canal in the main lagoon, will be reclaimed for industrial and commercial uses. Future land use plans also suggest significant reclamation projects for the northern and eastern shores of the present lake. Considerable encroachment has been observed in the short period of this study. The cooling water lagoon, a necessary facility for the refinery, and the small lagoon south of the highway are expected to be preserved for fish culture.

Flow through Lake Maryut is difficult to measure and is probably quite variable. The Kalaa Drain, entering the main lagoon through the smaller lagoon at the southwest corner, has a flow of about 600 000 m^3/day of which about 240 000 is raw and partially treated sewage, with some industrial wastes draining from the eastern areas of Alexandria. The entire Kalaa drainage area is about 15 000 ha. Umoum Drain, serving about 180 000 ha of agricultural land, carries about 5.8 million m^3/day of water, most of which passes directly to the Mex Pump Station for discharge to the sea. Small channels exist which allow interchange of flow between the drain and the lake. The interchange of flow is of a relatively low order, probably less than 5 percent. The influence of such flow on the lake is confined to a small zone along the drain. The Noubaria Canal discharges to the lake that water needed to operate the navigation locks at Ameria and at the Western Harbor. This inflow, dependent upon the amount of barge traffic in the canal, is estimated to be about 100 000 m^3/day at present. A small portion of the inflow is sea water from the Western Harbor. Untreated wastewater flow from the Inner Western Zone of Alexandria, containing a significant amount of industrial wastes, enters the main lagoon at three principal locations along the north side of the lake. These high strength wastewater inflows total about 100 000 m^3/day.

The inflow to Lake Maryut due to precipitation and runoff is of relatively little consequence. There are, on an average, six rainfalls annually which exceed 10 mm; two normally occur in both December and January, and one each in November and February. The entire watershed draining to the lake is roughly 200 000 ha in area. Assuming, conservatively, a runoff coefficient of 0.1, a 10 mm rainfall over the entire area would result in runoff of two million cubic metres. The extent of catchment area would spread the effects of such a rainfall over several days. Except for occasional nominal increases in flow through the lake, runoff has little real effect.

In summary, the main lagoon of Lake Maryut receives as inflow, not counting flow from Umoum Drain which has limited influence except near the drain, about 800 000 m^3/day, of which about 120 000 m^3/day are lost to evaporation. Inflow consists of about 100 000 m^3/day of untreated, strong industrial and domestic wastewater, 240 000 m^3/day of wastewater which has received limited treatment (mainly by natural self-purification in drains), and 360 000 m^3/day of relatively good quality agricultural return drainage and 100 000 m^3/day from the Noubaria Canal. Theoretically, the main lagoon affords a detention period on the order of 24 days. The actual flow-through time is probably in the range of 15 to 20 days; long enough for self-purification processes to produce a reasonably good quality discharge under present conditions, with the periodic exception of containing many algae. High algae counts have been confirmed by laboratory analysis of samples collected over the past several years.

Three factors combine to maintain the reasonably good quality water in the main lagoon of Lake Maryut. They are: shallow depth, wind-driven circulation with consequent mixing, and extensive algae growth. Shallow depths preclude stratification which would otherwise lead to objectionable anaerobic conditions at or near the bottom and to rapid degradation of water quality due to gas-lifted solids. Extensive areas of floating solids would in turn decrease the circulating effect of the winds and tend to decrease algal growth. Circulation due to wind maximizes uptake of oxygen from the air and, by convection, distributes oxygen in the water mass. Algae also provide additional oxygen during the day by photosynthesis. The beneficial effects of algae are only superficial, however, because algae are a means whereby nutrients are held in the lake. Algal growth converts soluble nutrients entering the lake into algal bodies which, upon death, settle to the bottom and accumulate. Nutrients not assimilated by plant and animal growth would otherwise tend to be flushed through the lake for discharge to the Western Harbor. In the long run, use of nutrients by algae and aquatic plants increases the store of nutrients in the lake in a manner approaching a geometric rate. The lake is already abundantly productive with a stored nutrient supply that will probably ensure its complete conversion to an organic land mass sooner or later, even if no further nutrient load is added.

The "aging" main lagoon of Lake Maryut will, at some point in time, cease to be a recognizable body of water. The natural processes of eutrophication provide the mechanism by which the present lake will ultimately become successively: a marsh, a swamp, and finally a land mass of wet, largely organic soils. How rapidly this will occur depends primarily on how the lake is managed during the next decade. Conditions which tend to hasten the eutrophication process are: continued and increasing growth of weeds and aquatic plants, discharge of toxic wastes and organic solids contained in wastewaters, and gradual decrease in surface area due to filling and other encroachments on the lake. Discharge of nutrients contained in agricultural return drainage also hasten the eutrophication process.

Weeds, marsh grass, and water hyacinths grow copiously in fresh water containing nutrients. The warm water, sunlight, and nutrient concentrations present in Lake Maryut are ideal for such growth. Once started, it is difficult to control the spread of such growths. While these plants assimilate nutrients during their growth, unless they are harvested and removed from the lake and watershed, the store of lake nutrients is not diminished. Soluble nutrients taken up by the plants are not flushed through the lake system. The plant growth also limits the effects of wind in maintaining mixing, reaeration, and transfer of oxygen. Anaerobic conditions usually result, particularly when the organic load is heavy, leading to less complete natural oxidation and an increasing rate of solids accumulation. Increased masses of hyacinths observed over the past year are also of concern because experience with these weed pests in Southeastern United States and elsewhere indicates that canals and lakes become quickly clogged by their rapid rate of growth.

Toxic wastes tend to slow natural purification rates and thereby increase the rate of solids accumulation. Organic material similarly increases the mass of solids to accumulate and taxes oxygen resources. The real danger, however, occurs when organic solids are not dispersed. Without dispersion, oxygen is readily depleted. Floating "sludge" masses, thick enough to support the weight of a person walking on them, now exist near the wastewater discharge points on the north side of the lake.

Encroachment, whether planned or uncontrolled, is also a problem. Filling-in along the lakeshore is taking place at several locations. Of particular concern is the matter of solid wastes disposal. A major disposal site for the last several years has been an area between the Industrial Highway and the railroad along the north side of the lake. Filling-in of this area is now nearly complete. It is of concern that Lake Maryut proper, along the Industrial Highway, may be the next area to be used for solid wastes disposal. Encroachment in this area will be relatively rapid unless dumping is rigidly controlled.

The Lake Maryut fishery must be considered because it contributes significantly to the food supply of Alexandria and is, therefore, of considerable economic importance. Local fishermen have expressed opinion that they welcome nutrients being discharged to the lake from domestic sewage, but they do not wish industrial discharges. On the other hand, technical opinion has been expressed[1] that there are sufficient nutrients in the lake, at present and for the future, from agricultural drainage alone, to support a major fishery for many years to come. Fish catches from the smaller lagoon south of the desert access road, which receives no direct wastewater discharge, are reported to be better than in the main lagoon. This fact tends to reinforce the technical opinion[2] that Lake Maryut's main lagoon is already much too highly loaded for optimum fish production, irrespective of the feelings of local fishermen.

Decision now about recommendations for Lake Maryut is difficult to make because of the many uncertainties regarding destiny of the lake. The continued discharge of untreated wastewaters, the prolific growth of weeds, and the encroachments are most likely to drastically shorten its useful life. It must be realized that it will be at least five years, but probably longer, before wastewaters can be discharged elsewhere. There have been expressed observations that the condition of the lake has stabilized

[1]Personal communication, Dr. Richard Neill, Fishery Expert, United States Agency for International Development, Cairo, on 28 November 1977.

[2]Personal communication, Dr. A.Ezzat, Fish Biology Expert, Alexandria University, 14 December 1977.

and that the water quality will not further degrade. Such opinions are not supported by data. On the other hand, there is strong evidence, but unsupported by long term, reliable data, that even though effective controls are instituted immediately, the lake will cease to exist as a usable body of water within a relatively short period of two to three decades. A prolific growth of hyacinths could reduce drastically the remaining time of existence.

The above information provides background for consideration of the propriety of discharge of Alexandria's wastewater into the Lake Maryut system and the appropriate level of treatment necessary prior to disposal. In order to predict the full effect of using Lake Maryut as a disposal medium for Alexandria's wastewater, the complete water system downstream from the point of wastewater discharge must be understood. The level of the lake is maintained below sea level to provide for drainage of agricultural return water. About 680 000 m^3/day must pass through the lake in order to maintain this level. This flow is added to the Umoum Drain flow at the Mex Pump Station intake and is lifted to the Mex Canal which discharges to a U-shaped indentation in the coast just west of the enclosed portion of Western Harbor, as shown in Figure 3-1. The canal, about 1200 m long with a high velocity of flow, discharges at the shoreline, where dispersion and mixing are of a relatively low order, as indicated by the band of lower-density water observed to hug the coast. The proposed expansion of the Port of Alexandria is likely to result in the construction of breakwaters to semi-enclose the entire U-shaped indention. This will effectively reduce the already limited dispersion and mixing and create an estuary-like body of water probably well stratified by the sea water occupying the lower levels and fresh water floating near the surface. The interchange of sea water is likely to be minimal, unless expensive flushing facilities are provided, and oxygen resources will be replenished only at a very slow rate. Organic pollutants derived from agricultural drainage and wastewater treatment plant effluent finding their way to this expanded harbor will tend to accumulate and cause an increasing water quality problem.

As Lake Maryut passes through the advanced stages of eutrophication, the lake detention time for incoming flow and the beneficial effects of self-purification will decrease. This will result in an increasing load in the Western Harbor "estuary" and hasten degradation there. The discharge of agricultural drainage only to the Western Harbor "estuary" will, in the distant future,

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also cause further degradation. However, the process will be hastened with discharge of municipal wastewaters having less than complete treatment. The problem of degradation of the "estuary" in the near future could be eliminated by the construction of an outfall structure to discharge 6 or 7 million m^3/day of wastewater and drainage outside the proposed new harbor. Such a project would entail considerable expense.

In the long run, therefore, it is of economic advantage to prolong further degradation of the Western Harbor "estuary" by either completely eliminating wastewater discharge into Lake Maryut or, if discharge is made to the lake, by providing the best level of treatment to the wastewater within economic reach.

If no other management of the lake were to be practiced, lake life could be maximized by providing nutrient removal from all wastewaters using tertiary treatment. Such a level of treatment is very complicated and costly. Its beneficial effect would be marginal in view of the significant nutrient load carried by agricultural drainage and the vast store of nutrients already present in the lake. Secondary treatment would remove the large majority of organic solids from wastewater which would tend, physically, to fill the lake. This level of treatment would also remove from the system nutrients bound up in those solids. Primary treatment could be expected to remove only 40 to 50 percent of the wastewater solids, thereby resulting in significantly greater solids and nutrient loadings than effluent with secondary treatment. It is calculated that by the year 2000, organic loading to the lake with only primary treatment would be in excess of present loadings. Therefore, within economic reach, the impact of wastewater on the lake can be minimized, if secondary treatment is employed.

Based on the above, it is appropriate to conclude that wastewater disposal to Lake Maryut with less than tertiary treatment is not equivalent in terms of benefit to other alternatives under consideration. Disposal to Lake Maryut must be classified as an interim solution, one which will postpone need for additional Western Harbor facilities for an unpredictable (with the information now at hand) period, depending upon how soon all secondary treatment systems can be in operation. Therefore, in evaluating alternatives, a Lake Maryut disposal alternative must be rated a far less effective long term solution to Alexandria's wastewater problems.

6.3 Wastewater Treatment

Preliminary Treatment

Preliminary treatment has been considered only for sea disposal with long submarine outfalls. Preliminary treatment, in the context of this study, means screening; the removal of grit, sand, and other inorganic solids (larger than 0.15 mm in diameter) which settle out at low flow velocities; and the removal of floating materials which, if discharged, would rise to the surface and thence float to the beaches. This level of treatment requires a less complex plant and relatively little land area. The plant, if located in developed areas, is normally enclosed for odor control. The materials removed are washed grit, which makes suitable fill material, screenings, and scum containing floatables such as plastic, paper, cloth, fruit skins, etc. Amounts are generally small and can be trucked away for disposal, or for grit, land-filled on site.

Primary Treatment

Primary treatment has been initially considered in formulating several alternatives. It would consist of preliminary treatment as described above, plus plain sedimentation and some form of sludge processing. Primary treatment will remove 50 to 60 percent of the suspended solid material in raw wastewater and 30 to 35 percent of the organic pollutional load. Sludge processing, considered for Alexandria for purposes of cost comparisons, involves centrifuge dewatering for disposal on land.

Secondary Treatment

Several methods of secondary treatment were selected for consideration: conventional activated sludge and modified activated sludge processes; trickling filters; oxidation ponds; and the somewhat similar anaerobic-aerobic lagoons. Although aerated lagoons were also considered, power costs for large installations were found to be prohibitive.

Trickling filters often present advantages in simplicity of equipment and resitance to process upset. However, very strong wastewaters in Alexandria require considerably more than normal filter area and volumes. The higher strength wastewater would make high rate filters necessary, with greater depth and high recirculation rates, which negate any real savings in power, the advantage trickling filters usually have over various activated sludge processes. Land areas required for trickling filters are somewhat larger than for activated sludge. Large quantities of filter rock, not locally available, would be needed also. Additional land for wider buffer areas would also be required as a result of greater likelihood of odors. A contemporary worldwide trend is away from construction of trickling filter plants for wastewaters such as found in Alexandria. Large plants (greater than 100 ML/day) of this type have not been built in the last several decades. For these reasons, the trickling filter process is not considered viable for Alexandria.

In recent years there has been a prevailing trend toward the use of activated sludge processes for large plants. Conventional activated sludge offers the least complication among the various modifications to the process and is normally selected for large plants, where operational difficulties may be expected. At this planning level of study, the conventional process has been chosen, as it offers more flexibility in operation than modified processes and an opportunity to vary quality of effluent to meet time-varying conditions with consequent savings in power costs. The activated sludge process offers an opportunity, with proper attention to operating conditions, to produce a consistently better quality effluent than other secondary treatment processes. On the other hand, a significantly greater degree of skill and operator know-how is needed to maintain proper operation, in order to realize the benefits of this process. Proper training of operators would be necessary, and an implementation program and funding would have to be established to provide the necessary trained manpower. For large plants under consideration in this study, conventional activated sludge methods are judged superior to other secondary systems. Sludge processing, for purposes of cost comparisons, was gravity thickening and centrifuge dewatering for disposal on land.

Early consideration was given to use of waste stabilization/oxidation ponds for secondary level treatment of major portions of Alexandria's wastewaters. Computation of land areas required, even allowing for high design loading rates which can be used in the warm, sun lit climate of Egypt, results in rapid elimination of such ponds as a viable treatment alternative. To handle the expected wastewater flow for the Alexandria area in the year 2000 in stabilization ponds would require an area on the order of three times the size of the present extent of the main lagoon of Lake Maryut. Land areas of this magnitude are not available within economically feasible reach of

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Alexandria.

For smaller installations, and for interim or temporary treatment facilities where development is only beginning, a waste stabilization pond concept has considerable merit. A principal disadvantage is the relatively large amount of land area required. However, staged enlargements for optimum use of construction funds are readily attainable and construction costs require less foreign currency, greater use of local technology, and basic construction materials. An initial consideration is planning for the amount of land required for the largest pond installation to be used before a pond system is converted to a conventional plant or other disposal method (as is possible for the outlying areas of Alexandria after the year 2000). The operation of ponds is relatively simple and inexpensive. Land committed to oxidation ponds can usually be converted to other uses; for example, agricultural, industrial, and/or residential when the ponds are no longer needed, without loss of land value. An inherent disadvantage of the ponds is the periodic discharge of suspended solids, largely algae, to the receiving medium. Evaporation in the ponds tends also to increase concentration of TDS in the effluent, a factor which would discourage plans to reuse the effluent for agricultural irrigation on salt sensitive crops.

A modification of the waste stabilization/oxidation pond concept, which has advantage and merit where wasteloads are strong, is the anaerobic-aerobic lagoon. The anaerobic-aerobic lagoon system differs nominally from the oxidation pond in that it consists of a smaller, deeper lagoon or pond into which incoming wastewaters are directed. Here the major portion of the solids settle out and are decomposed anaerobically. The liquid portion which passes to the shallower aerobic lagoons contains less organic load and, therefore, requires less land area. The overall benefit of this modification is a 15 to 25 percent savings in land area required, with no sacrifice in effluent quality. The disadvantage is the possible odor nuisance from the anaerobic pond, although layout can be planned to minimize such nuisance. Alternative plans employing the waste stabilization pond concept were based on the anaerobic-aerobic lagoon modification. These are principally associated with the relatively isolated and developing areas outside the major urban zone of Alexandria.

6.4 Industrial Waste Control

Introduction

The collection and treatment of industrial flow in Alexandria's wastewaters present problems. Although most wastewater of industrial origin can be handled by the municipal system without damage to sewers, treatment facilities, or receiving water environment, certain industries use toxic materials, such as oils, heavy metals, and acids which when discharged to the system, even in very diluted condition, cause physical damage to facilities, upset treatment processes, and create widespread adverse environmental impact. Generally, these detrimental substances can be traced back through the system to an industrial plant with relatively small flows. If kept separated, they can often be given economical in-plant treatment for removal or neutralization in plant. The balance of industrial wastewaters, if carefully separated, together with those properly treated or neutralized, can be discharged safely to the sewerage system.

Alternatives

In this study, three approaches to basic industrial waste control were considered. These were: (1) accept all flows in the sewer system without pretreatment; (2) collect toxic industrial wastes in a separate collection system for conveyance to a remote site and disposal in an evaporation pond; and (3) handle each toxic industrial waste problem individually, with in-plant treatment at the source, and accept the non-toxic and adequately treated industrial wastewaters in the municipal system. The alternative of a physical-chemical treatment plant for all industrial wastewaters was eliminated early in the consideration because of prohibitive costs, complexity, and requirements for highly trained operators. The first "no action" approach was rejected as unacceptable. Continual and increasing damage to collection and treatment facilities would require expensive maintenance, and damage to the receiving environment would be irreparable.

An outline design was prepared for a separate industrial wastes collection system and a preliminary estimate of cost made. Although estimated costs for a separate system were found to be quite high, the approach was retained as a viable alternative plan until thorough evaluation was made.

Costs of in-plant separation and treatment of industrial wastes cannot, with the data and information at hand, be accurately estimated. Although an industrial waste survey was made as a part of this study, the objective was only to identify and quantify the industrial wastes problem. Details needed for outline designs of separation and treatment systems at each plant for estimating costs were not obtained, nor did the scope of work intend that level of effort.

Recommendation

In-plant separation and treatment to meet individually established effluent standards is the method used in many industrial cities of the more developed countries. The practice is widespread in the United States, West Germany, England, Canada, and Australia. It is appropriate to recommend, on the basis of experience, in-plant separation and treatment,and acceptance in the municipal sewers of those industrial wastes which can be handled safely. This disposal of industrial wastewaters after pretreatment into Alexandria's sewerage system will require an active monitoring program and enforcement of sewer use laws to minimize any adverse effect this method might have on the proposed system.

During study of the industrial waste problem in Alexandria, it was observed that many industries use excessive amounts of water both in their process streams and for single-pass cooling. A significant reduction in the volume of industrial wastewater could result from in-plant conservation efforts with possible cascading reuses and reconstruction to improve plant water systems. Such activity would not only conserve water for other uses and reduce water supply costs, but also would decrease wastewater volumes which require conveyance, treatment, and disposal.

Additional investigation of the suitability of a separate collection and evaporation pond disposal concept for certain industrial areas was made, particularly those at the extreme ends of the study area where conveyance costs to a central system would be expensive,and where land area for evaporation ponds is nearby. Wastes from the industries in the eastern Abu Kir Bay area fit these conditions. Wastewaters from paper mills and other industries in the area would be collected and conveyed to land, now inundated, in the western portion of Lake Idku. A pond would be dyked off and completely separated from Lake Idku. Operation would be such that the water level in the pond would be lower than the lake to prevent seepage into the lake. Adequate and suitable space would remain in the lake for continued fishery activity.

CHAPTER 7

EVALUATION OF ALTERNATIVES

7.1 Plan Formulation

Alternative wastewater management plans selected for detailed analysis and comparison each need to satisfy a set of fundamental conditions. These include projected waste flows and loads, constraints from existing and ongoing wastewater programs, present water quality conditions, and water quality criteria for the anticipated future situations. These conditions have been established and discussed in Chapters 3 through 6 of this volume.

General concepts discussed in the previous chapter lead to a significant number of alternative plans which must be evaluated for the Alexandria area. These can best be categorized in terms of consolidation of sewer service zones, means for collection of wastewater, and mode of disposal. Categories are:

Consolidation:
- Separate - all zones remain separate (i.e., individual local systems and facilities).
- Partial - Eastern zones combined, as well as the West and Central zones, while Abu Kir, Nouzha, Mex-Dekheila, and Ameria zones remain separate.
- Full Consolidation - complete regional wastewater collection and treatment system to serve all sewer service zones in Alexandria (i.e., a single, centralized system).

Collection:
- Integrated collection of all area wastewaters (i.e., both domestic and industrial).
- Separate collection of toxic industrial wastewaters for independent conveyance and disposal.

Disposal:
- Sea - submarine discharge following preliminary treatment.
- Reuse - discharge to irrigation canals for agricultural crop use after secondary treatment.
- Evaporation - discharge to open desert lands for evaporation, without treatment.

As each means of collection can be combined with an independent mode of disposal and with an alternate level of consolidation to represent an overall wastewater management plan for the entire area, the number of alternatives is, hypothetically, quite large. A process of elimination on a regional or "global" level was used, therefore, to reduce the number of possible alternatives to a reasonable number of viable "hardware" plans. The process entailed determination of overall costs and benefits associated with broad, regional wastewater management plans for the entire Alexandria area.

From the analysis, specific viable alternatives were developed for each sewer zone of the region in order to determine the most feasible plan from both an economic and functional standpoint. Initial analysis of various regional approaches to wastewater management did not result in exclusion of options within specific sewer zones of the city which might involve a mode of disposal or collection which was found to represent high costs on an area-wide basis. Evaluation on the regional level was used to indicate general approach and to establish a set of more detailed, feasible alternatives for various portions of Alexandria.

7.2 Evaluation Methodology

Introduction

It is important that decisions about the Alexandria wastewater system incorporate all relevant functional and economic factors. Alternative regional schemes and zone plans have been developed to a degree sufficient for comparison of planning level cost estimates and evaluation of relevant functional factors. The alternatives considered have been based on concepts developed in Chapter 6. The economic and functional criteria applied are as follows:

Economic	Functional
Capital cost	Effectiveness and environmental impact
Operational cost	Reliability
Present worth with differential benefits	Flexibility
	Ease of implementation

Economic Evaluation

Cost comparisons between alternatives have been made using discount techniques. This takes into account both capital and operating costs with time and provides a means to appropriately evaluate the difficulty of staging major elements of certain plans which are not easily divisible into smaller components. Capital elements common to all alternatives being compared (such as lateral sewer systems and property connections) have been omitted from the evaluation.

Costs were estimated using the curves on Figures 5-1 through 5-7, with a 30 percent allowance for engineering and contingencies. Cost of land acquisition was also included. Taxes, duties, and estimated financing costs were excluded from analysis. Costs apply to mid-1977 and are not escalated since the evaluation entails comparison of true economic costs for which changes in the value of money are irrelevent.

Shadow prices were used in the economic evaluation. For conversion of foreign current costs the "parallel" rate (currently LE 0.70 = US $1.00) was used. A shortage of skilled and semi-skilled labor does exist in the county, while there is unemployment in Alexandria and Egypt as a whole. The take-home pay of construction labor in Alexandria (about pt 80 out of a gross cost of LE 1.25 per day) is approximately equal to take-home pay of farm labor in areas surrounding Alexandria. This suggests that unskilled labor rates are fairly reflective of a competitive nondistorted labor market and therefore no shadow price was applied to labor costs. The controlled price of electricity does not reflect true production cost which is estimated to be LE 0.025/kWh. This value has been used in making economic comparisons.

Annual operational costs have been estimated for projected 1990 flow conditions (at mid-1977 prices) and considered representative of the entire planning period from the time that proposed new facilities come on-line.

In order to give weight to many elements which can be staged for various alternatives, while at the same time making comparisons on an equal basis in relation to the timing of benefits, it has been assumed that all new facilities would be completed in 1983. This is done purely for economic comparison on an equivalent basis. It refers to amenability of staging and not to the actual recommended staging, which will require adjustments of both costs and benefits for whichever alternative is selected. Relative capital cost "lumpiness" has been expressed in terms of time required for construction of major elements such as treatment plants or outfalls. A major regional treatment plant, for example, would require construction to begin in 1979 to be on-line in 1983, while construction of an equivalent group of smaller local plants would begin a year or two later, thus gaining the economic benefit (on a present worth basis) of some deferral in expenditure.

The economic lives of facilities have been assumed as follows:

- Land: infinite.
- Pipelines, lagoons, ponds: 60 years.
- Treatment plants, pump stations: 30 years.

Operational cost has been assumed to continue at today's level through the construction period and to increase to the projected 1990 level in 1984. The economic horizon was taken to be the year 2015. A discounting rate of 10 percent has been used together with sensitivity checks at rates of 8 and 12 percent.

A comprehensive cost-benefit analysis is difficult where many benefits associated with proposed projects and alternative plans are of non-quantifiable nature. In comparing alternatives all of the various plans had equivalent sewerage benefits. Cost and benefits were compared in terms of present worth costs. In the case of the reuse alternative the economic benefit from agricultural reuse of wastewater was considered.

Functional Evaluation

Alternatives were also considered on a non-economic basis by reviewing and assessing issues related to a number of principal functional factors as listed below:

Effectiveness and Environmental Impact

- Protection of surface waters such as Lake Maryut, Lake Idku and the near-shore waters of the Mediterranean Sea for such beneficial uses as bathing, boating, fishing or industrial needs.

- Non-impairment of surface waters, local ground waters and land areas; also consideration of aesthetic improvements.
- Relationship between expected performance and total investment.
- Potential impact on the Mediterranean Sea and croplands due to discharge of toxic substances and other potentially harmful materials.

Reliability

- Likelihood that performance will be equal to expectations.
- Possible system failures due to natural disasters or catastrophies and the consequences of any such failure.
- Possible frequence and consequences of mechanical breakdown and process upsets due to power failures or inadequate operations.

Flexibility

- Sensitivity of system performance to changing patterns of urban development in Alexandria.
- Adaptability to future technological advances and new developments in the wastewater field.
- Ability to meet possible changes in future water quality requirements.
- Ability to satisfy any potential reclaimed water use markets.

Implementation

- Presence or absence of factors which would hinder public and government support.
- Feasibility from institutional and construction standpoints.
- Expectation of legal, financial or logistical obstacles.
- Compatibility with other ongoing programs and with current regional planning projects.

7.3 Regional Assessment

Alternative Levels of Consolidation

Three levels of consolidation for the future wastewater system in Alexandria were considered on a regional basis. These included:

Level 1 - Separate - all sewerage zones remain separate and independent with no regional treatment or disposal facilities involved.

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Level 2 - Partial consolidation whereby the Eastern zones combine as would the Western/Central zones, while the peripheral zones of Abu Kir, Mex-Dekheila, Nouzha and Ameria would each remain independent and separate.

Level 3 - Full consolidation whereby all zones would be interconnected by a regional conveyance system for central treatment and disposal.

Each level of consolidation as shown on Figure 7-1, was considered using two disposal schemes: (A) sea disposal or (B) agricultural reuse by crop irrigation. An integrated mode of collection (all domestic and industrial flows) was considered for each level of consolidation. The evaporation disposal alternative (C) can only be considered with full consolidation.

Economic comparison of the three consolidation levels is presented in Table 7-1. The economy of scale associated with large regional plants is evident in comparing both capital and operational costs between an entirely separate system and full consolidation. Partial consolidation due to less capital associated with conveyance and disposal under partial consolidation. It will cost more to convey wastewaters from outer areas to a central regional facility for treatment. In comparing Schemes A and B (sea disposal and agricultural reuse, respectively) it can be seen that at all three levels of consolidation considered, Scheme A is economically more attractive than secondary treatment for agricultural reuse. The present worth values expressed in Table 7-1 include, for Scheme B, consideration of the benefit of wastewaters to croplands by including the estimated economic value of increased crops through reuse.

From a functional standpoint, both the location of potential agricultural reuse areas at the extremes of the study area and the developing nature of much of the peripheral region reinforce a partial consolidation approach. The staging of proposed wastewater facilities in the outer zones must be flexible in order to adapt to changing rates of development in these areas. Wastewaters being predominantly of an industrial origin in the Abu Kir Bay and Mex-Dekheila areas supports the concept of separate and independent systems for outer zones of Alexandria.

TABLE 7-1

LEVEL OF CONSOLIDATION - REGIONAL COST COMPARISON

	Cost, LE million					
	No Consolidation		Partial Consolidation		Full Consolidation	
	A (Sea)	B (Reuse)	A (Sea)	B (Reuse)	A (Sea)	B (Reuse)
Conveyance[a]	100	120	105	125	165	175
Treatment[b]	100	210	80	190	75	185
Disposal[c]	150	75	125	65	135	70
Capital TOTAL	350	405	310	380	375	430
Annual O & M[d]	5	10	4	7	4	7
Relative Present Worth Cost[e]	1.13	1.42	1.00	1.24	1.13	1.33

(a) Interceptor sewers/force mains/pump stations.

(b) Treatment facilities/land acquisition.

(c) Effluent pump stations/force mains/submarine outfalls.

(d) Operation and maintenance costs based on 1990 flows.

(e) Present worth values based on 10 percent interest rate. For Scheme B involving reuse, the economic benefit to agricultural crop production is included.

Alternative Mode of Collection

Two regional approaches to the collection of area wastewaters have been considered, one involving integrated collection of all wastewater flows and the other involving separate collection of toxic industrial wastes which might (irrespective of treatment levels considered) have long-term deleterious effect on local water bodies and nearby environs.

As a basis for economic assessment, the two disposal schemes involving (A) sea discharge and (B) reuse by irrigation, were used as is shown on Figure 7-2. The costs for an alternative collection mode involving separate conveyance of toxic industrial wastes to a disposal site in the Western Desert are compared to those for an integrated system in Table 7-2. Capital costs for a plan involving a separate industrial pipeline/pump station conveyance system are found to be in the range of LE 40-60 million greater than for an integrated system under either disposal Scheme A or B. Operational costs would entail about LE 1.0 million per annum more than O & M costs associated with an integrated collection system. On a present worth basis these costs 16 to 22 percent greater than either integrated collection dispodal scheme.

The effectiveness of combined collection of sanitary sewage and industrial wastes depends on prevention of discharge of toxic and other unacceptable substances by industry. With a separate industrial collection system at least part of the toxic substances (certain metals, for example) could be accepted. Many industrial processes and strong waste discharges are intermittent. There would therefore be great difficulty in designing and effectively operating a waste treatment facility for these industrial wastes. Economic benefit would depend on the cost savings to industry compared with full plan costs, and on any improved reliability. Since any such system could not be designed to deal with all possible deleterious industrial materials discharged in wastewater, it also would be dependent on in-factory controls and pre-treatment.

A separate industrial waste collection system is not practically or economically viable if it must include a physical-chemical or physical-chemical-biological treatment facility. If such a facility is not included,

TABLE 7-2

MODE OF COLLECTION - REGIONAL COST COMPARISON

Cost, LE million

	Integrated[f] A (Sea) T	Integrated[f] B (Reuse) T	Toxic Industries Separate[g] Scheme A (Sea) R	+ TI	= T	Scheme B (Reuse) R	+ TI	= T
Conveyance[a]	105	125	90	70	160	105	65	170
Treatment[b]	80	190	70	-[h]	70	160	-[h]	160
Disposal[c]	125	65	110	30	140	60	30	90
Capital TOTAL	310	380	270	100	370	325	35	420
Annual O & M[d]	4	7	-	-	5	-	-	8
Relative Present Worth Cost[e]	1.00	1.24			1.22			1.40

(a) Interceptor sewers/force mains/pump stations.

(b) Treatment facilities/land acquisition.

(c) Effluent pump stations/effluent force mains/submarine outfalls.

(d) Operation and maintenance costs based on projected 1990 flows.

(e) Present worth values based on 10 percent interest rate. For Scheme B involving reuse, benefit to agricultural crop production is included as a negative cost.

(f) Refer to Table 7-1, under Partial Consolidation (Level 2).

(g) R - regular wastewater system (domestic and non-toxic industrial flows).
TI - separate system for toxic industrial flows including treatment.
T - total costs of both R and TI

(h) Physical-chemical treatment assumed unnecessary for initial assessments, if required would increase costs considerably.

the viability of separate collection depends on the environmental acceptability of evaporation disposal, without treatment, in a remote location in the Western Desert and on the possible benefit to industry in avoidance of pre-treatment to remove toxic materials. Pre-treatment necessary to protect sewer pipelines and pump stations would still be required.

In view of the high construction and operating cost, the probable controversy involved in implementing a separate collection system for toxic industrial wastes, and the doubtful overall economic benefits, it is recommended that an integrated sanitary and industrial system be constructed, and that industries be required to control and, where found necessary, pre-treat wastes.

Alternative Disposal Schemes

Three regional schemes, as shown on Figure 7-3, for disposal of Alexandria's wastewater flow, have been considered and evaluated. These comprised the following:

- Scheme A - discharge to the sea via deep submarine outfalls, following preliminary treatment.
- Scheme B - discharge to agricultural lands (both in the Abu Kir and Ameria areas) that require water for irrigation of crops, following secondary treatment.
- Scheme C - discharge in the Western Desert (beyond the El Nasr Canal) for disposal by evaporation.

The estimated capital, operating, and discounted costs of the above regional schemes are presented in Table 7-3. Scheme C involves considerable capital cost to convey all area wastewaters to an outlying area for evaporation. Sea disposal represents lowest capital and operating cost of any alternative scheme. On a present worth basis, Scheme A is 26 percent less than Scheme B and 36 percent less than Scheme C.

On the basis of effectiveness and environmental impact, Schemes A and B are also considered superior to desert evaporation, although superiority

TABLE 7-3

DISPOSAL SCHEMES - REGIONAL COST COMPARISON

	Cost, LE million		
	Scheme A Sea Disposal	Scheme B Reuse Irrigation	Scheme C Desert Evaporation
Conveyance[a]	105	125	360[f]
Treatment[b]	80	190	-
Disposal[c]	125	65	50[g]
Capital TOTAL	310	380	410
Annual O & M[d]	4	7	6
Relative Present Worth Cost[e]	1.00	1.24	1.36

[a] Interceptor sewers/force mains/pump stations.

[b] Treatment facilities/land acquisition.

[c] Effluent pump stations/effluent force mains/submarine outfalls.

[d] Operation and maintenance costs based on projected 1990 flows.

[e] Present worth values based on single payment of capital in year 1982 plus uniform series of O & M over 23-year period of 10 percent interest rate.

[f] Involves conveyance of area wastewaters through dual (staged) force mains nearly 100 km to the Western Desert.

[g] Evaporation pond requiring 175 km^2.

of these two alternatives depends on adequate control of the toxic constituents in industrial wastes.

In spite of its higher cost, Scheme B has an apparent advantage of providing for reuse of a presumed scarce resource, water. However, as is discussed in Appendix E, it has been determined that agricultural practices currently followed are so wasteful of water that conservation can make additional water available at far less cost than treatment and conveyance of wastewaters to irrigable areas. The cost of a reuse scheme, including consideration of potential benefit is approximately 25 percent greater than the alternative least cost sea disposal scheme. Reuse may be economically justifiable in the future, but is most likely to be justified for only a portion of total flow for part of the year. An inexpensive means of suitable disposal will still be needed, even if at some time beyond the planning horizon, additional wastewater is required for irrigation. Marine disposal now does not necessarily conflict with future agricultural reuse potential.

7.4 Development of Zone Plans

Eastern Alternatives

Two alternative "hardware" plans, as depicted on Figure 7-4, were developed for the existing Inner East Zone and the future Outer East Zone, the latter being composed of Ras el Soda, Siouf Keblia, and the Sadat City site areas. These plans are:

- Plan 1. All wastewaters conveyed to a regional preliminary treatment facility which would discharge through a deep submarine outfall to the Mediterranean Sea.
- Plan 2. All wastewaters conveyed to a regional secondary treatment facility, the effluent to be reused for crop irrigation (interim discharge to Lake Maryut also evaluated).

General plans, layouts, and element costs of both alternatives are presented in Appendix J.

Alternative Plan 1 was formulated to convey eastern area wastewaters to a major preliminary treatment facility located south of Sidi Bishr in

Ras el Soda (between the railway and Montazah Canal). Individual force mains serving Smouha, Siouf Keblia, Ramleh, Montazah, Maamoura, and Sadat City areas were sized as listed in Appendix J. New pump stations would be required at a number of sites, although many existing pump stations in the Inner East Zone would be maintained. Treated effluent would be pumped through a submarine outfall (2200 mm diameter) to a depth of 50 to 55 m in the Mediterranean Sea approximately 10 km distance off the coast at Sidi Bishr.

The second alternative plan was developed by laying out and sizing necessary gravity sewers, pump stations, and force mains to collect and convey eastern area (Inner and Outer East Zone) wastewaters to a treatment plant site located south of the Alexandria Hydrodrome and adjacent to the Kalaa Drain. Details of pipe sizes and lengths, pump and treatment plant capacities, and general alignments are also contained in Appendix J of Volume III.

Secondary level treated effluent would be transported to principal irrigation canals of the Abu Kir Drain and Abbis areas in the southwestern Nile Delta. Interim discharge of surplus flows would be to the Kalaa Drain which conveys flow to Lake Maryut near the northeastern end of the main lagoon.

Total capital and average operating costs associated with the two alternatives for the eastern areas are expressed in Table 7-4. Also listed are discounted costs in terms of annual value and present worth. Sensitivity of present worth to changes in discounting rate are shown as well. The present worth value for Plan 2 reflects the beneficial value to crop production for reuse of treated wastewaters. The value of reuse, as found in Appendix E, is estimated between LE 58 and LE 67 per feddan which results in a present worth value of approximately LE 10 million if systems are on line by the mid-1980's. This value is treated as a negative cost in comparing the net present worth of Plan 2 to that of Plan 1 which carries no such benefit.

Comparison shows that Plan 1 (sea disposal) would have a present worth cost of LE 23 - 28 million less than Plan 2 involving a regional secondary treatment plant system inclusive of reuse benefits. Plan 1 capital costs

TABLE 7-4

ECONOMIC COMPARISON OF VIABLE ALTERNATIVES FOR EASTERN ZONES

	Cost, LE thousand Plan 1 (Sea)	Cost, LE thousand Plan 2 (Reuse)
Sewers & Force Mains	38 500	51 730
Pumping Stations	11 450	10 560
Treatment Facilities	23 000[a]	94 120[b]
Disposal Facilities	55 600[c]	22 620[d]
Land Acquisition	3 840	540
Capital TOTAL	132 390	179 570
Average O & M	1 520	3 150
Relative Present Worth Cost[e] (at 10 percent discount rate)	1.00	1.09[f]

(a) Preliminary treatment plant in Ras el Soda.

(b) Secondary treatment plant near Hydrodrome.

(c) Submarine outfall (10 km - 2100 mm Ø).

(d) Effluent conveyance and distribution to irrigation canals.

(e) At 8 percent Plan 2 is 25 percent greater than Plan 1, and at 12 percent Plan 2 is 37 percent greater than Plan 1.

(f) Includes discount for benefit derived from reused wastewater on croplands.

are estimated to be 73 percent of Plan 2 capital costs. Average annual operating expenses associated with Plan 1 are 48 percent of Plan 2 annual operation and maintenance costs.

If reuse is not considered (i.e., cost of conveyance facilities and the benefit derived from wastewater application is excluded from economic comparison) so that Plan 2 involves the discharge of secondary treatment plant effluent into Lake Maryut (considered as an interim solution only, as discussed in Chapter 6), then Plan 1 capital costs are estimated to be 83 percent of Plan 2 capital costs, and operation and maintenance costs are estimated to be 53 percent of Plan 2.

From a functional standpoint, effluent reuse may have some long-term non-quantifiable benefits over wastewater discharge to the sea, but for the present and near future it has much lower practical and financial feasibility. Both modes of disposal are considered environmentally satisfactory. Operational reliability of a preliminary treatment plant, removing only grit and floatables, is much greater than that of a secondary plant, involving more complicated and sensitive biological processes and chemical controls. A preliminary plant can also be bypassed for short periods of time without significant impact on the receiving environment and take up less space than a secondary treatment facility. Shutdown of a secondary plant would create much greater adverse environmental impact.

It is concluded that, considering both economic and functional factors, sea disposal, following preliminary treatment, is the most cost-effective, predictable and reliable of the available environmentally acceptable methods of managing wastewaters in the eastern zones of Alexandria.

Abu Kir Alternatives

Three alternative "hardware" plans, as shown on Figure 7-4 have been developed for the Abu Kir Zone. These include:

Plan 1. All wastewaters conveyed to the eastern area preliminary treatment facility at Ras el Soda for sea discharge.

Plan 2. All wastewaters conveyed to an evaporation pond at Lake Idku.

Plan 3. Separation of Abu Kir Peninsula (primarily domestic) and Abu Kir Bay (predominantly industrial) wastewater; domestic flows conveyed to the Ras el Soda facility for sea discharge, with industrial flows conveyed east to an evaporation pond at Lake Idku.

Alternative Plan I was sized for an area ADWF of 173 ML/day to be conveyed some 5500 m southwest via a 1400 mm force main to the intake of the East Zone (Ras el Soda) preliminary treatment facility. Hydraulic capacity of the plant and outfall would be increased to accommodate the additional flow. The preliminary plant would have a capacity of 710 (173 + 537) ML/day and the outfall would be increased to 2500 mm diameter. Abu Kir's share of treatment and discharge costs (based on year 2000 ADWF) would be 24 percent (173/710).

The second alternative was formulated in terms of sewer sizes, lengths, pump station capacities, and force mains necessary to collect and convey eastward all of Abu Kir's projected sewage flows (ADWF of 173 ML/day by year 2000) to a 4500 ha evaporation pond at the western end of Lake Idku. A main pump station, with a peak flow capacity of 270 ML/day, would be necessary at Tabia together with 8000 m of 1400 mm diameter force main.

The third alternative would comprise two separate conveyance systems, one to transport primarily domestic wastewaters (ADWF 23 ML/day) along Abu Kir Peninsula to the Ras el Soda preliminary treatment plant intake, and the other to convey predominantly industrial flows (ADWF 150 ML/day) to an evaporation pond located at Lake Idku. A main pump station for peninsula flows would have a peak capacity of 52 ML/day and a 650 mm diameter force main would extend 5500 m to the Ras el Soda plant intake. The plant would be increased in capacity to 560 (23 + 537) ML/day of which Abu Kir's share would be 4 percent (23/560). The Sidi Bishr submarine outfall would not require re-sizing for this small additional flow. An industrial pump station at Tabia (peak capacity of 225 ML/day) would convey Abu Kir Bay flows 8000 m to Lake Idku through a 1300 mm diameter force main. The evaporation pond, sized for a year 2000 ADWF of 150 ML/day, would encompass 4000 ha.

Capital, average operating and discounted annual costs associated with the three Abu Kir Zone alternative plans are presented in Table 7-5, as are present worth costs at various discount rates. Comparison shows little difference in cost between the second and third alternatives; Plan 1 has higher costs for both capital and operations. It appears to be slightly more costly to convey all Abu Kir wastewaters to an evaporation pond than to separately collect domestic (peninsula) flow for conveyance to the East Zone system, but the difference is minor.

From a functional standpoint there are several significant differences between Plans 2 and 3. A separate collection system would be more flexible in terms of possible changes in land use and industrial development than a single conveyance system and could be more easily implemented. It would also reduce, to some extent, the amount of wastewater requiring evaporation and thereby decrease land requirements.

It has been concluded that, as costs are approximately equivalent and functional assessment favors Plan 3, the Abu Kir collection system be constructed as two independent systems--one serving the peninsula and another the industrial area along the bay, with the option, if found more expedient of conveying domestic wastes westward to the Tabia pump station, in lieu of construction of an Abu Kir East Zone force main. A final decision can be made at time of design for this portion of the system as the two plans are nearly comparable in present worth cost. None of the Abu Kir alternatives will affect the situation significantly in the Outer East Zone as independent and separate conveyance facilities are involved. Initial preliminary plant capacity and outfall size would be adequate to provide for the relatively small Abu Kir domestic flows if Plan 3 is implemented.

<u>Inner West and Central Alternatives</u>

Three hardware alternatives have been developed for the Inner West and Central Zones as shown on Figure 7-4. They include:

Plan 1. Conveyance of all wastewater flows to a central preliminary treatment plant (serving both zones) for subsequent disposal to the sea through a submarine outfall.

TABLE 7-5

ECONOMIC COMPARISON OF VIABLE ALTERNATIVES FOR ABU KIR ZONE

	Cost, LE thousand		
	Plan 1 (Sea)	Plan 2 (Evap)	Plan 3[a] (Sea/Evap)
Sewers & Force Mains	8 250	7 370	7 880
Pumping Stations	5 540	4 090	3 860
Treatment Facilities	6 500	18 900	16 320
Disposal Facilities	26 880	100	2 200
Land Acquisition	980	3 510	3 120
Capital TOTAL	48 150	33 970	33 380
Average O & M	640	240	210
Relative Present Worth Cost[b] (at 10 percent)	1.82	1.05	1.00

[a] Peninsula (domestic) flows conveyed to East Zone preliminary treatment facility; industrial flows conveyed to Lake Idku evaporation pond.

[b] At 8 percent discount rate Plan 1 is 82 percent greater than Plan 3 and Plan 2 is 5 percent greater than Plan 3.
At 12 percent Plan 1 is 70 percent greater than Plan 3 and Plan 2 is 5 percent greater than Plan 3.

Plan 2. Conveyance of all wastewater flows to a regional secondary treatment facility for agricultural reuse.

Plan 3. Coneyance of wastewaters to two preliminary treatment facilities (one serving the Central Zone and one the Inner West) for subsequent disposal to the sea through a single submarine outfall at Kait Bey.

Alternative Plan 1 involves conveyance, by a 1500 mm diameter force main, of wastewater from the Inner West Zone (ADWF 220 ML/day) to Kait Bey for preliminary treatment along with Central Zone flows (total ADWF 392 ML/day) and subsequent discharge through 2100 mm submarine outfall extending 10 km offshore. An effluent pump station designed for peak flows of 575 ML/day would be necessary in order to discharge the total combined flow from both zones.

The second alternative was laid out to collect year 2000 flows from the Central Zone (ADWF 173 ML/day) via a 253 ML/day peak capacity pump station at Kait Bey through 6600 m of 1400 mm diameter force main to a regional West Treatment Plant intake. A West Zone ADWF of 219 ML/day would also be conveyed by a major 2300 mm diameter gravity interceptor sewer westward along the Alex-Cairo railway to a 324 ML/day peak capacity influent pump station at the West Plant site. The regional secondary treatment facility would have an ADWF capacity of 392 ML/day and would be located at the site of the present West Sewage Treatment Plant being constructed near the Noubaria Canal on the north shore of Lake Maryut. Plant effluent would be pumped to the Maryut and Ameria Northwest agricultural sectors for reuse through crop irrigation. Interim discharge of excess flows would be to Lake Maryut.

Alternative Plan 3 involves construction of two preliminary treatment facilities; one at Kait Bey for Central Zone flows (ADWF 173 ML/day), and the other at the present West Treatment plant site for all Inner West Zone flows (219 ML/day). West Plant effluent would be pumped 6600 m to Kait Bey through a 1300 mm diameter force main for joint discharge with Central Zone effluent through a 1900 mm diameter submarine outfall extending 10 km offshore. An effluent pump station designed for peak flows of 495 ML/day would be necessary at Kait Bey in order to discharge flows from both the Central and Inner West Zones.

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Costs associated with the three alternatives are presented in Table 7-6 and include present worth sensitivity checks for variations in discounting rate. As in the costs for the eastern area, both total capital cost and annual costs for sea disposal are less than the costs for regional secondary treatment and discharge to irrigation canals for agricultural reuse, inclusive of the benefit for crop production. The present worth cost of Plan 3 is 36 percent less than that associated with Plan 2, and 9 percent less than Plan 1. Operational costs for sea disposal from two preliminary plants represent LE 1.27 million per year less than annual O & M costs for secondary treatment and reuse. The costs associated with constructing a single preliminary treatment plant system at Kait Bey (Plan 1) are higher than an alternative involving two plants; one an expansion of the West Treatment Plant, the other to be built at Kait Bey for Central Zone flows only.

If reuse is not considered (i.e., the cost of conveyance facilities and the benefit derived from wastewater application is excluded from economic comparison) in order that Plan 2 represents discharge of effluent from a secondary plant to Lake Maryut (an interim solution only, as established in Chapter 6), then Plan 2 is still found to involve 20 percent more capital cost and 40 percent greater annual operation and maintenance costs than Plan 3.

Although effluent reuse may have some long term advantages, it has, as found for the eastern area, lower practical and financial feasibility than sea disposal. Both of these modes of disposal are environmentally satisfactory (if industrial waste controls and pre-treatment are enforced). Sea disposal after preliminary treatment has the greater operational reliability and will create the least adverse consequences in the event of interruption of treatment.

Marine disposal, following preliminary treatment, is concluded to be the most cost-effective, practicable and reliable of the available environmentally acceptable methods of managing wastewater from the Inner West and Central Zones.

TABLE 7-6

ECONOMIC COMPARISON OF VIABLE ALTERNATIVES FOR WEST/CENTRAL ZONES

	Cost, LE thousand		
	Plan 1 (Sea-1 Plant)	Plan 2 (Reuse)	Plan 3 (Sea-2 Plants)
Sewer & Force Mains	18 020	16 650	13 500
Pumping Stations	5 770	5 350	4 240
Treatment Facilities	15 430[a]	71 870[b]	17 500[a]
Disposal Facilities	44 080[c]	20 820[d]	42 590[c]
Land Acquisition	3 290	390	1 200
Capital TOTAL	86 590	115 080	79 030
Average O & M	1 750	2 880	1 610
Relative Present Worth Cost[e] (at 10 percent discount rate)	1.09	1.36[f]	1.00

[a] Preliminary treatment at Kait Bey and (for Plan 3) at West Plant.

[b] Secondary treatment at West Plant.

[c] Submarine outfall (10 km - 1900 mm Ø).

[d] Effluent conveyance and distribution to irrigation canals.

[e] At 8 percent discount rate, Plan 1 is 8 percent greater than Plan 3 and Plan 2 is 33 percent greater than Plan 3. At 12 percent discount rate, Plan 1 is 8 percent greater than Plan 3 and Plan 2 is 33 percent greater than Plan 3.

[f] Includes economic benefit derived from reused wastewater on croplands.

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Outer West Alternatives

The Outer West Zone, like the Outer East and Abu Kir areas, is yet unsewered. There are three potentially viable alternative plans for the zone as illustrated on Figure 7-4. They are:

Plan 1. Collection and conveyance of all wastewaters westward to a waste stabilization pond facility along the north shore of West Lake Maryut.

Plan 2. Collection and conveyance of all wastewaters further westward to a larger, central waste stabilization pond located in the extremities of West Lake Maryut that would also treat flows from Ameria.

Plan 3. Collection and conveyance of all wastewaters eastward to an enlarged regional preliminary treatment facility; (formulated in Plan 1 for the Inner West and Central Zones); Outer West Zone flows thereby being discharged to the sea at Kait Bey.

The first alternative involves a collection/conveyance system designed for an ADWF of 161 ML/day by year 2000. A system of force mains, gravity sewers, and pump stations would convey these flows to a main intercepter sewer whereby flows would enter a 370 ha anaerobic-aerobic lagoon system located along the northern shores of West Lake Maryut. Effluent from the lagoon system would be conveyed through an open lined channel 5800 m to the West Noubaria Main Drain that will enter the sea at the shoreline beyond Agamy.

The second alternative plan involves the same collection and initial conveyance system as Plan 1 but sewage flows would be transported a greater distance (10.8 km) westward to a central waste stabilization pond system to be shared with Ameria. A 780 ha anaerobic-aerobic lagoon system would be necessary to treat the combined flows of the Outer Western and Ameria Zones (combined ADWF of 300 ML/day). The Outer West share of cost for this central lagoon system would be 54 percent (161/300). Effluent would be discharged to the nearby West Noubaria Main Drain canal, now under construction, for discharge to the sea at the shoreline west of Agamy.

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Alternative Plan 3 involves conveyance of Outer West Zone sewage flows eastward to the preliminary treatment facility formulated in Plan 1 for the Inner West and Central Zones. Outer West flows would be conveyed under the Umoum Drain, main railway, and Noubaria Canal through a 1200 mm diameter force main to an expanded West Treatment Plant facility. The preliminary treatment plant would be sized for a total ADWF of 380 (161 + 219) ML/day, of which the Outer West Zone's share of cost would be 42 percent (161/380) based on year 2000 average flows. A force main of 1700 mm diameter would then convey all Western area (Inner and Outer Zone) effluent to the Kait Bey station some 6600 m to the north. At this site a main Kait Bey effluent pump station, sized for a peak flow of 670 ML/day, would convey Central and Western area flows through a 2100 mm diameter submarine outfall terminating about 10 km from shore. The Outer Western Zone would share 26 percent (161/553) of the costs associated with this discharge facility (effluent pump station and outfall) while the remaining costs would be applied to the Inner West and Central Zones.

The total capital and average operational costs, as well as present worth of the three alternatives are presented in Table 7-7. It is seen from the table that capital, operational, and discounted costs associated with Plan 1 (north-shore lagoon) are lower than either alternative Plan 2 or 3. The present worth cost of Plan 3 is 136 percent greater than Plan 1 and Plan 2 is 55 percent greater than Plan 1.

Functionally, Plan 1 also has merits over the other alternatives. The separate lagoon system can be funded and staged independently of the West Plant and Kait Bey Outfall. As a considerable portion of the wastewater flow from the Outer West Zone is of an industrial nature, conveyance back to the urban center for treatment and disposal, as in Plan 3, provides less flexibility and a less reliable management approach than conveyance further westward to more remote environs. The anaerobic-aerobic lagoons will be less difficult to operate and can be more readily staged based on the actual rate of industrial growth over the planning period.

In conclusion, Plan 1, involving conveyance of sewage to lagoons located along the north shore of West Lake Maryut with effluent discharge

TABLE 7-7

ECONOMIC COMPARISON OF VIABLE ALTERNATIVES FOR OUTER WEST ZONE

	Cost, LE thousand		
	Plan 1 (Local)	Plan 2 (w/Ameria)	Plan 3 (West Plant)
Sewers & Force Mains	5 070	8 890	7 270
Pumping Stations	3 190	3 190	260
Treatment Facilities	8 830	8 870	8 250
Disposal Facilities	2 880	2 330	15 820
Land Acquisition	1 390	1 330	1 200
Capital TOTAL	21 360	24 610	32 800
Average O & M	230	240	470
Relative Present Worth Cost[a] (at 10 Percent)	1.00	1.55	2.36

[a] At 8 percent Plan 2 is 46 percent greater than Plan 1 and Plan 3 is 115 percent greater than Plan 1
At 12 percent Plan 2 is 60 percent greater than Plan 1 and Plan 3 is 140 percent greater than Plan 1.

to the West Noubaria Main Drain, is found to be the most cost-effective and flexible method of managing wastewaters in the Outer West Zone.

Ameria Alternatives

There are two viable hardware alternatives for Ameria as shown in Figure 7-4. These are:

Plan 1. Collection and conveyance of sewage flows to a waste stabilization pond system located to the immediate east of Ameria near the Noubaria Canal.

Plan 2. Collection and conveyance of sewage flows northward to a central waste stabilization pond system to be shared with the Outer West Zone.

General layouts, sizing details, and element costs are presented in Appendix J of Volume III.

Plan 1 involves gravity collection of Ameria's projected sewage flows of 137 ML/day to a 315 ha anaerobic-aerobic lagoon facility located east of Ameria City near the Noubaria Canal. Industrial wastewaters from the Free Zone and the Industrial Zone would be lifted by pump station (ADWF 85 ML/day) through a 750 mm diameter force main about 2000 m to the gravity sewer system.

The second alternative involves collection of Ameria Zone flows for conveyance northward through a 1000 mm diameter force main 2500 m to a 685 ha central anaerobic-aerobic lagoon facility located in Western Lake Maryut west of the Agamy/Ameria highway. Ameria's share of treatment and disposal costs, based on year 2000 ADWF, would be 46 percent (137/298), while the remainder would be attributed to the Outer West Zone. Discharge from a central lagoon would be through a 1500 mm diameter force main to the new West Noubaria Main Drain discharging to the sea west of Agamy.

Comparison of alternative plan costs is presented in Table 7-8. Construction of a separate local Ameria treatment system would be less costly in terms of capital and operation expenses than a central (shared) treatment system. This is true primarily because of the fact that there is little economy of scale in constructing large treatment lagoons (unlike the present worth cost of primary of secondary treatment plants). Plan 2 is 18 percent greater in relative cost than Plan 1.

TABLE 7-8

ECONOMIC COMPARISON OF VIABLE ALTERNATIVES FOR AMERIA ZONE

	Cost, LE thousand Plan 1 (Local)	Cost, LE thousand Plan 2 (w/West)
Sewers & Force Mains	11 830	13 370
Pumping Stations	1 120	2 550
Treatment Facilities	7 600	7 550
Disposal Facilities	1 010	1 990
Land Acquisition	1 180	1 140
Capital TOTAL	22 740	26 600
Average O & M	170	220
Relative Present Worth Cost[a] (at 10 percent)	1.00	1.18

[a] At 8 percent Plan 2 is 18 percent greater than Plan 1 and at 10 percent Plan 2 is 21 percent greater than Plan 1.

Plan 1 also has several functional advantages in that it is much more easily staged and more flexible to changes in urban development. Because it is a separate local system, the difficulty in implementing a program is also reduced. Therefore, it is concluded that Plan 1, involving separate treatment of area wastewaters, is the most viable and cost effective plan for Ameria Zone.

7.5 Formulation of the Area-Wide Plan

It has been shown in Section 7.3 and 7.4 that the most cost-effective, environmentally acceptable plan is marine disposal after preliminary treatment of domestic and industrial sewage both, as an overall concept and specifically for the Inner/Outer East Zones (and Abu Kir Peninsula Area), and the West/Central Zones. For these sewered areas, two outfalls are recommended.

In addition, the most economically suitable plan would incorporate treatment by independent anaerobic-aerobic waste stabilization lagoon systems for sewage from the outlying areas of Ameria and Mex-Dekheila (Outer West Zone). Effluent from the lagoon units would be discharged to the sea via the West Noubaria Main Drain. It has been established that separate disposal is the least cost solution for the predominantly industrial wastewater flows from the Abu Kir Bay area. These flows would be conveyed to an evaporation pond with no discharge into local bodies of water, while primarily domestic wastewater from the Abu Kir Peninsula would be conveyed to the East Zone system for marine disposal.

In order to make optimum use of existing treatment facilities, the East Sewage Treatment Plant should be converted for treatment of presently unsewered Nouzha Zone wastewaters and retained as a well operated secondary level facility with discharge to the Kalaa Drain. The West Sewage Treatment Plant facility, now under construction, should be retained to provide interim primary level of treatment until an expanded preliminary plant, incorporating the existing facility, can be constructed.

A sea disposal system for the major portion of Alexandria's wastewater has been found considerably less costly to construct and to operate than alternatives involving secondary treatment with interim disposal to Lake Maryut and agricultural reuse of a larger part of the flow for crop irrigation. The following costs, in LE thousands, indicate a relative comparison between the basic alternatives.

	Sea Disposal	Lake Maryut (Interim)	Agricultural Reuse
Capital Cost	210 120	240 450	294 450
Annual O & M	3 130	4 840	6 030
Relative Present Worth Cost	1.00	1.22	1.30

The present worth cost takes into consideration benefit to croplands associated with wastewater reuse by including economic crop benefit in this alternative plan. At a 10 percent discounting rate the interim disposal is 22 percent greater than sea disposal and reuse is 30 percent greater than sea disposal.

On economic grounds and for feasibility of implementation, sea disposal is preferable to treatment for near term agricultural reuse. This situation could change in the distant future for a greater portion of Alexandria's wastewater, which would still, however, require intermittent and emergency marine disposal provisions.

Simple conveyance of sewage to desert areas for disposal by evaporation would have prohibitively high conveyance costs and, although it would not affect today's human environment, may be sufficiently controversial to prevent early implementation. From a purely technological point of view, and assuming it would not become a health hazard by attracting humans, it does have potential merit. Overall, the cost and potential social difficulties attending desert disposal outweigh the additional protection which would be provided to area surface waters.

Both preliminary treatment plants and waste stabilization ponds (for Mex-Dekheila and Ameria) will be far more operationally reliable than secondary treatment plants. Viable treatment and disposal systems, with the exception of evaporation, will depend heavily on control and pretreatment of toxic and problem wastes by industry. Biological processes would be more sensitive to sudden toxic loads and industrial flow fluctuations than any other treatment system. A marine disposal system and anaerobic-aerobic lagoons will be much less sensitive to occasional toxic discharges and flow variations. An industrial waste evaporation pond, found less costly for the Abu Kir Bay area, has been evaluated as a more reliable system than treatment with discharge to either inland waters or the sea. Almost complete elimination of treatment processes which use sophisticated technology is deemed most effective and reliable from a functional standpoint, where location, land and environmental conditions permit.

The proposed master plan combines elements which provide environmental protection; reliability of system performance; minimal sensitivity to future changes in industrial development, land use, potential technological advancement or water quality criteria revision; and least cost. Greater public concern regarding the quality of the environment may well occur with improved standards of living. Such variables, together with other unknowns, make reliance on technologically sophisticated plans less flexible than simpler, more adaptable solutions.

The formulated area-wide plan is, in addition, no more difficult to implement than other alternatives which have been considered. It does not require over-consolidation of future sewerage zones. The plan provides for much less capital-intensive construction than would be needed for secondary treatment plants or for major conveyance facilities which need to extend long distances out of the city. The retention of existing sewage treatment facilities also eases implementation of the plan. Construction staging for lagoons, evaporation ponds, treatment plant and pump station equipment all allow rapid and cost-effective programs to be implemented.

In summary, formulation of an area-wide master plan, with emphasis on sea disposal, has been selected because it represents:

- the least cost alternative.
- the most effective approach to improving and protecting the environment of Alexandria.
- the least environmental impact on inland waters and the human environment and an acceptably low impact on the Mediterranean Sea.
- the most reliable system.
- no greater degree of difficulty for implementation than any other alternative.

FIGURE 7-1
SCHEMATIC DIAGRAM OF ALTERNATIVE LEVELS OF CONSOLIDATION

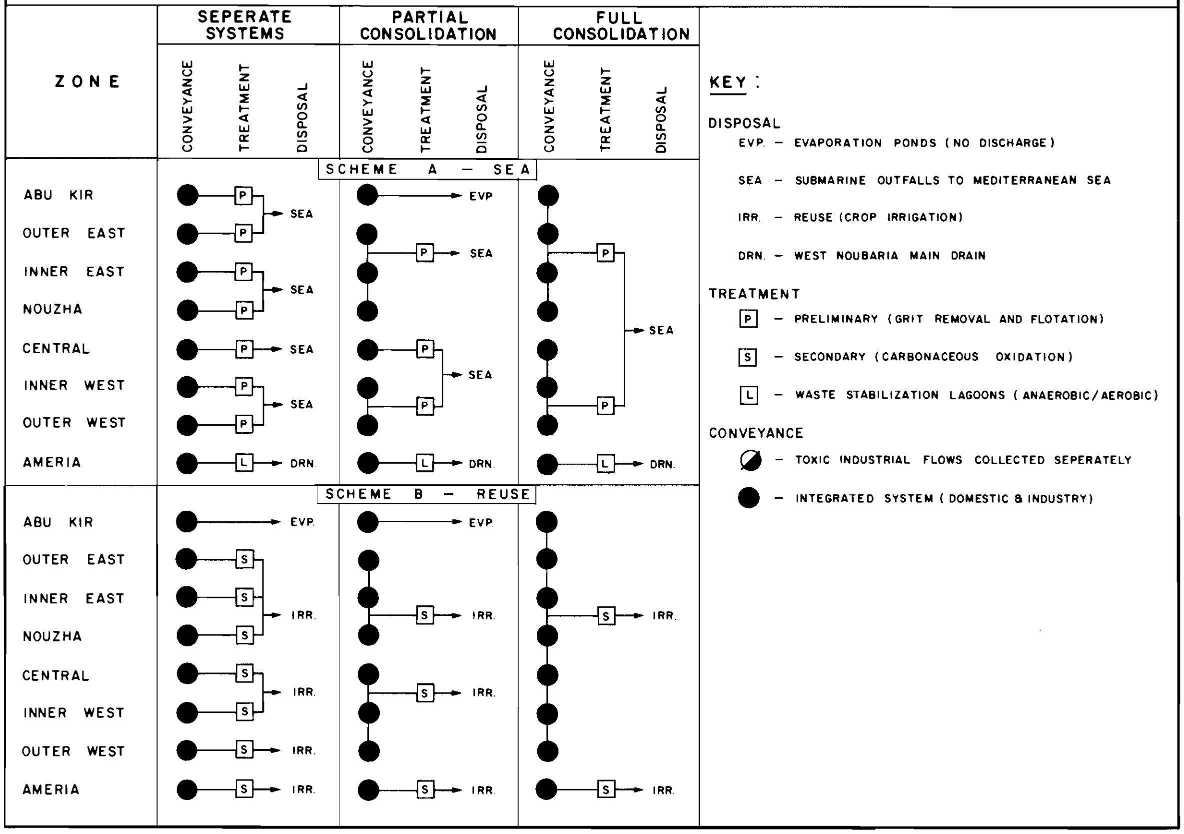


FIGURE 7-2
SCHEMATIC DIAGRAM OF SEPERATE TOXIC INDUSTRIAL WASTE COLLECTION SYSTEM

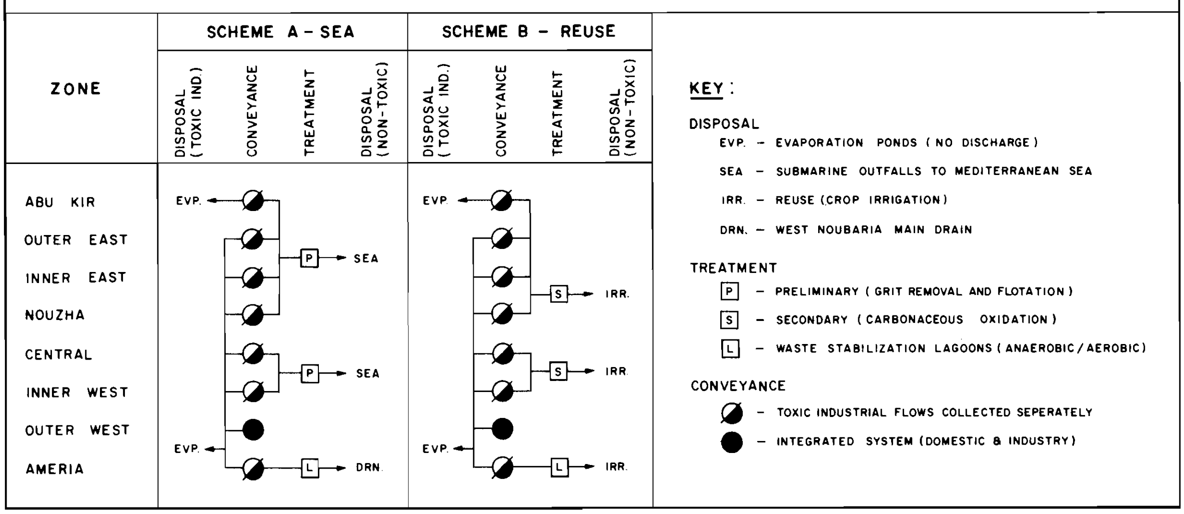


FIGURE 7-3
SCHEMATIC DIAGRAM OF ALTERNATIVE DISCHARGE SCHEMES

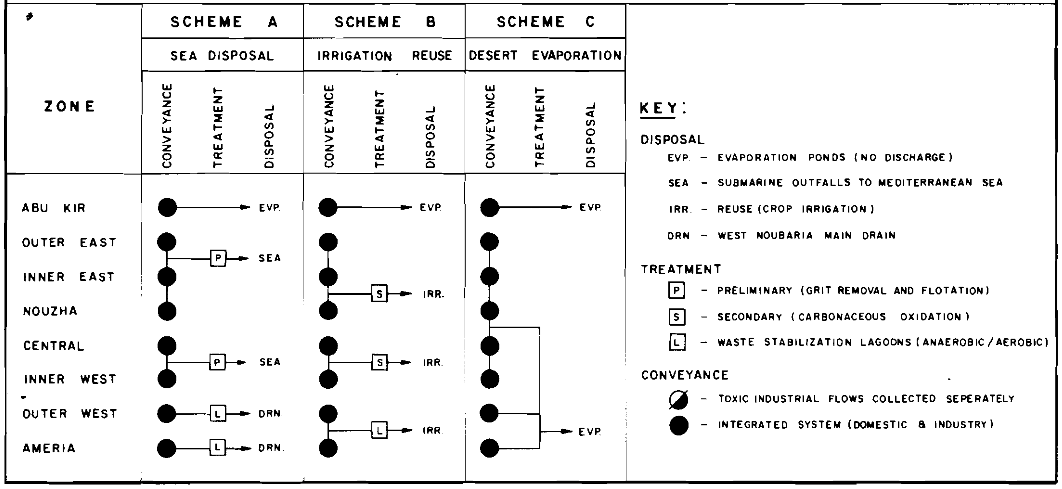


FIGURE 7-4
SCHEMATIC DIAGRAM OF VIABLE "HARDWARE" ALTERNATIVES

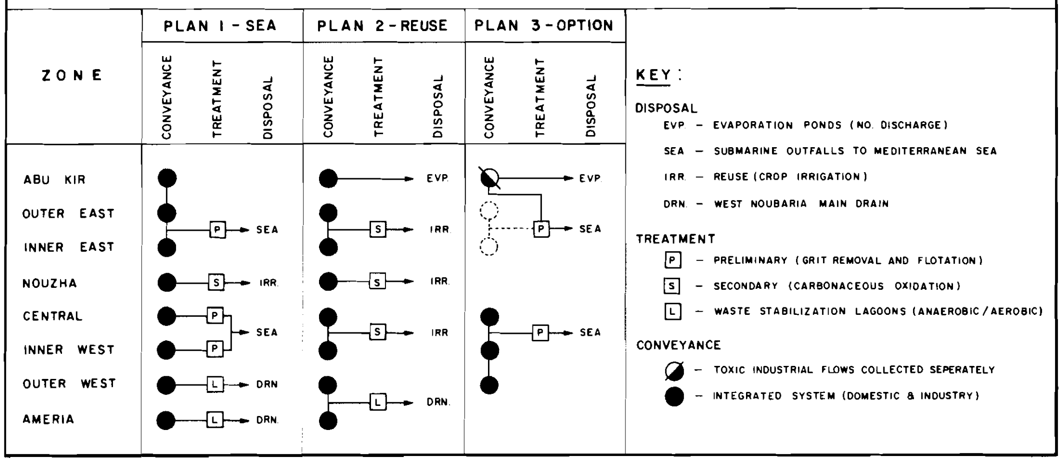
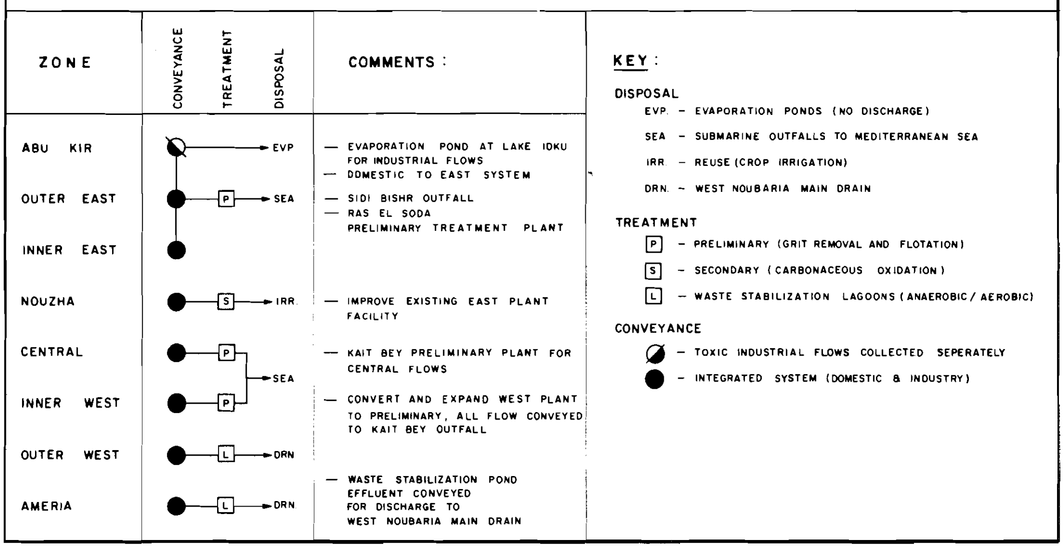


FIGURE 7-5
SCHEMATIC DIAGRAM OF RECOMMENDED PLAN



FIGURES 7-3, 7-4 & 7-5

CHAPTER 8

RECOMMENDED MASTER PLAN PROGRAM

8.1 Overall Master Plan

A Wastewater Master Plan program was formulated in detail after careful study of the feasibility of alternatives discussed in the previous chapter. Functional flexibility, least capita cost, operation and maintenance technical and administrative simplicity, ease of implementation, and environmental soundness determined choice of the plan. The plan is comprehensive in nature, including recommended construction projects, their scheduling, proposed system operations, itemization of costs by area/element, and an economic assessment of program feasibility based on benefits.

The major features of the recommended wastewater plan to serve Alexandria through the next several decades are shown on Figure 8-1. There are six principal aspects of the recommended plan, each related to a defined area. These are:

1. Eastern Zones. Wastewaters from the Inner East Zone and the Outer East Zone (Ras el Soda, Siouf Keblia, and the future Sadat City) will be conveyed to a 560 ML/day preliminary treatment plant in Ras el Soda with effluent to be discharged through a 2200 mm diameter submarine outfall at Sidi Bishr.
2. Abu Kir. Wastewaters from the Peninsula area (primarily domestic) will be conveyed to the East Zone treatment facility for sea discharge, while Abu Kir Bay (predominantly industrial) flows will be conveyed to a 4000 ha evaporation pond at Lake Idku.
3. Nouzha. Wastewaters will be conveyed to the existing East Sewage Treatment Plant which will be improved and renovated with a design capacity of 45 ML/day for secondary treatment prior to discharge to the Kalaa Drain. (Effluent will be reused for crop irrigation if agricultural conditions make it economically feasible.)
4. West/Central Zones. Wastewaters from the Inner West Zone will be conveyed to a 220 ML/day preliminary treatment plant (at the existing West Sewage Treatment Plant site), while Central Zone flows will be treated at a 175 ML/day preliminary plant at Kait Bey. Effluent

discharged from both facilities will be pumped through a 1700 mm diameter submarine outfall at Kait Bey.

5. Outer West. Wastewaters from the Mex-Dekheila area will be conveyed to a 370 ha waste stabilization pond (anaerobic-aerobic lagoons) in West Lake Maryut with discharge of effluent to the new West Noubaria Main Drain.
6. Ameria. Wastewaters will be conveyed to one or more waste stabilization ponds (anaerobic-aerobic lagoons) where 315 ha are required, in total, to serve the needs of a projected one-half million persons by year 2000. Discharged effluent will be pumped to the new West Noubaria Main Drain.

There are two principal areas within the Alexandria Governorate which are not expected to require sewering by the end of the planning period. These are the extreme west area at Agamy, where the seasonal influx in tourism is not expected to overload present individual septic tank/leach field systems before year 2000, and the remote village areas to the east, where continuance of present agricultural practices and negligible urban development is projected.

The proposed system is an integrated one. Both domestic sewage and industrial wastewaters have been incorporated in the recommended conveyance, treatment, and disposal systems. A separate industrial waste collection-disposal plan is not recommended because of high costs, difficulty of implementation, and potential for major operational problems. A regional control program for toxic wastes, involving treatment and/or separation and handling within industrial plants prior to discharge into the public sewerage system is an aspect of overall system administration to be incorporated into the plan. This is discussed in the following chapter on implementation.

The principal facilities recommended for construction include extension of the present sewage collection and conveyance system (including property connections, laterals, collectors or interceptors, pump stations, and force mains), three preliminary treatment plants, two waste stabilization ponds, an industrial evaporation pond, and two major submarine outfalls. Programs for the construction of such projects are proposed to extend over the next ten to fifteen year period.

8.2 Principal Wastewater Facilities

Property Connections

Sewer connections from dwellings and other premises to the manholes of street laterals are normally installed as part of general sewer construction contracts. The connections normally consist of 150 mm vitrified clay pipe within gravel concrete encasements, laid in shallow trenches at a minimum grade of about 20 cm per 10 m of length. Up to four dwellings are usually served by a single connection which lies below the sidewalk and enters a street sewer manhole without a drop connection. The use of "Y" branch and saddle connections directly into the lateral sewers is minimized in Alexandria because of potential damage by rodding and greater chance of clogging.

It is recommended that new dwelling connections to existing laterals be made directly to sewers by use of branch connections, where connection access to manholes would otherwise involve additional expense. Laying small (150 mm) size property connections at shallow depth adequately restricts the amount of debris which might otherwise enter and clog the lateral system. It is expected that cleaning and repair of connections will remain the responsibility of the property owner.

For areas to be sewered in the future, it is proposed that connections be constructed as in the past, in order to allow provision of service to the maximum number of people in the shortest period of time. Drainage inlets to laterals are not recommended in view of the magnitude of costs and serious nature of the present sanitary situation in unsewered areas. The proposed collection system is designed fundamentally to handle sewage. Assistance is needed to begin to catch up on a tremendous backlog of sewage collection work and to establish an ongoing program of connections which will keep pace with sustained urban development.

The number of property connections expected to be required in order to meet the needs of the recommended program has been estimated in Table 8-1. In order to catch up with development, it is expected that more than 370 connections per month will be necessary during the next 10-15 years.

TABLE 8-1

PROPERTY CONNECTIONS REQUIRED

	Number of Connections (1978-1988)	(1989-2000)	Total
Abu Kir[a]	5 280	3 200	8 480
Outer East	21 840[b]	17 840	39 680
Inner East[c]	4 160	4 160	8 320
Nouzha	3 520	480	4 000
Central[c]	440	400	840
Inner West[c]	840	720	1 560
Outer West	4,320	480	4 800
Ameria	8 880	16 240	25 120
TOTAL	49 280	43 520	92 800
Monthly Average[d]	373	302	

[a] Includes both Abu Kir Peninsula (90% of connections) and Kait Bay Industrial (10% of connections) areas.

[b] Includes 5,440 connections associated with Top Priority Projects (1978-1981) in the Ras el Soda area.

[c] New connections in areas now sewered.

[d] Average number of connections required per month.

Following this period, a lower rate of approximately 300 connections per month is anticipated. Although commonly borne by individual property owners, the expense of a sewer connection is an integral part of the overall cost of the wastewater program.

Lateral Sewers

The cost of the street sewer system has been estimated on a sewered area basis. Ground conditions and levels of development in various areas were taken into account in developing unit construction costs for the lateral system. Although preliminary engineering designs for individual lateral sewers in various areas of Alexandria are not required, typical designs are presented in Appendix H. Secondary sewer systems were costed on the basis of vitrified clay pipe (with O-ring joints) in sizes from 200 mm to 500 mm in diameter. Placement of manholes was assumed at each expected change of grade, direction, and pipe diameter at intervals no further apart than permitted by design criteria in Section 5.3.

The actual design and construction scheduling of lateral sewers must be coordinated with construction of principal collection and conveyance facilities, future roadway construction, and other urban development and redevelopment projects. In some cases, it will be appropriate to partially or completely sewer on the basis of existing development and later to re-sewer after development. Table 8-2 is a summary of approximate gross area extent and lateral sewer lengths necessary to collect wastewaters from the sewerage zones of Alexandria through year 2000.

Conveyance System

Conveyance of collected wastewaters (from the street sewer system to points of treatment and disposal) is proposed by an extensive system of collectors (also termed interceptors and gravity trunk sewers), pump stations, and force mains. The recommended conveyance system is presented by sewerage zone as follows.

East. It is recommended that new sewage pump stations be built to replace the old, surcharged Pump Stations Nos. 1, 2, and 5. The new facilities, as shown on Figure 8-2, would be designed to pump peak dry weather flows (year 2000), while existing stations would be retained for handling excess stormwater flow. In similar manner, Pump Station No. 3 would be retained for stormwater flow,

TABLE 8-2

EXTENT OF PROPOSED LATERAL (STREET) SEWER SYSTEM

	Sewered Area, ha			New Laterals, km		Total Lateral Sewers, km		
	1977	1985	2000	1985	2000	1977	1985	2000
Abu Kir[a]	--	90	300	30	70	--	30	100
Outer East	--	235	1950	60	425	--	60	485
Top Priority Projects[b]	--	500	500	50	--	--	50	50
Inner East	2300	2330	2440	35	130	815	850	980
Nouzha	--	205	400	25	20	--	25	45
Central	1245	1255	1270	20	40	440	460	500
Inner West	725	790	920	35	65	250	285	350
Outer West	10	85	210	20	30	5	25	55
Ameria	--	115	860	40	260	--	40	300
TOTAL	4280	5605	8850	315	1040	1510	1825	2865

[a] Includes both the Abu Kir Peninsula (80% of laterals) and Abu Kir Bay Industrial (20% of laterals) areas.

[b] New laterals associated with Top Priority Projects (1978-1981) are located in the Ras el Soda area of the Outer East Zone.

but instead of lifting dry weather flow from this area, a new 750 mm diameter gravity sewer would be constructed along the Corniche to convey sewage 1000 m to a new Pump Station No. 5. Four existing pump stations, Nos. 4 and 6, Montazah, and Maamoura appear adequate for year 2000 design dry weather flows, only requiring some rehabilitation (as part of the Top Priority Projects) for inclusion within the Master Plan program

Larger force mains will be necessary for new Pump Stations Nos. 2 and 5, as well as existing Pump Stations Nos. 4 and 6 and the Maamoura Pump Station. A 450 mm diameter force main 4400 m in length from Maamoura would discharge into the wet well of proposed Pump Station No. 2 which would then pump through a new 550 mm diameter force main 1250 m to a point adjacent to Pump Station No. 4, where a new 650 mm diameter force would convey flows from all three pump stations, 1300 m to the headworks of the recommended Ras el Soda treatment plant. A 550 mm and 450 mm diameter force main, each 500 m long, would also carry sewage directly to the new plant from Pump Stations Nos. 5 and 6, respectively. The present force mains serving Pump Stations No. 1 and Montazah are deemed adequate for year 2000 design flow conditions.

For the Sidi Bishr area, the existing Glym and Sarwat Pump Stations would be abandoned and replaced by a new 1000 mm collector along the Corniche that would convey wastewaters 2300 m to a new Sidi Bishr Pump Station. The new pump station, at 67 ML/day capacity, would lift flows to the treatment plant headworks through 1700 m of 750 mm force main.

Sewage flows from the north and west of the Smouha Club grounds would be conveyed by a new 1500-1800 mm collector along Mohammed Aly Street 2900 m to a new Smouha Pump Station located near the existing siphon under the Mahmoudia Canal. The existing Hadara (Smouha) Pump Station would be abandoned. The new 208 ML/day design capacity pump station would lift sewage from the new Mohammed Aly and the existing Hagar el Nawatia collectors to the Ras el Soda treatment facility via a 6500 m force main. This force main would make use of an existing 1200 mm diameter main (2500 m) that now connects Pump Station No. 11 to the East Treatment Plant.

Pump Station No. 11 would be abandoned with construction of a new 750-1300 mm gravity sewer intercepting sewage flows from the upper Hagar el Nawatia collector for conveyance 2400 m to a new 258 ML/day Abu Soliman Pump Station.

This sewer would also collect flows from the Egyptian Copper Works and eliminate the need for existing Pump Stations No. 9 and 10. The Abu Soliman Pump Station would lift flows from the new Hagar el Nawatia diversion sewer, the existing Abu Soliman collector, and a new 5660 m collector from Siouf Keblia to the headworks of the Ras el Soda plant through a 3100 m force main 1350 mm in diameter.

The new branch collectors would convey sewage from the Siouf Keblia area via a 1600-1700 mm diameter main collector which in turn would carry the flow 1050 m to the new Abu Soliman Pump Station. Construction of the gravity system would eliminate Pump Stations Nos. 7 and 8.

The Ras el Soda area would be served by a new 500 mm to 1600 mm diameter collector carrying sewage in a westerly direction some 3400 m for discharge to a new 224 ML/day pump station. A rebuilt (TPP) Hospital Pump Station would connect to the Ras el Soda collector by 1150 m of new 350 mm force main. Area sewage would be pumped to the new treatment plant headworks through 800 m of 1300 mm diameter force main.

Construction of 2600 m of 900 mm diameter force main and 113 ML/day pump station for the future Sadat City is recommended, when the area begins to develop within the next ten years. If flows remain small, this system may discharge to the Ras el Soda collector, but construction of a separate 1800 mm diameter relief sewer, 3400 m in length, will be necessary for tie-in to the new Ras el Soda Pump Station if the area does develop to the extent envisioned (one-half million inhabitants) by year 2000. Downstream conveyance facilities have been sized to accommodate the projected flows from this area.

Abu Kir Zone. Abu Kir Peninsula wastewaters would be conveyed, as shown on Figure 8-3, by a system of gravity sewers, pump stations, and force mains to a 52 ML/day main pump station. Flows from the low-lying beach areas on either side of the transverse limestone ridge would be pumped to a collector adjacent to the Abu Kir railway. The main pump station would convey sewage some 8000 m to the Ras el Soda preliminary treatment plant headworks, through a 650 mm diameter force main.

Wastewaters from existing and future industrial developments along Abu Kir Bay would be pumped 8000 m south to an evaporation pond built at Lake Idku, through a 1300 mm diameter force main. A pump station of 225 ML/day peak capacity is required for projected year 2000 design flows. Several kilometres of 1400 mm diameter collector sewers are envisioned for collection of industrial flows. Conveyance system capacity is based on projected industrial flows within the study area; it is possible that additional industrial flows originating outside of the Alexandria Governorate will continue to drain to the Tabia Pump Station at Abu Kir. Such waste flows should be handled in a separate manner upstream.

Nouzha. It is recommended that wastewaters from the Nouzha area be collected by construction of a 3300 m diameter gravity sewer along the existing railway line to a new Nouzha Main Pump Station of 74 ML/day capacity. The collector would serve existing lateral sewers and flows from a new 350 m diameter force main built from Fisherman's Village Pump Station. The Nouzha Main Pump Station would convey flows to the existing East Treatment Plant through 930 m of 750 mm diameter force main, as shown on Figure 8-2.

West/Central. A 1200 to 1400 mm diameter gravity interceptor is proposed to collect domestic and industrial wastewaters that presently flow into Lake Maryut from the Inner West Zone via Mohsen Pasha Drain, Gabbary Drain, Industries Pump Station, and Pump Station No. 3. A new 5750 m collector will eliminate need for seven existing pump stations: Nos. 1 and 3; New and Old Forn el Garaya; Gheit el Enab Main and Auxiliary; and Industries Pump Station. Pump Station No. 3, however, would be retained with addition of new pumps, related equipment and a larger force main to accommodate future flows. Mohsen Pasha Pump Station would be abandoned with diversion of tributary wastewaters south through existing gravity sewers to the Mohsen Pahsa Drain. All wastewaters from the Inner West Zone would be conveyed to the intake works of an expanded West Treatment Plant, as shown in Figure 8-4. Stormwaters would continue to overflow to Lake Maryut.

An effluent conveyance system would also be necessary to transport treated flows to the Kait Bey submarine outfall facility. An effluent pump station located at the expanded West Plant preliminary treatment facility would lift West Zone effluent 6600 m through a 1300 mm diameter force main to a Kait Bey outfall pump station for sea discharge. Construction of this conveyance system would be staged for compatibility with Kait Bey outfall construction completion.

After completion of the Top Priority Projects, present Central Zone conveyance facilities will be sufficient for projected wastewater flows. No additional new construction of major collectors, pump stations, or force mains for handling sewage in this area is anticipated. The present Kait Bey pump station works will be abandoned with construction of a new preliminary treatment facility on site, which will serve the central system by gravity.

Outer West. It is recommended that a major sewage collection system be constructed in this presently unsewered area for conveyance of wastewaters to a waste stabilization pond located along the western shores of Lake Maryut. A conveyance system of collectors, pump stations, and force mains would be involved, as shown on Figure 8-5.

Wastewaters from the area between the Noubaria Canal and the Umoum Drain would be collected at the Tanneries Pump Station for conveyance 2500 m through a 300 mm diameter force main, to a 1000 mm diameter gravity interceptor 500 m in length. Flows from the area just west of the Umoum Drain would also enter this interceptor after collection at Valley of the Moon Pump station. A 250 mm diameter force main, 600 m in length, is proposed. A final 1500 mm diameter gravity collector 1000 m long would convey all upstream Mex flows and discharges from the inland Dekheila area to a main junction near the proposed treatment pond site.

A separate system, composed of gravity interceptors along the coast (800 m of 600 mm and 600 m of 750 mm diameter trunk sewer) followed by a Main Dekheila Pump Station of 16 ML/day capacity and 1100 m of 350 mm diameter force main, is proposed for conveyance of coastal flows inland to the main junction. A 1400 mm diameter gravity sewer 1600 m long would convey industrial flow from the far western areas to the main junction. A final 800 m long influent sewer of 2300 mm diameter would convey all flows from the main junction to the proposed Mex-Dekheila ponds for treatment.

Ameria. The proposed conveyance system to serve the northern, industrial zones and the southern, predominantly residential portions of new Ameria is shown on Figure 8-5. The northern collection system would convey flows through 10 km of 750 mm diameter and 3 km of 900 to 1200 mm diameter gravity collectors to a 85 ML/day Industrial Pump Station discharging to a 750 mm diameter connecting force main 2000 m long. The southern system, composed of our principal branches would convey primarily domestic wastewater, as well as the northern industrial flows, by gravity to the proposed stabilization pond site, northeast of the envisioned New Ameria City near the Noubaria Canal. The four branches would range from 600 mm to 1500 mm in diameter and comprise 20 km of interceptor sewers which would handle sewage flows projected to be equivalent to a population of nearly one million persons by the year 2000.

Preliminary Treatment Plants

Construction of three preliminary treatment facilities at Kait Bey, Ras el Soda, and the West Treatment Plant site is proposed. Each facility would include:

- an inlet pump station (where necessary for influent flows).
- screening.
- grit removal and washing.
- removal of floatables.
- an effluent pump station for submarine outfall discharge.

The Kait Bey facility at 175 ML/day capacity would be located near the existing Kait Bey outfall pump station and occupy an area of about 4 ha, which would include space for installation of additional (primary) treatment units at some future stage, if needed. The Ras el Soda plant, designed at 560 ML/day capacity, would occupy about 5 ha of open space in the El Ezbit Darbala neighborhood (south of the Alex-Rosetta railway, but north of the Montazah Canal) directly inland from Sidi Bishr. The West Plant facility would be located on the site of the present West Sewage Treatment Plant along the western shore of Lake Maryut just east of the Noubaria Canal (see Figure 8-4). When present construction is completed, the West Plant is intended to have a primary treatment capacity of 85 ML/day. The recommended plan incorporates this plant into the expanded preliminary treatment facility, designed for 220 ML/day capacity. It is expected that 75 ML/day of primary capacity can be converted, requiring construction of an additional 145 ML/day preliminary plant works.

Pumping of influent gravity flows is necessary at the West Plant facility. As a low lift, high volume, variable inflow pump system is required, a screw type pump installation is proposed. This type of pump which operates well at lifts of less than 8 m is capable of handling most solids and debris with minimal difficulty and will pump at variable rates without any need for sophisticated control equipment.

Each of the three preliminary plants would include mechanical screening, rather than manual screening, in order to protect effluent pumps against damage by solid objects, avoid interference with subsequent treatment processes, and prevent rags and other large floating objects from clogging diffuser ports or appearing on the sea surface. The proposed screens would be of the catenary type to minimize underwater moving parts and the need for greater maintenance. The screenings would be discharged to a drainage platform or conveyor for drainage and conveyance by truck to a landfill. Comminutors are not recommended because they are difficult to maintain and are not well suited for the large flows involved.

Grit removal is necessary to prevent loss of capacity in the outfalls by grit accumulation, wear on pumps, and blockage of diffuser ports. Grit would be removed in aerated grit chambers. Each aerated unit would be equipped with air diffusers to allow grit to settle while keeping the organic solids in suspension. Grit would be removed by a catenary chain device, discharging to an inclined conveyor, where it would be washed and drained for subsequent transportation by truck to a landfill.

Air diffusion and surface skimming would be used for removal of floatables. Tank units at Kait Bey and Ras el Soda would be enclosed for odor control. A system of valving and piping would be included at all three plants to facilitate dewatering for periodic maintenance.

It is proposed that mixed-flow, non-clog, variable speed wastewater pumps be used for the outfall pump stations. Continuous operation is desirable because of the large size of motors and starters, as well as for optimum operation of long outfalls. All equipment would be enclosed in buildings.

Preliminary engineering design layouts of the treatment facilities at Kait Bey, West Plant, and Ras el Soda are presented in Appendix I. The outline drawings show general features for each of the proposed facilities including location, arrangement, leading dimensions, and elevations for principal components. The drawings have been prepared in sufficient detail to develop more refined cost estimates for the recommended plan. Tabulations of principal design criteria loadings, equipment requirements, power requirements, standby capacity, and other design considerations are also presented in Volume III, Appendix I.

Submarine Outfalls

Two submarine outfall discharge systems are proposed for conveyance of preliminary treatment plant effluent flows to the Mediterranean Sea. The Kait Bey outfall, designed for peak dry weather flow of 500 ML/day, would involve a 1700 mm diameter pipeline extending approximately 10 km into the sea off Kait Bey Point in the vicinity of the existing short outfall. Discharge depths will be in the range of 50-55 m below sea level. The Sidi Bishr outfall, designed for a peak flow of 850 ML/day, would entail a 2200 mm diameter pipeline extending the same distance and depth as the Kait Bey outfall into the sea.

Materials initially considered for outfall construction include prestressed concrete and coated ductile iron pipe although, during design review, other materials such as fiberglass or coated and lined steel pipe should be considered. Concrete pipe would have bell and spigot joints with double rubber O-rings. Tunneling the entire distance beneath the sea bed was found infeasible due to prohibitive costs.

Expected construction procedures would include the following:

1. Complete burial through the surf zone for pipe protection and concealment from view.
2. Provision of sheeting in the surf zone.
3. Trench excavation by drag line, clamshell, suction dredge or airlift, operating from an anchored work barge. (Explosives may be necessary in some areas if rock outcrops cannot be avoided).
4. Grating of trench bottom.
5. Installation of pipeline with mechanical pipe-laying equipment from a barge crane, followed by testing of joints.
6. Placement of gravel bedding under and along pipeline to mid-height of outfall while it is yet supported.
7. Backfilling of trench with gravel and rock after pipe-laying equipment has been moved forward.

Detailed design and subsequent construction of two such submarine outfalls requires extensive engineering information, the initial portion of which is presented as Volume IV of this report. The information has been collected through a marine studies program that will be completed by mid-1978.

East Treatment Plant Improvements

The existing 65 ML/day East Sewage Treatment Plant would be operationally upgraded to provide full secondary level of treatment for wastewaters from the Nouzha area at a design capacity of only 45 ML/day. The facility is not expected to require significant equipment modifications in order to attain this level of treatment because of reduced hydraulic load. The plant will require extensive operational changes, most of which are discussed in some detail in Special Report No. 2.

Waste Stabilization Ponds

Waste stabilization ponds in the form of anaerobic-aerobic lagoons are proposed to serve the Outer West Zone (Mex-Dekheila) and Ameria Zone. The Mex-Dekheila lagoon, sized for a year 2000 ADWF of 161 ML/day, would be located along the western shore of West Lake Maryut and would occupy about 370 ha as shown on Figure 8-5. The Ameria lagoons would comprise about 315 ha and would be located northeast of Ameria City just west of the Noubaria Canal. The Ameria treatment facility would be sized for an ADWF of 137 ML/day based on a year 2000 forecast population of one-half million residents and projected industrial developments.

The anaerobic-aerobic treatment system would consist of initial small, deep, anaerobic ponds receiving raw wastewaters, followed by shallow aerobic lagoons (identical to normal oxidation ponds), as shown in preliminary layouts presented in Appendix I. The total amount of land necessary for the ponds and an adequate surrounding zone would be purchased during the initial stage of plan implementation. Approximately 750 ha are required.

After remaining in the stabilization ponds for a minimum of 30 days, effluent in both systems would be discharged to the West Noubaria Main Drain. In the case of Ameria, this would involve a 150 ML/day capacity low lift pump station located along the new West Noubaria Main Drain. In the case of the Mex-Dekheila system, effluent would be conveyed 4800 m via a 1.6 m deep by 7 m wide lined channel to the West Noubaria Main Drain. A low head pump station at 175 ML/day capacity would then also pump effluent into the drain.

Discharge into the West Noubaria Main Drain, now under construction (Figure 8-1), will afford significant dilution of the effluent stream. Furthermore, the Main Drain will discharge to the Mediterranean Sea at a location where marine currents afford much greater dispersion than in the harbors of Alexandria or Abu Kir Bay.

Evaporation Pond

A 4000 ha holding pond that will allow for evaporative disposal of a projected ADWF of 150 ML/day (by year 2000) is recommended for the Abu Kir Bay Industries Area. The evaporation pond would be constructed at the western end of Lake Idku which is about 8000 m from the Tabia Pump Station (located at the end of Abu Kir Drain). A preliminary layout and section drawing is presented in Appendix I, Volume III.

The size of the pond may need to be reconsidered, in order to accomodate additional industrial waste flows that originate outside the Governorate, in the upstream portions of the Abu Kir Drain system. As several major industries located outside the study area might,in the future, be required to handle their waste products in another manner than present disposal to the agricultural drain system, they have not been considered in initial determination of treatment facility size or costs, although the year 2000 design flows for the Abu Kir Bay area do allow a capacity margin. As an evaporation pond can be constructed in stages, expansion for additional industrial waste flows in the future can be readily attained if found necessary.

The pond would be constructed so as to be entirely separate from Lake Idku without permitting seepage or drainage from the pond to enter the lake or vice-versa. Odor from the evaporation pond is expected to be detectable along the Alex-Rosetta road and railway line during certain conditions of high humidity and offshore winds. Control of access to the pond system will be essential. Aesthetic problems are expected to arise with such a disposal system, but because of the remote location, they will have far less impact on the environment than continued discharge of industrial wastes into the bay.

8.3 Project Staging

General Considerations

The magnitude of major construction projects envisioned for the recommended plan and the expected limited availability of funds will impose significant constraints on formulation of a realistic construction staging program. Two principal factors have been taken into consideration in proposing staged construction. The first is the relative priorities of the elements of the program (taking into account the fact that some elements cannot provide any benefit until certain actions are taken or developments proceed). The second is the probability that limited funds would be made available for financing the projects.

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At every stage, the intent is to maximize early benefits, while deferring expenditure where possible. The greatest return in terms of benefit for a given expenditure is achieved by putting the existing system into proper operation, especially insofar as present inadequate operation has potentially serious public health significance. This was the basis used for inclusion of Top Priority Projects proposed in Special Report No. 4 for rehabilitation and upgrading of pump stations, cleaning and rehabilitation of sewers, and provision of alternative means of disposal for unacceptable materials currently dumped into the sewers.

Cost aside, the greatest need for wastewater system improvement in Alexandria is satisfactory removal of human wastes from the vicinity of dwellings, yards and streets, because of environmental health implications. At a somewhat lower level of priority, but still important from social, health, and and economic points of view, is protection of all bathing beaches.

On these grounds, strong initial emphasis on system rehabilitation and lateral sewer construction is proposed. Early treatment and disposal improvements would be primarily directed toward placing existing plants in service and constructing the eastern treatment and outfall facilities. The Ras el Soda/ Sidi Bishr facilities will have a greater influence on surf zone conditions than will construction of new Kait Bey facilities. If funds permit, and rate of early development justifies, the Outer West stabilization pond facilities and possibly the Abu Kir industrial waste evaporation pond system could be given a relatively higher priority.

Four stages of construction for the recommended plan have been defined:

First Stage, 1979-1983	Third Stage, 1989-1994
Second Stage, 1984-1988	Fourth Stage, 1995-2000

The first stage of construction overlaps with the immediate phase works of Top Priority Projects (1978-1981). Stages I and II, each five-year programs, are intended to result in maximum return on investment by providing direct solutions to many of the existing problems. The two remaining stages, each of six-year length, are intended to meet demand of projected future development and are primarily collection sewer system expansion projects.

Major construction activity is proposed during the first and second stages in order that principal facilities may be on line by the late 1980's. Wastewater facility projects which can be effectively staged and constructed to meet immediate needs, such as pump stations, waste stabilization lagoons, evaporation ponds, treatment plant facilities, and some pipelines have been considered. The recommended staging program for proposed principal facilities, including estimated element capital costs, is summarized on Figure 8-6.

Top Priority Projects (1978-1981)

The immediate works necessary for the Alexandria sewerage system to achieve an ongoing level of acceptability have been termed Top Priority Projects. These works, which extend over the next four-year period, are now underway. These projects provide for a limited amount of new sewer construction and the improvements necessary in order that the present system can operate at an acceptable level. The activities are placed in three categories:

I - Institutional and Operational Changes. Changes in plan, policy, and daily operations which require adoption and implementation as soon as possible.

II - Repair and Replacement. Items of construction needed to repair or replace facilities in the existing system which are no longer operable or have become obsolete or overloaded, in order to restore system capacity and provide greater reliability.

III - New Service. Items of construction which will provide service as soon as practicable, to a portion of the city that has already reached a high level of development, but is yet unsewered.

Because of limited funding, many new service projects that were first considered under Top Priority Projects had to be delayed. Therefore, sewer construction for many areas initially designated "top priority", such as Siouf Keblia, Abu Kir, Nouzha, and Mex-Dekheila has been included in the initial stages of the recommended plan. Presentation of immediate phase Top Priority Projects, their staging and cost implications, is found in Special Report No. 4 submitted August, 1977.

In total, Top Priority Projects constitute an estimated unescalated cost of LE 36.5 million over the next four-year period; Category I (institutional) and II (repair) items represent 5 percent and 67 percent of total cost, respectively, and are associated with ongoing annual improvements. Category III (new construction) items which comprise the remaining 28 percent of cost are included as part of recommended plan capital costs in the following section.

During this phase of activity, further detailed studies (e.g., industrial toxic waste assessments), and design of first stage Wastewater Master Plan projects would also occur. These would involve considerable efforts in financial planning, organizational modification for more effective implementation, new system control programs (sewer use ordinance, industrial regulations, monitoring, etc.), along with design and specifications for principal construction projects.

First Stage (1979-1983)

Major works constructed during the first stage (five-year program) would be predominantly in the eastern areas. The Ras el Soda (preliminary) Plant and Sidi Bishr Outfall would be constructed so as to be on-line by 1983. Sewer pipelines in Ras el Soda (not under Top Priority Projects) would be constructed, as well as a major pump station. Conveyance facilities from the coastal area of the Inner East Zone to the Ras el Soda Plant would also be constructed.

Lesser works proposed for construction during the first stage program include limited conveyance facilities in the Inner West area (expansion and improvement of Pump Station No. 2 system for tie-in to the new West Treatment Plant) and implementation of lateral sewer projects in Nouzha and portions of the Mex-Dekheila area. Continuation of street sewer construction projects and property connections is proposed in the West/Central and Eastern zones.

Land acquisitions for all principal facilities of the recommended plan would be made during this first stage. These would include lands for facilities at Ras el Soda, Mex-Dekheila, Lake Idku, Ameria, and possible expansion at Kait Bey. Programs for retention of land needed for all subsequent stage pump stations and major conveyance structures would also be established and implemented.

Second Stage (1984-1988)

Development emphasis during the second five-year stage would be in the Inner West and Central Zones, with construction of the Kait Bey treatment plant and submarine outfall, as well as expansion and subsequent tie-in of the West Treatment facility. Additional principal collectors would be constructed in the Inner West Zone.

Additional conveyance systems would also be constructed in the eastern areas during Stage II, which would tie-in the Siouf Keblia, Abu Soliman, and Smouha areas to the new Ras el Soda Treatment Plant. The Abu Kir Peninsula area would also be connected by construction of a principal force main and pump station. If the proposed Sadat City becomes a reality at the level of development envisioned, additional conveyance structures from the area would also be constructed to connect to the eastern zone sewerage system.

Treatment facilities of lesser magnitude would be constructed in outer areas of the city including an evaporation pond at Abu Kir Bay and waste stabilization ponds at West Lake Maryut (for Mex-Dekheila) and Ameria. Conveyance facilities would include completion of a collection system to the East Treatment Plant from the Nouzha area, an Abu Kir Industries main collector, pump station and force main, and principal sewers in the Mex-Dekheila area. The initial stage of an extensive sewer system for the proposed new City of Ameria would also be constructed during this time.

Third and Fourth Stages (1989-2000)

Further expansion of collection facilities that would permit service to new development and increased population in all sewerage zones would occur during the two latter six-year stages from 1989 through year 2000.

Although possibly less cost-effective, delayed construction of conveyance and treatment facilities may also occur during the third and fourth period. This will especially be the case for those areas such as Sadat City and Ameria which may be delayed in terms of growth if government funds remain limited or priorities for urban development continue to undergo change.

Significant delays in construction of inner area projects (those of the East and West/Central Zones) can mean major portions of Alexandria will not receive benefit from an adequate wastewater system for many years to come. From the standpoint of environment, continued and increasing pollution of both Lake Maryut and the city's beaches would be assured for another several decades. Major and costly interim measures would be involved in order to provide even a rudimentary level of sewer service to the expected additional new population of the area, until such facilities as proposed could be constructed. The consequences of a delayed construction program are normally greater cost over a longer period of time with postponed and often reduced benefit for an entire area.

8.4 Operation and Maintenance

Introduction

GOSSD-Alexandria has an ongoing operations and maintenance program administered by three departments: Sewer Maintenance, Mechanical and Electrical, and Water Pollution Control. Repair and extension of the existing sewerage system plus major addition of new collection and treatment facilities will place demands on these departments which will necessitate redefining and expanding their functions. Future needs are best expressed in terms of the principal functions. Organizational structure and proposals for improved management are dealt with in the following chapter.

Operations

This function involves operation of pump stations and treatment facilities in a continuous and effective manner. Operators of such facilities will in the future require a background in proper operating procedures and an understanding of the interdependence of all wastewater facilities in meeting the goals of the sewerage organization.

The recommended plan will not increase significantly the number of pump stations in the system, but it will place increased responsibility on pump station operators to develop more effective operating procedures. Pump station operators will be required to ensure that pump stations and power generators are operated as required for effective wastewater conveyance. Pump stations must be operated in a manner which will prevent surcharged sewer conditions while providing a steady flow to treatment facilities over a range of wastewater flow conditions. Procedures need to be developed for operations when one or more components is malfunctioning. Operators should be required to keep continuous pumping records.

The recommended plan will result in an expansion of the number and type of wastewater treatment facilities in service. In addition to upgraded secondary treatment operations at the East Plant, operating procedures must be developed for interim primary treatment at the West Plant, future preliminary treatment at three new facilities, anaerobic-aerobic treatment at two stabilization ponds, and evaporation pond control. Methods for disposal of grit, sludge, scum, and screenings must be outlined. Laboratory procedures must be developed to monitor performance of each facility and to refine operating techniques. The variety of treatment processes and operating procedures will necessitate an extensive training program for operators and laboratory staff. Investment in a highly qualified operations staff will ensure a good performance level at the proposed facilities. Personnel policies which minimize staff turnover should also be designed to protect the investment.

Maintenance

The recommended plan will require an expanded maintenance program for an extended wastewater collection/conveyance system and all mechanical and electrical equipment, in order that facilities function properly throughout their useful lives. Routine inspection of new and existing facilities will also be necessary to identify potential problems.

Sewer maintenance crews will be required to execute a routine maintenance plan designed to prevent interruption of sewer service. Emergency response procedures will be necessary for periodic sewer breaks and flooding problems. Additional capabilities for repair and replacement of sewers are required. Improved maintenance procedures, an expanded sewer maintenance staff and additional vehicles will be needed to service the enlarged sewer collection system. The Top Priority Projects sewer cleaning program is intended to alleviate the backlog of sewer clogging problems and to assist in the development of an effective preventive maintenance program. Waste collection programs are to be established for mazout, manure, toxic wastes, and septage, all of which are presently discharged to the sewer system.

Mechanical and electrical maintenance procedures are necessary for the improved pump stations, an expanded fleet of vehicles, and the various treatment facilities. Routine inspection and maintenance programs need to be carried out and procedures for effective service and repair should be developed.

Personnel Requirements

Operation and maintenance of the proposed facilities will require an expanded staff at GOSSD-Alexandria. Executive, administrative, and project development responsibilities will increase as described in Section 9.2 of the following chapter. Estimated staffing requirements which correspond to the recommended plan are shown in Table 8-3. Although the existing labor intensive operation and maintenance effort is expected to continue, training programs and more

TABLE 8-3

STAFFING REQUIREMENTS FOR THE RECOMMENDED PLAN

		Staffing Level[a]			
	Existing	Stage I	Stage II	Stage III	Stage IV
Executive					
General Director	8	18	21	24	27
Administration					
Personnel and Training	18	28	32	36	39
Budget and Finance	71	86	92	97	103
Legal	9	15	16	17	18
Public Services	7	14	16	18	20
Operation and Maintenance					
Water Pollution Control	109	270	450	500	520
Sewer Maintenance	648	760	1100	1250	1400
Mechanical and Electrical					
Pump Stations	397	440	460	470	470
Transportation	307	500	540	570	610
Sub-total (O+M)	1461	1970	2550	2790	3000
Project Development					
Design	7	14	16	18	20
Project Execution	52	65	68	71	73
TOTAL	1633	2210	2811	3071	3300

(a) Number of personnel required by the last year of each stage.

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modern equipment are proposed in order to improve productivity. Considered in the staffing plan are additional services provided by GOSSD-Alexandria, including waste collection programs, industrial wastes monitoring, and administrative services, which are described in the following chapter.

Qualifications required of an operations and maintenance staff will vary with level of responsibility. Operators will not face substantial changes in wastewater collection and treatment technology. However, more careful attention to proper operating procedures will be essential. Similarly, improved maintenance will rely heavily on adherence to routine maintenance and inspection procedures. The essential qualifications of GOSSD-Alexandria personnel should be personal motivation and willingness to learn. While individuals with experience in wastewater operations and maintenance will be few, a good training program with interested personnel should be adequate for future staffing needs. A summary of personnel needs by job title and qualifications is shown for year 2000 conditions in Table 8-4.

Equipment Requirements

An estimate of necessary repair and maintenance equipment, corresponding to the recommended plan, is shown in Table 8-5. Also shown is an estimate of the vehicle fleet requirements, including those vehicles to be used for separate waste collection programs. Through the Top Priority Projects sewer cleaning and training programs, operation and maintenance activities can be noticeably improved by use of modern equipment.

Recurring expenditures for laboratory equipment, spare parts, and replacements will increase throughout implementation of the recommended plan. These costs, as well as costs for fuel, electricity, and other supplies are estimated as a percentage of annual payroll costs, in order to develop operation and maintenance cost projections in the following section of the chapter.

8.5 Cost of the Master Plan

Capital Costs

Capital costs for the recommended Wastewater Master Plan program are based on construction cost, plus 30 percent allowance for contingencies and engineering (determined for individual proposed facilities), and land acquisitions needed for their construction. Costs, all of which are expressed in terms of

TABLE 8-4

ANTICIPATED STAFFING QUALIFICATIONS

Position	Approx. Number Required[a]	Qualifications
Administrators	25	Graduate of High Institute of Technology or holder of professional degree; senior level experience.
Engineers and Professional	200	University degree
Clerical Staff	200	Technical degree from trade school or clerical aptitude
Supervisors	75	Technical degree from trade school; senior level experience.
Technicians	300	Technical degree from trade school or mechanical experience
Skilled Laborers	900	Experience in equipment operation and maintenance
Unskilled Laborers	1600	No pre-qualifications
TOTAL	3300	

[a] Based on present staffing positions and qualifications with increases necessary for operation and maintenance of proposed facilities for year 2000.

TABLE 8-5

EQUIPMENT AND VEHICLE REQUIREMENTS FOR OPERATION OF THE RECOMMENDED PLAN[a]

Mechanical Shop

Gear Head Center Lathe	2
Precision Lathe	2
Metal Arc Welder	2
Gas Cutting Equipment	5
Vertical Drilling Press	2
Bench Drilling Press	5
Heat Treatment Furnace	2
Anvil	5
Pedestal Grinder	5
Bench Tool Grinder	10
Beam Crane/Winch	2
Air Compressor	2
Tables (making out)	5
Benches	30
Machine Tools(lot)	2
Hand Tools(fitters box)	40
Cabinets	40
Fire Extinguisher	40
First Aid Kit	15

Sewer Maintenance

Air Compressor(trailer mounted)	40
Dump Trailer	25
Cleaning Machine (trailer mounted)	20
Portable Pumps	40
Portable Generators	40
Portable Blowers	80
Portable Lights (lot)	100
Gas Testing Apparatus	50
Oxygen Masks	100
Ladders	80
Hand Tool Kit (lot)	200

Electrical Shop

Transformers (step down)	10
Battery Chargers	5
Temp. Test Equipment	5
Voltage Test Equipment	10
Voltage Meas. Equipment	10
Resistance Meas.Equipment	10
Vibration Meas. Equipment	5
Speed Indicators (strobe)	5
Power Analysis Equipment	2
Fire Extinguisher	40
Benches	25
Hand Tool Kit(electrical)	30
Cabinets	30
First Aid Kit	10

Garage/Warehouse

Air Compressor	3
Hydraulic Lift	5
Lubrication Equipment	2
Battery Charger	3
L.P.Steam Unit(portable)	2
Portable Hydraulic Jack	5
Tire Changer	2
Wheel Balance	2
Hand Tool Kit(mechanical)	25
Work Benches	20
Cabinets	15
Fire Extinguisher	50
First Aid Kit	20

Vehicle Fleet

Utility Trucks	60
Waste Collection Trucks[b]	90
Heavy Repair Trucks	30
Vacuum Tank Trucks	50
Pickup Trucks	25
Passenger Cars	40

[a] Based on year 2000 conditions.

[b] For mazout, manure, and toxic wastes collection programs.

mid-1977 price levels do not include escalation.

Costs for construction of all proposed facilities associated with the recommended plan are expressed in Tables 8-6 through 8-9 and summarized in Table 8-10. Included are the estimated costs of new works connected with the Top Priority Projects, most of which are located in the Outer East Zone at Ras el Soda. Costs are presented by sewer service area for the various stages of the recommended construction program.

Table 8-6 covers property connection costs which are expected to amount to LE 11.6 million over the entire planning period, corresponding to an estimated 92 800 new connections (Table 8-1) throughout Alexandria. Table 8-7 lists lateral sewer costs which are expected to amount to LE 147.24 million by year 2000. Of an estimated LE 17.73 million required during the first stage, LE 5.28 million is associated with street sewers for Top Priority Projects in the Ras el Soda area.

Conveyance costs are presented in Table 8-8. Approximately LE 102 million is estimated to be required for construction of the proposed collectors, pump stations and force mains; over 80 percent of which is associated with Stage II (1984-1988) projects. Treatment and disposal facility costs are presented in Table 8-9 for each principal element; total cost of site acquisition for the facilities is also expressed. Stage I facility construction is estimated to require LE 73 million while LE 86 million would be needed during Stage II for a total of LE 159 million over the entire period.

Capital costs for the entire Wastewater Master Plan construction program are summarized in Table 8-10. A total, capital cost of LE 447 million will be required over the planning period of 23 years. Of this amount, LE 36.5 million is associated with Top Priority Projects involving repairs and improvements to the existing system and provision of some new service between 1978 and 1981. The first stage construction program involves a cost of LE 102 million over a five-year period from 1979 to 1983. During the second stage of construction from 1984 to 1988, an additional LE 228 million is required for the proposed wastewater facilities. The subsequent two six-year stages entail a total cost of LE 80.6 million.

TABLE 8-6

COST OF PROPERTY CONNECTIONS

	Capital Cost, LE thousand Stage I (1979-1983)	Stage II (1984-1988)	Stage III&IV (1989-2000)	Total (1978-2000)
Abu Kir Peninsula	--	600	360	960
Outer East	1 105[a]	1 625	2 230	4 960
Inner East	270	250	520	1 040
Sub-total	1 375	2 475	3 110	6 960
Central	30	25	50	105
Inner West	30	75	90	195
Sub-total	60	100	140	300
Nouzha	40	400	60	500
Outer West	15	525	60	600
Abu Kir Bay Ind.	--	60	40	100
Ameria	--	1 110	2 030	3 140
Sub-total[b]	55	2 095	2 190	4 340
TOTAL	1 490	4 670	5 440	11 600

[a] Includes LE 190 000 for connections under Top Priority Projects (1978-1981).
[b] Outer areas of Alexandria which are yet undergoing major industrial and residential development.

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TABLE 8-7

COST OF LATERAL (STREET) SEWER SYSTEM

	Capital Cost, LE thousand Stage I (1979-1983)	Stage II (1984-1988)	Stage III&IV (1989-2000)	Total (1979-2000)
Abu Kir Peninsula	--	6 250	1 820	8 070
Outer East	10 400[a]	17 400	30 600	58 400
Inner East	845	4 325	8 630	13 800
Sub-total	11 245	27 975	41 050	80 270
Central	1 000	1 200	2 600	4 800
Inner West	1 905	4 275	4 890	11 070
Sub-total	2 905	5 475	7 490	15 870
Nouzha	1 725	4 375	700	6 800
Outer West	1 850	3 750	2 000	7 600
Abu Kir Bay Ind.	--	900	1 000	1 900
Ameria	--	11 800	23 000	34 800
Sub-total	3 575	20 825	26 700	51 100
TOTAL	17 725	54 275	75 240	147 240

[a] Includes LE 5280 thousand for Ras el Soda area under Top Priority Projects (1978-1981).

TABLE 8-8

COST OF CONVEYANCE FACILITIES[a]

	Capital Cost, LE thousand		
	Stage I (1979-1983)	Stage II (1984-1988)	Total (1978-2000)
Eastern[b]	11 870	34 455	46 325
Top Priority Projects[c]	3 930	--	3 930
West/Central	1 865	16 320	18 185
Nouzha	115	3 040	3 155
Outer West	295	7 570	7 865
Abu Kir Bay Industries	215	6 885	7 100
Ameria	595	14 820	15 415
TOTAL	18 885	83 090	101 975

(a) Includes all proposed collectors, pump stations and force mains.

(b) All conveyance facilities in Inner and Outer East Zones and Abu Kir Peninsula area.

(c) Proposed Top Priority Project conveyance facilities located in the Ras el Soda area of the Outer East Zone.

TABLE 8-9

COST OF TREATMENT AND DISPOSAL FACILITIES

Element	Capital Cost, LE thousand Stage I (1979-1983)	Stage II (1984-1988)	Total (1978-2000)
Ras el Soda Plant	13 875	--	13 875
Sidi Bishr Outfall	46 000	--	46 000
Sub-total	59 875	--	59 875
Kait Bey Plant	470[d]	11 970	12 440
Kait Bey Outfall	760[d]	39 240	40 000
West Treatment Plant[b]	420[d]	10 580	11 000
Sub-total	1 650	61 790	63 440
Outer West Ponds	245[d]	12 515	12 760
East Treatment Plant[a]	5[d]	145	150
Abu Kir Evaporation Pond	130[d]	6 710	6 840
Ameria	90[d]	4 780	4 870
Sub-total	470	24 150	24 620
Land Acquisition	11 300	--	11 300
TOTAL	73 295	85 940	159 235

(a) Improvements for secondary treatment of Nouzha area flows.

(b) Expansion of primary plant for preliminary treatment only of Inner West flows.

(c) Estimated cost of land acquisition for all major elements of the plan under proposed period of acquisition from 1979 to 1981.

(d) Design and specification for Stage II elements.

TABLE 8-10

SUMMARY OF CAPITAL COSTS

	Stage I (1979-1983)	Capital Cost, Stage II (1984-1988)	LE million Stage III&V (1989-2000)	Total (1978-2000)
East[a]	81.9	64.9	44.2	191.0
West/Central	7.8	83.7	7.6	99.1
Nouzha	1.9	8.0	0.7	10.6
Mex-Dekheila[b]	3.0	24.3	2.1	29.4
Abu Kir Bay Ind.	5.1	14.6	1.0	20.7
Ameria	2.3	32.5	25.0	59.8
Master Plan TOTAL	102.0	228.0	80.6	410.6
Top Priority Projects[c]	36.5	-	-	36.5
				447.1
		Component of Cost (Percent)		
Direct Foreign Exchange	(48)	(26)	(0)	(26)
Indirect Foreign Exchange	(9)	(25)	(30)	(22)
Local Currency	(43)	(49)	(70)	(52)
	(100)	(100)	(100)	(100)

[a] Inner and Outer East Zones plus Abu Kir Peninsula area.

[b] Outer West Zone.

[c] TPP costs occur between 1978 and 1981; LE 9.4 million is for new construction projects (Category III items) in the Ras el Soda area of the Outer East Zone, the remaining capital cost is associated with repair and general improvements (Category I and II items) within the existing system.

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Detailed and complete tabulations of recommended plan capital cost by element, year, service area, and component (direct foreign, indirect foreign and local currency) are presented in Appendix M. Also itemized in Volume III are specific construction costs for individual conveyance facilities, i.e., all collectors, force mains, and pump stations, principal components of treatment facilities, and further cost definition on land acquisitions.

Operational Costs

Operational costs for the recommended plan are based on annual cost necessary to operate and maintain the various components of the proposed wastewater system, inclusive of existing operations which are to be retained as part of the new program. Operational costs have been calculated using information presented in Section 8.3 on personnel, equipment and materials needed to effectively operate and maintain the future system.

Annual operation and maintenance costs, as shown in Table 8-11, are presented for the last year in each construction stage. Annual expenditure for operation and maintenance is expected to increase from a present value of LE 1.1 million to LE 1.8 million by 1983, when the first stage construction projects are completed and operating. Upon completion of second stage projects, operational expenditures are expected to increase to nearly LE 2.3 million per year. By the planning horizon (year 2000), annual operations and maintenance is expected to reach LE 2.7 million. Escalation has not been considered in developing these costs.

8.6 Economic Aspects of the Plan

Overall Economic Feasibility

The recommended program is determined to be economically feasible if its benefits are equal to or exceed its costs. The relationship of benefits to costs is generally determined by analyzing the project quantitatively; the costs of construction and continued operations and maintenance are compared with the gains that society may expect from the project.

Primarily, a sewerage project benefits health standards, by reducing the incidence of water and food-borne disease. In major urban areas, such as Alexandria, reduction of disease affects the lower income groups who are most likely to live in unsewered areas. Direct, financial benefits of the recom-

TABLE 8-11

OPERATIONAL COSTS OF THE RECOMMENDED PLAN

	Annual Operational Cost, LE thousand			
By:	Stage I 1983	Stage II 1988	Stage III 1994	Stage IV 2000
Salaries and Benefits[a]	1390	1750	1980	2110
Energy[b]	195	240	280	285
Materials and Repairs[c]	130	160	185	195
Other Expenditures[d]	80	100	115	120
TOTAL	1795	2250	2560	2710

[a] Salaries and benefits based on proposed staffing (Table 8-3) and a 50% increase in present average wage levels improved for staff qualifications.

[b] Includes fuel for vehicle fleet, standby power generation and electricity for pump stations and treatment plants.

[c] Includes all repairs , spare parts and other maintenance materials.

[d] Includes office supplies, intra-governmental services, and administrative expenses.

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mended program are, therefore, not readily quantifiable.

The overall economic impact of any proposed project may be categorized as follows: benefits which could be obtained from alternative use of the same resources (the opportunity cost); the potential dislocation due to competition for scarce resources, e.g., skilled construction labor, and the possible strain on the economy as a result of designating a large percentage of scarce capital resources to a specific region or program.

A project's economic viability and feasibility, therefore, must be considered in terms of both internal and external factors. Is it worthwhile, by itself, and does it represent a net contribution to the national and local economy ?

From a macroeconomic point of view, projects which improve the basic economic infrastructure have a multiplier effect. Every dollar spent for basic services/facilities is multiplied in terms of its overall impact on the economy as it either: (1) passes on a short term basis through the economic structure; or (2) becomes a basis for, or incentive to, further investment.

There has been little available research regarding the short term multiplier effect of investment in sewerage facilities. Where a considerable portion of investment is exogenous, however, as is the case for the recommended wastewater plan projects, there is some evidence that infusion of capital produces multipliers in excess of two. That is, each unit of investment can be expected, over time, to increase gross local product by two additional units. While such an increase is a temporary phenomenon in the case of each investment unit, the magnitude and long term nature of the proposed plan schedule make this potential multiplier an important element of the economy for the Alexandria region. The result is both beneficial and detrimental. It is beneficial in that there would be long term additions to personal income as employment opportunities increased, demand for goods and services grew, and increased availability of funds for investment occurred. However, possibly excessive demand for scarce goods and services might also result in short term inflationary pressures. These would tend to moderate in time as the economy adjusted to the expanded demand.

Long term investment-inducing impacts of the recommended plan are also difficult to quantify. The existence of adequate water and sewerage facilities is often a major criterion in selecting an industrial plant location because of the obvious connection between these facilities, industrial process requirements, and worker health and productivity. Alexandria possesses most, if not all, of the other necessary infrastructure, e.g., power, labor supply, transportation, ready access to markets, to attract industry. Present inadequacy of the wastewater system may, therefore, be one of the principal deterrents to new large-scale investment.

Large construction projects, such as those envisioned in the Wastewater Master Plan, are directly and indirectly linked to other sectors of the economy. For example, such projects require indigenous raw materials and manufactured products. In the latter case, the demand produced for concrete pipe might induce investment in additional production facilities over time. Although less likely, investment in electrical switchgear, motors, and other more complex equipment might also be induced. The short term need for skilled construction and operations workers will, in all probability, affect the available supply of such workers. This will cause temporary shortages, but in the long run create a larger pool of laborers with these basic skills.

Cost Benefit Analysis

Because of the difficulty of identifying specific benefits attributable to each of the various elements of the overall plan, and because of the time required to attain general benefits, economic feasibility has been evaluated for the entire program including Top Priority Projects, through year 2000 and operation (at year 2000 levels) to the year 2010.

Benefits. Benefits include both those which accrue directly to users of the system and those which produce an indirect improvement in quality of life within the community. Benefits may also be categorized as quantifiable or non-quantifiable, depending on the availability of data and/or whether the improvement is viewed subjectively or objectively. While quantification of benefits can often be a convincing way of justifying a project, these benefits are not necessarily the most important to be obtained. In the case of wastewater systems, some of the most important benefits cannot be measured directly.

Principal quantifiable benefits that are to be derived from the recommended plan include: (1) benefit to new users to whom service is to be made available and who thereby avoid the costs of a private disposal system; (2) benefit to present residential users as a result of the reduced incidence of sewage backups onto or adjacent to their property; (3) benefit to community at large in terms of increased value of land served by the expanded sewerage system; (4) benefit to industry of the availability of a functioning collection, treatment, and disposal system, the avoindance of the direct costs of constructing a private system, and avoidance of the indirect nuisance costs of stoppages; (5) recreational benefit to present and future beach users brought about by eliminating nearby sewage overflows; and (6) economic value of reduced labor force absenteeism caused by wastewater-related illnesses. These benefits have been estimated as follows:

1. New user benefit. It is assumed that value to new users is equal to approximate connection cost (LE 150), based on projections in Table 8-1 and 8-6
2. Residential/commercial user benefit. Residential/commercial user benefit is based on projected Sewer Maintenance Department expenditures of GOSSD-Alexandria.
3. Land value benefit. Estimated benefits were based on a 10 percent increase in land value to newly sewered areas within the city, and a 20 percent increase in land value to newly sewered areas outside the city.
4. Industrial user benefit. Before 1961, GOSSD-Alexandria imposed a sewer user charge of LE $0.003/m^3$ of water consumed by industrial users. Benefit is calculated on this charge infalted by increase in Consumer Price Index and on current and projected industrial water usage as shown in Table 4-8.
5. Recreational user benefit. There are an estimated one million visitors to Alexandria during the summer season; a number of which is anticipated to double by year 2000. Assuming an average stay per individual of 10 days, this is equal to 10 million visitor days at present, increasing to 20 million visitor days by year 2000. Based on present known daily expenditures, the amount spent by visitors who are attracted by more sanitary beaches is calculated using average local expenditures for other Middle Eastern (primarily Arab), European, and Egyptian visitors. A value is also determined

for on-beach outlays, e.g., tables, umberellas, and food.

6. Lessened absenteeism and health costs benefit. It has been assumed that labor force members lose five working days a year due to wastewater-related illnesses. Assuming an urban mean household income of LE 500 in 1976 increasing at 2 percent per annum in real terms, the estimated days of illness are gradually reduced 75 percent as the proposed sewerage system comes on line. Labor force increases assumed for the analysis are consistent with existing statistics and Alexandria population projections.

The primary unquantifiable benefit is associated with general public health. Alexandria's poor environmental health conditions have been discussed in Chapter 3. An undefined, but obviously substantial part of these conditions is attributable to the lack of a sewerage system for a significant portion of the pupulation and unsatisfactory conveyance, treatment, and disposal facilities within the existing system. Alleviation of these conditions can be expected to result in a generally higher level of public health with consequent improvement in the quality of life in Alexandria.

Other unquantifiable benefits include:

1. greater ability to attract industrial and commercial investment as a result of improved health conditions and the availability of public sewerage for their wastewaters,
2. multiplier effects of investment and increased operation and maintenance costs for proposed wastewater facilities,
3. linkages to other sectors of the national economy which may enhance local and national industrial capability and capacity, and
4. increased attractiveness of the Alexandria region for development of tourism.

Costs. Costs used are those determined for financial planning with certain adjustments. The various cost items (construction, land, operation and maintenance, administration, and engineering) are best estimated at constant 1977 prices. Although they include contingency allowances necessary for budgeting purposes, the values do not include payments such as financing duties or taxes because such costs do not represent actual utilization of resources.

In addition, adjustments are made to certain costs, making them more representative or real costs under free market conditions. This is done by assigning shadow costs. For cost/benefit analysis, consideration has been given to assigning certain shadow costs to capital, foreign currency, labor and construction materials, and electricity. Although firm quantification is never possible, it appears that economic conditions are such that the following prices can be used for preliminary economic decision making:

1. Capital. Given Egypt's current capital shortage, projects with lower initial costs are relatively more desirable. Therefore, use of a reasonably high discount rate appears to be advisable. The evaluation is based upon discount rates of 8, 10, and 15 percent.
2. Foreign Currency. For purposes of economic evaluation, the "parallel" exchange rate, which is currently 70 piasters to the US dollar, has been used. A sensitivity analysis assuming a 10 percent lower value (77 pt = US $1) has also been performed.
3. Construction Labor. Current wages paid in Alexandria for unskilled labor reflect a competitive labor market. This and a shortage of skilled construction workers, which also creates competitive market situations, suggest that no adjustment to labor costs is required in economic evaluation.
4. Materials and Supplies. As with other project input costs, non-competitive market price distortions should be eliminated when assigning values to construction materials and supplies (electricity, fuels, etc.). Currently, prices of many basic construction materials such as steel, cement, and lumber are government regulated. The controlled prices are below actual cost of production. In order to arrive at a value more reflective of the actual cost to Egypt, world market prices (CIF) of imported construction materials have been used. In-country transport costs have then been added to the CIF price to arrive at a total cost of materials. This procedure was followed for all items. Domestic prices of materials have been used for non-price controlled items, e.g., sand and gravel, and for those which represent a small share of total construction costs. As power is also regulated, electricity costs are not reflective of true costs for production. An estimated cost of 2.5 pt/kWh has been used in economic evaluations.

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Comparison of Costs and Benefits. A benefit/cost analysis has been performed at three different discount rates with the results subjected to sensitivity analysis. An estimate of the internal rates of return based on the resulting benefit/cost ratios has also been made.

1. Discounting Rate. The current rate of interest in Egypt for government-backed loans is 8.5 percent. Indications are that foreign loans for projects such as those proposed in the recommended plan are considered reasonably acceptable at discount rates of 10 percent and are fully acceptable at discount rates of 15 percent or more. For these reasons, discount rates of 8, 10 and 15 percent were selected.
2. Economic Life of New Facilities. The economic lives of proposed new facilities are estimated to be:

Sewers	50 years (no recovery)
Structures	40 years
Equipment	20 years
Land	No depreciation

Based on the best estimate of benefits and costs as shown in Table 8-12, the benefit-cost ratio for the recommended master plan exceeds unity for discount rates of 8 and 10 percent and falls slightly below unit at 15 percent. The internal rate of return (the discount rate at which benefits are equal to costs) is approximately 13 percent. Sensitivity checks on those variables of large magnitude generally support the best estimate of the benefit-cost ratios. While these ratios may fall below unity within the expected range of variability of the estimated benefits and costs, the existence of significant but unquantifiable additional benefits must be credited to the project.

The internal rates of return associated with the sensitivity analyses presented in Table 8-12 ranged from 9 to 16 percent. Assuming the extreme care of 25 percent decreases in recreation and land value benefits and a 10 percent increase in project costs, the internal rate of return is approximately 6 percent. Conversely, assuming a 25 percent increase in land value and recreation benefits and a 10 percent reduction in project costs, the internal rate of return is greater than 20 percent.

TABLE 8-12

SUMMARY OF COST/BENEFIT ANALYSIS

	Present Worth. LE Million		
at Discount Rate =	8 percent	10 percent	15 percent
Benefits:			
New users	6.5	5.3	3.4
Current users	3.1	2.4	1.3
Land value	117.9	101.6	74.4
Industry	9.0	6.8	3.8
Recreation	117.9	94.6	59.9
Absenteeism	59.1	43.8	22.8
TOTAL	313.5	254.5	165.6
TOTAL PROJECT COST[a]	271.5	237.8	176.1
at Discount Rate =	8 percent	10 percent	15 percent
Benefit to Cost Ratios			
Best Estimate	1.15	1.07	0.94
Sensitivity			
10% reduction in Land value	1.11	1.03	0.90
25% reduction in Land value	1.05	0.96	0.83
10% increase in Land value	1.19	1.11	0.98
25% increase in Land value	1.26	1.18	1.05
10% reduction in Recreation	1.11	1.03	0.91
25% reduction in Recreation	1.05	0.97	0.85
10% increase in Recreation	1.19	1.11	0.97
25% increase in Recreation	1.26	1.17	1.02
10% reduction in Project Cost	1.28	1.19	1.04
10% increase in Project Cost	1.05	0.97	0.85

(a) Capital plus operations and maintenance costs of the complete recommended plan including Top Priority Projects.

The calculated benefit/cost ratios indicate that the recommended master plan is economically feasible and should be implemented rapidly in order that benefits can be derived from the projects at the earliest possible time.

8.7 Environmental Evaluation

From an environmental perspective, the recommended Master Plan offers many benefits to the Alexandria region. Apart from the environmental health improvements noted elsewhere, the most significant environmental benefits will be improvement of the urban and suburban environments by removal of human wastes and the elimination of raw domestic and industrial wastewater discharges to Lake Maryut. The reduction in waste loads to the lake should improve both the value of the lake as a fishery, and the quality of the Mex pump station's discharge to the Mediterranean Sea.

The present pollution of Abu Kir Bay will also be greatly reduced by the construction of an evaporation pond for Abu Kir's industrial wastewater, although the exact location of the pond must be carefully selected to minimize damage to Lake Idku's fishery. The modest physical property requirements of treatment facilities in central Alexandria should minimize the impact upon land use of the recommended plan.

Properly designed ocean outfalls for wastewater disposal, as proposed in this plan, can have minimal environmental consequences. The large dilution of wastes immediately after discharge is a natural and reliable "treatment process" to reduce pollutant concentrations not offered by alternative means of disposal. Pre-treatment will minimize visible effects due to flotable substances. Initial and subsequent dilution, combined with rapid bacterial die-off, can reduce or eliminate the need for effluent chlorination to protect Alexandria's beaches. The ocean discharge of Alexandria's wastewater could, in fact, have a significant beneficial impact by supplying nitrogen and phosphorus to the nutrient-poor waters of the Mediterranean, possibly improving the area's marine fisheries.

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The most important environmental issue associated with the recommended plan is the effective control of toxic industrial wastes before their discharge to the sewers. If an effective sewer-use law is implemented and enforced as called for in the plan, then the Mediterranean is an environmentally acceptable receiving water for Alexandria's non-toxic wastes. If, however, toxics are not controlled at their source, the environmental consequences of their release to the Mediterranean could be irreparable, no matter by what means the industrial discharges find their way to the sea.

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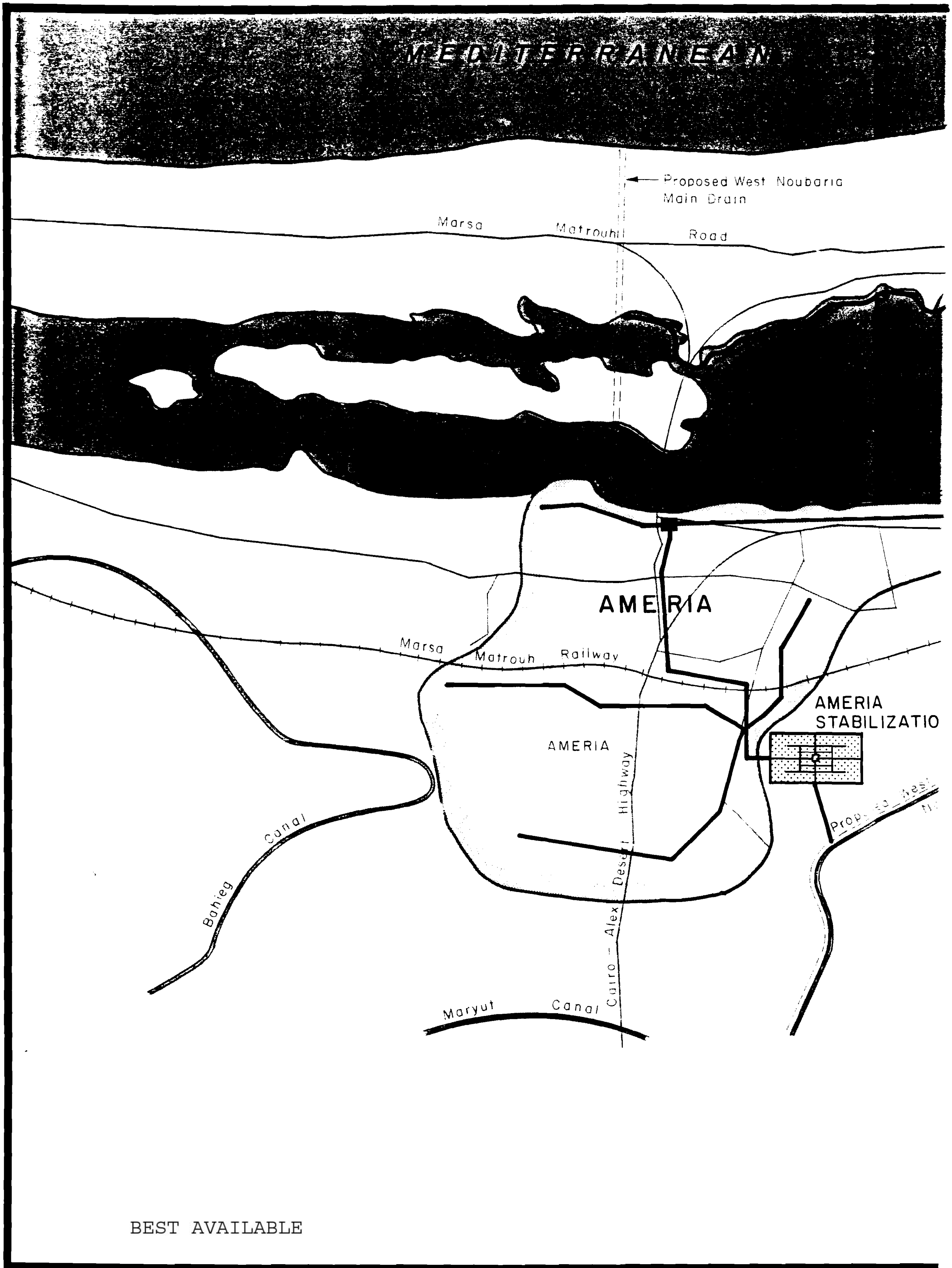

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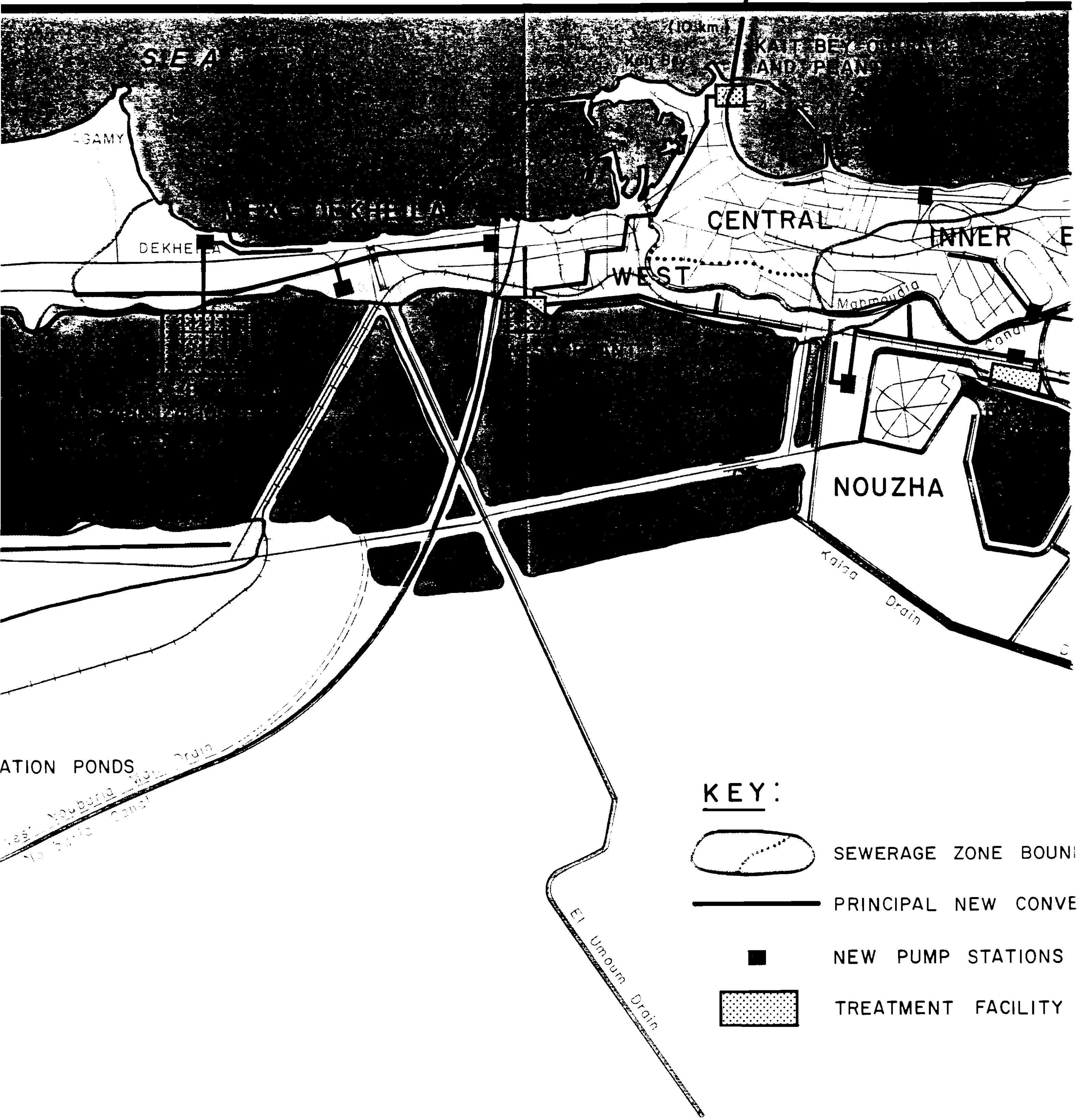

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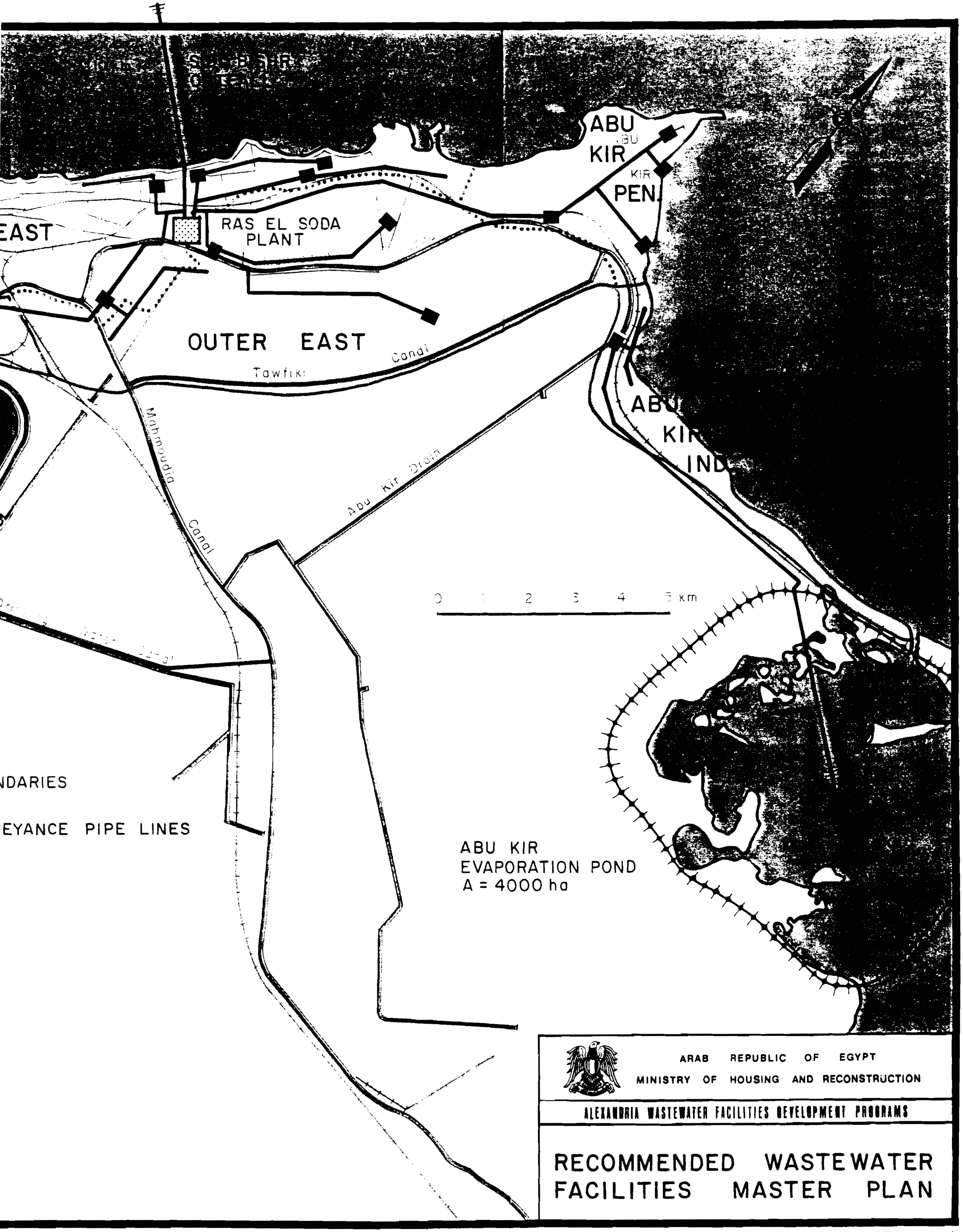
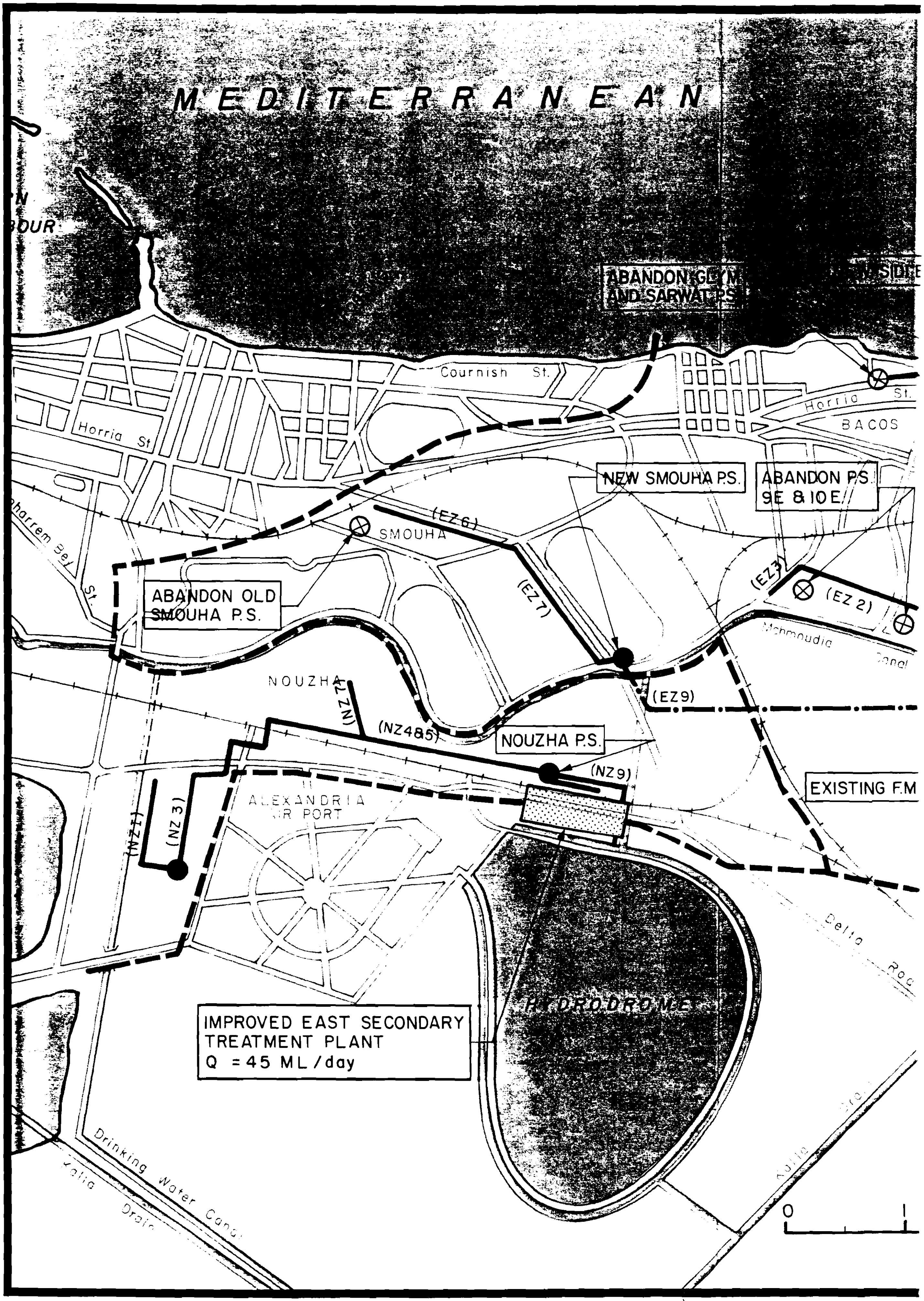

ABU
KIR
PEN.
RAS EL SODA
PLANT
EAST
OUTER EAST
Tawfiki Canal
Mahmoudia Canal
Abu Kir Drain
0 1 2 3 4 5 km
NDARIES
EYANCE PIPE LINES
ABU KIR
EVAPORATION POND
A = 4000 ha
ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION
ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS
RECOMMENDED WASTEWATER
FACILITIES MASTER PLAN

FIGURE 8-1

BEST AVAILABLE



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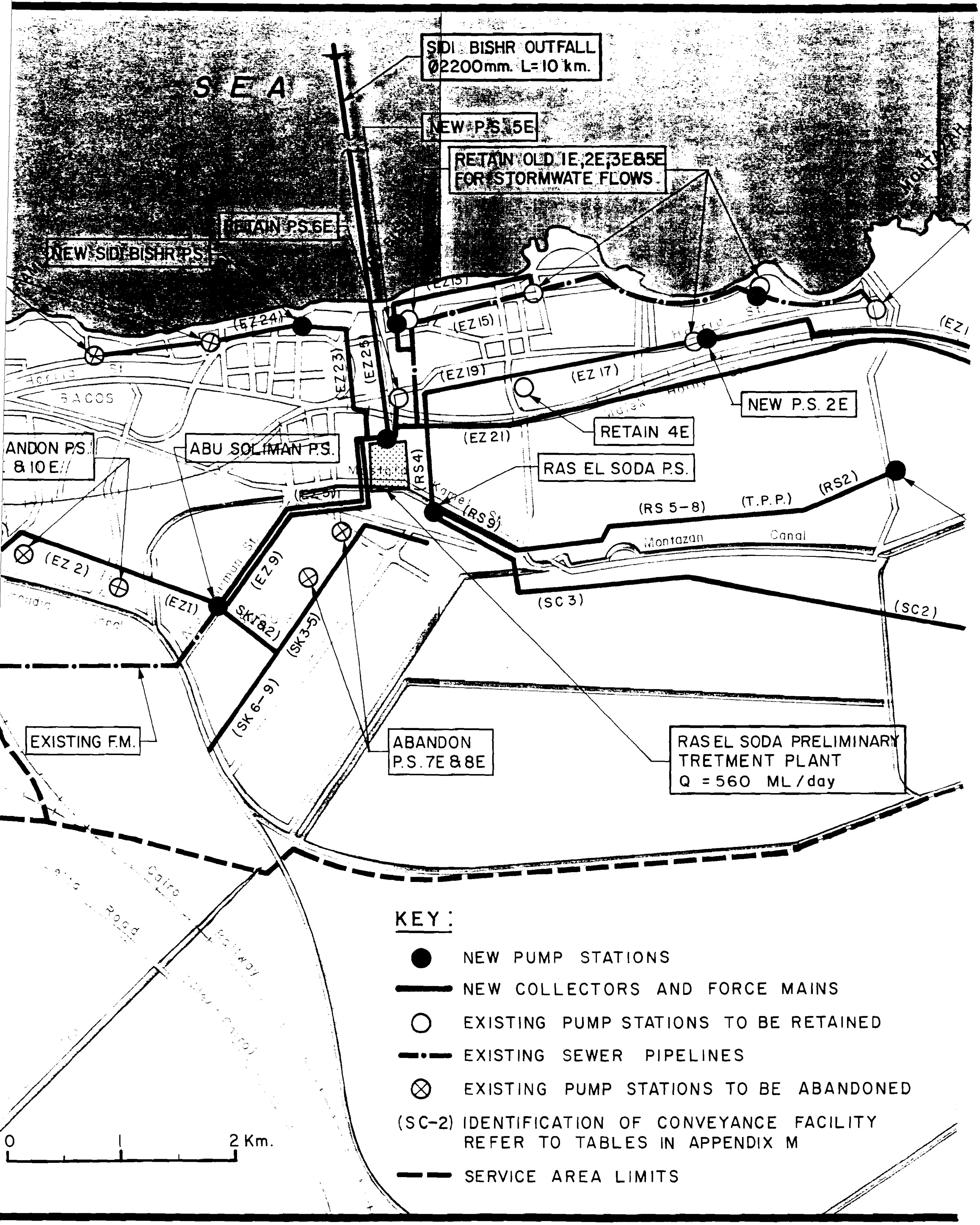

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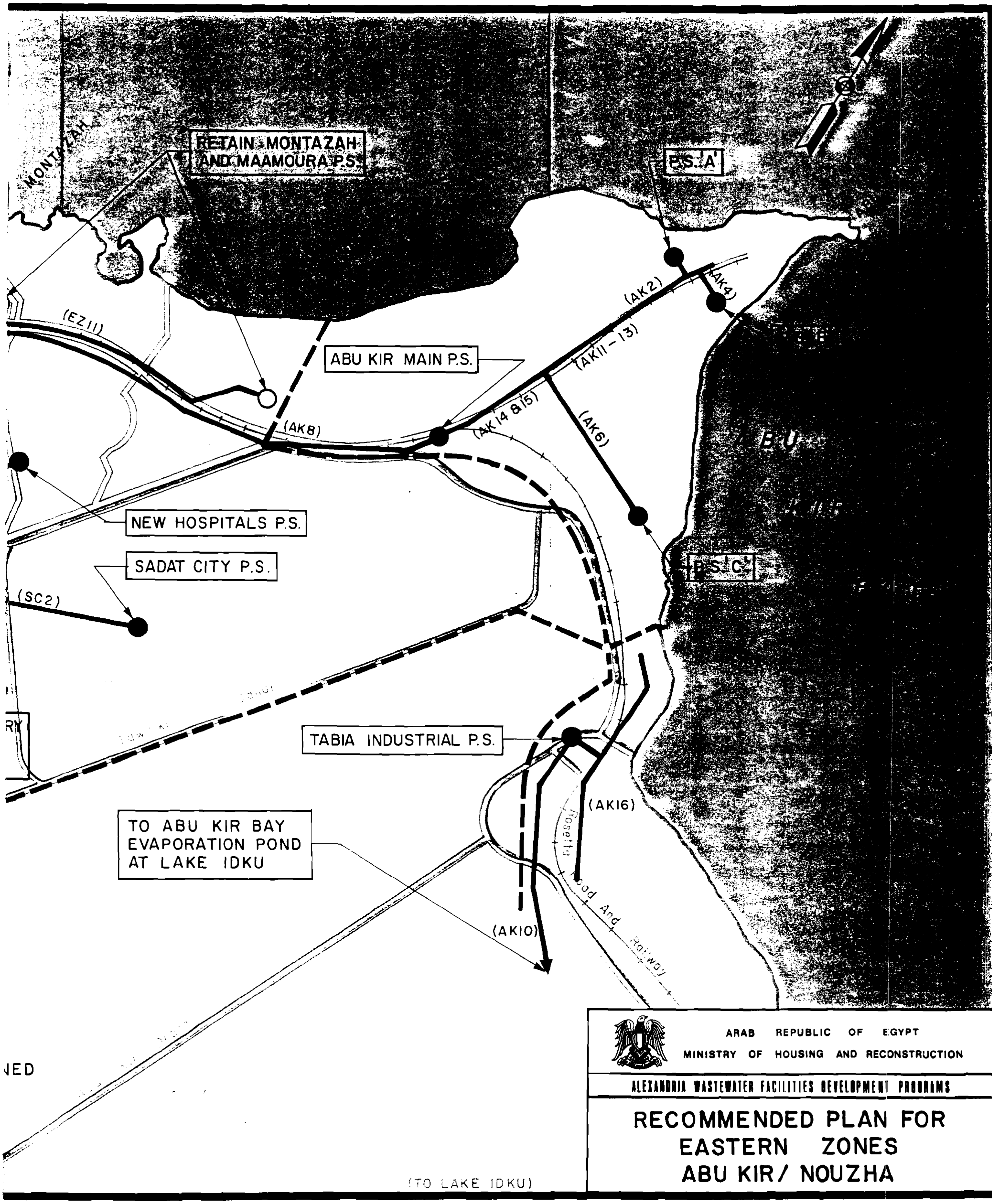
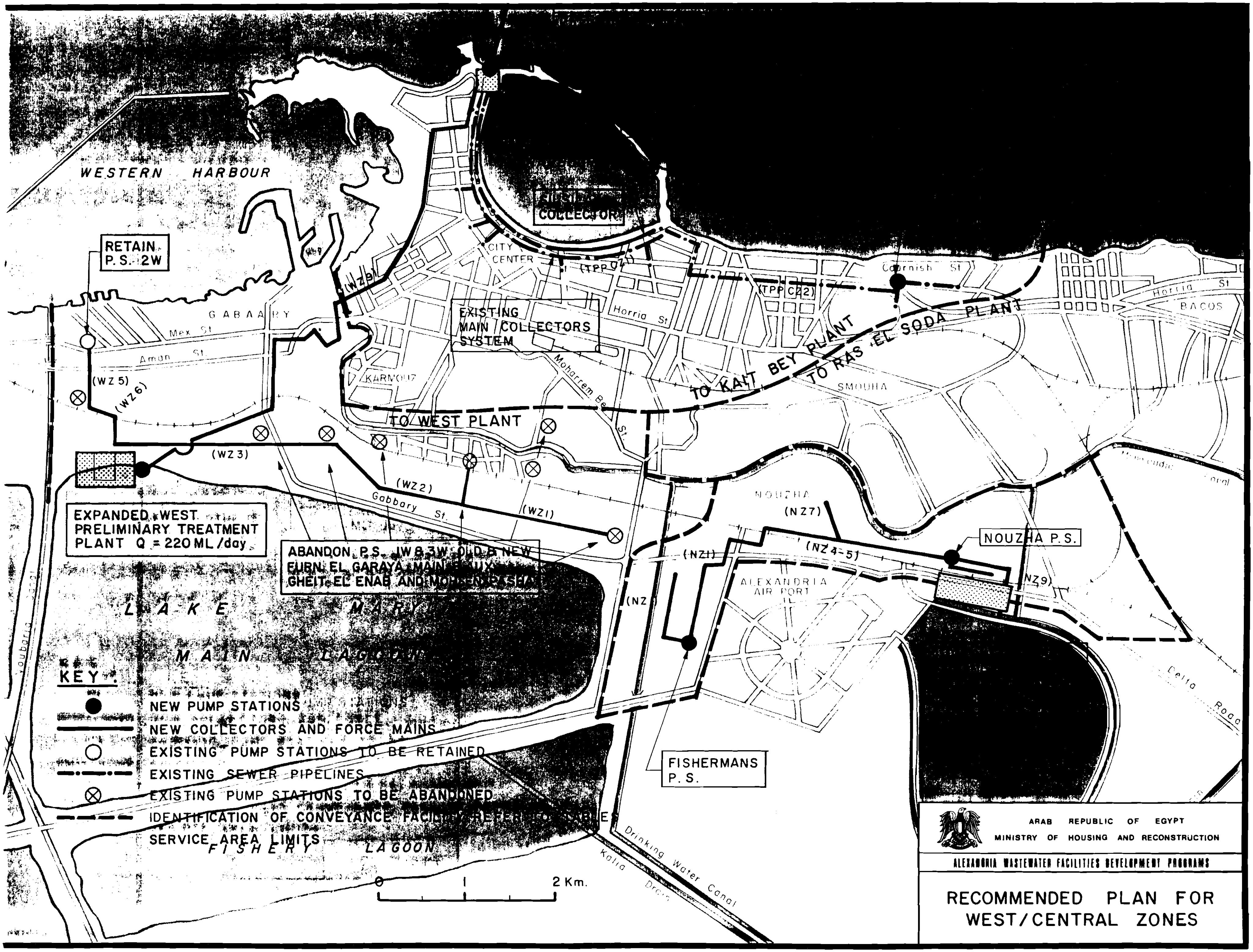


ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

RECOMMENDED PLAN FOR EASTERN ZONES ABU KIR/ NOUZHA

FIGURE 8-2



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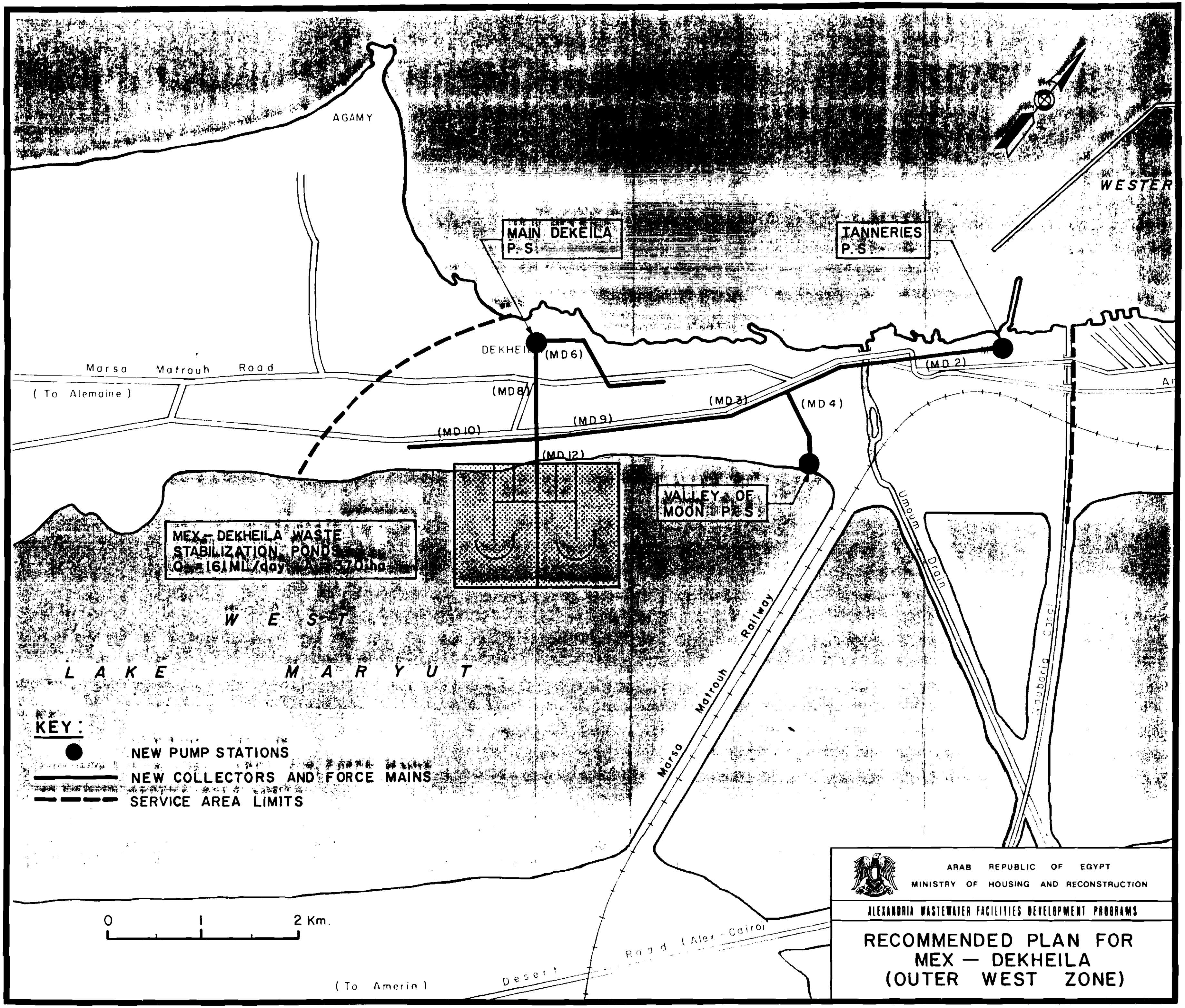

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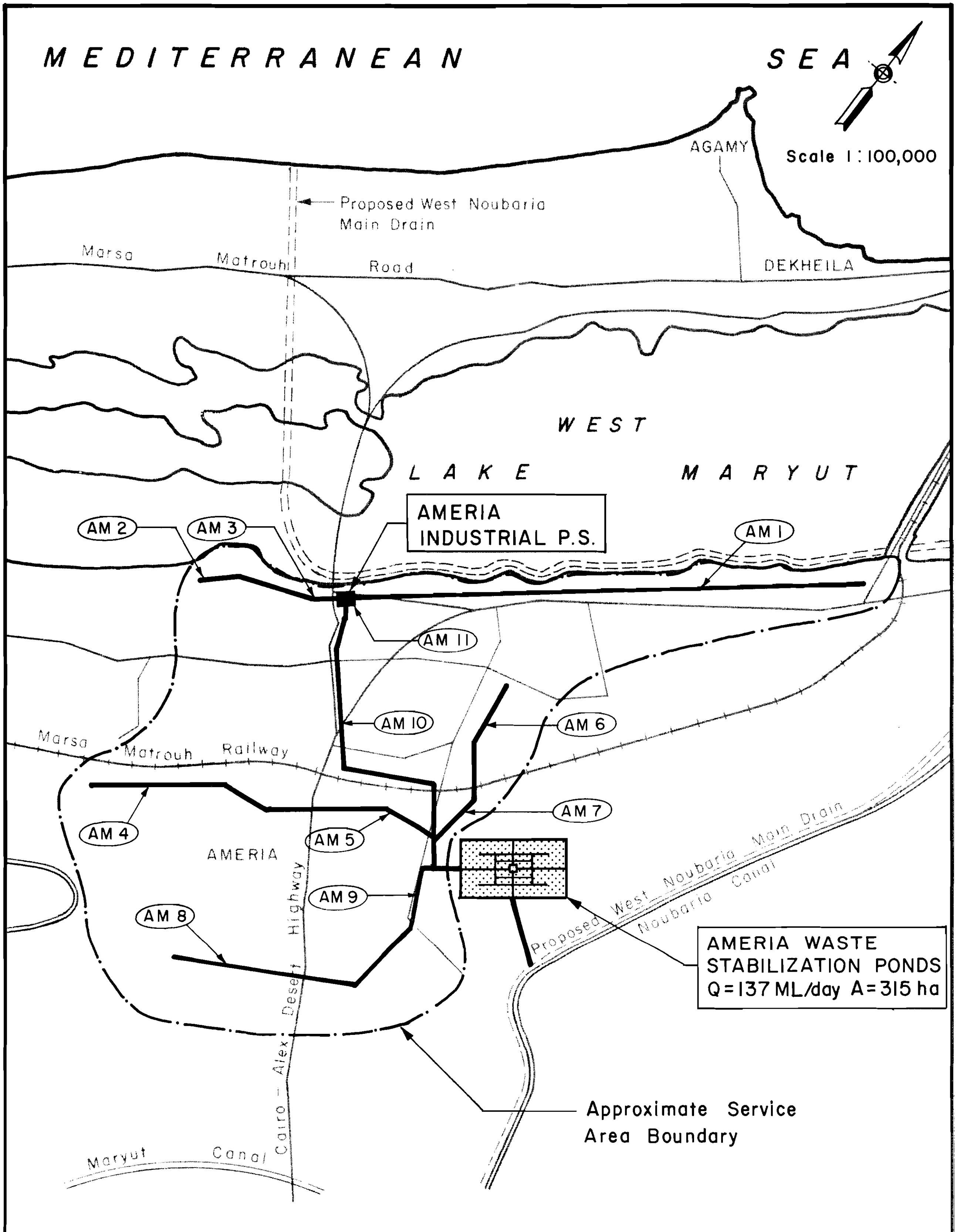

ARAB REPUBLIC OF EGYPT
MINISTRY OF HOUSING AND RECONSTRUCTION

ALEXANDRIA WASTEWATER FACILITIES DEVELOPMENT PROGRAMS

RECOMMENDED PLAN FOR AMERIA ZONE

FIGURE 8-5

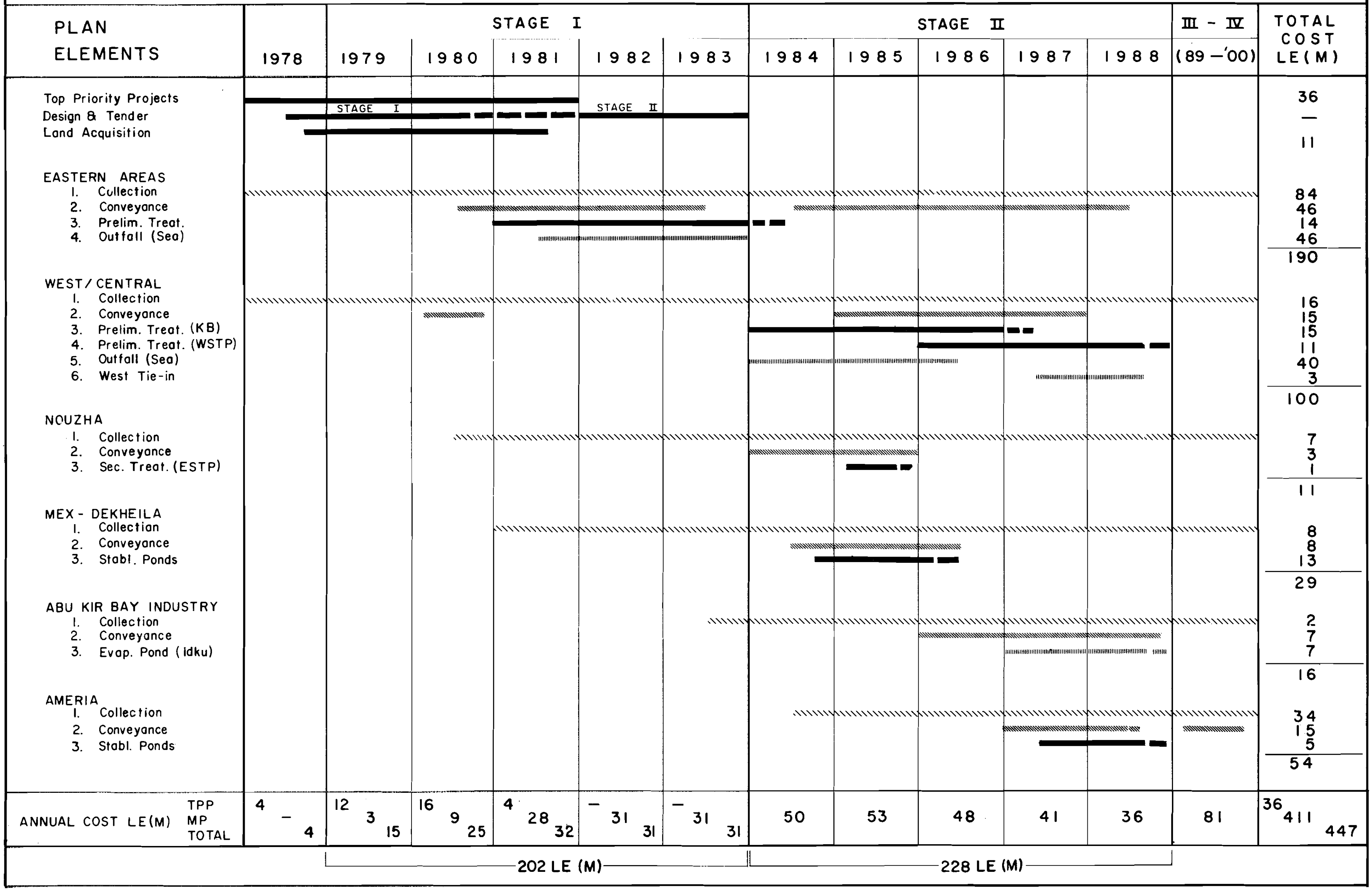

FIGURE 8-6 MASTER PLAN CONSTRUCTION STAGING PROGRAM

FIGURE 8-6

CHAPTER 9

PROJECT IMPLEMENTATION

9.1 Management Improvement

General

Implementation of the recommended Wastewater Master Plan will require strengthening the organization and management systems of GOSSD-Alexandria. Specific management improvements are proposed for each department, and recommendations for the overall organization of GOSSD-Alexandria are presented. Most of the recommended improvements are proposed to take place in the near term, while the others may appropriately be postponed until commencement of later stages of the Wastewater Master Plan program.

Overall Organization

The Wastewater Master Plan will increase organizational responsibilities in three major areas: project management, funds management, and internal administration. The recommended organization, depicted on Figure 9-1, addresses these needs through the establishment of a Project Monitoring Unit, an Internal Audit Unit, and the position of Deputy General Director. No necessary additional structural changes are proposed; rather, additional functions are assigned to the existing departments as summarized below:

Function	Proposed Organizational Location
Training and Staff Development	Personnel and Training
Sewer Use Regulation Enforcement	Legal
Central Records and Management Information System	Public Service
Collection Services for Mazout, Manure, Septage, and Industrial Wastes	Sewer Maintenance
Operation and Maintenance of All Treatment Facilities	Water Pollution Control
Industrial Wastewater Monitoring	Water Pollution Control

Executive Direction

Implementation of the recommended Master Plan through GOSSD-Alexandria requires continuing executive direction that must include a full-time General Director. Also, GOSSD-Alexandria should have:

1. Clearly defined objectives. The organization presently appears to have no development or operating targets. For example, there is no plan to improve public awareness of the proper use of a wastewater system.
2. A Deputy Director. Even with a full-time General Director, the span of control is too great to permit effective management. A Deputy Director is needed to assume the more routine managerial matters and to assist the General Director as he may direct in other matters. Decisions on how best to utilize the services of a deputy would depend in part on the managerial strengths of both the director and his deputy, and the preferences of the General Director. At this time, however, it would seem appropriate to assign supervision of the four supporting staff administrative departments to a Deputy Director, thereby allowing the General Director to concentrate on the departments concerned with project development, operations, and maintenance.
3. Assignment of responsibility to each department head for the management and operating functions under his supervision. This should be a priority task of the General Director, with the aim of ensuring direct accountability to him for the effective performance of all required operations and development tasks.

Administration

Personnel and Training Department. The duties of the present Personnel Department should be expanded to include all staffing and training development responsibilities for GOSSD-Alexandria. Reflecting these changes, it should become the Personnel and Training Department.

An effective staff development program requires a staffing plan which includes forecasts of the type and numbers of employees needed in each unit of the organization. A preliminary staffing plan for GOSSD-Alexandria was shown previously in Table 8-3. This plan includes estimates of staffing increases required to bring existing staffing in all departments up to a level needed to handle additional functions and to operate and maintain an expanding utility system.

Training requirements should be determined by systematically reviewing the capabilities of existing staff in comparison with job requirements.

Training will be necessary for employees as new systems and procedures are implemented. A general policy of upgrading employee skills is needed because GOSSD-Alexandria is limited in its ability to attract and retain individuals that already possess appropriate training and experience. Employees possessing aptitudes for the work to be done must be recruited, and then the necessary skills must be developed among them through formal and informal training programs. Examples of the types of training needed within GOSSD are presented in Table 9-1.

Both Tables 8-3 and 9-1 are examples of quantitative and qualitative aspects of staff development planning that must be undertaken if GOSSD-Alexandria is to improve its overall level of performance. Maintaining and updating of staffing schedules should be assigned as a full-time duty to the Personnel and Training Department.

Low levels of compensation and lack of incentives in the personnel system will be persistent barriers to the implementation of an effective staff development program. No significant changes are expected in the near term. GOSSD should, therefore, find innovative approaches to improving the attractiveness of employment. Some possible approaches include:

- Developing and implementing occupational health and safety programs; acquiring safety devices for laborers working under hazardous conditions; conducting health and safety training sessions; providing bathing facilities for the operation and maintenance staffs of the organization.
- Aggressively seeking funding for meaningful bonus provisions for employees with the bonus system based solely on performance and contribution to organizational objectives.
- Carefully reviewing the status of each employee to assure that every allowable benefit and allowance is received.
- Carefully reviewing allowable employee welfare programs to determine whether new programs of interest and economic benefit to employees can be established. A possibility would be the provision of transportation services to employees.
- Reviewing the discretionary benefits such as food and clothing allowances, and aggressively seeking to increase them wherever possible.
- Providing tuition assistance with time off from work for further

TABLE 9-1

RECOMMENDED TRAINING REQUIREMENTS

Departments	Trainees	Approx. Number	Qualifications for Training	Subject Area	Training Period	Methodology	Location
Sewer Maintenance Department	All personnel	600	None	Health and safety practices in sewerage maintenance	Continuing	Demonstration during TPP sewer cleaning project	On-the -job
Mechanical and Electrical Department	Operation Supervisors	20	Mechanical aptitude and literacy	Operation of pump stations	1 week	Study of system and detailed manual review	Classroom and on-the-job
	Operators	200			Continuing	Training in operating procedures	On-the-job
Project Execution Department	Drafting section	5	Secondary or Technical School	Drafting	2 hr per day for 6 weeks	Introduction to basic engineering drawing	Classroom and on-the-job
Design Department	All personnel	5	Basic engineering education	Design of wastewater collection and pumping facilities	Continuing	Enrollment in specific applicable design courses; training as counterparts to consultants	University of Alexandria and on-the-job
Project Execution Department	All personnel	20	Basic engineering education	Project Management	Continuing	Close participation with consultants in managing Master Plan project scheduling, cost control and inspection	Classroom and on-the-job
	Project Monitoring Specialist (proposed)	1					
Water Pollution Control Department				Wastewater monitoring			
	Laboratory Manager	1	Graduate School (chemistry)		3 weeks	Study of quality control, record keeping, lab safety, industrial operations liaison, specifics of industrial wastewater analysis	Lab facilities at East Treatment Plant
	Laboratory technicians	2	Technical School (basic chemistry)		3 weeks	Study of lab techniques for wastewater analysis, quality control, record keeping, lab safety	Lab facilities at East Treatment Plant
	Field technicians	10	Technical School		4 weeks	Study of sampling techniques, record keeping, job safety	On-the-job at selected industrial locations

education (this type of benefit should be tied to an employment contract guaranteeing a minimum period of service with GOSSD-Alexandria after completion of training).

Budget and Finance Department. Financial systems should be reviewed to assure that proper capital project accounting systems are in place prior to the initiation of major development projects. The project accounting system should include appropriate measures for capitalizing items. Appropriate asset records must be generated and incorporated into the accounting system along with the associated depreciation accounting systems. Cost accounting procedures should also be developed and implemented after review and restructuring of GOSSD-Alexandria have been completed.

If the sewerage operations are to be supported by revenues from sewer use charges, ledger entries must be established for cash receipts and accounts receivable. Also, a system of billing and collection must be designed and implemented after the rate structure is determined.

An auditing procedure should be established for the GOSSD-Alexandria organization to provide continuing checks on the propriety of transactions, to assess the validity of reported data, to provide an overview of the financial situation, and to initiate improvements and refinements in the financial systems. The internal audit unit should be established under the supervision of GOSSD-Cairo, but also provide relevant financial information to the General Director of GOSSD-Alexandria. External auditing by the Ministry of Finance and the Central Agency for Auditing will continue to provide an independent appraisal of the financial activities of the entire organization.

Legal Department. The Legal Department should work with the Water Pollution Control and Sewer Maintenance Departments in the comprehensive waste discharge monitoring effort that will be necessary to eliminate violations of the sewer use ordinance. The legal staff should be responsible for notifying industrial customers of waste discharge violations, developing an acceptable time schedule for industries to comply with the sewer use regulations, and, where necessary, initiating legal proceedings to collect fines and to limit further waste discharge violations. Meetings of representatives from major industries and the Alexandria Governorate with the Legal Department would aid in the enforcement of sewer use regulations by informing the appropriate officials of waste discharge violations and the intention of GOSSD-Alexandria to eliminate these violations.

Public Services Department. In addition to its present responsibilities, the Public Services Department is best suited to establish and maintain management information and central records systems. The management information system may be implemented in the following sequence:

- Listing all data and reports being generated in the organization.
- Having the listing analyzed by the General Director and department heads to determine which data and reports should continue to be generated.
- Identifying needs for additional data or reports.
- Developing the data base and the formats for the needed additional reports.

Responsibility for timely completion and submission of requested data and reports should be assigned to specific individuals. A central file should be established in the Public Services Department with an employee assigned to maintain the records system and to follow up on delinquent report submissions. This central data file, available to all departments, will provide the basic inputs for information specifically desired by management.

Operations and Maintenance

Sewer Maintenance Department. Proper maintenance of the wastewater collection system is of vital importance in improving its effectiveness and contributing to public health. The principal areas of proposed improvements in the department are outlined below:

- Maintenance of existing sewers must be reduced by eliminating surcharged sewer conditions. Improved coordination with the Mechanical and Electrical Department Staff which tend to operate pump stations only after gravity sewers become surcharged, should reduce deposits of solids and clogging of sewers.
- Sewer cleaning procedures must be modernized and upgraded. The system-wide cleaning contract recommended in the Top Priority Projects includes an evaluation of the most appropriate techniques for maintenance of the sewerage system on a continuing basis, the design of a staffing plan, and the preparation of lists of required

equipment. It also provides for supervisor training in new maintenance techniques, use of equipment, safety procedures, and scheduling of daily work.

- Maintenance records of the sewerage system must be upgraded and reproduced in a form convenient for the use of sewer maintenance crews. These improved records may be developed from the base maps prepared in the Master Plan. They may be updated and amended by field survey and maintenance crews using data collected in their routine field operations.

In addition, the Sewer Maintenance Department should be given the authority, funding, and staff necessary to collect and dispose of problem industrial wastes, mazout, and animal manure. The Department is presently responsible only for the collection and disposal of septic tank sludge. GOSSD-Alexandria appears to be the only organization with the incentive to institute and manage these additional waste collection services. During the sewer cleaning program associated with Top Priority Projects, the sewer maintenance staff should receive training in the collection of these waste materials and begin to develop new ongoing waste collection services.

Water Pollution Control Department. As the Wastewater Master Plan is implemented, operation and maintenance responsibilities of the Water Pollution Control Department will be expanded to include three preliminary treatment plants, two waste stabilization ponds, an evaporation pond, and a secondary treatment facility. To ensure that proper operating procedures are followed under a variety of operating conditions, studies conducted through the design phases should produce:

- A detailed operating manual for each facility.
- A summary of operating procedures to be posted in an appropriate location for each facility.
- Training guidelines for instructors and supervisors.

As construction work progresses, the Department should implement training programs and institute standard operating procedures for the facilities. These practices should be continued for all future treatment facility additions.

A waste monitoring team should also be established within the Water Pollution Control Department. The anticipated industrial growth in

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Alexandria will necessitate particular emphasis on sewer use regulation because of the potential for toxic or hazardous industrial waste discharges. The waste monitoring team would review applications for industrial sewer connections, collect and analyze wastewater samples, and keep records of industrial waste discharge characteristics. When sewer use violations occur, the waste monitoring team would work with the Legal Department to issue notices to violators and, when necessary, to initiate legal action. The Water Pollution Control Department has established programs in water quality monitoring and laboratory analyses and, therefore, is the appropriate location for a waste monitoring team.

Mechanical and Electrical Department. The Mechanical and Electrical Department should restructure its operating procedures, in a manner similar to that of the Water Pollution Control Department, through:

- A detailed operating manual for each facility.
- A summary of operating procedures posted in an appropriate location for each facility.
- Training guidelines for instructors and supervisors.

Pump stations should be run more frequently to eliminate the practice of surcharging gravity sewers. As discussed previously, this practice results in clogged sewers, reduced sewer capacity, and in an increased workload for the Sewer Maintenance Department.

The transportation garage and workshop should be expanded to accommodate the larger fleet of vehicles necessary to improve current operations, and the additional fleet that will be necessary to provide service to newly sewered areas. Projected equipment and vehicle requirements were shown in Table 8-5. An ongoing vehicle replacement program is needed to eliminate outdated and inefficient vehicles without causing large fluctuations in the annual equipment budget. Through the contract sewer cleaning program in the Top Priority Projects, the Mechanical and Electrical Department may acquire additional modern sewer maintenance vehicles and cleaning equipment.

Project Development

The management improvement recommendations for engineering functions are intended to "gear-up" to the Master Plan development program. Although a portion of the engineering workload will be assigned to consultants, GOSSD-Alexandria should take advantage of the opportunities for its employees to gain on-the-job training during the design and construction supervision stages of the major projects.

Present indications from the GOSSD-Alexandria staff are that the Design and Project Execution Departments, responsible for project development, will operate under direct supervision from the GOSSD project development functions in Cairo. The responsibilities of the General Director in GOSSD-Alexandria will then be focused on administration, and operation and maintenance of the Alexandria wastewater system. During the upcoming development program, the Alexandria and Cairo staffs should be highly coordinated. The project development expertise centralized in Cairo will benefit from the local knowledge of the Alexandria staff; the General Director should be informed of all project activities in Alexandria. For these reasons, the establishment of a "Project Monitoring Unit" is recommended.

The Project Monitoring Unit should give the senior officials of GOSSD-Alexandria a means of keeping abreast of project progress against schedule, and cost against budget. The Project Monitoring Unit should be directly responsible to the General Director. As soon as a project is initiated, it would become the responsibility of a Project Monitoring Specialist in this unit to review plans, schedules, and costs for new projects until a facility is completed and placed in operation. The Project Monitoring Specialist's principal responsibilities would be: (1) to coordinate all project-related activities; (2) to identify potential problems or obstacles to completion early enough to permit corrective action; and (3) to keep the General Director GOSSD-Alexandria informed of plans and progress for all projects being undertaken. The Specialist would monitor progress through personal contacts and periodic conferences with all project participants, e.g., designers, contracting officials, purchasing agents, and finance officers. The system need not be complex, but should be formalized in a procedures manual.

9.2 Proposed Schedule for Implementing Management Recommendations

Recommendations

The concepts for improved wastewater systems management outlined above provide a foundation for strengthening the management of the sewerage functions in Alexandria. Recommendations are grouped into three categories according to their priority.

Recommendations for Immediate Attention

1. Appoint a full-time General Director.
2. Appoint a Deputy General Director.
3. Define the operating and capital development objectives of the wastewater program.
4. Assign responsibility to department heads for management and operating functions under their supervision.
5. Prepare a description of the operational relationships among the various departments.

Recommendations for Top Priority Projects Consideration

Administration.

Personnel and Training Department.

1. Expand Personnel Department responsibilities to cover all staffing and training needs and requirements. Retitle as Personnel and Training Department.
2. Prepare a plan forecasting staffing requirements.
3. Develop job descriptions.
4. Seek to improve employee compensation and benefit levels.
5. Make tuition assistance available for further education.

Budget and Finance Department.

1. Establish asset records for all new capital items.
2. Provide for the depreciation of all capital items.
3. Establish audit procedures to ensure accurate accounting for all development funds received.

Legal Department.

1. Implement, with the aid of the Water Pollution Control Department, existing sewer use regulations for industrial wastes.
2. Meet with major industries and the Alexandria Governorate to inform them of the sewer use regulations and plans for enforcement.
3. Develop a time schedule within which industries must comply with sewer use regulations.

Operations and Maintenence.

1. Eliminate surcharged sewer conditions.
2. Modernize and upgrade sewer cleaning procedures and equipment.

3. Expand authority of GOSSD-Alexandria to collect and dispose of problem industrial wastes, oil, and mazout.
4. Acquire additional sewer maintenance vehicles.
5. Enlarge the transportation garage and workshop.
6. Establish a vehicle and equipment replacement program.
7. Improve and reproduce maintenance records for the use of work crews.
8. Prepare detailed operating manuals for each pumping station and treatment facility.
9. Post operating procedures in an appropriate location in each pumping station and treatment facility.
10. Develop, with the Personnel and Training Department, occupational health and safety programs.
11. Acquire safety devices for laborers working under hazardous conditions.
12. Provide bathing facilities for the operations and maintenance staffs.
13. Establish a waste monitoring team within the Water Pollution Control Department.

Project Development.

1. Establish a Project Monitoring Unit in Alexandria.

Audit Unit.

1. Establish and set duties and responsibilities.

Recommendations for Future Consideration

Administration.

Personnel and Training Department.

1. Provide supplementary training, in-service or elsewhere, for employees as new systems and procedures are introduced.
2. Review personnel regulations to determine that all benefits are being provided employees.
3. Work with the Project Development Department to assure that "on-the-job" training possibilities during the design and construction stages are made available to their personnel.

Budget and Finance Department.

1. Develop and implement cost accounting procedures.

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Legal Department.

1. Notify customers of waste discharge violations.
2. Initiate legal proceedings to limit further waste discharge violations or to collect fines.

Public Services Department.

1. Determine what reports and data must be generated by GOSSD-Alexandria (with the assistance of the General Director and department heads).
2. Establish a central records system.

9.3 Financial Projections

Introduction

The financial implications of the recommended Wastewater Master Plan are best presented through projections of the financial position of GOSSD-Alexandria during the proposed stages of the program. This section considers various elements of financing, including operating and capital costs, inflationary trends, cash flow needs, and revenues. Appendix M, Recommended Plan Costs and Finance, summarizes the historical financial performance of GOSSD-Alexandria and provides supporting data for financial analyses presented in this section. Financial feasibility and possible financing plans are considered in Section 9.4.

Forecasting Frame of Reference

The forecasting mode is a consolidated set of financial statements most commonly used to evaluate the performance of a commercial enterprise. These statements include an income statement (profit and loss), a cash flow statement (sources and uses of funds), and a balance sheet (statement of financial position). The principal Master Plan forecasts span a period from 1978 to 1988, illustrating financial impact of the main thrust of the construction program (Stages I and II), as well as completion of the Top Priority Projects. Long range forecasts are also prepared to 1994 and the year 2000 in order to carry financial analyses through construction Stages III and IV to the planning horizon.

Financial statements presented herein are considerably more detailed than those currently used by GOSSD-Alexandria. Greater emphasis is placed on cash requirements, assets and depreciation, and revenues. The magnitude of transactions and complexities of financial management envisioned in implementation of the Wastewater Master Plan will necessitate greater attention to budgeting and financing considerations in the future. The financial statements which follow are intended to provide a basis for evaluating the financial feasibility of the recommended plan, and to serve as a guide for local financial planning techniques.

Cost Escalation

Project costs presented in the previous chapter are based on 1977 cost levels; all costs in this chapter, however, are escalated using anticipated rates of inflation. The Urban Consumer Price Index rose 13.5 percent from mid-1975 to mid-1976; base components of this index, prepared by the Public Agency for Mobilization and Statistics, are primary goods whose prices are controlled through government subsidy. Current estimates of inflation in the Egyptian economy indicate an annual rate of 18 percent during 1977; this higher rate, reflecting changes since the last officially published index, is based on both price controlled and free trade items. The predictability of near future inflation rates is limited, particularly during a period of change in the economy; for this analysis, anticipated economic trends provide a basis for forecasting, and include the following:

- Substantial foreign investment is expected to stimulate Egypt's economy, producing in the short term even greater increases in the local inflation rate.
- After an initial "gearing up" period, and adjustment to rapid economic growth, conservative economic policies will be employed to stabilize the country's economy and reduce inflation in the long term.
- Careful planning and a stabilized economy will result in a rate of inflation parallel to that of well developed foreign economies.

The rate of inflation for foreign equipment and supplies is assumed to maintain a moderate level throughout the planning period. A summary of forecasted inflation rates for both local and foreign goods is shown below.

It should be noted that the effect of inflation can be considerable in long range planning. For example, an inflation rate of 7 percent annually will result in a 475 percent increase over current cost of imported goods by the year 2000. The cost of local goods will increase 450 percent by 1988 and 1000 percent by year 2000.

Year	Annual Rate of Cost Escalation, Percent Domestic Goods and Services (Local)	Foreign Equipment and Supplies (Imports)
1978	20	7
1979	20	7
1980	19	7
1981	18	7
1982	16	7
1983	14	7
1984	12	7
1985	10	7
1986	8	7
1987- 2000	7	7

Capital Costs

A summary of capital costs at 1977 price levels for the recommended plan was presented in Table 8-10. Table 9-2 summarizes escalated costs of the program itemizing various components of the proposed wastewater system. Presentation of the future financial situation of GOSSD-Alexandria must also recognize the ongoing Top Priority Projects by considering their capital costs through 1981. While not a part of the staged construction program, vehicle acquisition and replacement costs must also be included as these are properly shown as capital expenditures; the ongoing responsibilities of GOSSD to replace vehicles, equipment and other components of the system as necessary should be emphasized. The summary of projected capital expenditures indicates the major requirement for capital funds during the initial portion of the planning period and particularly during Stage II from 1984 to 1988.

Operating Costs

Estimated costs of operation and maintenance of the wastewater system during various stages of development were also presented in the previous chapter together with recommended levels of staffing. Operation and maintenance activities are expected to remain labor intensive; improvements in productivity and overall skills should result from proposed training programs and more modern equipment. Improved maintenance, repair and replacement programs will require in the future greater expenditures for spare parts and materials.

A summary of annual escalated operating costs is presented in Table 9-3. In addition to the recurring costs such as personnel and materials, deferred

TABLE 9-2
PROJECTED CAPITAL EXPENDITURES
(LE thousand, Escalated)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989-1994	1995-2000
Staged Construction Projects[a]													
Dwelling Connections	-	287	366	470	597	693	1 886	2 747	3 305	3 599	3 845	13 334	19 297
Street Sewers	-	401	780	2 078	9 858	13 819	29 252	32 421	35 547	38 326	40 952	181 137	271 950
Gravity Collectors	-	38	128	2 248	3 736	4 262	23 535	33 070	36 533	47 056	27 306	-	-
Force Mains	-	8	465	855	2 427	3 800	4 918	7 480	9 566	9 143	13 329	-	-
Pump Stations	-	131	1 554	3 412	3 808	604	5 959	7 276	3 882	9 414	10 315	-	-
Treatment Facilities	-	329	373	6 540	8 586	11 026	21 357	23 624	21 711	23 629	23 191	-	-
Outfalls	-	524	580	21 684	25 366	27 930	27 401	29 350	26 767	-	-	-	-
Land	-	2 130	9 605	8 383	-	-	-	-	-	-	-	-	-
TOTAL	-	3 848	14 121	45 650	54 378	62 134	114 308	135 968	137 311	131 167	118 938	194 471	291 247
Other Capital Expenditures													
Top Priority Projects[b]	3 927	12 388	14 758	16 135	-	-	-	-	-	-	-	-	-
Vehicles[c]	-	-	-	-	70	75	45	48	55	56	59	670	646
TOTAL	3 927	12 388	14 758	16 135	70	75	45	48	55	56	59	670	646
Total Capital Expenditures	3 927	16 236	28 879	61 785	54 448	62 209	114 353	136 016	137 366	131 223	118.997	195 141	291 893

(a) Based on Chapter 8 recommendations and inflation rates presented in Section 9-3.

(b) Based on recommendations in Special Report Number 4, Values include expenditures on sewers, pump stations, and vehicles while all other TPP costs are included in operation and maintenance cost under 'Deferred Maintenance'.

(c) Includes cost of vehicle addition and replacements; from 1978 through 1981 such costs are part of Top Priority Projects.

TABLE 9-3
PROJECTED OPERATION AND MAINTENANCE COSTS[a]
(LE thousand, Escalated)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1994	2000
Salaries/Benefits	1 239	1 542	1 938	2 398	3 648	4 392	5 189	5 940	6 628	7 444	8 418	14 275	22 830
Fuel	31	40	53	69	108	133	152	167	185	202	216	353	552
Utilities	116	142	180	220	399	490	586	650	701	813	938	1 687	2 543
Materials & Repairs	104	135	173	222	338	404	480	541	601	714	774	1 334	2 099
Other Expenditures	71	94	116	150	222	260	304	342	386	432	490	822	1 320
Deferred Maintenance[b]	1 447	1 913	2 147	--	--	--	--	--	--	--	--	--	--
TOTAL	3 008	3 866	4 067	3 059	3 904	5 679	6 711	7 640	8 483	9 605	10 836	18 471	29 344

(a) Operation and maintenance costs are based on historical operating costs GOSSD-Alexandria, recommended staffing levels presented in Chapter 8, and expanded operation and maintenance activities anticipated in accordance with the recommended plan; all costs are escalated at assumed local inflation rates.

(b) Deferred maintenance includes those portions of the Top Priority Projects expenditures which are not categorized as capital in Table 9 - 2 such as contract sewer maintenance and sewer use law implementation.

maintenance costs are shown during the years 1978, 1979, and 1980. Certain maintenance items are not performed on a regular basis because, either a facility is designed to operate as long as possible without maintenance (then taken out of service for extensive repair), or unusual maintenance requirements result from inadequate routine maintenance. For the purpose of financial analysis, deferred maintenance includes costs of Top Priority Projects which are not attributable to replacement or acquisition of fixed assets for the wastewater system as shown in the capital expenditures summary.

Fixed Assets and Depreciation

Current accounting procedures at GOSSD-Alexandria do not incorporate records of fixed assets and depreciation expenses. Since this information is essential for conventional financial analyses, a survey of existing assets was conducted with assistance of GOSSD-Alexandria. The methodology and results of this survey are presented in Appendix M of Volume III.

Projected fixed assets for GOSSD-Alexandria from 1978 through year 2000 are presented in Table 9-4. These include existing fixed assets in service and incorporate capital improvement assets projected in accordance with the staged program. Proposed facilities which will be under construction for more than one year are recorded as "Work in Progress" during that period and transferred to "Depreciable Values" in the year during which they are placed in service.

Depreciation is a major non-cash operating cost that gives recognition to obsolescence and deterioration of wastewater system assets over their useful lives. A Schedule of Depreciation Expenses for the recommended plan is presented in Table 9-5. Straight-line depreciation is assumed using the book value of capital assets and the following useful lives:

Asset	Useful Life, Years	Annual Depreciation Rate
Sewers	50	2.0%
Structures	40	2.5%
Equipment	20	5.0%
Vehicles	10	10.0%
Land	∞	Not Depreciated

TABLE 9-4
SCHEDULE OF CAPITAL ASSETS
(LE thousand, Escalated)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1994	2000
Assets Added During the year													
Sewers	-	3 308	11 042	14 420	18 459	10 455	100 925	32 323	46 121	133 735	60 892	32 412	48 541
Structures	-	-	-	-	189	16 670	-	-	3 636	20 916	-	-	-
Equipment	-	-	-	-	4 578	11 611	-	-	1 550	-	-	-	-
Vehicles	150	567	591	152	70	75	45	48	55	56	59	112	108
Land	-	-	-	-	-	-	3 549	-	1 916	-	-	-	-
TOTAL	150	3 875	11 633	14 572	23 296	38 811	104 519	32 371	53 278	154 707	60 951	32 524	48 649
Assets Retired													
Vehicles	51	193	200	52	63	68	40	43	44	45	48	85	77
Depreciable Values													
Sewers	112 871	116 179	127 221	141 641	160 100	170 555	271 480	303 803	349 924	483 659	544 551	926 835	1 201 953
Structures	5 026	5 026	5 026	5 026	5 215	21 885	21 885	21 885	25 521	46 437	46 437	129 851	129 871
Equipment	14 725	14 725	14 725	14 725	19 303	30 914	30 914	30 914	32 464	32 464	32 464	81 179	81 179
Vehicles	1 351	1 725	2 116	2 216	2 223	2 230	2 235	2 240	2 251	2 262	2 273	2 437	2 619
TOTAL	133 973	137 655	149 088	163 608	186 841	225 584	326 514	358 842	410 160	564 822	625 725	1 140 302	1 415 622
Work in Progress													
Sewers	3 308	11 612	15 818	43 312	66 837	106 886	92 953	165 698	231 295	195 684	220 224	32 412	48 541
Structures	-	239	1 241	6 405	12 817	2 581	22 879	45 742	57 650	60 229	83 414	-	-
Equipment	469	2 157	4 320	10 492	11 707	5 292	12 310	20 347	28 846	38 394	48 715	-	-
Land	-	2 130	11 735	20 118	20 118	20 118	16 569	16 569	14 653	14 653	14 653	-	-
TOTAL	3 777	16 138	33 114	80 327	111 479	134 877	144 711	248 356	332 444	308 960	367 006	32 412	48 541
Land	5 898	5 898	5 898	5 898	5 898	5 898	9 447	9 447	11 363	11 363	11 363	26 016	26 016
Book Value of Capital Assets	143 648	159 691	188 100	249 833	304 218	366 359	480 672	616 645	753 967	873 782	1 004 034	1 198 750	1 490 179

TABLE 9-5
SCHEDULE OF DEPRECIATION EXPENSES
(LE thousand, Escalated)

	Percent	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1994	2000
Annual Depreciation Expense														
Sewers	2.0	2 257	2 324	2 544	2 833	3 202	3 411	5 430	6 076	6 998	6 973	10 891	18 537	24 039
Structures	2.5	126	126	126	126	130	547	547	547	638	1 161	1 161	3 246	3 247
Equipment	5.0	736	736	736	736	965	1 546	1 546	1 546	1 623	1 623	1 623	4 059	4 059
Vehicles	10.0	135	173	212	212	222	223	224	224	225	226	227	244	262
TOTAL		3 254	3 359	3 618	3 907	4 519	5 727	7 747	8 393	9 484	9 983	13 902	26 086	31 607
Book Value of Assets Retired														
Vehicles		51	193	200	52	63	68	40	43	44	45	48	85	77
Accumulated Depreciation (Net of Retirements)														
Sewers		62 227	64 551	67 095	69 928	73 130	76 541	81 971	88 047	95 045	102 018	112 909	214 406	344 078
Structures		1 994	2 120	2 246	2 372	2 502	3 049	3 596	4 143	4 781	5 942	7 103	26 581	46 063
Equipment		8 279	9 015	9 751	10 487	11 452	12 998	14 544	16 090	17 713	19 336	20 959	45 313	69 667
Vehicles		833	813	825	985	1 144	1 299	1 483	1 664	1 845	2 026	2 205	3 219	4 251
TOTAL		73 333	76 499	79 917	83 772	88 228	93 887	101 594	109 944	119 384	129 322	143 176	289 519	464 059
Net Capital Asset Values		70 315	83 192	108 183	166 061	215 990	272 472	379 078	506 701	634 583	744 460	860 918	909 231	1 026 120

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Sources of Funds

Service Charge. Service charges for wastewater collection and disposal are normally based on: (1) water consumption; (2) number of wastewater fixtures per unit served; or (3) flat rate fee per unit served for various customer classifications. Charges based on water consumption alone are most commonly applied due to simplicity, a direct correlation between water consumption and wastewater production, and ease of collection and administration. Industries in Alexandria in the late 1950's were assessed a sewer service charge of 0.3 pt/m^3. The billing and collection procedures, carried out independently of AWGA operations, resulting in an ineffective sewer revenue program which was discontinued in 1962.

Revenue that an organization must accrue to be financially viable usually covers operating expenses (including depreciation) and also provides satisfactory return on investments. A reasonable financial rate of return on value of net fixed assets for wastewater utilities is six percent or slightly higher. Where revenue requirements are too high, alternative revenue sources may be used; service charges may then be designed to recover only a portion of total costs as operating costs.

Feasibility of sewer service charges in Alexandria is difficult to assess under present circumstances due to changing economic conditions and paucity of realiable information on income and cost of living. Comparison has been made between proposed sewer service charges, current water service charges, and industrial user charges in effect during the late 1950's as shown in Table 9-6. The charges compared include:

1. Average charge for water to AWGA customers in 1976 (escalated for comparison in later years).
2. An escalated 1961 industrial user charge.
3. A sewer service charge designed to recover operating costs and depreciation and to provide a 5 percent rate of return on investment.
4. A sewer service charge designed to recover operating costs and provide a small additional reserve to facilitate cash flow.

The comparison indicates that sewer service charges for attaining financial viability could be considered as a heavy burden based on previous water and sewer service charges. A charge to recover only operating costs, however, would be comparable to earlier industrial user charges, amounting to

TABLE 9-6

COMPARISON OF WATER AND SEWER SERVICE CHARGES

Service	Average Service Charge, pt/m^3 1976	1981	1988	2000
Water				
- AWGA Charge in 1976[(a)]	1.6	3.8	7.7	17.3
Sewer				
- GOSSD Industrial User Charge in 1961[(b)]	0.6	1.4	2.9	6.5
- Proposed Sewer Service Charge for Financial Viability[(c)]	-	4.5	13.6	20.3
- Proposed Sewer Service Charge for Operating Cost Recovery[(d)]	-	1.2	2.9	6.0

(a) Water revenue at AWGA in 1976 was LE 2.3 million with billed water production of 148 x 10^6 m^3 (60% of total production). Average charge (1.6 pt/m^3) was escalated to later years using projected local inflation rates.

(b) GOSSD-Alexandria industrial user charge was 0.3 pt/m^3 in 1961; values shown are based on escalation to 1976 using the Urban Consumer Price Index and escalation to later years using projected local inflation rates.

(c) Based on recovery of operating costs, depreciation, and 6 percent rate of return on net fixed assets in service. Billable wastewater flow assumed of projected wastewater flow from sewered customers (Table 4-10) that is based on revenue collection experience of AWGA.

(d) Based on annual recovery of operation costs, plus one month of operating costs for the following year to facilitate cash flow. billable wastewater flow estimated as in (c).

slightly more than one-third of present water service charges. This reduced service charge is assumed to be a more realistic goal for any newly instituted revenue program.

It should be emphasized that the above analysis is based on average service charges and does not consider rate structure and cost allocation among classes of customers which is necessary for harmony with the present social structure of Egypt. Water rates in Alexandria, for example, vary from 0.1 pt/m^3 for domestic use, to 0.4 pt/m^3 for industries, to a high of 5.5 pt/m^3 for port customers. Sewer service charges might also take into account variation in waste strength as unit cost of treatment for some industrial wastes can exceed that of normal domestic flows.

Sewer Connection Charge. GOSSD-Alexandria presently charges new customers for the cost of sewer connection; subsidies are available to those new sewer customers who, based on amount of monthly rent, may be unable to pay the charge. Revenue from connection charges is expected to increase from present levels in direct proportion to the extensive new sewer connections envisioned in the recommended program. Due to low income level in many presently unsewered areas, it is assumed that one-fourth of all new connections will not be assessed a sewer connection charge.

Charge to Beneficiaries. Another source of capital revenue commonly used by wastewater utilities are charges to developers who directly benefit from availability of sewers in their developments. Considering the extent of development that will occur during the next several decades, such a charge to beneficiaries of the wastewater capital program should be considered. For financial projections presented herein, it is assumed that one-third of the cost for constructing street sewers in developer-owned areas can be charged to developers.

Long Term Loan. Long term loans might be utilized if the sewerage authority could develop an excess of cash, after deduction of operating costs, for direct contribution to capital cost and debt service payment. As discussed, costs for operations, sewer connections, and a portion of street sewers in developer-owned areas might reasonably be recovered through revenues to GOSSD-Alexandria. It is unlikely, however, that sufficient additional funds can be locally generated in order to pay debt service, particularly in view of the magnitude of investment required for the recommended plan. Presently, GOSSD-Alexandria is not authorized to incur debt; capital investment funded by the government is jointly authorized by the Ministry of Housing and Reconstruction, the Ministry of Planning, and the Ministry of Finance.

Government Contribution. As shown in Table 9-7, a summary of projected customer contributions to GOSSD-Alexandria indicates that substantial equity participation from the national government will be required to fund the capital development program of the recommended wastewater master plan. A combination of Egyptian and foreign capital may well be utilized to provide necessary funds for the Alexandria wastewater system. The availability and potential sources of such funds are discussed in Section 9.4.

Projected Financial Statements

Income Statement. Income statements are used to determine financial profit or loss of any organization. Revenue less operating cost and depreciation expenses determine net operating income which, in the absence of interest expense or reserve funds at GOSSD-Alexandria, is equivalent to net income. Net income has been used to determine financial rate of return on net fixed assets in service for the recommended plan.

The projected income statement for GOSSD-Alexandria is presented in Table 9-8. The sewer service revenue program designed to recover operating costs is shown beginning in 1981. It is unlikely that greater revenues can be generated from this source to recover depreciation costs. Therefore, a deficit in net income is projected each year over the planning period while no return on net fixed assets in service is generated. As already mentioned, GOSSD-Alexandria cannot be considered a financially viable entity in regard to projected income levels.

Cash Flow Statement. A cash flow statement summarizes sources and uses of funds and indicates adequacy of cash flow. In general, it is not sufficient to merely cover cash outlays with operating revenues and capital contributions, due to a tendency for cash receipts to lag behind cash outlays. The recommended wastewater master plan program of capital developments and expanding operations will require a large amount of working capital.

Table 9-9 presents a projected cash flow statement for GOSSD-Alexandria based on implementation of the wastewater master plan. The statement shows requirements for and sources of cash not otherwise visualized such as those due

TABLE 9-7

PROJECTED CUSTOMER CONTRIBUTIONS
(LE thousand, Escalated)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1994	2000
Customer Data													
Number of New Sewer Connections[a]	1 640	1 720	1 880	2 080	2 280	2 320	5 600	7 360	8 080	8 160	8 160	3 690	3 560
Total Sewer Connections	77 640	79 360	81 240	83 320	85 600	87 920	93 520	100 880	108 960	117 120	125 280	147 420	168 780
Operating Revenues													
Average Sewer Service Charge, pt/m^3[b]	-	-	-	1.2	1.5	1.8	2.1	2.3	2.5	2.7	2.9	4.4	6.0
Annual Service Charge Billings, LE thousand	-	-	-	3 625	5 447	6 550	7 714	8 765	9 766	11 033	12 423	21 175	33 461
Connection Charge Revenues													
Connection Charge,[c] LE/connection	148	178	213	253	300	346	395	441	486	525	561	900	1 353
Connection Charge Billing, LE thousand[d]	182	230	300	395	513	602	1 659	2 435	2 945	3 213	3 434	2 490	3 613
Charge to Beneficiaries[e] LE thousand	-	-	-	356	1 495	2 101	4 648	5 152	5 649	6 090	6 507	4 739	7 116

(a) Based on construction scheduling for the recommended Wastewater Master Plan.

(b) Service charges designed to recover annual operating costs and, in addition, one month operating costs in following year (to facilitate cash flow requirements) plus 5% of total cost for coverage on uncollectable billings; billable wastewater flow assumed at 60% of projected wastewater flow from sewered customers (Table 4-10) based on revenue collection experience of AWGA.

(c) Based on estimated connection cost of LE 125 at mid-1977 costs.

(d) Assumes that 25 percent of all new connections will not be billed due to inability to pay for future low income areas.

(e) Includes charges to developers for one-third cost of sewers in newly developed areas beginning in 1980; 40% of sewer costs in the East, West, and Central Zones and 60% of sewer costs in Nouzha, Outer West, Abu Kir Bay, and Ameria assumed to be in areas owned by developers.

TABLE 9-8

PROJECTED INCOME STATEMENT
(LE thousand, Escalaed)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1994	2000
Revenue													
Service Charges[a]	-	-	-	3 625	5 447	6 550	7 714	8 765	9 766	11 033	12 423	21 175	33 641
Less Provision for Un-collectable Revenue	-	-	-	173	259	312	367	417	465	525	592	1 008	1 602
TOTAL	-	-	-	3 452	5 188	6 238	7 347	8 348	9 301	10 508	11 831	20 167	32 039
Operating Cost[b]	3 008	3 966	4 067	3 059	3 904	5 679	6 711	7 640	8 483	9 605	10 836	18 471	29 344
Income Before Depreciation	(1 561)	(1 953)	(4 507)	393	473	559	636	708	800	903	995	1 696	2 695
Depreciation[c]	3 254	3 359	3 618	3 907	4 519	5 727	7 747	8 393	9 484	9 983	13 902	26 086	31 607
Net Operating Income	(4 815)	(5 312)	(8 225)	(3 514)	(4 046)	(5 168)	(7 111)	(7 685)	(8 684)	(9 080)	(12 907)	(24 390)	(28 912)

(a) Based on service charges designed to recover annual operating costs plus a reserve to provide working capital (equal to one month of operating costs) for the following year, plus 5% provision for uncollectable revenues. Service charge is assumed instituted in 1981.

(b) From Table 9-3, Projected Operation and Maintenance Costs.

(c) From Table 9-5, Schedule of Depreciation Expenses.

TABLE 9-9

PROJECTED CASH FLOW STATEMENT
(LE thousand, Escalated)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1994	2000
Source of Funds													
Net Income[a]	(4 815)	(5 312)	(8 225)	(3 514)	(4 046)	(5 168)	(7 111)	(7 685)	(8 684)	(9 080)	(12 907)	(24 390)	(28 912)
Depreciation[b]	3 254	3 359	3 618	3 907	4 519	5 727	7 747	8 393	9 484	9 983	13 902	26 086	31 607
Increase in Current Liabilities[c]	-	1 767	2 050	5 598	1 257	2 051	4 935	8 024	5,158	-	2 463	-	-
Decrease in Current Assets (Excluding Cash)[d]	-	-	-	-	-	-	-	-	-	-	-	-	-
Capital Contributions from Customers[e]	182	230	300	751	2 008	2 703	6 307	7 587	8 594	9 303	9 941	7 229	10 729
Capital Contributions from Government[f]	6 403	17 370	33 608	55 185	51 965	61 645	105 076	120 446	122 848	122 528	98 879	24 033	35 889
TOTAL	5 024	17 414	31 351	61 927	55 703	66 958	116 954	136 765	137 400	132 734	112 278	32 958	49 313
Use of Funds													
Investment in Utility Plant[g]	3 927	16 236	28 879	61 785	54 448	62 209	114 353	136 016	137 366	131 2[illegible]3	118 997	32 524	48 649
Decrease in Current Liabilities[h]	-	-	-	-	-	-	-	-	-	1 921	-	-	-
Increase in Current Assets (Excluding Cash)[i]	-	85	106	616	528	318	718	564	454	507	395	-	-
TOTAL	3 927	16 321	28 715	62 401	54 976	62 527	115 071	136 580	137 820	133 651	119 392	32 524	48 649
Net of Sources Less Uses	1 097	1 093	2 636	(474)	727	4 431	1 883	185	(420)	(917)	(7 114)	434	664
Cash at Beginning of Period[j]	578	1 675	2 768	5 404	4 930	5 657	10 088	11 971	12 156	11 736	10 819	4 250	6 500
Cash at End of Period[k]	1 675	2 768	5 404	4 930	5 657	10 088	11 971	12 156	11 736	10 819	3 705	4 584	7 164

(a) Taken from Projected Income Statement, Table 9-8

(b) Taken from Schedule of Depreciation Expenses, Recommended Master Plan, Table 9-5.

(c),(d) Calculated from Projected Balance Sheet, Table 9-10.

(e) Includes contributions from sewer connection charges and benefit charges to beneficiary developers as shown in Projected Customer Contributions, Table 9-7 . One third of each year's connection charge billings is assumed to be collected in the following year; 5 percent of all connection charges are assumed to be uncollectable.

(f) Includes government funding required to supplement customer contribution to ensure a sound financial posture throughout the period of study and maintain sufficient level of working capital for sound financial management.

(g) Taken from Estimated Capital Expenditures, Table 9-2

(h)(i) Taken from Projected Balance Sheet, Table 9-10.

(j)(k) Based on cash required to finance one month of operating costs plus one month of capital expenditures in order to facilitate cash flow.

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to changes in the level of inventories or accounts receivable. Such a statement is essential for developing management options to avoid cash shortages and should be revised at least semi-annually throughout the implementation of the recommended plan.

Significant increases in investment in utility plant will occur in accordance with a staged construction program. The primary source of funds necessary to avoid cash deficits is considered as capital contributions from the national government. Capital contributions from government and from customers exceeds capital investment costs during the first stage of the recommended program (1979-1983) in order to provide necessary working capital for Stage II (1984-1988). Due to the magnitude of contribution required from government compared with other sources of funds, adequacy of cash flow will depend primarily on availability and timing of government funds.

Balance Sheet. A balance sheet quantifies, in monetary terms, the financial position of any organization. The statement shows fixed and current components of assets, distribution of capital between debt and equity, and growth or deterioration of retained earnings. The ratio of current assets to current liabilities can also reflect potential cash management problems.

The projected balance sheet, presented in Table 9-10, shows growth of utility plant in service from LE 190 million in 1978 to LE 1228 million by year 2000. As current liabilities will exceed current assets from 1983 to 1988, there will be an additional need for careful cash management during Stage I. The balance sheet further demonstrates a deteriorating effect of a program which does not provide sufficient revenues to fully cover operating and depreciation expenses on total equity as annual deficits in net income cause increasing deficits in retained losses. Maintaining the assets of GOSSD-Alexandria will require a continual infusion of government funds until a time when customer contributions can cover both operating and capital costs.

9.4 Financial Feasibility

Foreign Investment

The preceding discussion and financial projections indicate that financial feasibility will be primarily dependent on availability of government funds.

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TABLE 9-10

PROJECTED BALANCE SHEET
(LE thousand, Escalated)

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1994	2000
ASSETS													
Fixed Assets													
Utility Plant in Service[a]	139 871	143 553	154 986	169 506	192 739	231 482	335 961	368 289	421 523	576 185	637 088	1 166 338	1 227 969
Less Accumulated Deprecia-tion[b]	73 333	76 499	79 917	83 772	88 228	93 887	101 594	119 944	119 384	129 322	143 176	289 519	464 059
Net Fixed Assets in Service	66 538	67 054	75 069	85 634	104 511	137 595	234 367	258 345	302 139	446 863	493 912	876 819	763 910
Work in Progress[c]	3 777	16 138	33 114	80 327	111 479	134 877	144 711	248 356	332 444	308 960	367 009	32 412	48 541
TOTAL	70 315	83 192	108 183	165 961	215 990	272 472	379 078	506 701	634 583	755 823	360 921	909 231	812 451
Current Assets													
Cash[d]	1 675	2 768	5 404	4 930	5 657	10 088	11 971	12 156	11 736	10 819	3 705	4 684	7 164
Accounts Recivable - Service Charges[e]	-	-	-	302	454	546	643	730	814	919	1 035	1 765	2 803
Less Uncollectabel Service Charges[f]	-	-	-	173	259	312	367	417	465	525	592	1 008	1 602
Accounts Receivable - Capital Contributions[g]	61	77	100	132	171	201	553	811	982	1 071	1 145	830	1 204
Less Uncollectable Capital Contributions[h]	9	12	15	20	26	30	83	122	147	161	172	125	181
Inventories[i]	220	286	366	470	715	854	1 015	1 145	1 271	1 510	1 637	2 822	4 440
TOTAL	1 965	3 143	5 885	6 027	7 282	12 031	14 632	15 381	15 415	15 005	8 286	11 234	17 394
Total Assets	72 280	86 335	114 068	172 088	223 272	284 503	393 710	522 082	649 998	770 828	369 204	920 465	829 845
LIABILITIES													
Equity													
Capital Contributions[j]	76 541	94 141	128 049	183 985	237 958	302 306	413 689	541 722	673 164	804 995	913 815	1 085 777	1 152 752
Retained Earnings(Losses)[k]	(4 815)	(10 127)	(18 352)	(21 866)	(25 912)	(31 080)	(38 191)	(45 876)	(54 560)	(63 640)	(76 547)	(169 967)	(329 873)
TOTAL	71 726	84 014	109 697	162 119	212 046	271 226	375 498	495 846	618 604	741 355	337 268	915 810	822 879
Current Liabilities													
Accounts Payable[l]	327	1 353	2 384	5 149	4 537	5 184	9 529	11 335	11 447	10 935	9 916	2 710	4 054
Deposit[m]	227	968	1 987	4 820	6 689	8 093	8 683	14 901	19 947	18 538	22 020	1 945	2 912
TOTAL	554	2 321	4 371	9 969	11 226	13 277	18 212	26 236	31 394	29 473	31 936	4 655	6 966
Total Liabilities	72 280	86 335	114 068	172 088	223 272	234 503	393 710	522 082	649 998	770 828	369 204	920 465	829 845

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NOTES TO ACCOMPANY TABLE 9-10

(a) Utility Plant In Service is the sum of Depreciable Value plus Land appearing on Table 9-4.

(b) Accumulated Depreciation taken from Table 9-5.

(c) Work In Progress taken from Table 9-4.

(d) Cash balance on 31 December taken from Table 8-17. End of year balance sufficient to finance one month of operating costs (Table 9-8) plus one month of capital expenditure shown on Table 9-2.

(e) Accounts receivable are estimated to equal one month of service charge billing for each year shown in Table 9-8.

(f) Taken from Table 9-8.

(g) Accounts receivable are estimated to equal one-third of the sewer connection charges in each year as shown in Table 9-7.

(h) Estimated to be 5 percent of connection charge billings.

(i) Inventory for 1978 based on end of year balance from 1976 GOSSD-Alexandria financial records; inventories in succeeding years assumed to increase with increased expenditures for materials and supplies operating costs.

(j) Capital Contributions are the cumulative sum of the annual Capital Contributions of Customers and Government as shown on Table 9-9. The initial balance for 31 December, 1978 was established as the difference between Total Equity and Retained Losses in 1978. This approach was necessary because a balance sheet displaying retained earnings and Capital Contributions was available.

(k) Retained Earnings (Losses) are the cumulative earnings or losses appearing in Table 9-8, as Net Operating Income. Under the proposed revenue program Operating Income after depreciation will result in operating losses during the entire period 1978-2000 which will require and operating subsidy from government.

(l) Accounts payable are equal to one month of capital costs.

(m) Deposits include contractor deposits of 5 percent and contractor insurance of 1 percent based on the amount of work in progress for each year.

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Locally generated funds cannot support the magnitude of costs associated with the recommended plan. Two sources of government funds have been identified and analyzed. The first source includes foreign loans to the Egyptian government. A number of capital development projects throughout Egypt, including water and wastewater programs, are currently being financed by foreign investors. The second source is Egyptian Government capital development funds which are allocated to the public utilities sector. Financial feasibility of the Wastewater Facilities Master Plan will require use of both of these sources of capital funds. Availibility of local currency is expected to represent the most restrictive financial management constraint.

Financing of foreign exchange costs associated with the proposed construction program may be accomplished by foreign investors. The United States Agency for International Development represents current interest in the Alexandria wastewater program through financing US $15 million of the Top Priority Projects program designed to achieve institutional improvements, rehabilitation of the existing sewerage system, and some priority extensions. The loan was made to the Arab Republic of Egypt under the following terms:

- Repayment over 40 years with a grace period of 10 years.
- Interest at a rate of 2 percent per annum during the first 10 years and 3 percent per annum thereafter.
- Egyptian government funds are made available for local currency portion of project costs.
- Specific recommendations for improved management of the wastewater system, outlined in the loan agreement, are implemented.

Direct foreign exchange cost (DFEC) of the staged construction program will be considerably higher than those of the Top Priority Projects as shown below:

Stage	Years	DFEC, LE (Escalated)
I	1981-1983	68 190 000
II	1984-1988	105 741 000
III & IV	1989-2000	-

DFEC is projected to occur only during the first two construction stages for equipment, machinery, and other components of the proposed wastewater

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system that are not manufactured in Egypt. Should USAID finance these portions of the program, approximately $97 million would be required for Stage I and $151 million would be required for Stage II. The contingency that such a level of foreign investment may not be available from USAID or any other single foreign investor suggests a project segmenting concept for financing the overall program.

The recommended plan outlines a program for construction of wastewater collection, conveyance, treatment, and disposal facilities in six separate geographical areas of Alexandria. Some construction will occur in already developed areas of the city while other works are proposed for areas such as Ameria and Sadat City where urban development is expected to occur rapidly in the near future. Should foreign exchange costs of the plan exceed the financing capability of a single foreign investor, the construction program can be readily broken into marketable segments. Segmenting may be accomplished by grouping capital investment costs according to:

- Principal physical components of the new wastewater system such as outfalls or treatment facilities; and/or
- Geographical (sewer service) areas of the city.

A financing plan that segments the construction program must be carefully designed so that the utility of the financed component or area is not dependent on the possible financing of an additional segment. Public health problems in currently developed areas of the city should have a high funding priority. Consideration must also be given to the ratio of foreign to local currency requirements as well as the availability of both foreign and local currencies.

A breakdown of the staged construction program is presented in Table 9-11. The developed East and West/Central Zones of Alexandria which represent the most immediate financing needs in the program require a higher percentage of foreign currency than do construction programs in partially developed outer areas. Wastewater facility needs in the Mex-Dekheila, Nouzha, Abu Kir, and Ameria zones are somewhat less certain as they are more dependent on magnitude and timing of future developments. Appendix M of Volume III presents financial statements similar to those shown in the financial projections in this chapter, but assuming that only Wastewater Master Plan projects in the East and West/Central zones would be undertaken. Similar financial analyses can be carried out in order to assess financing for other segments

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TABLE 9-11

GEOGRAPHICAL BREAKDOWN OF CONSTRUCTION PROGRAM

(LE thousand, Escalated)

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1994	2000
East												
Direct FEC	641	1 213	19 009	21 650	22 584	2 636	4 778	4 594	2 358	3 585	-	-
Indirect FEC	105	247	2 108	3 385	3 645	4 816	6 830	6 103	5 640	5 242	17 790	26 642
Local	2 763	4 009	12 932	21 332	24 731	23 705	35 817	33 240	29 210	28 311	88 740	132 647
TOTAL	3 509	5,469	34 049	46 367	50 960	31 157	47 425	43 937	37 208	37 138	106 530	159 289
West/Central												
Direct FEC	19	351	-	913	1 008	19 977	21 089	21 973	5 646	6 222	-	-
Indirect FEC	72	199	443	361	480	3 046	3 247	4 422	4 756	3 921	3 069	4 614
Local	248	1 882	2 905	2 490	3 435	21 046	23 351	28 097	24 196	20 308	15 299	22 962
TOTAL	339	2 432	3 348	3,764	4 923	44 069	47,687	54 492	34 598	30 451	18 368	27 576
Outer West												
Direct FEC	-	-	-	78	156	1 151	851	-	-	-	-	-
Indirect FEC	-	-	169	284	339	9 288	9 742	473	506	540	828	1 245
Local	-	510	1 214	1 519	2 081	14 974	15 579	2 326	2 512	2 685	4 131	6 201
TOTAL	-	510	1 383	1 881	2 576	25 413	26 172	2 799	3 018	3 225	4 959	7 446
Nouzha												
Direct FEC	-	-	-	43	34	932	845	-	-	-	-	-
Indirect FEC	-	-	89	272	404	997	915	528	565	603	306	459
Local	-	-	317	1 166	1 813	4 895	4 681	2 599	2 806	2 999	1,524	2 288
TOTAL	-	-	406	1 481	2 251	6 824	6 441	3 127	3 371	3 602	1 830	2 747
Abu Kir												
Direct FEC	-	-	-	57	112	-	-	1 439	2 608	2 776	-	-
Indirect FEC	-	-	-	-	-	87	98	3 132	4 781	3 568	423	625
Local	-	4 080	4 848	129	490	398	469	5 605	8 614	6 443	2 103	3 096
TOTAL	-	4 080	4 848	186	602	485	567	10 176	16 003	12 787	2 526	3 721
Ameria												
Direct FEC	-	-	-	154	168	-	-	-	847	1 434	-	-
Indirect FEC	-	-	-	-	-	1 140	1 326	3 836	8 392	7 497	10.063	15 133
Local	-	1 360	1 616	545	654	5 220	6 350	18 944	27 730	22 804	50 195	75 335
TOTAL	-	1 360	1 616	699	822	6 360	7 676	22 780	36 969	31 735	60 258	90 468
Master Plan Total												
Direct FEC	660	1 564	19 009	22 895	24 062	24 696	27 563	28 006	11 459	14 017	-	-
Indirect FEC	177	446	2 809	4 302	4 868	19 374	22 158	18 494	24 640	21 371	32 479	48 718
Local	3 011	11 841	23 832	27 181	33 204	70 238	86 247	90 811	95 068	83 550	161 992	242 529
TOTAL	3 848	13 851	45 650	54 378	62 134	114 308	135 968	137,311	131 167	118 938	194 471	291 247

of the overall plan.

Local Investment

The bulk of capital funding for the Wastewater Master Plan will be required from the national government. The local and indirect foreign exchange costs, comprising Egypt's local share, are shown below:

Stage	Period	Local Currency, LE (Escalated)
I	1979-1983	111 671 000
II	1984-1988	531 951 000
III	1989-1994	194 471 000
IV	1995-2000	291 247 000

Capital costs of the program represent a substantial drain on national funds available for fixed capital investment. As shown in Table 9-12, the Ministry of Planning has projected an increase for such investment from LE 1175 million in 1977 to LE 2350 million in 1982, however, utilities investment is expected to remain a small percentage of the total. Estimates in the Five-Year Plan show LE 17 million in local capital and LE 8 million in foreign investment earmarked for Alexandria over the 1978-1982 period.

Wastewater investment (at 1977 costs) in Alexandria is projected to require from LE 1.6 million in 1977 to LE 30.9 million in 1982, with LE 40-50 million necessary during several years of Stage II construction.

Availability of local capital required for the plan will depend on: (1) improvements in the economy, as anticipated through increases in productivity and capital growth in Egypt; and (2) a shift in funding priorities toward public utilities and wastewater systems in particular. Historical capital investment data are somewhat distorted as it reflects poor economic conditions in recent years, although planning projections are optimistic. Generation and management of local funds will be of critical importance to implementation of the Wastewater Master Plan and project segmenting may present the only viable solution to temporary funds shortages. As discussed under foreign investment considerations, priority projects should be established in order to implement the Wastewater Master Plan in segments.

TABLE 9-12

ARAB REPUBLIC OF EGYPT
PAST AND PROJECTED INVESTMENT EXPENDITURES
(LE million, Unescalated)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Gross National Product	3 778	4 154	4 847	5 548	6 245	6 861	7 651	8 569	9 611	10 794
Capital Formation										
Gross Fixed Capital[a] Formation (Government Financed)	424	613	1 088	1 004	1 175	1 584	1 865	2 153	2 223	2 350
Less Foreign Loans, Arab and[b] Foreign Capital Partnership	n.a.	n.a.	n.a.	n.a.	n.a.	539	628	735	795	865
Net Fixed Capital Formation	-	-	-	-	-	1 045	1 237	1 418	1 428	1 485
Utilities and Wastewater Investment										
Utilities Investment[a] in Egypt	23	29	39	32	35	39	43	50	53	54
Wastewater Investment[c] in Egypt	6	10	12	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Wastewater Investment[d] in Alexandria	0.6	0.7	0.5	1.0	1.6	3.9	15.2	23.4	44.6	30.9

(a) Data for 1973-1975 taken from MOHR/USAID Housing Studies, August 1977, data for 1973 through 1982 taken from the Five Year Plan, 1978-1982 Ministry of Planning, Arab Republic of Egypt.

(b) Data for 1973 to 1977 period not available.

(c) Data for 1973-1975 taken from MOHR/USAID Housing Studies, August 1977, projections by Ministry of Planning not available

(d) Based on GOSSD-Alexandria records for 1973 through 1977; 1978 through 1982 based on Top Priority Projects and Wastewater Master Plan project costs.

Financing Plan Summary

1. Operation and maintenance costs should be recovered through sewer service charges to customers based on metered water usage; billing and collection should be accomplished in cooperation with the Alexandria Water General Authority. Wastewater rate schedules should consider social structure and incorporate surcharges for high strength wastes.
2. The cost of constructing sewer connections should be recovered through a connection charge to sewered customers; ability-to-pay should be considered in collecting these charges.
3. One-third of the cost of providing collection sewers in developer-owned areas should be charged to the benefiting developer.
4. Direct foreign exchange costs of the proposed construction program should be financed through loans from foreign investors; if foreign investment levels are lower than necessary, segments of the program should be financed from other sources to preserve continuity in its implementation.
5. The remaining local share should be financed through contributions from the national government; the necessary shift in capital development priorities should be emphasized in order that the public utilities sector receives increased support from government investments.

FIGURE 9-1 PROPOSED ORGANIZATION GOSSD - ALEXANDRIA

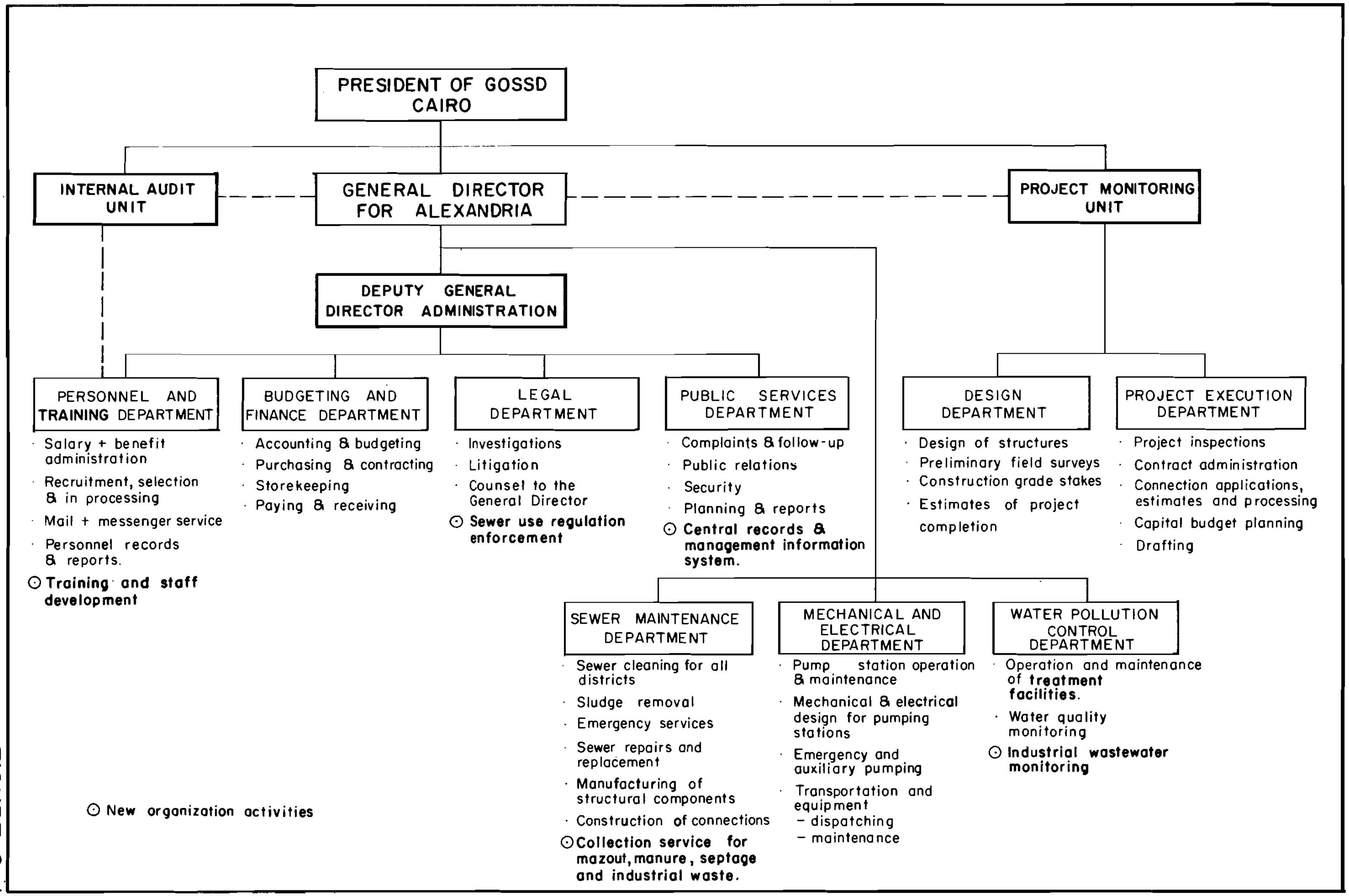

FIGURE 9-1

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