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Alexandria Wastewater Master Plan Study

INITIAL ENVIRONMENTAL IMPACT STATEMENT

VOLUME II
DRAFT TECHNICAL REPORT

Microfilmed From
Best Available Copy

Camp Dresser & McKee Inc.
Environmental Planning Division

with Marine Environmental Services
C.T. Main International Inc.
Arab Technical and Economical Consulting Office

ARAB REPUBLIC OF EGYPT
MINISTRY OF DEVELOPMENT & NEW COMMUNITIES

Your Ref. :

Our Ref. : MODANC/ACR-254-79

MINISTER'S OFFICE
1, Ismail Abaza Street,
Cairo, A.R.E.,

April 9, 1979

Mr. Joseph C. Wheeler
Assistant Administrator
for the Near East Bureau
United States Agency for
International Development
State Department
WASHINGTON D.C. 20523

Dear Mr. Wheeler:

Subject: Alexandria (A.R.E.) Wastewater Master Plan Study - Initial Environmental Impact Statement Draft Report

We are pleased to submit herewith the Initial Environmental Impact Statement (IEIS) for the Alexandria Wastewater Master Plan Study consisting of:

Volume I: Draft Statement for the IEIS
Volume II: Draft Technical Report for the IEIS

Pursuant to the National Environmental Policy Act of 1969 (P.L. 91-190) and Environmental Procedures (USAID Regulations, 22 CFR Part 216), as amended by Executive Order 11991, May 24, 1977, this IEIS has been prepared to fulfill the requirements for publication by USAID as a Draft Environmental Impact Statement (DEIS).

This Draft Statement for the IEIS presents the findings that the Ocean disposal system as recommended by the Master Plan is the environmentally preferred alternative. The finding is based on an extensive evaluation of the environmental, ecological, public health, economic, and engineering details which are presented and discussed in Volumes I and II of this report.

Very truly yours,

Dr. Hassan Marie
Chairman
Advisory Committee for Reconstruction

cc: USAID/IIDPS
GCSSD - MOH

ARAB REPUBLIC OF EGYPT

THE MINISTRY OF HOUSING AND RECONSTRUCTION

INITIAL ENVIRONMENTAL IMPACT STATEMENT
For The
Alexandria Wastewater Master Plan Study

VOLUME II

FINAL TECHNICAL REPORT

OCTOBER 1978

Prepared By
CAMP DRESSER & MCKEE INC.
Environmental Planning Division

With

MARINE ENVIRONMENTAL SERVICES
CHAS. T. MAIN INTERNATIONAL INC.
ARAB TECHNICAL AND ECONOMICAL CONSULTING OFFICE

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CHAPTER 1

INTRODUCTION

This Final Report of the Initial Environmental Impact Statement (FIEIS) is presented in two volumes:

Volume I: Final Statement for the IEIS (FIEIS)
Volume II: Technical Report and Appendices for the FIEIS.

Volumes I and II comprise a two part presentation of the Final Report for the Initial Environmental Impact Study of the Alexandria Wastewater Master Plan Study. The Master Plan Study (MPS) was conducted for the Arab Republic of Egypt (A.R.E.) during the period 1977-1978 by Camp Dresser and McKee, Inc., International Division (CDM) in association with Charles T. Main International, Inc. (MAIN), and the Arab Technical and Economical Consulting Office (ATECO), under contract to the Ministry of Housing and Reconstruction (MOHR) of the A.R.E. with financial assistance from the U.S. Agency for International Development (USAID) Cairo, A.R.E.

This volume of the FIEIS (Vol. II) is the Technical Report of the study including an Appendices of pertinent reference materials which present the basic details upon which the FIEIS of Volume I is based. The form and tenor of Volume II, as with Volume I, is in accordance with the purpose of the updated NEPA requirement for an EIS.

In summary, this Volume II Technical Report and Appendices consists of:

a) material prepared by the EIS Team for deriving the Final Statement (Vol. I of the FIEIS);

b) material which substantiates any analysis fundamental to the Impact Statement presented in Volume I;

c) material which is analytic and relevant to the decision to be made; and

d) presented as a separate bound volume which can be circulated with Volume I, the Environmental Impact Statement, or be readily available on request.

Volume I of this FIEIS is presented in a report format consistent with the updated requirement of NEPA Regulations as revised for an EIS. That is, according to the purposes of the updated NEPA report format, Volume I is a concise presentation of pertinent EIS information derived from the extensive environmental and technical detail compiled and analyzed by the EIS Team as presented in Volume II of this report.

The IEIS study was conducted by the Environmental Planning Division of Camp Dresser and McKee, Inc. (CDM) in association with Marine Environmental Services (MES), Chas. T. Main International, Inc. (CTM), and the Arab Technical and Economical Consulting Office (ATECO), under contract to the Ministry of Housing and Reconstruction (MOHR) of the A.R.E. with financial assistance from the U.S. Agency for International Development (USAID) Cairo, A.R.E.

Volumes I and II of this Environmental Impact Statement were prepared by a team of interdisciplinary scientists and engineers, all of whom contributed major text segments of this report.

All members of this team, with the exception of report reproduction and drafting personnel, spent significant amounts of time as resident investigators at the study site in Alexandria, Egypt.

The members of this EIS Study Team and their principal task designations follow:

1. Camp Dresser & McKee Inc. - Environmental Planning Division (CDM):

   - James R. Woglom, Officer-in-Charge and Environmental Planner
   - John J. Donohue, Project Manager and Environmental Analyst
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2. Marine Environmental Services (MES):

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   - Charles B. Officer, Physical Oceanographer
   - John H. Ryther, Biological Oceanographer

3. Chas. T. Main, Inc. (CTM):

   - Burton B. Bryan, Biosystems Analyst
   - Myron Gildesgame, Socio-Economic Analyst
   - Roland Scott, Socio-Economic Analyst

4. Arab Technical and Economical Consulting Office (ATECO)

Glossary, Acronyms, and Conversion Units. A listing of technical terms, abbreviations, acronyms, and units of measurement and their conversions are presented in Chapter 8 of this volume.

CHAPTER 2

ADMINISTRATIVE SUMMARY

2.A General

By summarizing the salient issues, data, and analyses discussed in the remainder of this report, this chapter provides a basis for the assessment of the environmental impacts of USAID's proposed financial assistance to a wastewater master plan for the city of Alexandria.

The National Environmental Policy Act of 1969, as amended in 1975, requires that an Environmental Impact Statement address:

- the environmental impact of the proposed action
- any adverse environmental effects which cannot be avoided, should the proposal be implemented
- alternatives to the proposed action
- the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity
- any irreversible and irretrievable commitments of resources which would be involved in the proposed action, should it be implemented.

All of these items are addressed in this summary chapter within the limits of available information.

2.B Existing Environmental Setting Without the Project

2.B.1 Physical Elements

2.B.1.a Study Area. Alexandria, the second largest city in Egypt, is located on the Mediterranean Sea about 200 km northwest of Cairo. The city is bounded by the Nile River Delta on the east and the Western Desert on the west. The study area conforms with the boundaries of the Alexandria Governorate and is bounded by the Mediterranean Sea on the north and Abu Kir Bay on the east. To the south, lie several prominent features, among them Lake Maryut, Nouzha Airport, the Taufigi Canal, and the Abu Kir-Rosetta Highway. To the west, it includes Mex-Dekheila and Agamy, and to the southwest, Ameria. The total study area is estimated to be 66,000 ha.

2.B.1.b Topography. The dominating physical features of the Alexandria area are the Mediterranean Sea, the lower Nile Delta, Lake Maryut, the vast Western Desert, and myriad canals and drains. The basic topographic features which have caused the linear development of Alexandria include a limestone ridge and marine lagoon (Lake Maryut), both of which parallel the sea in an east-west alignment through much of the study area. The height of the ridge varies from 5 to 22 m, while much of the land south of it is at or below sea level. These and other topographic features are shown on Fig. 3-4.

2.B.1.c Geology and Soils. The study area is situated at the extreme northwestern boundary of the Nile deltaic basin and its intersection with the shoreline of the Mediterranean Sea. The surficial geological features and materials of the study area essentially rest on a stable substratum superimposed on the western limb of a deep-seated stratigraphic depression which more or less accounts for the containment of the superimposed Nile Delta.

The predominant geological features of the study area are the shoreline of the Mediterranean Sea, the northeastern region of the Western Desert, the western segment of the lower Nile Delta, the Lake Maryut and Lake Idku marine lagoons, and a ridge of calcareous sandstone and dense limestone often referred to as an oolitic limestone or, historically, as the limestone of Alexandria.

Both the calcareous-rock ridge and the marine lagoons parallel the Mediterranean shoreline and extend in an east-west direction throughout the study area. The position of the ridge is situated from 500 to 1,500 m inland from the marine shoreline, varies in height from 5 to 22 m, and structurally accounts for a "high ground" feature having an approximate width of 1 to 4 km. Seismically, the area is considered to be relatively stable, and earthquake activity in the study zone, based on existing

information, is not expected to pose unusual problems for construction of the recommended facilities.

The current day shoreline of Alexandria undergoes normally expected dynamical influences of a marine environment and can be regarded as being relatively stable. That is, expected erosional, depositional, and other geological modifications are similar to other marine shorelines influenced by similar conditions and intensitites of oceanographic processes.

In summary, soils found in the study area range from fairly well sorted beach sands at the shoreline to deposits of silts and marine clays associated with the current day lake lagoons of the area and past marine transgressions. Furthermore, the area, based on subsoil types, can be divided into five general zones with soil makeup ranging from sandy subsoils, which, in some instances, are cemented or partially cemented; admixtures of clay, silt and sand, some of which form lenses within a basically sandy substrate; deposits of marine clays and gypsiferous evaporite deposits associated with the formation of marine lagoons; and deposits of fine-grained deltaic soils admixed with organic debris.

Based on available information, the various geologic and soils characteristics of the study area were reviewed in evaluating potential environmental impacts which might emanate from the proposed courses of action related to the Alexandria Wastewater Project.

Details related to the geology and soils of the study area are presented in Chapter 3.

2.B.1.d Climate, Meteorology, and Air Quality. The climate in Alexandria is characterized by windy, mild, wet winters and relatively calm, hot, and dry summers. Prevailing winter weather is generally cold, 10 degrees to 15 degrees C with intermittent periods of mild and rainy weather. The summer weather is generally dry and hot but cool sea breezes temper the heat. Annual rainfall in Alexandria is about 200 mm and confined almost entirely to the October through April period. Prevailing winds are from the northwest during most of the year, averaging about 4 m/sec. The mean maximum temperatures in winter and summer are 18 degrees and 30 degrees C, while the mean minimums are 9 and 23 degrees C, respectively. The average relative humidity is about 70 percent.

Because of known deleterious effects on health and economy, air pollution is an important problem in industrial communities. An air quality survey was conducted as part of a master's thesis by a graduate student at the University of Alexandria. In general, air quality in Alexandria does not meet U.S. federal ambient air quality standards established by the U.S. Environmental Protection Agency and appears to be worse than some heavily industrialized areas in the U.S. A summary of air quality data is presented in Chapter 3.

2.B.1.e Water Resources (including Water Quality).

2.B.1.e.i Marine Waters. Physical characteristics of the Mediterranean Sea are being studied as part of the oceanographic surveys in progress since July 1977 and scheduled for completion later in 1978. These surveys include studying offshore current at the surface and at various depths, determining bathymetric profiles along proposed outfall alignments, and assessing the physical and biological characteristics of the offshore waters. In general, the bathymetric profiles and offshore currents indicate use of ocean outfalls is feasible for wastewater disposal. Specific marine characteristics based on available information are discussed in Chapter 3.

2.B.1.e.ii Freshwater Environment. There are two shallow freshwater lakes within the project boundaries. Both of these, Lake Maryut and Lake Idku, contain brackish waters with varying degrees of salinity, but only Lake Idku is connected to the sea. Lake Maryut represents the southern boundary of Alexandria, while Lake Idku lies along the outskirts of the city and is connected to Abu Kir Bay. Because the Aswan High Dam has affected the fertility of the coastal waters, these and other delta lakes have become important fisheries. Neither of these lakes have as much survey data as the Mediterranean, but the information available is presented in Chapter 3.

2.B.1.e.iii Groundwater. In general, the quality of groundwater in the Alexandria region, and particularly in the study area, for purposes of drinking and irrigation, is extremely poor. Analyses of currently available data on groundwater all bear witness to the predominance of brackish and unfresh water being contained within the subsurface soil deposits and consolidated bedrock formations of the Alexandria area. There are few, if any, occurrences of groundwater in the study area which can be considered as being freshwater according to the normally accepted definition.

Past and current waterwell borings throughout the Alexandria area have, in general, yielded a groundwater product which is at best significantly brackish and, in a considerable number of instances, must be regarded as being absolute brine. The persistent brackish character of the groundwater is because of several basic reasons. These are:

- a continuous seawater infiltration into the terrestrial substratum
- bedrock strata and many of the soils are permeated with soluble marine salts and gypsum
- the overall negligible yield of atmospheric freshwater recharge.

There are, of course, other reasons. However, the above itemize those which are the principal causes of the brackish groundwater conditions. Depth to the so-called water table, if indeed there is a true water table based on normally accepted definition, is generally very shallow and is usually found within a few meters of the ground surface. This is chiefly because of the low topographic relief of the Alexandria area and the infiltration of sea water into the terrestrial substratum.

There is a paucity of coherent basic groundwater data for the study area. Existing data, while locally useful, are based on widely scattered and relatively shallow (a few tens of meters) borings and lack completeness as to parameter recording. This is especially true regarding the possible existence of a deepseated (i.e., in excess of 100 m or so) freshwater aquifer which may or may not exist in the subsurface of the Alexandria area. However, the existence of a deepseated aquifer must be regarded as a possibility. However, for all practical considerations, if such an aquifer does exist, it will probably not be determined within the forseeable future; this type of study and evaluation is beyond the scope of this report. It is mentioned here to focus attention on a possible valuable resource should it be present, because the impacts of potential salt sinks within the Alexandria region, especially to the west, could have an irreversible deleterious impact.

Further analysis and evaluation of study area groundwater conditions are presented in Chapter 3.

2.B.2 Biological Elements

2.B.2.a Terrestrial Ecology. The land within the project area consists of urban development, freshwater lakes and marsh, irrigated agricultural land and desert. Few wild animals live in the urban or agricultural areas, and the project would have negligible impact. However, many species of waterfowl use marsh areas for winter range. Species of birds found in the delta region are listed in the technical appendices of this report. There are virtually no terrestrial species in the desert areas proposed for use as evaporation ponds.

2.B.2.b Marine Ecology. Alexandria lies on the coast of the moderately deep eastern basin of the Mediterranean, a nutrient poor marine habitat where phosphate appears to limit productivity. Productivity and species variety are both low, with most of the Mediterranean fauna consisting of species identical to or closely related to those of the Atlantic. Egyptian waters have probably felt the impact of man's activities more than any others in the world considering the effects of both the Suez Canal and the Aswan High Dam. Completion of the Suez Canal has allowed significant migration from the fauna-rich Red Sea to the eastern Mediterranean,

resulting in the replacement of some native species; Red Sea species now constitute a significant fraction of the eastern Mediterranean fisheries.

Construction of the Aswan High Dam has drastically reduced the quantity of nutrients released to the Mediterranean by the Nile, resulting in a drop in Egyptian marine catches from 37,000 tons in 1962 to 8,100 tons in 1970. In 1975, Alexandria's marine catch was 2,875 tons, and the freshwater catch may be assumed to be about 5,000 tons, also reflecting a decline from previous years. Pollution from industrial and agricultural wastes discharged to Abu Kir Bay at Tabia is probably responsible in part for the decline in shrimp, grey mullets, and soles in Abu Kir catches, and overfishing of coastal waters is a general problem of the entire Alexandria region. Pollution from the discharge of domestic wastes by the Kait Bey outfall is not, however, implicated in fishery declines and, in fact, may alleviate the overfishing problem somewhat by supplying needed nutrients.

2.B.2.c Freshwater Ecology. The freshwater resources of the Alexandria region consist of the interconnected basins collectively known as Lake Maryut in the central part of the governorate and the marine lagoon south of Abu Kir Bay called Lake Idku. The ecology of both systems is not well understood, but existing data and conclusions are summarized below.

The bulk of data available for Lake Maryut describes its Main Basin, a shallow, brackish, very productive, and highly eutrophic habitat. The average depth is about 1 m, and the basin is well mixed with little stratification. The basin receives heavy industrial and domestic wastewater pollution from four discharges along the northern shore and the Kalaa Drain in its southeastern corner. Extensive studies in 1960 indicated a high primary productivity of 6 $gC/m^2/day$ in the Main Basin, 10 times that of Lake Idku and 20 times that of the Nouzha Hydrodrome; undocumented reports have, however, indicated a decrease in Maryut's primary productivity since that time. The flora and fauna are characterized by large numbers of very few species, as indicated by the fact that 90 percent of the fish population and commercial catches are of the genus, *Tilapia*. Fishery data are unreliable, but conversations with fishermen indicate that most of the catches come from the Noubaria Canal and Umoum Drain, while a marine biologist at the University of Alexandria indicates that only 20 percent of Lake Maryut's fishery comes from the Main Basin. In summary, the Main Basin of Lake Maryut is an extremely fertile, highly productive body of water, one whose advanced state of eutrophication threatens its usefulness to man. Useful ecological data on the other basins of Lake Maryut are not currently available.

Lake Idku is a shallow marine lagoon, approximately 13,000 ha in area, connected to Abu Kir Bay by the Rouqaz inlet on its northwestern shore. The eastern half to two thirds of Lake Idku is covered by a dense plant growth, while the western portions remain relatively clear of vegetation. Mean primary organic production is reported as 0.6 $gC/m^2/day$, with values in the western portion twice that of the overgrown eastern portions. The

fish fauna of Lake Idku are essentially the same as that of Lake Maryut, and the majority of fish are again of the genus, Tilapia. In addition, a valuable shrimp fishery in Abu Kir Bay depends on Lake Idku to provide a brackish post-larval habitat. Fishery data to indicate Lake Idku's importance relative to Lake Maryut are unreliable, and opinions on the subject conflict. 1970 statistics indicate that Lake Idku landings are intermediate between the minimum and maximum values reported for Lake Maryut, while another source indicates that more fish are now landed at Idku than at Maryut.

2.B.2.d Special Status Species. Neither the Egyptian Government nor the Alexandria Governorate lists any species in the project area as having any special status. The only endangered species listed by the Fish and Wildlife Service of the U.S. Department of the Interior found in Egypt is the slender-horned gazelle. It would be highly unlikely to find this desert-dwelling animal in the project vicinity.

2.B.3 Human (Socioeconomic and Cultural) Elements

2.B.3.a Population and Housing. The current population is about 2,300,000 and expected to reach 4,700,000 by the year 2000. Population densities vary according to district; however, overall net density is about 2,800 people per sq km. An estimated 350,000 seasonal residents live in Alexandria during the summer, and this number is expected to reach 595,000 by the year 2000. The vast majority of the people live in multi-family housing with the few private villas being used as consulates, officials' residences, or homes for foreign business personnel. There is a critical housing shortage for all classes of people, especially the poor. According to one official, about 17,000 people live in tents on the outskirts of the city.

2.B.3.b Public Health Issues. Public health statistics from WHO and the Egyptian census show that health conditions in Alexandria are extremely poor. More than one out of eight infants die by the end of the first year, and the incidence of water-related diseases such as typhoid and paratyphoid, infectious hepatitis, and dysentery are two to ten times higher than the national average. The incidence of cholera during the 1970 outbreak was six times the national average and the highest in Egypt. Observation of streets flooded with wastewater, in both sewered and unsewered areas, confirms the relation between Alexandria's inadequate wastewater management and its poor public health.

2.B.3.c Economy. Alexandria is Egypt's primary port city and its second largest urban center. With the planned expansion of the western harbor port facilities, Alexandria will be able to handle 70 percent of the nation's maritime traffic. The city is also heavily industrialized and

only 4 percent of its workers are involved in agriculture. Primary businesses include manufacturing, commerce, transportation, communications, services, and insurance. Primary industries include textiles, food processing, petroleum products, chemicals, metals, and paper and soap production. With the proposed new port facilities and industrial growth, economic expansion is expected to continue. The average annual per capita income in Egypt is currently about L.E. 110 (U.S. $155).

2.B.3.d Land Use. The governorate is composed of about 46 percent desert, 28 percent agricultural land, 16 percent urban development, and 10 percent water. The city is difficult to classify as strictly residential, commercial, or industrial, because there is significant mixing throughout the city. Most of the city is densely populated with a mixture of small shops and apartments. There is only a small amount of open space, primarily the beach areas, Montazah Palace, and a few small parks. Most industries are located along a crescent beginning at Abu Kir Bay and running west along the Mahmoudia Canal to Mex-Dekheila. Ameria and its free zone industrial development area are expected to receive residential and commercial development in coming years. Sadat City, a proposed development for 500,000 people by the year 2000, is currently planned to be located in agricultural lands southwest of Abu Kir. Extensive tourist development is proposed for the Agamy area.

2.B.3.e Government Organization. Alexandria is classified as a city governorate and combines the functions of both governorate and city administrations. Government services within Alexandria are provided by branches of national ministries, and the governorate itself, because of few locally-derived revenues, is basically an arm of the national government. The principal organization for wastewater facilities in Alexandria is the General Organization for Sewage and Sanitary Drainage (GOSSD). Its parent organization in Cairo is the Ministry of Housing and Reconstruction (MOHR). GOSSD is responsible for managing, improving, maintaining, and operating the city's wastewater facilities. However, it lacks adequate trained personnel for the task. All major decisions for the design and construction of new facilities are made in Cairo.

2.B.3.f Community Facilities.

2.B.3.f.i Wastewater. The city's wastewater, water, solid waste, transportation, recreation, and cultural facilities are described in Chapter 3. Existing wastewater collection facilities consist of a network of sewers, pump stations, and force mains serving the east, west, and central zones of the city. Treatment facilities consist of a secondary activated sludge plant (East Plant) placed in operation in 1975 and a primary treatment plant (West Plant) under construction since the early 1960s (estimated completion, 1979). Disposal facilities consist of the east plant discharge, the Kait Bey outfall, and numerous other raw wastewater discharge points

along the Mediterranean beaches and Lake Maryut. Existing collection facilities are basically adequate for current needs. However, extensive construction is needed to meet the city's requirements through the year 2000.

2.B.3.f.ii Water Supply. Alexandria is fortunate to have a municipal water utility serving potable water at generally adequate pressure to most of the city's population. The Alexandria Water General Authority has expanded its physical facilities in the past and currently meets most needs. Principal problems include poor raw water quality, poor plant operation and maintenance, and inadequate supervision or training of personnel. The existing facilities are inadequate for future demand, and a major improvements program has been proposed.

2.B.3.f.iii Solid Wastes. There is no comprehensive solid waste management program in Alexandria. Residents in middle and upper income areas pay private contractors to collect refuse from their homes. Refuse from lower income groups and many shops is disposed of in the streets. Insufficient attempts are made to clean the streets, and piles of refuse are visible throughout the city. Refuse is often dumped into sewers, creating blockages and maintenance problems. Existing conditions contribute to the breeding of flies and other disease vectors.

2.B.3.f.iv Transportation. Because of physical limitations, Alexandria has developed on a narrow strip of land, and intracity traffic follows an east-west pattern. Street traffic, normally congested and noisy, consists of an assortment of motor vehicles mixed with animal-drawn carts and pedestrians. Public transportation includes electrified streetcars and light rail vehicles (collectively called trams), buses, and railroad service. Trams serve only Alexandria, while buses and railroads provide connections to other communities. Alexandria is also connected to Cairo and the southern parts of Egypt by two paved roads, the delta road and the desert road. The city does not have regularly scheduled commercial plane service. The western harbor is the country's major port and handles the majority of import-export traffic.

2.B.3.f.v Recreation. Alexandria's major recreation attraction is its beaches, and thousands of visitors vacation here during the summer months. However, many beaches are polluted from either continual or intermittent wastewater discharges. Corrective measures are required to reduce the public health hazards from bathing in polluted waters.

2.B.3.g Cultural Resources. Alexandria has only fragments of its long history intact, and a few remaining remnants are on display in the Greco-Roman Museum. Among other cultural facilities are the Municipal Library, the University of Alexandria, Kait Bey Fort, and several botanical gardens. The city has a sports stadium, two sporting clubs, and the grounds

of the former royal palace at Montazah have become a park for all to enjoy. Many cultural events are sponsored by the various foreign government consulates in Alexandria, and foreign film festivals occasionally appear at the city's cinemas.

2.C Future Environmental Setting Without Improved Wastewater Facilities

Chapter 4 described, in general terms, the environmental impacts of the "no-action" alternative under which no improvements are made in Alexandria's wastewater management practices. The deterioration in public health conditions would be the most obvious and serious change, but the ecological balance of Lake Maryut and Alexandria's Mediterranean fisheries would also be endangered.

2.C.1 Elements not Expected to Change

The physical characteristics of location, terrestrial and marine topography, geology and soils, climate, and groundwater are not expected to change substantially with or without improved wastewater facilities. The oceanographic situation is also unlikely to change. Of the biological and human elements of the environment, however, only the governmental organization and cultural resources can be reasonably assumed to remain the same without improved public wastewater facilities.

2.C.2 Elements Expected to Change

Of the environmental characteristics which would change if no action is taken, a distinction must be made between those which would occur regardless of Alexandria's wastewater management practices, and those which would be a direct result of the failure to improve wastewater facilities. The population, land use, and economy of the Alexandria region can all be expected to change with or without improved public wastewater facilities, because of ambitious industrial development programs summarized in Tables 4-2 and 4-3. Current population projections indicate a near doubling of population--from 2.3 million persons now to 4.7 million persons in the year 2000; the economic and demographic forces these numbers represent are too powerful to be halted by inadequate wastewater facilities. The public health implications of explosive population growth without adequate wastewater facilities are disastrous, particularly given Alexandria's status as an international port and national industrial center. Tourism also presents an ideal means of disease transmission to the rest of Egypt, although one which would diminish in importance as the industry declines in response to increasing health hazards. While only 15 percent of the current population live in unsewered areas, this would increase to about

40 percent by the year 2000, and the public health hazards described for these areas in Chapter 3 would affect 1.9 million persons.

The ecological balance of Lake Maryut and Alexandria's Mediterranean fisheries would also be endangered by the increase in raw wastewater discharges. The actual conditions in the lake would depend on the balance between flushing rate, nutrient levels, and the rate of phytoplankton growth, but trial calculations indicate that the annual catch from the Main Basin of Lake Maryut would drop sharply. Pollution from the Mex Pump Station discharge to Dekheila Bay and the Mediterranean would also increase. Pressure on the Mediterranean fisheries would intensify, as a result of population growth and decreased freshwater catches in Lake Maryut. Unabated wastewater pollution along the shore of the Mediterranean could also cause irreparable damage to fisheries and place Egypt in an increasingly embarrassing international position.

In summary, both the social and ecological environment of Alexandria would be profoundly damaged by the failure to improve wastewater facilities. Although the precise extent of these damages is hard to assess, the "no-action" alternative is clearly unacceptable, and corrective action is required immediately.

2.D Description of Alternative Wastewater Master Plans

Chapter 5 describes the wastewater facilities alternatives considered by the Wastewater Master Plan and the plan's procedure to eliminate unsuitable options. The preferred plan is summarized at the end of the chapter, and the locations of the recommended treatment and disposal facilities are shown on Fig. 5-1.

2.D.1 Alternative Considerations

Wastewater master plans are described in terms of collection, treatment, disposal, and consolidation alternatives. In Alexandria, there are four disposal alternatives. These are:

- disposal to the Mediterranean through sea outfalls or canals and/or drains
- disposal to Lake Maryut
- disposal to the land for crop irrigation
- disposal to evaporation ponds.

Treatment process alternatives consist of:

- preliminary treatment
- primary treatment
- secondary treatment
- anaerobic-aerobic lagoons.

About 50 percent of the year 2000 wastewater design flow is of industrial origin, of which about 70 percent (i.e., 35 percent of the total flow) cannot be accepted by conventional wastewater facilities because of excessive grease, suspended solids, acids, bases and/or toxic constituents. The Master Plan addresses two alternatives for the control of these strong industrial wastes: (1) separate collection and transportation to an evaporation pond, and (2) pretreatment by the industry before discharge to the municipal sewer along with the city's domestic wastes.

Because of the number and location of sewer service areas, consolidation alternatives are numerous (see Fig. 5-1). Ten sewer service areas within the governorate of Alexandria were consolidated into eight planning districts. These revised districts and, in some cases, the former sewer service areas they represent are:

- -Abu Kir (Abu Kir)
- -Outer East (Siouf Keblia, Ras el Soda, Sadat City)
- -Inner East (East Zone)
- -Nouzha (Nouzha)
- -Central (Central Zone)
- -Inner West (West Zone)
- -Outer West (Mex-Dekheila)
- -Ameria (Ameria).

The consolidation possibilities involving these eight districts include:

- -no consolidation
- -total consolidation
- -partial consolidation.

2.D.2 Evaluation Criteria

Because of the innumerable master plans which can be developed using eight service areas, two industrial waste collection alternatives, four wastewater treatment alternatives, and four wastewater disposal alternatives, the Master Plan report adopted an elimination procedure beginning with a regional approach. Cost-effectiveness and noneconomic parameters such as reliability, flexibility, implementation, and engineering judgment became the evaluation criteria.

2.D.3 Regional Alternatives

The initial screening procedure involved four regional master plans, each using a different disposal alternative. These plans, shown schematically on Fig. 5-2, principally involve:

A. sea disposal following preliminary treatment
B. lake disposal following secondary treatment
C. effluent reuse for crop irrigation following secondary treatment
D. evaporation ponds.

The total capital costs, average annual operating cost, and total present worth for these alternatives are shown below. In those stages of planning during which the environmental analyses of this report were performed, Alternatives C and D were not developed in detail because of their far greater cost. Reuse of highly saline effluent could not be justified, if adequate, less expensive supplies of fresh water were available; nor could desert evaporation, if Alternatives A and B satisfied planning criteria at considerably less expense. In the final stages of engineering analysis in the Master Plan Study, Alternative B was eliminated from consideration for environmental and other reasons, and only regional Alternatives A, C, and D are presented in the Final Report; technically detailed service-area alternatives for both sea disposal and reuse are also developed in the final Master Plan Report.

Regional Alternatives (L.E. x 10^6)

	A	B	C	D
Capital cost	314	316	359	410
Average annual O&M	3.8	6.0	6.5	5.6
Present worth	228	249	280	304

Note: All costs shown in this report are based on the Preliminary Draft Final Report of the Alexandria Wastewater Master Plan dated 5 January 1978. Cost estimates included in the final submission of the Master Plan may differ somewhat, but those shown indicate the relative costs with sufficient accuracy to allow informed comparison of alternatives.

2.D.4 Industrial Wastewater Management Alternatives

The industrial wastewater survey conducted as part of the Master Plan revealed that the industries of Alexandria currently discharge about 870 Ml/day of wastewater, of which 230 Ml/day carry some pollutional load. These contaminated industrial flows are stronger than Alexandria's domestic wastes, and many cannot be accepted by a conventional wastewater system without pretreatment. Apart from unacceptably high concentrations of suspended solids, grease, and corrosive acids or bases, industrial wastewaters often contain materials which are potentially toxic, mutagenic, or in some other way harmful to the environment. Section 5.C.2 of this report notes some of the major industrial waste problems discussed in Appendix C of the Master Plan. Technical Appendix 5 in this report summarizes Master Plan Appendix C, lists the major industries with toxic effluents and presents the pretreatment recommendations contained in the Rough Draft of the Toxic Industrial Waste Study.*

* See Tech. App. No. 5A and 5B, Vol. II, this report.

The alternatives considered in the Master Plan for the management of strong industrial wastes consisted of either (1) industrial pretreatment and discharge to the municipal sewers, or (2) separate collection and conveyance to an evaporation pond. Costs for the common facilities required for Alexandria's domestic and pretreated industrial wastes are compared below with those for the separate systems, under both the Lake Maryut and sea disposal alternatives. It should be noted that pretreatment costs are not included in the combined system alternative because their determination required detailed study of individual industries beyond the scope of the original Master Plan contract. Preliminary designs and costs estimates of pretreatment facilities are included in the Rough Draft of the Toxic Industrial Waste Study.*

Industrial Wastewater Management Alternatives (L.E. x 10^6)

	No Separation		Strong Waste Separation	
	Sea Outfall	Lake Maryut	Sea Outfall	Lake Maryut
Capital Cost	314	316	363	366
Average annual O&M	3.8	6.0	4.3	6.2
Present worth	228	249	263	282

As experience elsewhere indicated pretreatment within individual industries is generally the most cost-effective and practicable means of controlling toxics, the Master Plan recommended the pretreatment alternative for management of most of Alexandria's industrial wastewaters. However, the Master Plan recommended the separate conveyance of industrial wastes from Abu Kir to an evaporation pond at nearby Lake Idku because of its lower cost in this region.

2.D.5 Consolidation Alternatives

Without performing a rigorous economic analysis, consideration was given to three consolidation alternatives--no consolidation, total consolidation, and partial consolidation. Both no consolidation, involving eight treatment and disposal facilities, and total consolidation, involving one system, were judged to be technically and economically inappropriate. However, the possible partial consolidation alternatives, involving eight sewer service areas, are numerous and more detailed evaluations were conducted.

* See Tech. App. No. 5A and 5B, Vol. II, this report.

2.D.6 Service Area Alternatives

2.D.6.a Evaluation Criteria. In the stages of Master Plan study during which environmental analyses were performed, detailed service-area alternatives were only available for the two least-cost alternatives, sea and lake disposal. These are the alternatives presented below, and provide the basis for the environmental impact analyses of sea and lake disposal presented in Chapter 6. Since that time, those service area alternatives discussed below which employ secondary treatment and lake disposal, have been replaced in the Final Master Plan Report by alternatives employing identical treatment facilities for agricultural irrigation, consistent with the Master Plan's rejection of lake disposal as an acceptable alternative. Environmental impacts of sea disposal, lake disposal, irrigation and evaporation are all addressed in detail in Chapter 6 of this report.

Because of the geography of Alexandria and the intent to salvage existing facilities, the Inner West and Central zones were consolidated into the western planning area and the Outer and Inner East into the eastern planning area prior to conducting alternative studies. Separate studies were conducted on the remaining four peripheral areas--Abu Kir, Outer West, Ameria, and Nouzha. Costs for the various consolidation alternative studies were based on preliminary engineering designs of the required facilities.

2.D.6.b Eastern Alternatives. Alternatives considered for the eastern area were:

1. discharge to Lake Maryut following secondary treatment for the eastern area

2. discharge to Lake Maryut following secondary treatment from a regional plant serving both eastern and western areas

3. discharge to the sea following preliminary treatment for the eastern area.

These alternatives are shown schematically on Fig. 5-5, and their costs are summarized below. Alternative 3 was chosen for the preferred Master Plan because of its cost effectiveness, greater reliability because of a simpler treatment process, and insurance of continued satisfactory disposal afforded by ocean dilution.

Eastern Alternatives (L.E. x 10^6)

	1	2	3
Capital cost	157.07	150.50	132.39
Average annual O&M	2.89	2.57	1.52
Present worth	121.0	114.0	98.0

[1]Costs include collection, treatment, and disposal facilities for both toxic wastes and remaining flow.

2.D.6.c Abu Kir Alternatives. Alternatives considered for Abu Kir included:

1. disposal of all wastewater in an evaporation pond
2. disposal of all wastewater at sea through the eastern area outfall
3. disposal of domestic wastewater at sea and industrial waste in an evaporation pond.

These alternatives are shown schematically on Fig. 5-5, and their costs are summarized below. Alternative 3 was recommended for the preferred Master Plan because of its cost effectiveness in comparison with Alternative 2 and its greater flexibility when compared to Alternative 1.

Abu Kir Alternatives (L.E. x 10^6)

	1	2	3
Capital cost	33.87	48.15	33.38
Average annual O&M	0.24	0.64	0.21
Present worth	23.00	37.00	22.00

[1]Costs include collection, treatment, and disposal facilities for both toxic wastes and remaining flow.

2.D.6.d Western Alternatives. Alternatives considered for the western area were:

1. discharge to Lake Maryut following secondary treatment for the western area

2. discharge to Lake Maryut following secondary treatment from a regional plant serving both western and eastern areas

3. discharge to the sea following preliminary treatment for the western area.

These alternatives are shown schematically on Fig. 5-5, and their costs are summarized below. Alternative 3 was chosen for the preferred Master Plan because of its cost effectiveness, greater reliability because of a simpler preliminary treatment process, use of the existing West Treatment Plant for preliminary treatment of Inner West wastewater, and insurance of continued satisfactory disposal afforded by ocean dilution.

Western Alternatives (L.E. x 10^6)

	1	2	3
Capital cost	94.38	88.66	79.03
Average annual O&M	2.32	1.77	1.61
Present worth	78.00	71.00	64.00

[1]Costs include collection, treatment, and disposal facilities for both toxic wastes and remaining flow.

2.D.6.e Outer West Alternatives. Alternatives considered for the Outer West included:

1. discharge to the new Noubaria Drain following treatment in an anaerobic-aerobic lagoon

2. discharge to the new Noubaria Drain following treatment in a regional anaerobic-aerobic lagoon for the Outer West and Ameria

3. discharge to the sea following preliminary treatment through the Kait Bey outfall.

These alternatives are shown schematically on Fig. 5-5, and their costs are summarized below. Alternative 1 was recommended for the preferred Master Plan because of its cost effectiveness, simplicity of operation, and greater flexibility to adapt to future land use changes.

Outer West Alternatives (L.E. x 10^6)

	1	2	3
Capital cost	21.36	24.61	32.80
Average annual O&M	0.23	0.24	0.47
Present worth	11.00	17.00	26.00

[1]Costs include collection, treatment, and disposal facilities for both toxic wastes and remaining flow.

2.D.6.f Ameria Alternatives. Alternatives considered for Ameria included:

1. discharge to the new Noubaria Drain following treatment in an anaerobic-aerobic lagoon

2. discharge to the new Noubaria Drain following treatment in a regional anaerobic-aerobic lagoon for the Outer West and Ameria.

These alternatives are shown schematically on Fig. 5-5, and their costs are summarized below. Alternative 1 was selected for the preferred Master Plan because of its cost effectiveness, simplicity of operation, and greater flexibility to adapt to future land use changes.

Ameria Alternatives (L.E. x 10^6)

	1	2
Capital cost	22.74	26.60
Average annual O&M	0.17	0.22
Present worth	15.0	18.0

[1]Costs include collection, treatment, and disposal facilities for both toxic wastes and remaining flow.

2.D.6.g Nouzha Alternatives. The Master Plan recommends that Nouzha's wastewater be discharged to Lake Maryut after passage through the existing East Treatment Plant. Under the recommended plan, no other flow would be

treated by the East Plant, and its capacity would remain adequate for the Nouzha area through the year 2000. For these reasons, and because Nouzha is adjacent to the East Plant, no other alternative was considered for the Nouzha area.

2.D.7 The Preferred Plan

The preferred plan is shown schematically on Fig. 5-6. Briefly, it consists of:

1. two ocean outfalls, one at Sidi Bishr with preliminary treatment facilities in Ras el Soda serving the eastern area and domestic wastewater from Abu Kir, and the other at Kait Bey with preliminary treatment facilities at Kait Bey for the Central Zone and at the existing West Plant for the Inner West Zone

2. an evaporation pond in Lake Idku for industrial waste from Abu Kir

3. two anaerobic-aerobic lagoons, both with discharge into the new Noubaria Drain, one each for the Outer West and Ameria

4. use of the existing East Plant for Nouzha.

2.E Environmental Impacts of Alternatives

Chapter 6 discusses the environmental impacts associated with the four disposal alternatives and the construction and operational impacts connected with building and operating the proposed collection, treatment, and disposal facilities.

2.E.1 Primary Impacts-Ocean Disposal

2.E.1.a Ocean Outfall Assimilation Characteristics. Because of substantial experience with the operation and performance of existing outfalls, theoretical predictions about outfall performance can be made. Section 6B presents data from several existing outfalls and summarizes the theory of performance predictions. Extensive marine studies have been conducted off the coast of Alexandria as a part of the Master Plan Study, in order to satisfy the basic data requirements of preliminary planning and design of the proposed outfall system. Technical Appendix No. 8, Vol. II of this EIS report, presents pertinent details which have been appropriately incorporated into the evaluation of potential environmental impacts that could result from wastewater disposal to the sea, as recommended in the Master Plan Study.

2.E.1.b Environmental Impacts-Outfall Alternatives. Based on projected flows and loads from various service area consolidation schemes, impacts on the sea environment were estimated. In summary, the following are predicted:

- negligible effect on the DO concentration of the receiving water
- estimated wastewater nutrient concentrations should not have any detrimental effect and actually might enhance the productivity of the eastern Mediterranean near the outfall locations
- little chance for bacterial pollution at the beaches from wastes discharged from a diffuser 8-10 km offshore and in water depths of about 50 m
- possible adequate dilution will be available to negate potentially adverse impacts from toxic industrial wastewater discharges, based on known existing industrial wastewater characteristics
- creation of sludge deposits from the deposition of suspended solids which would probably confine themselves to an area of about 4 km at the ends of each outfall
- reduction of benthic animal species in the vicinity of the sludge deposits
- potential loss of nutrients for agricultural reuse.

2.E.1.c Mitigating Measures. Any bacterial pollution associated with the outfalls could be mitigated by effluent chlorination, the effectiveness of which may be limited by the low degree of treatment received before discharge. Primary treatment before discharge could mitigate problems associated with sludge bank formation as well as improve the efficiency of any effluent chlorination. Finally, the strong enforcement of a sewer use ordinance (see Technical Appendix 6), and construction and operation of the pretreatment facilities recommended in the Toxic Industrial Study would be effective mitigation measures for any problems associated with toxic constituents of industrial wasteflows, as discussed in Section 7.E.4 of this report.

2.E.2 Primary Impacts-Lake Disposal

2.E.2.a Lake Characteristics. Lake Maryut currently receives untreated domestic and industrial wastewater from two of the three sewered areas. Because of these discharges and agricultural drainage, the lake is highly eutrophic. This condition required the evaluation of several interrelated effects, to determine probable alternative impacts. These included:

- the effect of domestic and industrial wastewater characteristics on the lake environment

- the effect of the lake environment on domestic and industrial wastewater characteristics

- the effect of the resulting lake discharge on the Mediterranean (lake effluent is discharged to Dekheila Bay and the western harbor).

Because there is a general lack of information about the ecology of Lake Maryut, reliable quantitative assessment was impossible. However, general conclusions about the effects of various alternatives could be made and these are summarized below.

2.E.2.b Environmental Impacts-Nouzha Discharge. In this alternative, the only wastewater discharged into Lake Maryut would be secondary-treated effluent from the Nouzha area. The net effects on Lake Maryut in comparison to current conditions are:

- reduction of flow into the lake and increased lake retention time

- reduction of wastewater and nutrient loadings

- fish production might increase to some extent but would probably be subjected to large fluctuations because of periodic conditions of anoxia.

Because of increased retention time, the ecological stability of the lake would not significantly improve; however, there would probably be an improvement in effluent water quality pumped to Dekheila Bay and the western harbor.

2.E.2.c Environmental Impacts-Eastern and Western Discharges. In these alternatives, wastewater from the eastern and western areas would be discharged into Lake Maryut through either two separate or one regional secondary treatment plant. The net effects on Lake Maryut are:

- reduction in BOD_5 and suspended solids loadings

- increase in nutrient loadings

- enhancement of photosynthetic plant production and corresponding secondary organic loading

- increased photosynthetic activity by day and possible oxygen depletion by night, resulting in anoxic conditions and possible fish mortalities

- if organic productivity rates were less than expected, surplus nutrients would remain dissolved in the water and contribute to the eutrophication of Dekheila Bay and the western harbor after leaving the lake.

In summary, the ecological stability of the lake would not significantly improve and, in spite of secondary treatment, lake conditions might not be any better than the current highly eutrophic state.

2.E.2.d Environmental Impacts-Toxic Industrial Waste. If an industrial waste ordinance is implemented and enforced, current and future industrial wastewater discharges should have no adverse environmental impact beyond increasing wastewater loadings and nutrients. The same general effects described above should apply. If pretreatment was not required, toxic materials present in the industrial wastes would interfere with the secondary treatment process, reduce treatment effectiveness and disrupt the lake ecosystem.

2.E.2.e Mitigating Measures. In all cases, ecological conditions in Lake Maryut can be improved by eliminating the discharge of all wastewater. However, if any wastewater discharge is continued, decreasing lake retention time by diverting agricultural drainage from the Umoum Drain would help the lake environment. Paradoxically, this means less effective treatment in the lake and poorer water quality in Dekheila Bay and the western harbor. There is no mitigating measure to prevent this. To mitigate possible adverse impacts from industrial wastewater discharges, the Master Plan recommended instituting an industrial waste ordinance.*

2.E.3 Wastewater Irrigation

There are four areas near Alexandria where treated effluent could be used for agricultural irrigation (see Fig. 6-1). These are:

-Abu Kir Drain
-Abbis
-Maryut Sector
-Ameria Northwest.

Costs for agricultural reuse alternatives are based on effluent conveyance to these areas. Secondary treatment prior to effluent reuse was specified in the Master Plan. The public health and operational concerns of lesser degrees of treatment are discussed in Chapter 6.

* See Tech. App. No. 6, Vol. II, this report.

2.E.3.a Environmental Impacts. The impacts associated with the reuse of secondary treated effluent are:

- Crop yields in the four areas mentioned above can be expected to diminish, if irrigated with undiluted wastewater because of excessive salinity.

- Wastewater reuse under favorable assumptions costs three to five times more than existing irrigation and fertilizing methods.

2.E.3.b Mitigating Measures. To make wastewater more suitable for reuse, the following measure could be taken:

- Mix treated effluent with irrigation water to lower unfavorable solids concentrations.

However, based on the amount of wastewater to be reused, and the required dilution to reduce dissolved solids, there is insufficient land for complete utilization in the four areas considered. Because only two-thirds or less of Alexandria's wastewater can be used within the available area, the remainder would have to be discharged into the lake or drains, resulting in the impacts described for Lake Maryut alternatives.

2.E.4 Evaporation Ponds

Three sites were considered for the evaporation of wastewater. These included:

- the saline portion of Lake Maryut west of the Agamy-Ameria road

- the central portion of Lake Idku

- the Western Desert.

2.E.4.a Environmental Impacts. The environmental impacts associated with western Lake Maryut were:

- disruption of salt manufacturing operations of the El Nasr Salines Co.

- aesthetic degradation of the proposed Agamy tourist development.

- contamination of possible deepseated freshwater aquifer.

Environmental impacts associated with the Lake Idku Pond were:

- interference with the portion of Lake Idku currently used for fishing

- irreversible land use change.

Because the Western Desert alternative was too costly, specific sites were not addressed in the Master Plan and specific environmental impacts could not be cited.

2.E.4.b Mitigating Measures. Impacts associated with the use of western Lake Maryut were considered irreversible, and use of this site was abandoned. The potential fishing interference in Lake Idku could be mitigated by confining the pond to the northeastern sector of the lake. This sector is adjacent to land reclaimed for agriculture and is very shallow and overgrown with aquatic vegetation. However, the change in land use is an irreversible and irretrievable commitment of land resources.

2.E.5 Disposal to the New Noubaria Drain

Proposed anaerobic-aerobic lagoons for Outer West and Ameria wastewater would discharge treated effluent into the Noubaria Drain currently under construction. Estimates of flow in the drain are uncertain, but available data indicate that lagoon effluent would constitute about 12 percent of the Drain's flow downstream of the Outer West discharge. Water quality in the Drain is expected to be poor regardless of the lagoon discharges, because of the organic matter and nutrients usually found in agricultural drainage. Preliminary calculations presented in Section 6.B.5 indicate that the additions of nutrients and organic matter from the lagoons are unlikely to cause any significant adverse impact relative to those anticipated from the agricultural drainage.*

A tourist development is planned for the Agamy area, including bathing beaches which extend beyond the mouth of the Noubaria Drain. If such developments are as extensive as planned, effluent chlorination at the lagoons may be required to protect bathing water quality; the need for such facilities can best be assessed at a later date. Industrial waste control in these two service areas is particularly important given the biological character of the treatment processes.

2.E.6 Construction Impacts

The following impacts can generally be associated with the construction of the collection, treatment, and disposal facilities proposed by various Master Plan alternatives:

- increased traffic congestion
- inconveniences to people and businesses
- additional noise and dust in the vicinity of the job site
- additional street litter from construction debris

* Also, see Tech. App. No. 7, Vol. II, this report.

- public safety hazards from open excavations and other construction activities
- skilled labor shortages
- construction equipment and material shortages
- damage to archaeological artifacts
- negative aesthetics
- interference with crop irrigation
- interference with crop production
- interference with boating and fishing
- relocation of housing
- land use changes
- construction-related water and air pollution
- damage to street utilities.

2.E.7 Operational Impacts

The following impacts can generally be associated with the operation of the collection, treatment, and disposal facilities proposed in the various Master Plan alternatives:

- use of new sewers for solid waste disposal
- hydrogen sulfide generation
- airborne pollutants from treatment plant operations such as odors, aerosols, gases, and particulates
- noise
- wastewater flooding resulting from equipment failures
- improper sludge or screenings disposal
- equipment damage from corrosive industrial wastes
- continued pollution of Lake Maryut.

2.E.8 Mitigating Measures

Because specific alignments and sites for pipelines and pump stations could not be identified at this stage of planning, construction and operational mitigating measures could only be generally addressed. Chapter 6 contains a discussion of all impacts mentioned above and suggests measures to mitigate their impacts.

2.E.9 Secondary Impacts

Secondary environmental impacts are those which are attributed to the growth and land use changes induced by implementation of proposed alternatives. Little or no significant growth or land-use change is foreseen from the improvement of Alexandria's wastewater facilities, and to the best of our knowledge, no violation of U.S. or Egyptian environmental law could be attributed to such growth if it were to occur.

2.F Environmental Impacts of the Preferred Alternative

Chapter 7 discusses the preferred Master Plan, the criteria used to select it, beneficial and adverse environmental impacts, mitigation measures, short-term uses and long-term productivity, and irreversible and irretrievable commitments of resources.

2.F.1 Selection Criteria

The criteria used to select the preferred Master Plan were:

- economics (cost effectiveness)
- ecological impact
- reliability
- flexibility
- social acceptability.

Each of these criteria are defined, and their influence on the preferred plan selection is discussed in detail in Chapter 7. Based on evaluating these criteria in comparison with other disposal alternatives, it would appear that the preferred Master Plan is the most logical choice for the city of Alexandria.

2.F.2 Beneficial Impacts

The major beneficial impacts resulting from the proper implementation of the preferred wastewater master plan should be improved public health and bathing water quality, increased attractiveness for tourism, stimulation

of the local economy, job training, increased marine productivity, and the elimination of raw wastewater discharges into Lake Maryut.

2.F.3 Adverse Impacts Which Cannot Be Avoided

Adverse impacts which could specifically apply to the construction of the preferred plan facilities include:

- increased traffic congestion
- inconveniences to people and businesses
- additional noise and dust in the vicinity of the job site
- additional street litter from construction debris
- public safety hazards from open excavations and other construction activities
- skilled labor shortages
- construction equipment and material shortages
- damage to archaeological artifacts
- negative aesthetics
- interference with boating and fishing
- relocation of housing
- land use changes
- construction-related water and air pollution
- damage to street utilities.

Adverse impacts which could specifically apply to the operation of the preferred plan facilities include:

- use of new sewers for solid waste disposal
- hydrogen sulfide generation in sewers as a result of blockages
- airborne pollutants from treatment plant operations such as odors, aerosols, and gases
- noise
- wastewater flooding resulting from equipment failure

- improper screenings disposal

- equipment damage from corrosive industrial waste.

Adverse impacts associated with effluent disposal from the recommended facilities include:

- possible sludge bank formation at the end of the sea outfalls and reduction of benthic species

- possible bacterial pollution along the beaches at Agamy from lagoon discharges into the new Noubaria Drain

- potential bacterial pollution along the remaining Alexandria coastline from sea outfall discharges

- possible contamination of the aquatic environment by toxic industrial wastes

- irreversible land use change from the construction of lagoons and an evaporation pond and possible loss of some bird habitat

- possible seepage from lagoons or evaporation ponds into underground or neighboring surface waters.

2.F.4 Mitigation Measures

Mitigation measures for impacts associated with constructing the preferred plan facilities can be summarized by:

- development of a construction management and supervision program

- anticipation of adverse impacts during preliminary and final design and planning specific mitigating measures

- choosing sites or alignments which have the least adverse impact.

Mitigation measures for impacts associated with operating the preferred plan facilities include:

- implementation of a suitable solid waste disposal system

- enclosing treatment facilities which are likely to produce adverse airborne pollutants or generate excessive noise

- selection of corrosion resistant materials in areas receiving corrosive industrial wastes.

Mitigation measures for impacts associated with the disposal of Alexandria's wastewater include:

- installation of primary treatment facilities, to reduce suspended solids and subsequent sludge deposits

- installation of disinfection facilities, to reduce bacterial pollution

- enforcement of an industrial waste ordinance

- installation of impermeable barriers in lagoons and evaporation ponds, to prevent seepage

- relocation of the evaporation pond site at Lake Idku, to minimize adverse impacts on the lake's ecology.

2.F.5 Short-Term Uses and Long-Term Productivity

Most construction impacts are of short-term duration and are reversible upon completion of the project. Mitigation measures to reduce the effect of these impacts have been summarized above. Basically, short- and long-term losses associated with these impacts are insignificant when compared to existing health and sanitation problems and the benefits to be gained by construction of the preferred plan facilities.

2.F.6 Irreversible and Irretrievable Commitment of Resources

Irreversible and irretrievable commitments of resources because of construction and operation of the preferred plan facilities include:

- potential loss of nutrients for agricultural reuse
- construction materials
- manpower and energy requirements
- pump station and treatment facility sites
- costs for construction of the facilities
- costs for the continued operation of the facilities.

CHAPTER 3

EXISTING ENVIRONMENTAL SETTING WITHOUT THE PROJECT*

3.A General

The current environmental setting is the starting point from which future environmental impacts of wastewater management alternatives must be made. This chapter discusses not only the physical, biological, and human elements of the existing environmental setting, but also those natural and social processes and constraints which have determined current conditions and will influence future ones.

Alexandria is located on the Mediterranean Sea in the northwest corner of the Nile Delta and at the eastern edge of the Western Desert about 200 km northwest of Cairo (see Fig. 3-1). Among Egyptian cities, Alexandria is second only to Cairo in population size. The city is of considerable importance to commerce; it is also a major resort where hundreds of thousands of Egyptians and others from the Middle East gather to enjoy the extensive beaches and relief from the summer heat.

Alexandria was founded in 331 B.C. by Alexander the Great. The city has experienced rise and fall, peace and war, austerity and prosperity and has lived under the rule of Greeks, Romans, Persians, Turks, French, and British. In 1922, a parliamentary kingdom under British domination was established in Egypt, but the country emerged as a self-governing republic after a military revolt in 1952. Industrialization and rapid population growth have radically changed the cities of Egypt, and Alexandria is no exception; such public services as wastewater collection and disposal, solid waste management, and public transportation have all felt the strains of the city's growth. Natural resources, such as Alexandria's bathing waters and Lake Maryut, have also been affected by Alexandria's development, and these pressures can only be expected to increase.

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*Metric units and their English system equivalents can be found after the glossary of this report.

Fig. 3-1 Study area location map

The old city developed around the natural harbor on either side of the Anfushi Peninsula (see Fig. 3-2). This area is now fully developed with residential and commercial uses. As population increased, development occurred, mainly to the east along relatively high ground. Development in this eastern area has not yet reached saturation, but the remaining suitable land is being rapidly occupied. Considerable land between the Montazah Palace and Abu Kir is now used for parks, reserves, and military purposes; and it is not likely to be soon developed otherwise. Industrial development has taken place along the Western Harbor west of the dock area in Mex, along the railroad and the Mahmoudia Canal south of the central city, and, more recently, to the east along Abu Kir Bay between Abu Kir and El Miaddiya. Considerable portions of industrial areas are also developed for low-income housing and associated commercial uses, mostly in dense configurations. Limited space is available for the projected industrial expansion in these established areas, and it would be necessary to develop industrial sites west along Lake Maryut and southwest in Ameria to meet future needs. Residential expansion is expected to occur to the east, utilizing available land in the vicinity of Montazah, Abu Kir, and Ras el Soda and to the southwest in Ameria. Increases in population density in the older areas of the city are expected to be slight.

3.B Physical Elements

3.B.1 Study Area

The study area is the Alexandria governorate and is bounded on the north by the Mediterranean Sea, on the east by Abu Kir Bay, and on the south by several prominent geographical features (Fig. 3-2). These include the Cairo-Alexandria Desert Highway causeway across Lake Maryut, the Nouzha Airport and Hydrodrome, the Taufiqi Canal, and the Abu Kir-Rosetta Highway. The study area extends to the west to include lands beyond the Noubaria Canal which are either now developing or are expected to before the year 2000. These lands are the Mex-Dekheila industrial and residential complexes, the proposed Agamy touristic site, industrial sites along both sides of Lake Maryut west of the Marsa Matrouh Railroad, the residential and commercial lands of Ameria, and a site southeast of Ameria set aside for a petrochemical complex. The study area is approximately 60 km long and 11 km wide, and its approximate total size is 66,000 ha. This includes all of the existing Alexandria wastewater system as well as many unsewered areas, the main portion of Lake Maryut, and the drains and waterways into which the system discharges.

3.B.2 Topography

The dominating physical features of the Alexandria area are the Mediterranean Sea, a segment of the lower Nile Delta, Lake Maryut, a bedrock

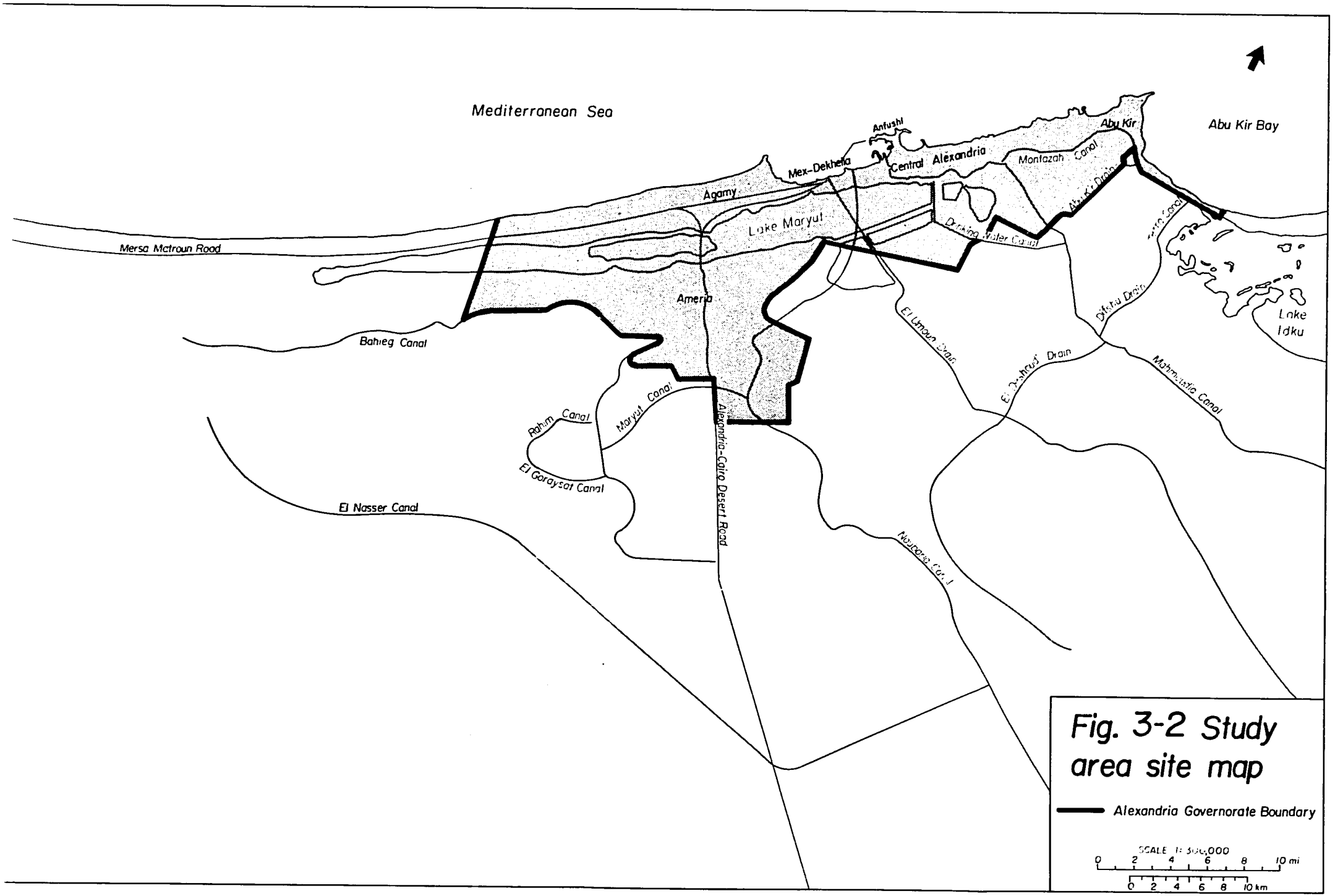


Fig. 3-2 Study area site map

Alexandria Governorate Boundary

SCALE 1: 300,000

0 2 4 6 8 10 mi

0 2 4 6 8 10 km

ridge which parallels the coast, and the eastern segment of the vast Western Desert. Also of major importance are the canal and drain systems.

The basic features which have caused the linear development of Alexandria are the bedrock ridge and the marine lagoon, Lake Maryut, both of which parallel the sea and extend the length of the study area. The ridge of limestone and sand is 500 to 1,500 m inland from the sea; its height varies from 5 to 22 m within the study area. The marine lagoon, which varies in width from 5 to 6 km, lies inland from the ridge. The width of the high ground dominated by the ridge varies from 1 to 4 km. Much of the original lagoon area has been reclaimed for farmland by filling portions of it and by constructing a network of drains and canals. The remaining portions are known as Lake Idku, which is east of the Mahmoudia Canal, and, the rest, Lake Maryut.

West of Noubaria Canal and south of the marine lagoon, the desert land rises to a rolling plateau of 30 to 50 m.

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 man-made breakwater structures which further enclose the harbors and reduce the circulation of currents. Two other prominent 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. Between Anfushi and Abu Kir, the shoreline consists of a series of small, rocky projections into the sea with sandy beaches between. East of Abu Kir is another wide bay. A submerged, rocky ridge extends across the open part of this bay and effectively decreases the normal shoreline currents and, consequently, their flushing effects.

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

Canals are a prominent topographical feature. They convey water from the Nile River which serves as the raw water supply for the Alexandria water system. Water is conveyed into the study area by a comprehensive system of multi-purpose canals, principally the Mahmoudia and Noubaria canals. The canals are used for navigation, irrigation, water supply, and disposal of domestic, agricultural, and industrial wastewaters, in addition to being the source of raw water for the potable water supply. The Mahmoudia Canal, which was built in 1820, has been a strong influence on the development of Alexandria and the northwest delta region. It also has become a dominating physical feature, because it forms a ridge.

The location of drainage facilities has been influenced by both the topography and the Mahmoudia Canal. A large portion of the northwestern delta farmland varies in elevation from about -1.5 m to 8 m (0.0 is sea level). To drain this land, the system must be below sea level, and pumps are required to lift the flow into the sea. Near Alexandria, there

are two extensive drainage areas divided by the ridge formed by the Mahmoudia Canal. One of the drainage areas, north and east of the canal, is served by the Abu Kir Drain system which discharges to Abu Kir Bay. The other drainage area, south and west of the Mahmoudia Canal, discharges water through several drain systems to Lake Maryut. Additionally, the area north of the shoreline ridge drains to the Mediterranean Sea. The stormwater is collected in sewers and either is discharged with sanitary wastewater, or is discharged as an overflow to the sea at the shoreline.

Typical cross sections of the area are contained in Fig. 3-4.

3.B.3 Geology And Soils

3.B.3.a Geology. The study area, the Alexandria Governorate (Fig. 3-2), is surficially situated at the extreme northwestern boundary of the Nile Delta basin and its intersection with the shoreline of the Mediterranean Sea.

The surficial geological features and materials of the study area essentially rest on a currently stable substratum of the western limb of a deep-seated stratigraphic depression. This ancient substratum supports the current-day surficial geology of the northwestern delta region and is characterized by a "basin-like" structural profile. The western limb of this profile dips easterly toward a deep-seated "keel" of a subsurface structural depression which more or less accounts for the containment of the superimposed Nile Delta geologic complex.

Fig. 3-3[1] shows a depth contour representation of this structural depression as it relates to the Miocene Formation which forms one of the major subsurface stratigraphic rock units of the depression. The subsurface expression of the Miocene Formation serves to dimensionally illustrate the broad subsurface aspects of the geological geometry on which the study area is surficially located and has generated into its current geological character.

The base of the Miocene Formation came into existence approximately 25 million years ago. However, its current/structural expression has resulted from what has probably been a more or less continous down-warping caused by deep-seated crustal stresses and probably by the cumulative weight of superimposed fluviomarine sediments deposited during the evolution of the Nile Delta.

Geodynamically, this extensive subsurface depression, some 230 km in width, is part of what Said[2] classifies as the "Unstable Shelf" of North Africa. According to Said, one of the most characteristic features of the "Unstable Shelf" zone is that it has been flooded by repeated marine transgressions throughout its geologic history. Accordingly, the recent surficial and subsurface deposits of the Alexandria area represent a stratigraphic composite of past and recent marine sediments admixed with past and recent terrigenous sediments of fluvial and eolian origin.

The predominant geological features of the study area are the shoreline of the Mediterranean Sea, the northeastern regions of the Western Desert, the western segment of the lower Nile Delta, the Lake Maryut and Lake Idku marine lagoons, and a ridge of calcareous sandstone and dense limestone often referred to as an oolitic limestone or, historically, as the limestone of Alexandria.

Both the calcareous-rock ridge and the marine lagoons parallel the Mediterranean shoreline and extend in an east-west direction throughout the study area. The position of the ridge is situated from 500 to 1,500 m inland from the marine shoreline, varies in height from 5 to 22 m, and

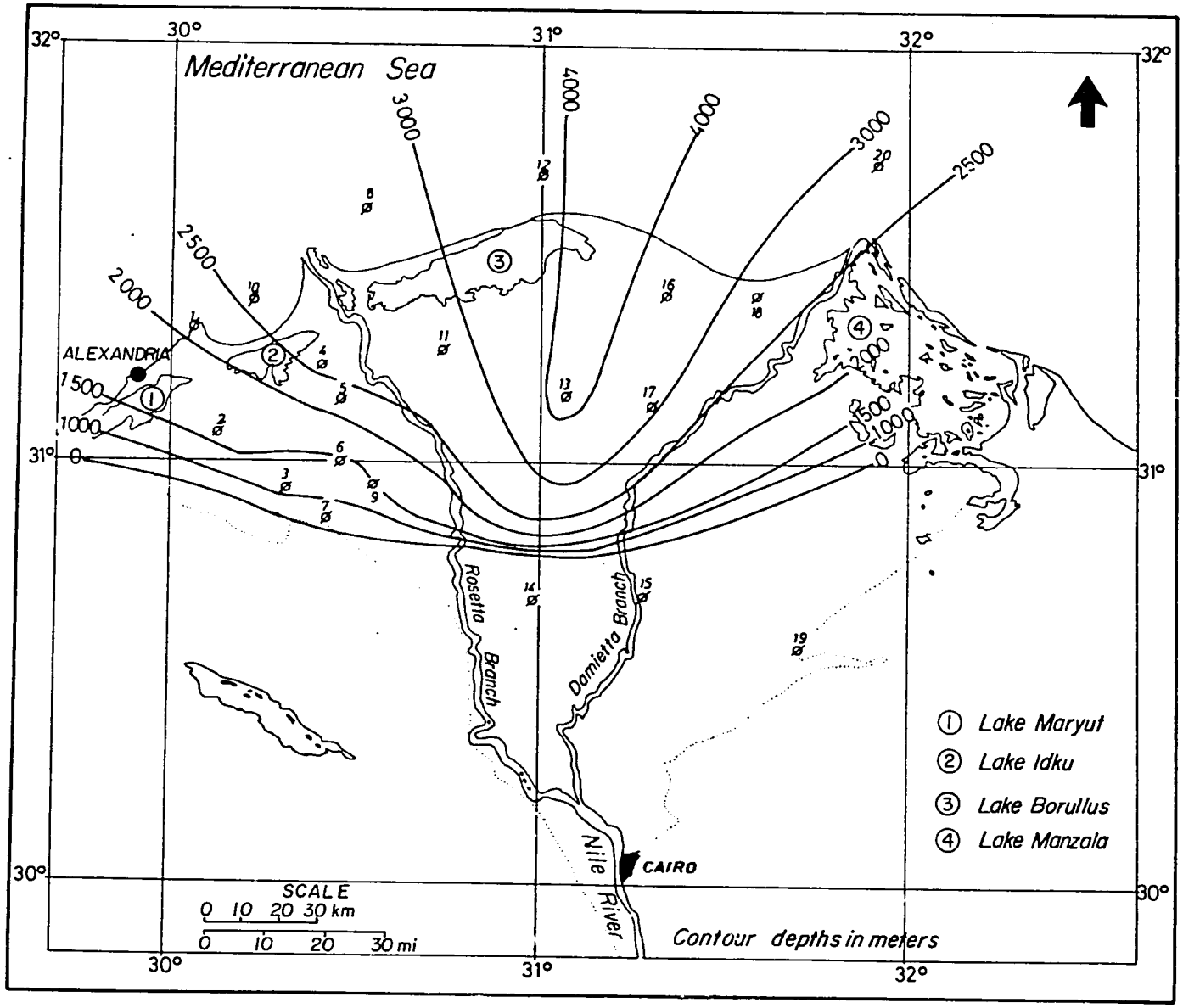


Fig.3-3 Structure contour map of Base of Miocene. (Nile Delta Area, Egypt)

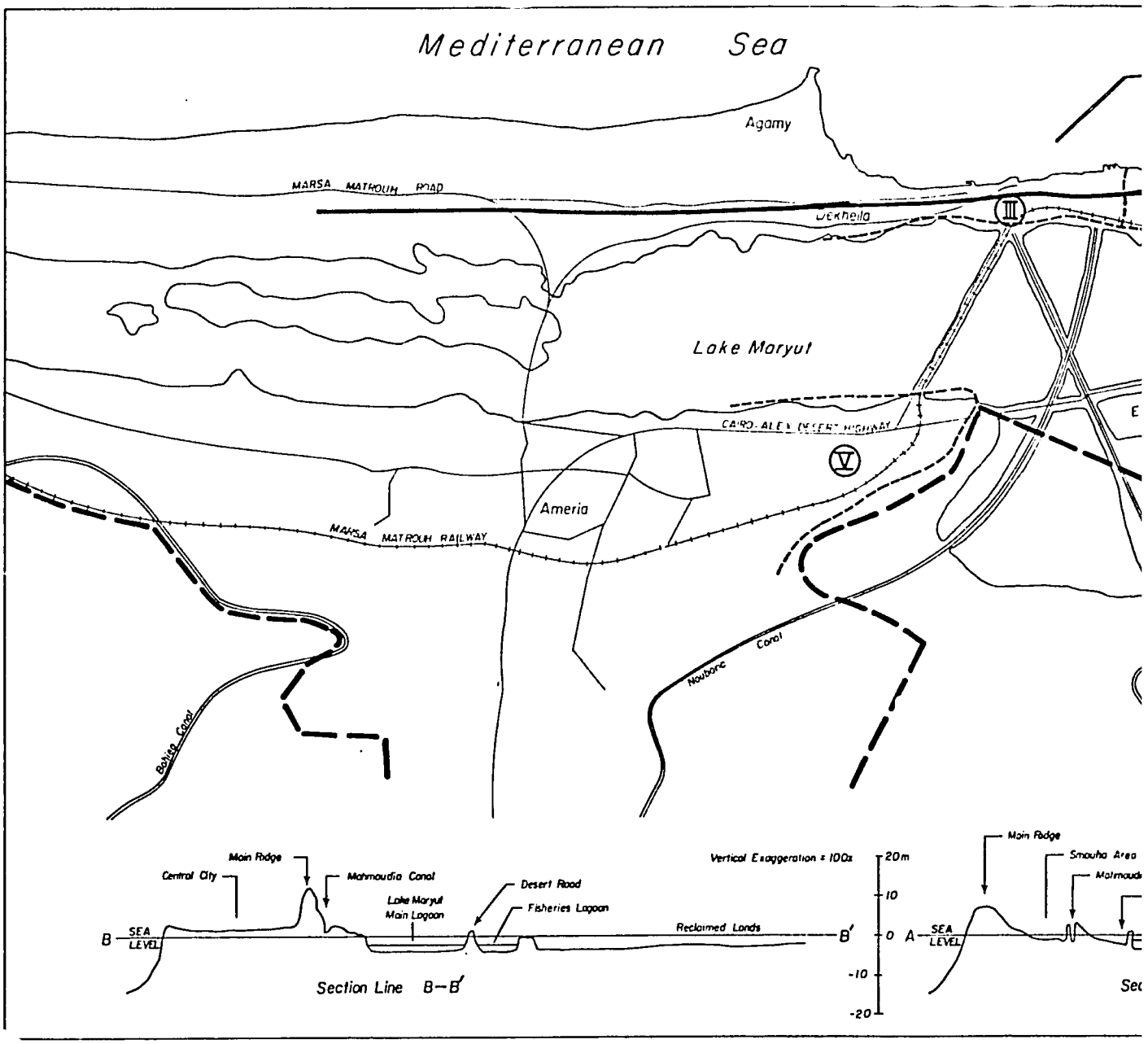
structurally accounts for a "high ground" feature having an approximate width of 1 to 4 km. A topographic profile of the ridge and lagoon features is presented in Fig. 3-4.

The surficial calcareous-rock of Alexandria forms a low ridge which extends westward as a low line of hills parallel to the shoreline of the sea and forms the eastern extremity of what has been designated as the Abu Sir-Dekheila Ridge by previous investigators. According to Hume[3], the Abu Sir-Dekheila Ridge is a very conspicuous feature of the landscape, extending from Alexandria westward through Dekheila and past Abu Sir to beyond El Imayid, some 75 km to the west of Alexandria. Actually, this ridge is really one of a succession of similar ridges, some of which are found to the north as part of the current day sea floor and others of which are found to the south and form part of the Maryut Upland Plains, approximately 19 km inland and to the west of the study area.

Also, according to Hume[3], the calcareous rock forming the ridge system in the Alexandria area is mainly composed of oolitic dune sands which have been partially dissolved in the presence of carbonic acid from repeated penetration by coastal rain waters into the dune sediments. During repeated evaporation cycles, the various interstitial solutions containing soluble bicarbonate of lime are drawn by capillary action back to the surface of the dune structure, thereby cementing the loose dune sands into the solid limestone rock which forms at the summit of the ridges. Hume's explanation accounts for the presence of hard limestone strata which has been recorded as resting on top of unconsolidated subsurface sediments in certain of the soils test borings in the study area.

3.B.3.a.i Seismicity. Regionally, earthquakes recorded in the eastern Mediterranean area during the past quarter century have occurred predominantly to the north of Egypt in the eastern basin of the Mediterranean Sea and to the west on the coastline of Libya. The greatest frequency and intensity of earthquakes in the Middle East centers in Iran and Turkey. The study area is considered to be seismically stable, and earthquake activity, based on existing information, is not expected to pose a hazardous problem.

3.B.3.a.ii Subsidence. Subsidence may be defined as the downward movement of the natural ground surface on or close to which no structures have been built. Although Said[2] categorizes the study area as being part of the "Unstable Shelf," he is addressing geological events occurring over a period measured in thousands to millions of years. The geodynamics associated with the concept of the "Unstable Shelf" would not normally be considered of a geologically hazardous nature as related to proposed activities for the Wastewater Facilities Development Program. However, some investigators believe that some depression of the northern edge of the delta took place in post Roman occupation time, as is indicated by certain of the Roman "rock-tombs" on the shore at Alexandria now below sea level. Here, again, based on existing information, this


Mediterranean Sea
Agamy
MARSA MATROUH ROAD
Dekheila
III
Lake Maryut
CAIRO-ALEX DESERT HIGHWAY
V
Ameria
MARSA MATROUH RAILWAY
Nouberie Canal
Babian Canal
Main Ridge
Central City
Mahmoudia Canal
Lake Maryut Main Lagoon
Desert Road
Fisheries Lagoon
Reclaimed Lands
B
B'
SEA LEVEL
Section Line B–B'
Vertical Exaggeration = 100x
20m
10
0
-10
-20
Main Ridge
Smouha Area
A
SEA LEVEL

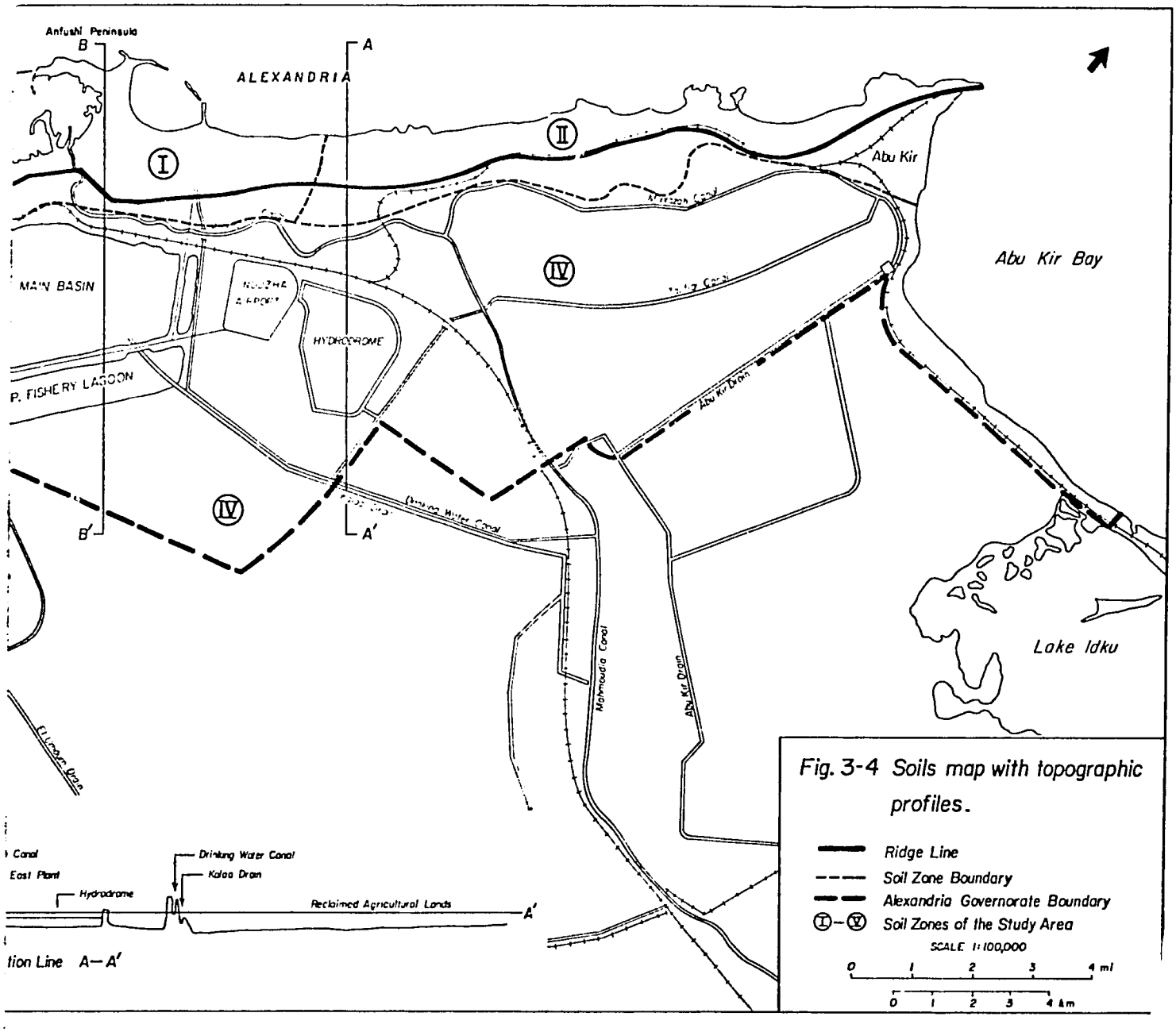


Fig. 3-4 Soils map with topographic profiles.

does not indicate subsidence of a hazardous nature.

Based on the calcareous composition of some of the substrata in the study area, there are probably some subsurface solution cavities present. However, available information cannot support a meaningful analysis as to their size or location and to what degree these would pose a geologic hazard, if any. Test borings associated with proposed engineering activities would identify such cavities and would provide the caution for appropriate construction design and practice.

3.B.3.a.iii Slumping and Landslides. Available information does not indicate an areawide problem. Locally, there are some soils which might characteristically be subjected to slope failure. Site tests will indicate necessary engineering and construction practices, to stabilize such failure conditions.

3.B.3.a.iv Marine Shoreline Stability. The current day shoreline of Alexandria undergoes normally expected dynamical influences of a marine environment and can be regarded as being relatively stable. That is, expected erosional, depositional, and other geological modifications are similar to other normal marine shorelines influenced by similar conditions and intensities of oceanographic processes. The onshore wave action which buffets the Alexandria shoreline can be highly intense during the winter seasonal period, and provision for appropriate engineering design and constructional procedure will require special attention.

3.B.3.b Soils. Geodynamically, the study area has been flooded by repeated marine transgressions during its past and recent geological history. Additionally, the periods between these marine transgressions were intermittently predominated by fluvial, fluviomarine, and eolian environmental influences which have contributed their erosional debris as admixed sedimentary materials in the surficial and subsurface makeup of the study area.

Accordingly, these accumulations of sedimentary materials, consisting of particulated rock and organic debris, are currently represented by a stratigraphic composite which has generated the soils, ridgerock, and in large measure, the offshore sediments of the study area.

The soils, or unconsolidated sedimentary debris, of the onshore segment of the study area have been evaluated and classified by previous investigators.[4,5,6] Reports and publications from these investigators have served as the basic reference sources for the review and evaluation of the soils considered in this report.

In summary, soils found in the study area range from fairly well-sorted beach sands at the shoreline to deposits of silts and marine clays associated with the current day lake lagoons of the area and past marine transgressions. Furtnermore, the area, based on subsoil types, can be divided into five general zones with soil makeup ranging from sandy subsoils, which, in some instances, are cemented or partially cemented; admixtures of clay, silt, and sand, some of which form lenses within a

basically sandy substrate; deposits of marine clays and gypsiferous evaporite deposits associated with the formation of marine lagoons; and deposits of fine-grained deltaic soils admixed with organic debris.

The aforementioned ridge of calcareous sandstone and/or limestone separates the surficial soils of Alexandria into two general categories. North of the ridge, beach deposits occur which are predominantly of sandy composition, which may or may not contain varying amounts of silt, clay, shell fragments, and other organic debris. Deposits south of the ridge generally consist of marine clays and silts which contain varying amounts of sand, finely dispersed organic material, gypsum, and marine salts.

Within the study area, certain of the natural geological features and, quite extensively, the natural stratigraphic sequences and soil compositions, especially within the first few meters from ground surface, have been modified by artifact conditions within recent times. So much has been done within the last hundred years with reference to artificial canals, shoreline modifications, land reclamations, and constructional excavations and fill that it is difficult to distinguish with certainty between what is natural and what is artificial. However, for the purposes of this environmental statement, the soils evaluation reported by Dr. T. K. Liu[4] qualifies as an updated reference. The distribution of soil zones reported by Liu is presented in Fig. 3-4. He emphasizes that the boundaries are approximate and that different and inter-mixing soil layers should be expected in a given soil zone.

A summary of his subsoil evaluations and comments follows:

Zone 1: includes most of the older portion of the city and has subsoils consisting 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: covers the high ground east of the old city (Zone 1), extends to Abu Kir point, and 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: encompasses the area west of the old city (Zone 1) and north of Lake Maryut and 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 cm 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.

Liu also reports that "swelling soils" which are common in Cairo have not been found in the Alexandria study area. He is probably referring to what is technically termed expandable (or expansive) soil or rock. Expandable geologic materials include montmorillonite clays, soils containing anhydrous sodium sulfate, and certain shales. Of the clay-type expandable materials, adobe, a name applied to clayey and silty deposits found in desert basins, is well known. The composition of adobe is a mixture of clay and silt with other mineralogical materials, usually of calcareous composition.

Also of particular value for evaluating the subsurface conditions of the study area is the subsurface investigation made by M.I. Attia[5]. He reports on 20 subsurface borings conducted during 1954 within the study area. One of his bore holes, between Western Harbor and the main basin of Lake Maryut, showed a stratigraphic sequence in which significant thicknesses of hardened oolitic limestone appears to be resting on several tens of meters of unconsolidated marine sediments and then appears to repeat the same sequence several times within a total subsurface section measuring 117 m. The bore hole was started 4 m above sea level with the bottom of the boring at 113 m below sea level.

A summary of this boring is presented here, because the above described stratigraphic sequence appears to support the concept put forth by Hume[3] presented earlier in this report. Hume states that the calcareous ridge-rock of the area is not necessarily part of a contiguous bedrock sequence and may be intercalated within the subsurface with varying compositions and thicknesses of unconsolidated admixed sediments. The boring reported by Attia also supports Said's[2] interpretation of the "Unstable Shelf" the dynamics of which were associated with repeated marine transgressions onto a terrestrial environment. Similarly, reports on soil conditions in the area by Dr. A. Barakat and J. Bailey[6] appear to support the same interpretation.

Therefore, it is important to recognize that what appears to be a formation of contiguous limestone bedrock might well be a noncontiguous rock layer superimposed on top of significant sections of unconsolidated sediments; and therefore, it would not qualify geologically as a true bedrock outcrop.

3.B.4 Climate and Meteorology

3.B.4.a Regional Weather Characteristics. Climatic conditions over the southeast sector of the Mediterranean Sea were described by Moursy in his report, Storm Surges Along the Alexandria Coast.[7] Basically, air mass movements across this sector of the Mediterranean Sea are influenced by pressure systems over the Atlantic, Eurasia, and Africa and over topography bordering the eastern Mediterranean basin. During the cool season, November through April, a low pressure area generally forms over the warmer Mediterranean water, while in summer, June through September, pressures over the water are higher and more stable. October and May are generally the transition months between summer and winter weather.

The winter low pressure over the sea is generally bordered by high pressure ridges along the northern and southern coast. However, colder arctic air penetrates the northern high pressure ridges through gaps in northern mountain ranges. Winter storms with accompanying rain and high winds occasionally strike the shores of the eastern Mediterranean basin during these periods. Moursy summarizes the regional climatic features as windy, mild, wet winters and relatively calm, hot, and dry summers. In general, this pattern is true for Alexandria, and the specific conditions are discussed below.

3.B.4.b Alexandria Weather Characteristics. The prevailing winter weather is generally cold, 10 to 15 degrees C, with intermittent periods of mild weather. Winter is also the rainy season, and rainfall, while generally light to moderate, can be heavy during storms. In spring, the weather is changeable and characterized by occasional southerly, hot, dry, and dusty Kamassin winds of varying intensity and duration blowing from the desert. Summer weather is generally dry and hot, but cool Mediterranean breezes bring continual relief. In autumn, the weather is generally mild with occasional heat waves and cold spells.

Annual rainfall is about 200 mm (Meteorological Department, Cairo, 1968) and is confined almost entirely to the period from October to April. Rainfall data are presented in Table 3-1. Primarily, rainfall accompanies winter storms which originate over the sea on a frequency of about 5 to 7 days. Most rainfall comes from small squalls of limited extent which pass quickly under the influence of strong winds. Yearly evaporation rates exceed annual rainfall by about 1,900 mm per year.[8]

As shown in Table 3-2, prevailing winds are from the northwest during most of the year, and the mean annual wind speed is about 4 m/second. From April through September, the winds are principally from the north to northwest, while the rest of the year they are more variable and occasionally come from the southwest and northeast as well.

Weather patterns are quite constant from year to year, and winter storms arrive with predictable frequency. Most storms have assigned names, although occasional unnamed disturbances occur. By local tradition, Alexandrians claim to be able to predict the starting date and duration

TABLE 3-1.*

CLIMATIC SUMMARY - ALEXANDRIA

(for period 1942 to 1960)

Month	Mean Temperature °C Maximum	Mean Temperature °C Minimum	24 Hour	Mean Rainfall, mm	Bright[2] Sunshine, % Possible	Relative[1] Humidity, %	Mean Evaporation, mm/Month	Extreme Values Temperature °C Maximum	Extreme Values Temperature °C Minimum	Extreme Values Rainfall mm Maximum/day
January	18.3	9.3	13.5	48.3	72.1	71	136	26.3	2.4	47.9
February	19.2	9.7	14.0	28.4	68.5	70	136	36.4	2.4	27.0
March	21.0	11.2	15.6	14.0	72.5	67	167	40.4	6.2	12.7
April	23.6	13.5	18.3	2.7	75.2	68	165	41.6	7.0	5.5
May	26.5	16.7	21.4	1.5	81.0	70	180	41.8	10.5	8.0
June	28.2	20.2	24.2	Tr	85.8	72	171	42.1	11.7	0.1
July	29.6	22.7	26.1	Tr	87.1	73	177	38.1	17.5	Tr
August	30.4	22.9	26.7	0.5	88.7	73	177	39.7	17.4	8.8
September	29.4	21.3	25.3	0.4	84.7	69	177	39.9	15.7	3.6
October	27.7	17.8	22.8	7.9	81.6	68	171	39.0	11.9	12.0
November	24.4	14.8	19.3	32.2	75.5	72	132	36.5	7.4	32.5
December	20.4	11.2	15.2	56.2	62.7	74	118	28.6	4.2	36.7
Annual Mean	24.9	15.9	20.2	192.1	78.1	70	1,907	-	-	-

[1] Record period 1945 to 1960.
[2] Record period 1951 to 1960.
*Data extracted from the Climatological Normals, published by the Meteorological Department, Ministry of Military Production, A.R.E.

TABLE 3-2.*

PERCENTAGE FREQUENCY AND MEAN MONTHLY WIND SPEED FOR THE PERIOD (1952 to 1966) AT ALEXANDRIA

Month	Mean Wind Speed, m/sec	N	NE	E	SE	S	SW	W	NW	Calm
January	4.4	5.2	8.1	4.6	10.0	4.2	29.3	11.9	19.7	5.9
February	4.6	9.4	14.3	8.5	10.1	3.9	14.8	8.0	27.3	2.9
March	4.7	9.0	17.2	8.1	9.3	2.5	6.7	8.8	34.8	2.4
April	4.3	12.4	18.4	7.2	8.6	1.5	3.4	4.2	40.4	2.7
May	4.1	19.6	19.4	4.1	6.5	1.0	2.1	8.3	39.1	3.8
June	4.1	18.6	5.2	0.8	1.6	0.4	1.8	1.8	65.8	2.3
July	4.4	16.2	3.7	0.2	0.3	0.2	0.7	3.5	71.6	2.3
August	4.0	16.6	2.6	0.3	0.5	0.4	0.9	2.2	70.4	4.2
September	3.6	28.2	8.3	0.9	1.8	0.6	1.3	0.6	51.2	4.8
October	3.2	26.0	22.9	4.9	4.5	1.6	4.8	2.1	25.1	5.2
November	3.4	12.6	24.7	6.3	6.4	2.9	11.2	4.8	24.2	5.0
December	4.1	6.7	18.1	6.7	7.9	4.2	27.1	4.9	16.9	5.5

*Data extracted from the Climatological Normals, published by the Meteorological Department, Ministry of Military Production, A.R.E.

of each storm, based on its historical behavior. While there is some variability, Alexandria weather is more predictable than weather in other parts of the world. Tropical storms such as monsoons, typhoons, or hurricanes do not occur, but winds of hurricane force do accompany some storms.

The mean maximum temperatures for Alexandria vary between 18 and 30 degrees C, while the mean minimums vary from 9 to 23 degrees C. The annual mean temperatures are 25 and 16 degrees C, respectively. The recorded maximum and minimum temperatures during the 1952 to 1966 period were 42 degrees C and 2 degrees C.

The average relative humidity is about 70 percent which is generally associated with pleasant climate. However, there are occasional occurrences of uncomfortably high humidity during the summer. The humidity plus the effects of the salty spray make the atmosphere particularly corrosive, and inadequately protected metal decays quickly. Concrete and wood are also affected.

3.B.4.c Air Quality in Alexandria. Because of known deleterious effects on health and economy, air pollution is an important problem in industrial communities. An investigation of air quality in Alexandria was conducted by Ahmed Ibrahim Issa as part of his master's degree requirements in occupational health at the University of Alexandria. Mr. Issa gathered data on airborne pollutants at several sampling stations in three sectors of Alexandria, and his data and report are summarized below.

Mr. Issa divided the city into three sectors, based on the predominate activity in each. These were called:

- the western sector (industrial development)
- the middle sector (mixture of industrial, commercial, and residential)
- the eastern sector (residential development).

Twelve sampling stations were selected in each sector to collect data on different pollutants. Sampling was conducted for 24 hours and the pollutants assessed included:

- airborne and settled dust and their analyzed components, including nitrates, chloride, benzene, soluble organic matter, and ash
- trace elements: sodium, potassium, calcium, magnesium, manganese, iron, lead, copper, and zinc
- gases: nitrogen dioxide, sulfur dioxide, and carbon monoxide.

The results are summarized below and are presented in Tables 3-3 and 3-4. For comparative purposes, the U.S. federal ambient air quality standards are presented in Table 3-5.

3.B.4.c.i Airborne Dust. The concentration of airborne dust in the eastern residential sector was generally lower than that in the other two sectors. The highest concentration was in the middle (industrial, commercial, and residential) sector, which was not the case for settled dust. The concentration of airborne dust in the eastern residential sector which was the cleanest sector, except for the chloride concentration, is considered to be more than twice the U.S. ambient air quality standard for suspended particulates of 60 ug/m^3.

3.B.4.c.ii Settled Dust. The highest concentration of settled dust during the year 1975 was found to occur in the western industrial sector (49.2 $tons/km^2/month$). The lowest concentration was in the eastern residential sector (22.9 $tons/km^2/month$). The different concentrations of the constituents of settled dust at the three sectors showed that, with the exception of chloride content, the eastern residential sector was cleaner than the other two sectors.

3.B.4.c.iii Trace Elements. Concentrations of calcium, magnesium, manganese, iron, and copper in the eastern residential sector were generally lower than those in the other two sectors. Concentrations of zinc and sodium in the middle (industrial, commercial, and residential) sector were generally lower than those in the other two sectors. The concentrations of lead and potassium in the western industrial sector were generally lower than those in the other two sectors. In comparison, average concentrations of nine elements in Alexandria were higher than concentrations of the same elements in some cities in the U.S. such as Los Angeles, Detroit, New Orleans, and Pittsburgh, as shown in Table 3-6.

3.B.4.c.iv Gases. Concentrations of nitrogen dioxide and sulfur dioxide in the middle (industrial, commercial, and residential) sector were generally higher than those in the other two sectors. The lowest concentrations were in the western industrial sector. The yearly average concentrations of nitrogen dioxide, sulfur dioxide, and carbon monoxide were below U.S. ambient air quality standards which are 0.05, 0.03, and 9.0 ppm, respectively.

3.B.5 Water Resources

3.B.5.a Marine Waters.

3.B.5.a.i Physical Description of Offshore Area. The generalized bathymetry offshore from Alexandria is shown in Fig. 3-5. The continental shelf there is of a limited extent. Water depths increase

TABLE 3-3.

AVERAGE MONTHLY CONCENTRATIONS OF DUST IN ALEXANDRIA[1]

	Airborne Dust (ug/m^3)					
	Total Concentration	Chloride	Sulphate	Nitrate	Benz. Sol. Org. Matter	Ash
Western industrial sector	159.1	20.6	12.1	1.5	5.5	84.5
Middle (industrial, commercial, residential) sector	214.1	11.2	11.7	2.0	11.8	139.6
Eastern residential sector	129.1	15.9	8.8	1.4	7.6	64.7
City average	167.2	15.9	10.8	1.6	8.3	96.3
	Settled Dust ($tons/km^2$)					
Western industrial sector	49.2	3.3	2.5	0.09	9.2	27.0
Middle (industrial, commercial, residential) sector	46.1	1.1	2.4	0.12	13.3	24.1
Eastern residential sector	22.9	1.2	1.2	0.05	4.8	12.6
City average	39.3	1.8	2.0	0.09	8.9	21.5

[1] Data from report on Assessment of Some Air Pollutants in Some Locations in Alexandria by Ahmed Ibrahim Issa, University of Alexandria, High Institute of Public Health, Department of Occupational Health, Master's Thesis, 1966, Tables 29a and 29b.

TABLE 3-4.

AVERAGE MONTHLY CONCENTRATIONS OF AIRBORNE TRACE ELEMENTS AND GASEOUS POLLUTANTS[1]

Trace Elements (ug/m^3)

	Na	K	Ca	Mg	Mn	Fe	Pb	Zn	Cu
Western industrial sector	18.20	14.75	15.20	4.09	0.07	1.40	0.09	2.53	0.025
Middle (industrial, commercial, residential) sector	13.07	16.50	17.40	3.70	0.08	2.16	0.14	1.79	0.045
Eastern residential sector	17.35	15.00	13.00	3.60	0.06	1.26	0.14	2.30	0.025
City average	16.20	15.40	15.10	3.70	0.07	1.60	0.12	2.20	0.030

Gaseous Pollutants (ppm)

	Sulfur Dioxide	Nitrogen Dioxide	Carbon Monoxide
Western industrial sector	0.017	0.006	-
Middle (industrial, commercial, residential) sector	0.059	0.014	5.3
Eastern residential sector	0.038	0.008	3.5
City average	0.038	0.009	4.4

[1]Data from report on Assessment of Some Air Pollutants in Some Locations in Alexandria by Ahmed Ibrahim Issa, University of Alexandria, High Institute of Public Health, Department of Occupational Health, Master's Thesis, 1966, Tables 29d and 30.

TABLE 3-5.

SUMMARY OF AMBIENT AIR QUALITY STANDARDS[1]

Contaminant	Interval	Federal Standards (Primary)		Federal Standards (Secondary)	
		PPM	ug/m^3 (25°C)	PPM	ug/m^3 (25°C)
Sulfur dioxide	(Annual) Arithmetic mean	0.03	80	-	-
	24-hour concentration	0.14	365	-	-
	3-hour concentration	-	-	0.50	1,300
Particulate (suspended)	(Annual) Geometric mean	-	75	-	60
	24-hour concentration	-	260	-	150
Carbon monoxide	8-hour concentration	9	10 mg/m^3	9	10 mg/m^3
	1-hour concentration	35	40 mg/m^3	35	40 mg/m^3
Photochemical oxidants	1-hour concentration	0.08	160	0.08	160
Hydrocarbons (nonmethane)	3-hour concentration (6 to 9 A.M.)	0.24	160	0.24	160
Nitrogen dioxide	(Annual) Arithmetic mean	0.05	100	0.05	100
Lead (proposed)	(Monthly) Arithmetic mean	-	1.5	-	1.5

[1] Standards established by the U.S. Environmental Protection Agency.

TABLE 3-6.

AVERAGE MONTHLY CONCENTRATIONS OF TRACE ELEMENTS IN AIRBORNE DUST IN ALEXANDRIA AND SOME NORTH AMERICAN CITIES (ug/m^3)

Trace Elements	Alexandria			Los Angeles	Detroit River Area	Windsor, Ontario, Canada	New Orleans	Pittsburgh
	Minimum	Average	Maximum					
Na	6.7	16.1	37.2	6.6	-	-	-	-
K	6.3	15.1	24.2	3.9	-	-	-	-
Ca	9.5	15.3	20.5	-	11.1	18.4	-	-
Mg	1.2	3.7	9.6	8.1	0.9	2.3	-	-
Mn	0.02	0.08	0.17	0.22	0.2	0.27	0.03	0.38
Cu	0.01	0.03	0.06	0.5	0.08	0.18	0.04	0.12
Fe	1.0	1.6	2.7	6.2	2.4	5.75	1.2	7.6
Pb	0.11	0.12	0.19	8.3	0.4	0.5	0.3	0.5
Zn	0.4	2.2	2.3	-	0.2	0.08	0.09	1.09

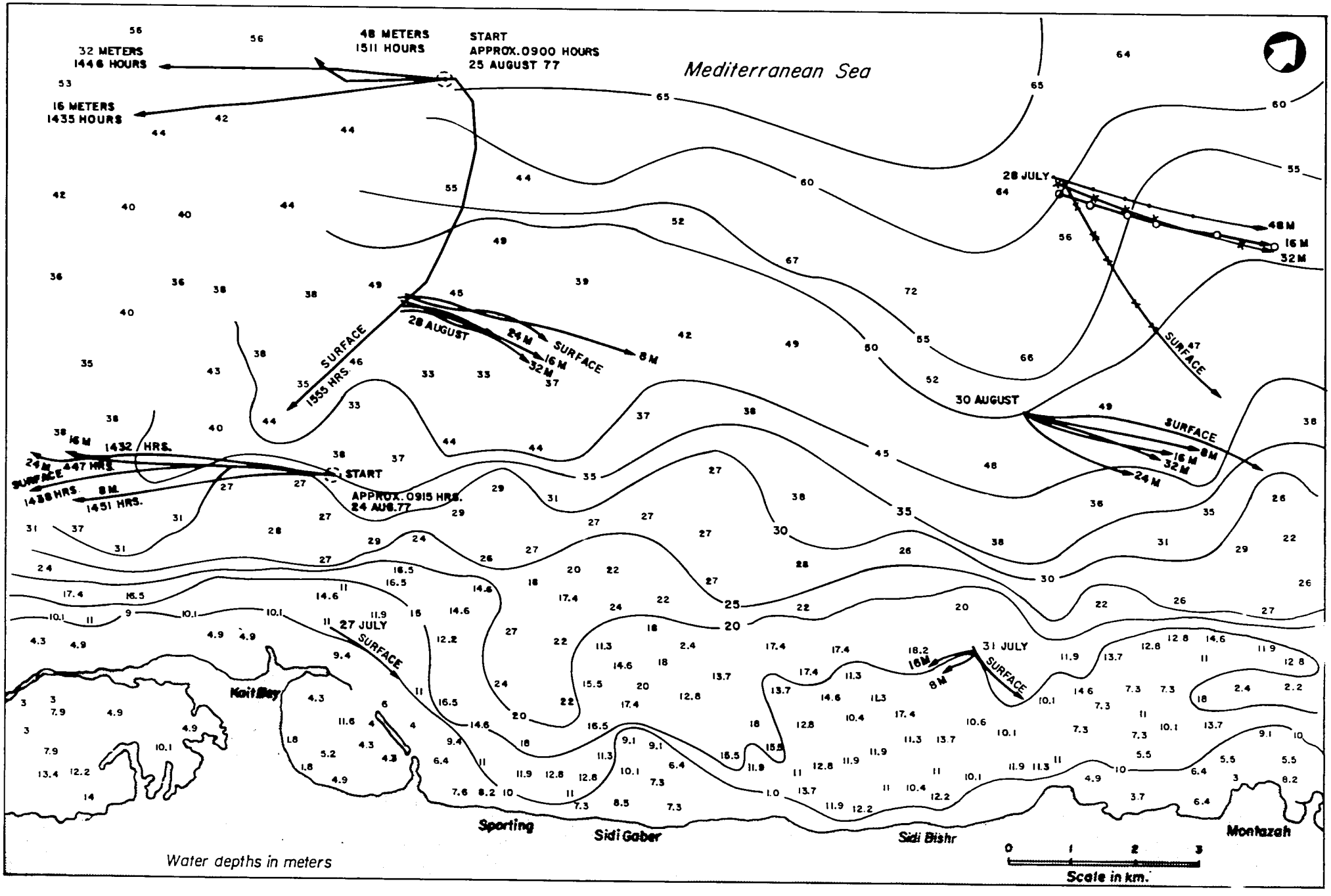


Fig.3-5 Bathmetry Offshore Alexandria and Drogue Paths Obtained in July and August, 1977

in a regular manner from the shore. The 30-m depth contour is approximately 3 km offshore; the 40-m contour 6 km offshore; and the 50-m contour to 10 km offshore. For an ocean outfall, this bathymetric configuration is a distinct advantage in providing deep water depths in an open area at a relatively short distance offshore.

Figs. 3-6 and 3-7[10] are bathymetric profiles offshore from Sidi Bishr and Kait Bey. These profiles were prepared from continuous echo sounder records taken on survey boat runs normal to the generalized depth contours; precision navigation control is used. The profiles are along the general location tracks for the proposed Sidi Bishr and Kait Bey outfalls. Except for a few sharp features, which have been noted on the figures, the bathymetry is fairly regular; the vertical exaggeration of the figures is 100:1. On the Sidi Bishr alignment, the bottom depths increase in a continuous but irregular manner out to about 6 km offshore and then increase in a smooth manner further offshore. On the Kait Bey alignment, bottom depths increase rapidly out to 4 km offshore and then, in a more gradual manner, further offshore. There are two rather precipitous drops of 10 m at 6 km offshore and of 15 m at 9 km offshore. These two declivities may represent sedimentary rock outcrops along the continental slope. Their precise nature and geographic extent will be delineated through the continuing oceanographic surveys of echo sounding, subbottom profiling, and side scan sonar profiling in conjunction with sediment coring. These surveys will provide the requisite background information for the engineering determinations of the pipeline tracks in the ocean outfall alternative.

The bottom sediment characteristics offshore from Alexandria have been studied by El Sayed.[11] He analyzed 50 bottom grab samples, covering an area of 30 km alongshore Alexandria and out to 10 km offshore. The sampler failed to secure bottom samples from some localities near shore where the bottom is rocky. Of the 50 samples, 12 are described as encrusted calcareous rocks and the remainder as sands to silts. The calcareous rock samples were confined to a band immediately offshore in 14-m water depth and to a broad area west of Abu Qir. The sediment samples show a regular progression from sands to silty sands to sandy silts to clayey silts proceeding from the shore to the deeper water depths. They also show a corresponding change in porosity from a low value of 25 percent for the sands to a high of 60 percent for the clayey silts. The areal distribution of the bottom sediments is shown in Fig. 3-8 from El Sayed; the figure also shows the locations of the calcareous rock samples and the rocky areas near shore.

El Sayed also examined the organic content of the bottom sediments. For the general offshore area, he obtained relatively low values, ranging from less than 0.5 percent to 2.0 percent organic matter. These values are to be contrasted with those he obtained for the more confined areas of Alexandria's eastern and western harbors, being respectively 4.0 percent and 4.5 to 9.0 percent. In a cor-

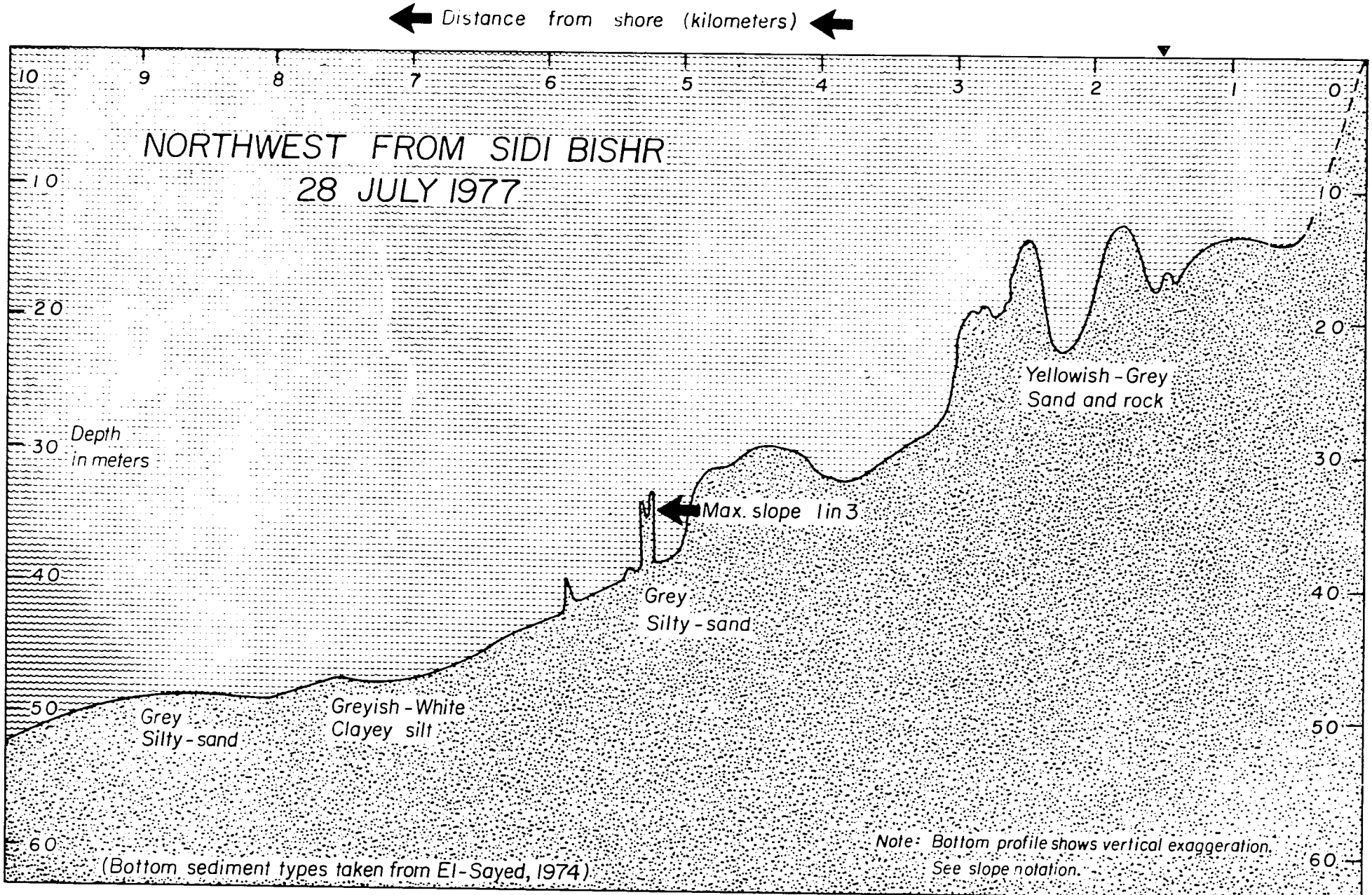


Fig.3-6 Approximate bathymetric profile - Sidi Bishr alignment

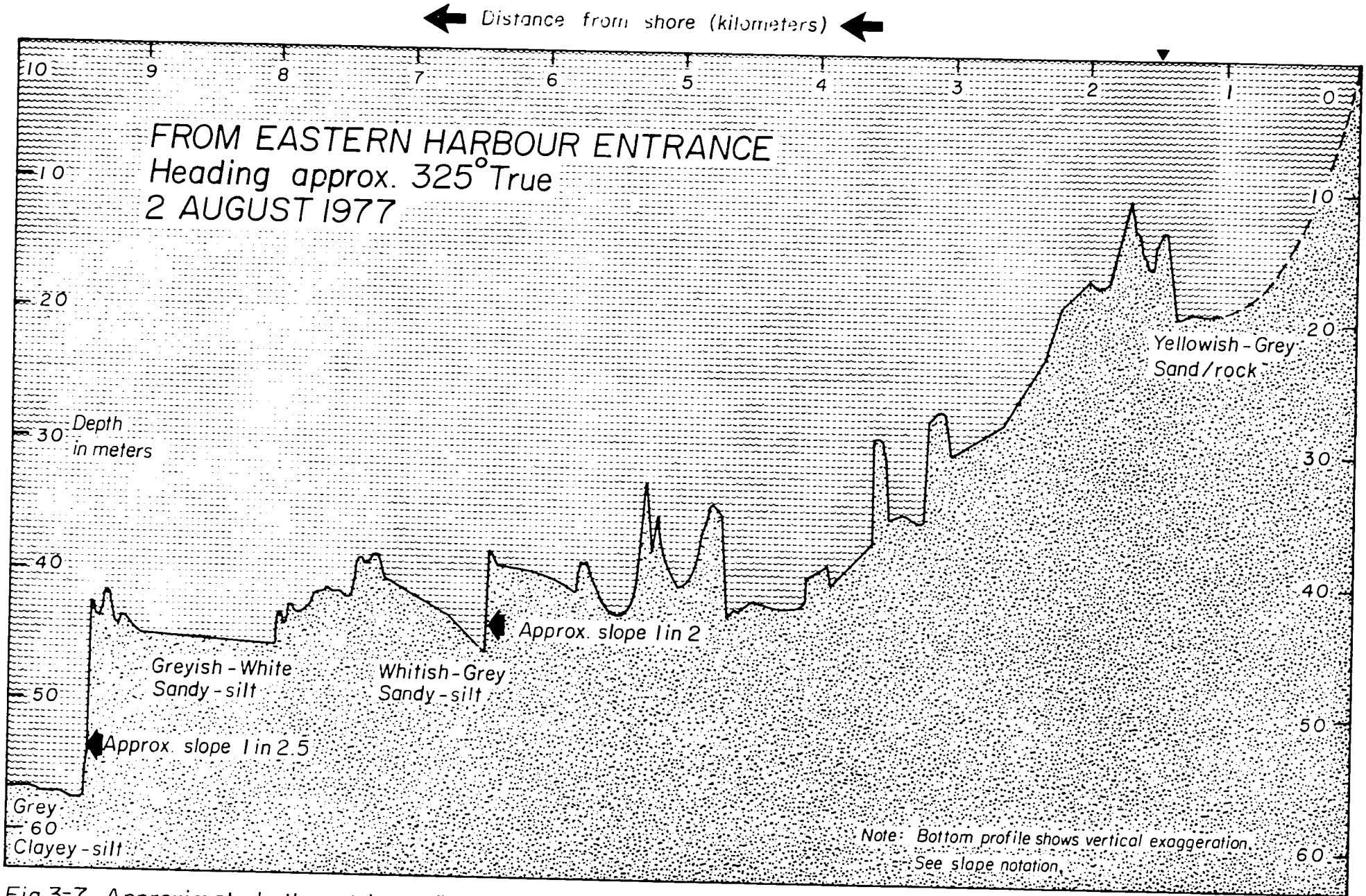


Fig.3-7 Approximate bathymetric profile - Kait Bey alignment

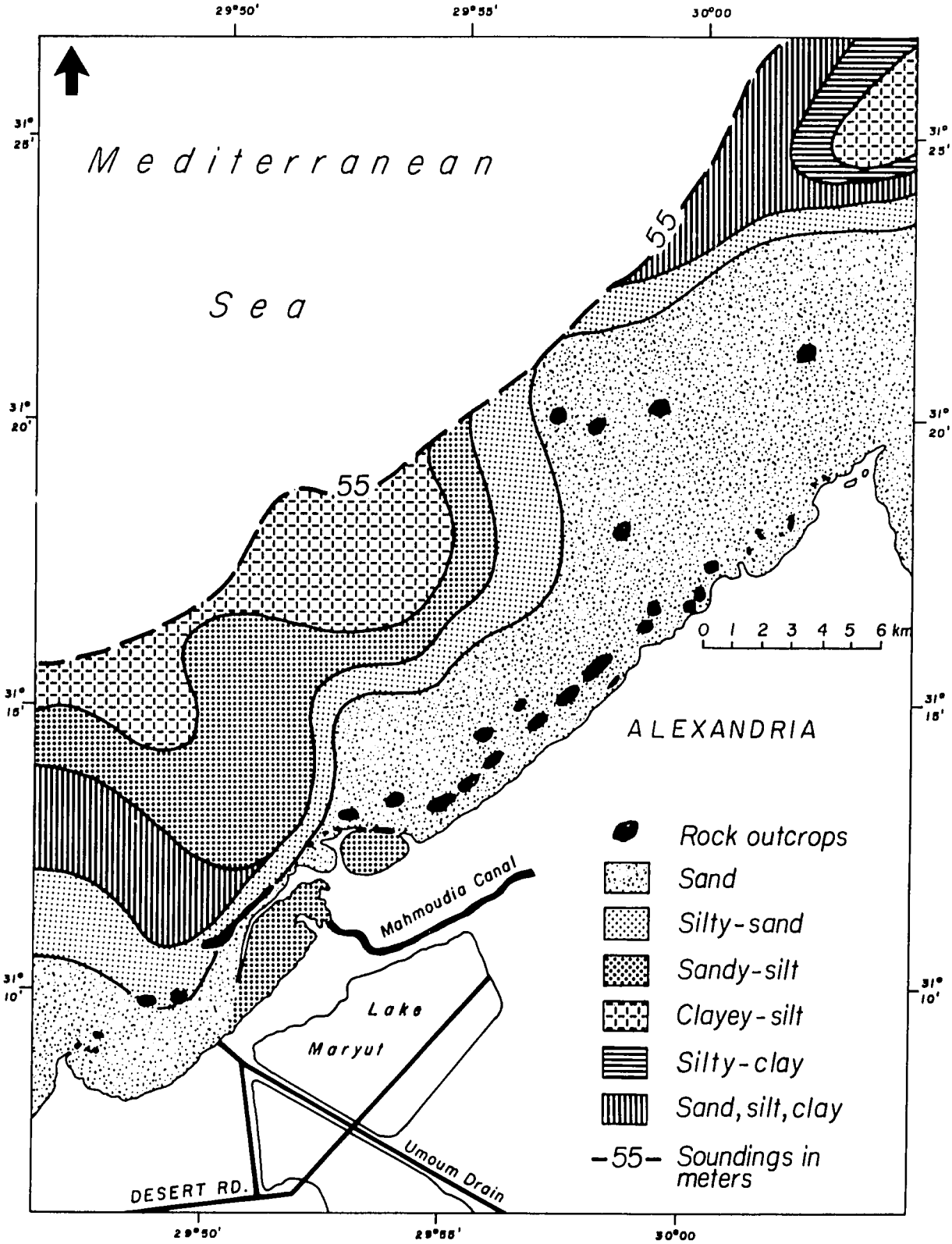


Fig.3-8 Areal distribution of bottom sediments

responding investigation, El Wakeel obtained a value of 7.5 percent organic matter for the sediments of the eastern harbor, and Ghanem and El Awady[13] obtained values ranging from 4.5 to 14.5 percent for the western harbor.

The coastal current patterns in the area offshore from Alexandria are particularly important in considering ocean outfalls. This has been one of the primary objectives of the oceanographic survey program. Prior to this program, there were only a few scattered measurements further offshore which indicated coastal currents of around 25 cm/sec in the northeasterly direction following the bottom contours, which sometimes reversed and flowed in a southwesterly direction with a comparable magnitude. We have summarized in the following paragraphs some of the pertinent results from this program of current meter observations and drogue and dye tracer studies.

Fig. 3-5 shows, in addition to the offshore bathymetry, paths taken by drogues during a study period of July and August 1977 at various locations along the Kait Bey and Sidi Bishr alignments. The depth of each drogue deployment is also shown. In each case, drogues beneath the surface traveled as a group in a coastwide direction either to the northeast or to the southwest. For inner locations, the surface drogues followed the same pattern as the deeper drogues. For the two locations furthest offshore, the surface drogues had a dominant onshore set, which decreased somewhat toward a coastwise set, as the drogue progressed inshore.

Fig. 3-9 shows the path taken by a surface dye patch and its resultant longitudinal and lateral dispersion. The release location was 9 km offshore on the Kait Bey alignment. In this case, the movement is to the east with an average speed of 28 cm/sec.

Fig. 3-10[14] is a summary of current speeds determined from the drogue and dye studies of July and August 1977. The curve in the figure is simply an empirical fit to the data. At the furthest distances offshore, 9 to 10 km, the coastal currents are around 25 cm/sec; at the intermediate distances of 6 to 7 km, they are 10 to 20 cm/sec; and at inshore locations, they are around 6 cm/sec on the Sidi Bishr alignment and around 22 cm/sec on the Kait Bey alignment.

The current meter data provides much the same results (see Table 3-7). The Kait Bey alignment data were obtained during a continuous measurement period from 3 to 31 August 1977 and the Sidi Bishr data from 21 to 31 August 1977. The table was prepared from hourly current magnitude and direction readings. All show a dominant coastwise current, the magnitudes being somewhat less than those obtained from the drogue studies. At 2.5 km offshore on the Kait Bey alignment, an onshore current exists for only 2 to 5 percent of the time and has a magnitude of only 3 cm/sec. At the 10-km location offshore, the onshore current is stronger, 7 to 8 cm/sec, and occupies

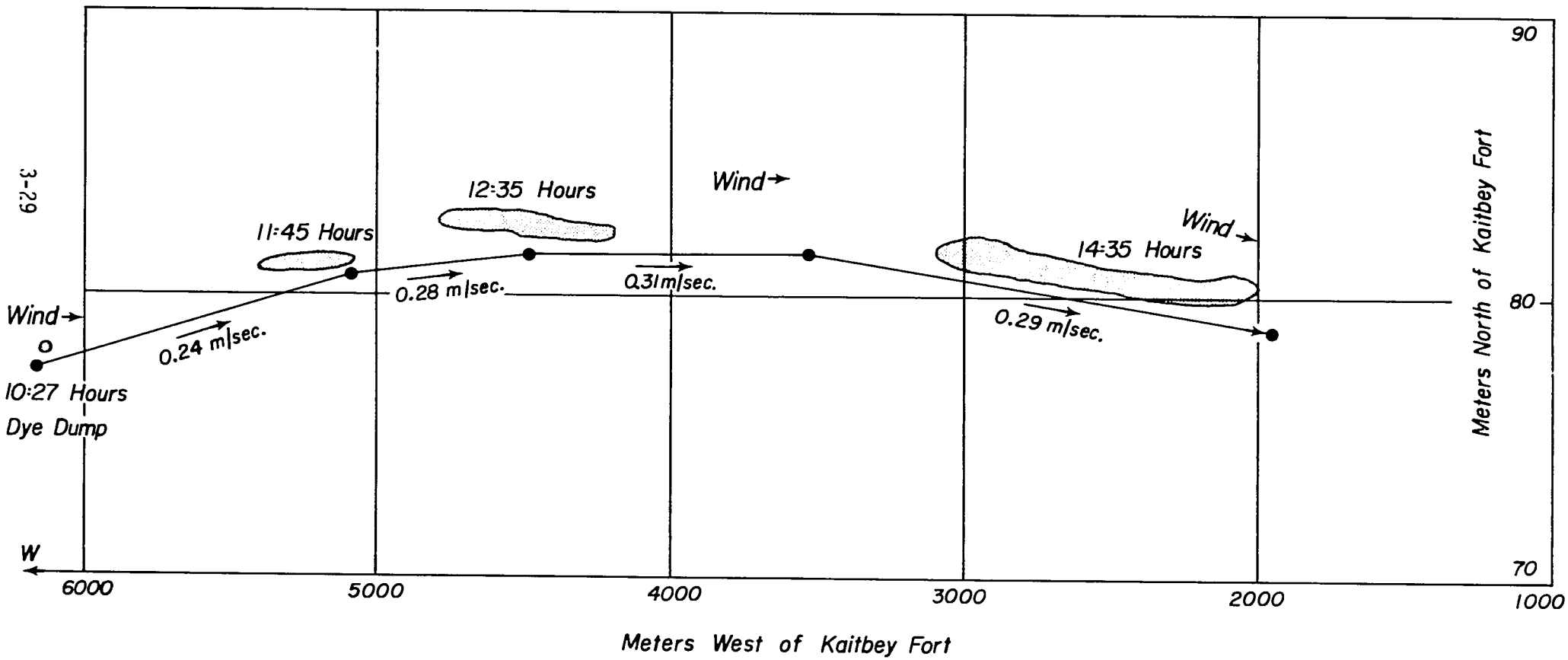


Fig. 3-9 Progress of dye patch in surface waters, August 31, 1977

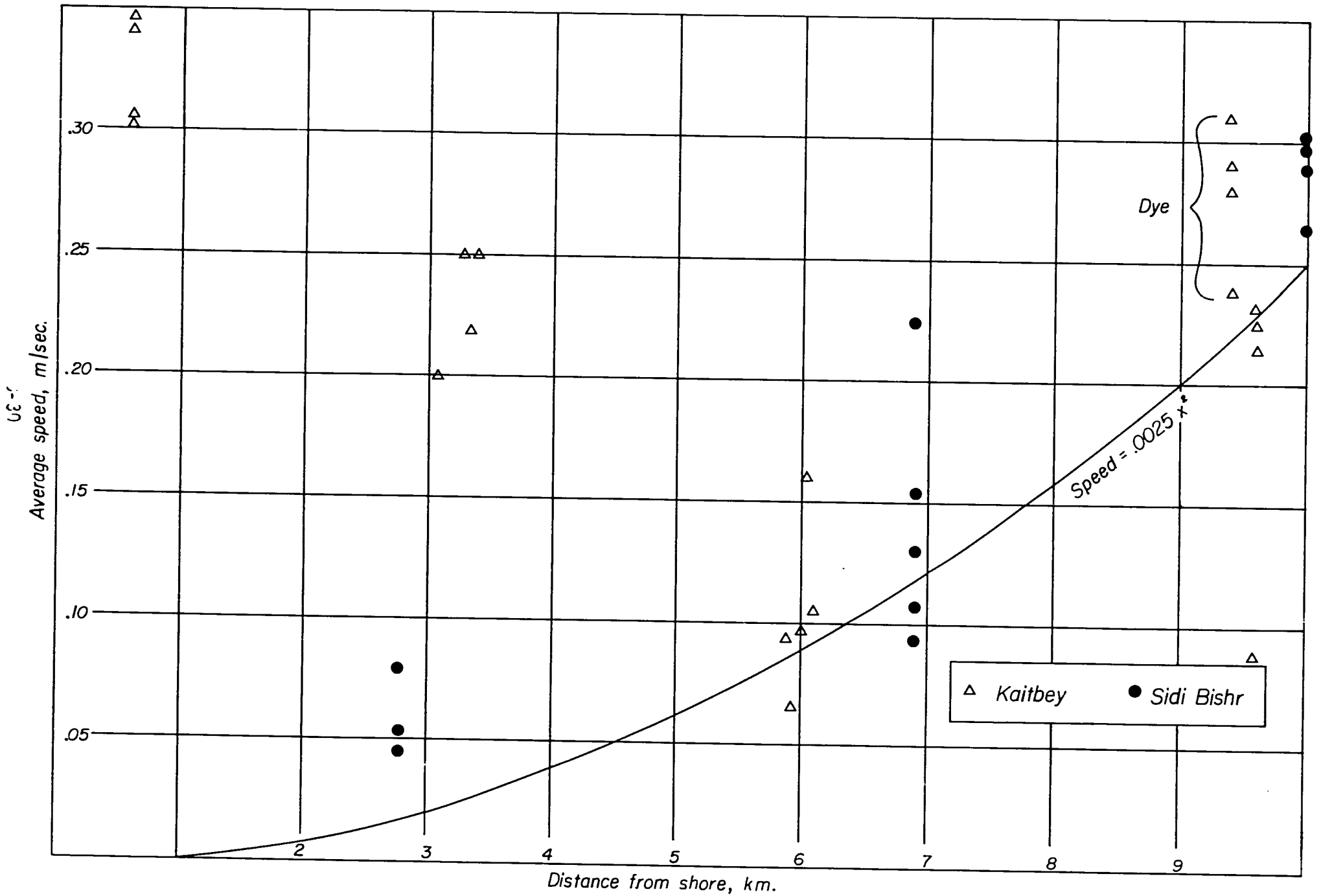


Fig.3-10 Current speeds by drogues and dye, July - Aug. 1977

TABLE 3-7.

OFFSHORE CURRENTS

Quadrant	Percentage of Time in Quadrant	Average Current in Quadrant (cm/sec)
Kait Bey alignment;	2.5 km offshore; water depth 28 m; meter depth 10 m	
Northeast coastal	50	16
Southwest coastal	41	10
Offshore	7	5
Onshore	2	3
Kait Bey alignment;	2.5 km offshore; water depth 28 m; meter depth 18 m	
Northeast coastal	54	10
Southwest coastal	33	6
Offshore	8	3
Onshore	5	3
Kait Bey alignment;	10 km offshore; water depth 55 m; meter depth 10 m	
Northeast coastal	42	14
Southwest coastal	45	12
Offshore	4	14
Onshore	9	8
Kait Bey alignment;	10 km offshore; water depth 55 m; meter depth 45 m	
Northeast coastal	42	13
Southwest coastal	39	13
Offshore	10	6
Onshore	9	7

TABLE 3-7. (Continued)

Quadrant	Percentage of Time in Quadrant	Average Current in Quadrant (cm/sec)
Sidi Bishr alignment;	3.5 km offshore; water depth 28 m; meter depth 10 m	
Northeast coastal	33	11
Southwest coastal	43	12
Offshore	21	7
Onshore	3	3
Sidi Bishr alignment;	3.5 km offshore; water depth 28 m; meter depth 18 m	
Northeast coastal	48	10
Southwest coastal	43	7
Offshore	2	5
Onshore	7	4

9 percent of the time. At 2.5 km offshore on the Sidi Bishr alignment, the results are much the same as for corresponding locations on the Kait Bey alignment. The periods of duration for the onshore currents are also, correspondingly, of limited duration of a day or less in between the more extended periods of the stronger northeast or southwest coastwise currents.

For the deep waters offshore from Alexandria and for the eastern Mediterranean in general, the temperature and salinity distributions have the following characteristics. In winter, the water column is reasonably uniform in salinity and temperature from the surface down to a depth of around 300 m. During late spring, the seasonal thermocline appears. By summer, there is a strong temperature gradient at around 30 m. By fall, the gradient has decreased in magnitude with the decrease in surface temperature, and it has descended in depth to around 60 m. Furthermore, evaporation exceeds precipitation in the eastern Mediterranean so that salinities in the upper portion of the water column will be around $39^{o}/oo$ or greater during the summer. In the past, Nile River water could be observed as far west as Alexandria. With the creation of Aswan Dam, no Nile water effects are now noticeable in the Alexandria area, as has been discussed by Sharaf El Din.

As part of the oceanographic survey off Alexandria, detailed observations of temperature, salinity, and dissolved oxygen (DO) have been made as a function of depth from the surface to the bottom and of distance out to 10 km along the Kait Bey and Sidi Bishr alignments. For the late summer and fall of 1977, temperature and salinity conditions are essentially uniform along each alignment as a function of depth and distance during each measurement period with a slight expression of the seasonal thermocline and with the existence of some low salinity water at near shore stations. These are related to major discharges at Mex and Kait Bey and to minor outfall discharges along the shore. Characteristic values of observed temperature and salinity and computed density at 10 km offshore are given in Table 3-8.

TABLE 3-8.

CHARACTERISTIC TEMPERATURE, SALINITY, DENSITY, AND DO VALUES AT 10 km OFFSHORE

Alignment	Date	Temperature	Salinity	Density	DO
Kait Bey	27/7/77	25.4°C	39.6°/oo	26.7 x 10 gm/cm	8.7 mg/l
Kait Bey	17/9/77	26.7	39.8	26.5	6.5
Kait Bey	9/10/77	25.2	40.1	27.2	-
Sidi Bishr	1/8/77	26.3	39.0	26.0	6.6
Sidi Bishr	7/9/77	26.5	39.0	25.9	6.3
Sidi Bishr	10/10/77	25.2	39.0	26.3	-

In general, the near surface waters of the eastern Mediterranean are well oxygenated and, away from the Nile River influence, nutrient impoverished. Characteristic DO values in deep water areas offshore from Alexandria range from 4.7 to 9.4 mg/l, representing a variation from 50 percent saturation to supersaturation; typical phosphate concentrations are 0.003 to 0.004 mg/l. Along the Kait Bey and Sidi Bishr alignments of the oceanographic surveys, DO values are uniformly high; depth-averaged values at 10 km offshore have been included in Table 3-8. For the offshore area, nitrates do not exceed 0.011 mg/l, and silicates are around 0.06 to 0.15 mg/l. Both of these are low values for oceanic areas. In Abu Kir Bay, nutrient levels are somewhat elevated, presumably because of the outflow from Lake Idku. There phosphates reach 0.14 mg/l and silicates 0.34 mg/l.

There are several major wastewater discharges to the ocean along the Alexandria coast. They include various industrial waste discharges to the western harbor and vicinity, the Mex pump discharge from Lake Maryut, the Kait Bey outfall, the industrial waste discharges to Abu Kir Bay, and the numerous minor discharges along Alexandria beaches. Some of their effects on water quality and related matters are discussed below.

One of the more noticeable effects is that of the beach discharges. Fig. 3-11[16] shows the locations of these numerous wastewater discharges. On calm days, surface oil slicks extend well out to sea from each of these discharges. Discharge locations are also clearly distinguishable by the concentrations of sea birds around them. Even during dry weather spells in winter, these subsidiary outlets frequently discharge wastewater. Furthermore, at times the combined effect of all beach discharges can be distinguished by a brown water surface area extending some several hundred meters out from the beaches, which forms a distinct front with the blue Mediterranean water.

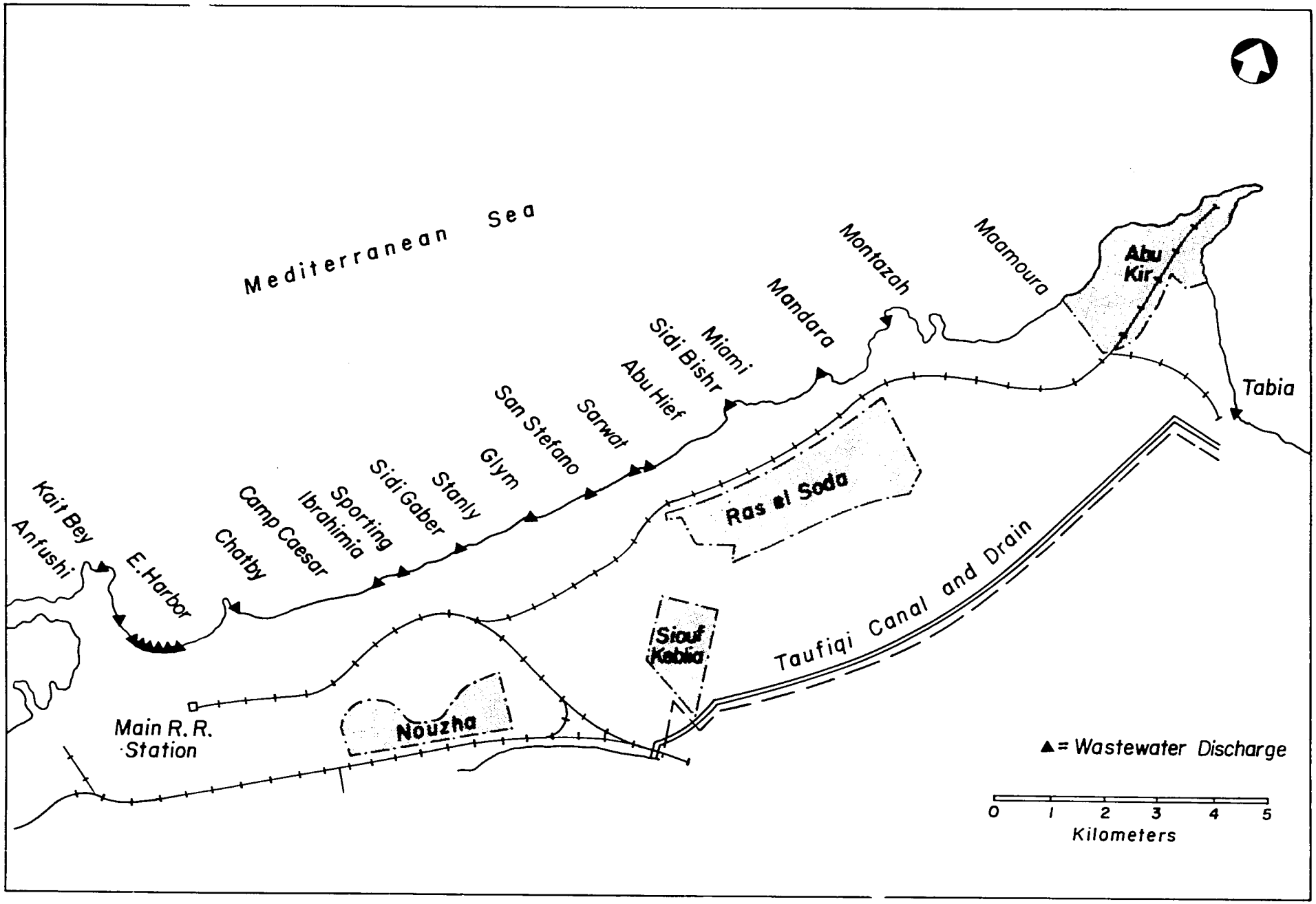


Fig.3-11 Alexandria beaches and discharges.

Visual pollution and odors are particularly noticeable in the eastern harbor, which is a relatively enclosed body of water and has seven outlets discharging to it. Visual inspection shows that Alexandria beaches suffer considerably from oil pollution in the form of extensive deposits on the beach sands. This pollution would appear to be related to either the oil pipeline terminal located at El Mex or to the large number of ships which can be seen offshore waiting to enter the western harbor. In addition, rubbish (plastics, containers, etc., as well as organic matter) is found washed up on the beaches. The relative contribution to the origin of this material from wastewater discharges, other sources such as ships offshore, or simply shoreline dumping of wastes from restaurants and residences is moot.

The High Institute of Public Health of Alexandria University has carried out an extensive program aimed at determining the extent and effects of pollution of nearshore waters off Alexandria, resulting from wastewater discharge. Their investigations have included analyses of nearshore waters off the beaches. The samples were collected just below the surface about 50 m offshore at 22 beaches and analyzed for total coliforms, the fecal coliform, Escherichia coli, and fecal streptococci. An analysis for the winter of 1975 is shown in Fig. 3-12.[16] Using the log mean of E. coli as an indicator and adopting the following standard often used for coastal bathing waters,

> 2,000 E. coli per 100 ml - heavy pollution
200 - 2,000 E. coli per 100 ml - moderate pollution
< 200 E. coli per 100 ml - light pollution,

the beaches of Halka, Mahkama in the eastern harbor, Sporting, Sidi Gaber, Police Club, and Glym near the pump station are shown to be heavily polluted. Sidi Bishr, Miami, Montaza, and Maamoura are only lightly polluted; all others suffer from moderate pollution.

The latest results from the High Institute of Public Health are summarized in a report by Hakim.[17] Table 3-9 from this report is a summary of arithmetic means and standard deviations for total coliform, E. coli, and fecal streptococci for the summer of 1976 at several selected beaches. The results are different in detail from one beach to the next compared with those of Fig. 3-12; but they, nevertheless, show the same general condition of moderate to heavy pollution for most of the beaches. The report also contains the results of an interesting survey of people at three of the beaches. Surveyed were the Maamoura, Ibrahamia, and Mandara, beaches which, on the basis of the results in Table 3-9, would be described, respectively, as lightly polluted, moderately polluted, and heavily polluted. The survey made up of both bathers and nonbathers was concerned with the incidence of diseases which could be related to swimming. Results are given in Table 3-10. There is a distinct difference in the incidence of these diseases between bathers and nonbathers; however, the incidence of these diseases was much the

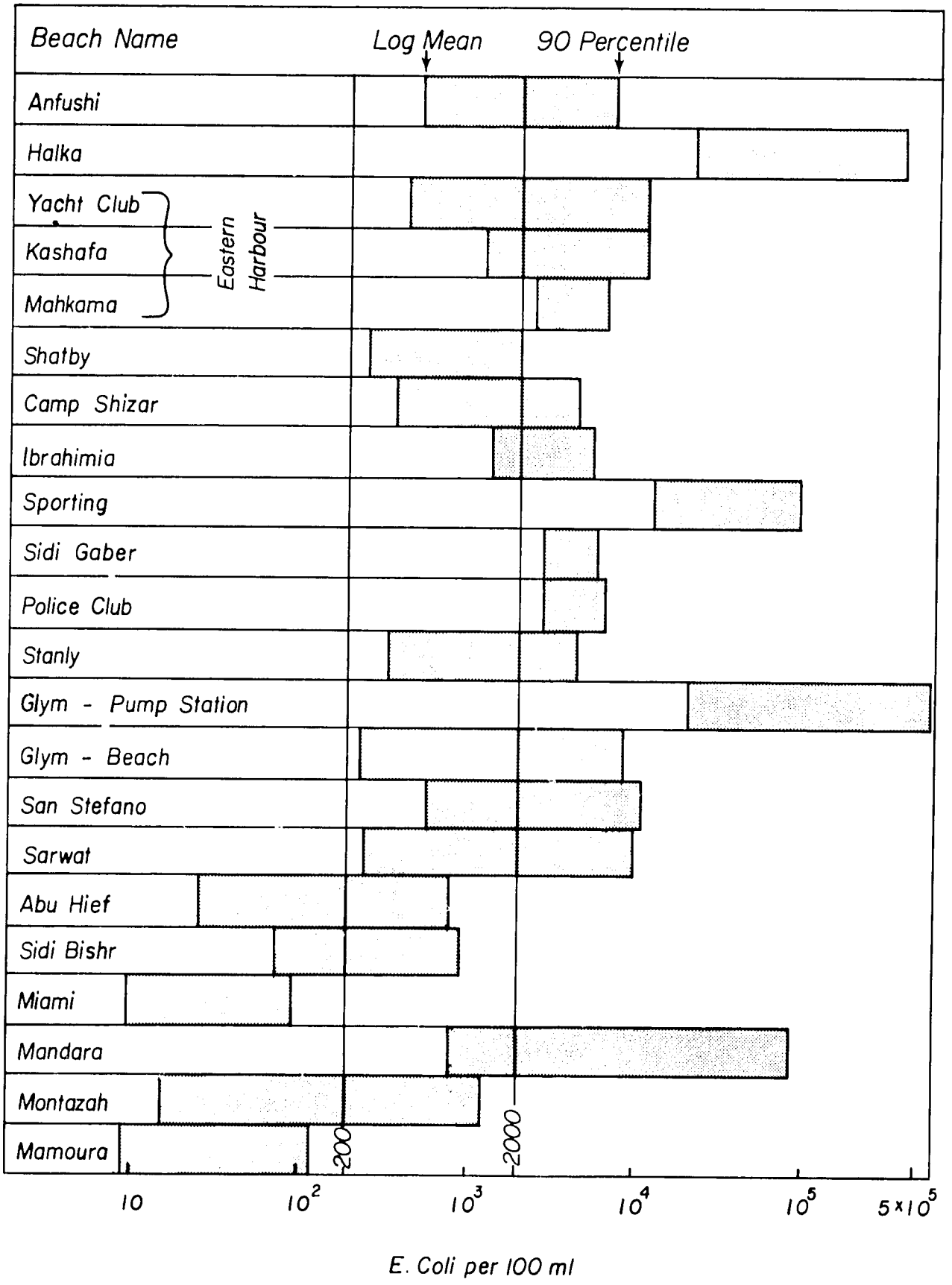


Fig. 3-12 Bacteriological analyses of nearshore waters
Dec. 1975 - March 1976

TABLE 3-9.

ARITHMETIC MEANS AND STANDARD DEVIATIONS OF BACTERIAL COUNTS BY BEACH AND SITE PER 100 ml

Beach	Station	Coliforms		E. coli		Fecal Streptococci	
		$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
Montazah	A	1,845	2,431	531	840	20	16
	B	9,843	12,397	1,540	2,650	348	506
	C	881	1,320	150	131	52	37
Abo Haif	A	8,943	13,077	1,343	993	1,331	1,170
	B	2,177	2,166	290	140	273	143
	C	1,443	986	875	1,321	478	444
Glym	A	144,807	246,994	8,780	13,230	2,043	1,954
	B	20,000	4,583	1,555	2,380	6,033	4,366
	C	16,767	12,529	4,667	5,543	4,433	5,802
Sporting	A	378,100	625,296	23,100	15,926	254,333	187,474
	B	436,900	583,719	84,900	110,482	93,333	127,336
	C	803,000	1,383,406	800,400	1,385,294	81,800	137,010
Camp Cesar	A	1,420	849	168	107	294	396
	B	477	242	216	212	447	457
	C	9,110	12,916	3,742	6,286	1,863	2,384
Anfoushi	A	1,607	2,333	940	1,178	9,017	12,999
	B	9,010	12,995	3,743	6,286	4,110	5,972
	C	1,887	2,105	287	248	2,153	1,721
Mandara	A	1,533,333	750,555	1,533,333	750,555	1,753,333	1,120,060
	B	800,267	1,385,410	800,133	1,385,525	153,767	265,206
	C	1,603,167	1,380,156	1,169,833	1,196,779	810,167	1,376,848
Ibrahimia	A	3,867	1,270	90	72	258	193
	B	3,133	1,270	395	477	224	180
	C	12,367	11,014	405	460	4,057	6,023
Maamoura	A	64	74	16	11	363	115
	B	65	49	37	49	845	1,347
	C	93	128	23	20	125	102

TABLE 3-10.

RELATIONS BETWEEN BATHING AND COMPLAINT BY BEACH

	Maamoura				Ibrahimia				Mandara			
	Bather		Nonbather		Bather		Nonbather		Bather		Nonbather	
	No.	Percentage	No.	Percentage	No.	Percentage	No.	Percentage	No.	Percentage	No.	Percentage
Vomiting and/ or diarrhea	9	1.6	3	1.2	8	1.6	1	0.3	24	3.1	7	1.8
Red eye	12	2.1	-	-	12	2.3	1	0.3	16	2.1	-	-
Fever	2	0.4	-	-	4	0.8	1	0.3	4	0.5	1	0.3
Skin lesions	13	2.3	1	0.4	14	2.7	-	-	14	1.8	3	0.8
Ear infection	4	0.7	1	0.4	6	1.2	-	-	8	1.0	1	0.3
Upper respiratory tract	12	2.1	2	0.8	23	4.5	1	0.3	17	2.2	6	1.5
Colics	5	0.9	0	-	1	0.2	1	0.3	6	0.8	1	0.3
More than one	5	0.9	-	-	1	0.2	-	-	-	-	-	-
Total complaining	62	11.0	7	2.8	69	13.5	5	1.5	89	11.5	19	5.0
No complaint	498	89.0	252	97.2	442	86.5	307	98.5	677	88.5	378	95.0
Grand Total	560	100	259	100	511	100	312	100	766	100	397	100

same at all three beaches. As discussed by Shuval, for any given concentration of coliforms in wastewater or in the environment, the incidence of pathogens may be 10 to 100 times greater in Egypt than in the U.S., where the above standards were developed, because most Mediterranean countries have 10 to 100 times greater enteric disease rates. Furthermore, as also discussed by Shuval, many pathogens including viruses survive in seawater for significantly longer times than do coliform bacteria, so that the latter are not necessarily reliable disease indicators.

Bacterial disappearance, or die-off, studies have been included as part of the ongoing oceanographic survey program. An interesting technique has been used to make the determination of die-off rates under the actual conditions offshore from Alexandria. At the start of the sampling period, dye was injected into the surface waters at the principal point of discharge of the Kait Bey outfall, as indicated by the visible wastewater boil at the surface. The dye served to mark a particular sample of wastewater and the decrease in dye concentration to indicate the physical dilution with seawater of the marked wastewater patch. The dye patch was then followed, and samples were taken at various time intervals. The samples were analyzed for total coliforms and enterococci. These results were then corrected for the physical dilution of the patch at the sampled time, to provide the disappearance rates.

These data have been plotted in Fig. 3-13. There is a wide scatter in the data, but they do show a rather rapid die-off of bacteria with time. The two lines which have been included in the figure set the data boundaries and are for a die-off rate of one order of magnitude every hour. The lines could be varied by from a half hour to 2 hours. World wide values in daylight generally range from 1 to 8 hours for a 90 percent reduction in bacteria and depend among other things on water temperature; values measured elsewhere in the eastern Mediterranean have also been found to be about 1 hour or less.

Industrial development along the western shore of Abu Kir Bay has led to a significant pollution of the waters from the Tabia Pump Station discharge to beyond the Maadia Channel, which is the entrance to Lake Idku. Wastewater in the Abu Kir Drain, which is elevated and discharged to the bay at the pump station, consists of irrigation drainage from the agricultural areas of Behaira Governorate and various industrial wastes from the Hafr El Dawar and Tabia areas. Industrial wastes are from large textile, paper, and canning industries.* Total wastewater and irrigation flows to Abu Kir Bay from the pump station are substantial and vary from 1,500 to 2,000 Ml/day.

Such a large amount of wastewater discharge has had a detrimental effect on the aquatic life of the bay from the discharge to the east for a distance of about 20 km. The entrance to Lake Idku is

* See Tech. App. No. 5A and 5B, Vol. II, this report.

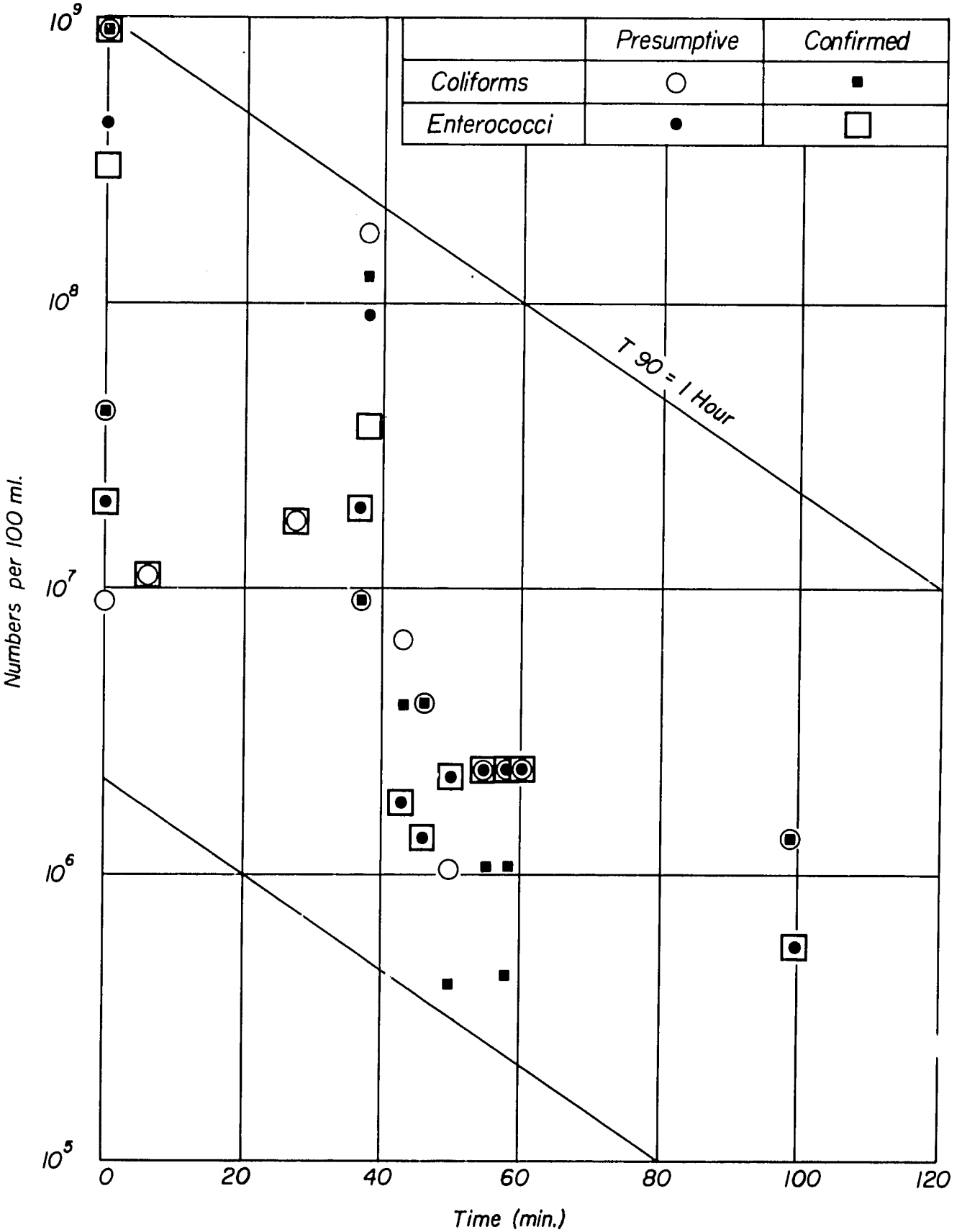


Fig.3-13 Bacterial concentrations in sewage plume, corrected for physical dilution

located 9 km to the east of the discharge point. The discharge forms an extensive and well-defined plume of polluted waters, which can be distinguished visually from the unpolluted bay waters by its characteristic brown to reddish brown color. On calm days, the plume forms fronts at its outer boundaries; the fronts collect floating detrital matter and also serve as a visual indication of the extent of the wastewater plume. The plume characteristically extends a few hundred meters to the west of the discharge and several hundred meters offshore in addition to its elongation to the east.

The High Institute of Public Health has studied the polluted waters of Abu Kir Bay. Their investigations have been summarized in a report by Mitwally et al.[21] The report covers a sampling period from November 1976 to May 1977. The location of the sampling stations as well as the Abu Kir Drain discharge and industries are shown in Fig. 3-14, taken from this report. Table 3-11 is a summary of the chemical analyses of the ten samples obtained during the period at the ten stations shown in the figure; the first four stations are within the drain system and the rest in the bay. Results for the bay stations show highly polluted conditions with low DO values which gradually increase away from the discharge point, high ammonia and nitrate nitrogen values, and high biochemical oxygen demand (BOD) values which gradually decrease away from the discharge point.

There is little information as to effects on coastal water quality from the Mex and Kait Bey discharges as well as from industrial waste discharges in the western harbor region.

3.B.5.b Freshwater Environment.

3.B.5.b.i Physical Description of Lake Maryut. Four large shallow lakes (Manzala, Borullus, Idku, and Maryut) lie along the Egyptian Delta a short distance from the Mediterranean coast (see Fig. 3-3). Covering an area of some 200,000 ha, these delta lakes are only about 1 m deep. All but Lake Maryut are currently connected to the sea, and all four are brackish with waters of various degrees of salinity.

The two smallest of the delta lakes, Idku and Maryut, lie within the environs of the city of Alexandria and within the current study area. Lake Maryut, the smallest of the four, represents the southern boundary of the city proper, which is spread out along its length in the narrow area between the lake and the Mediterranean. Lake Idku lies along the eastern outskirts of the city in the Abu Kir district.

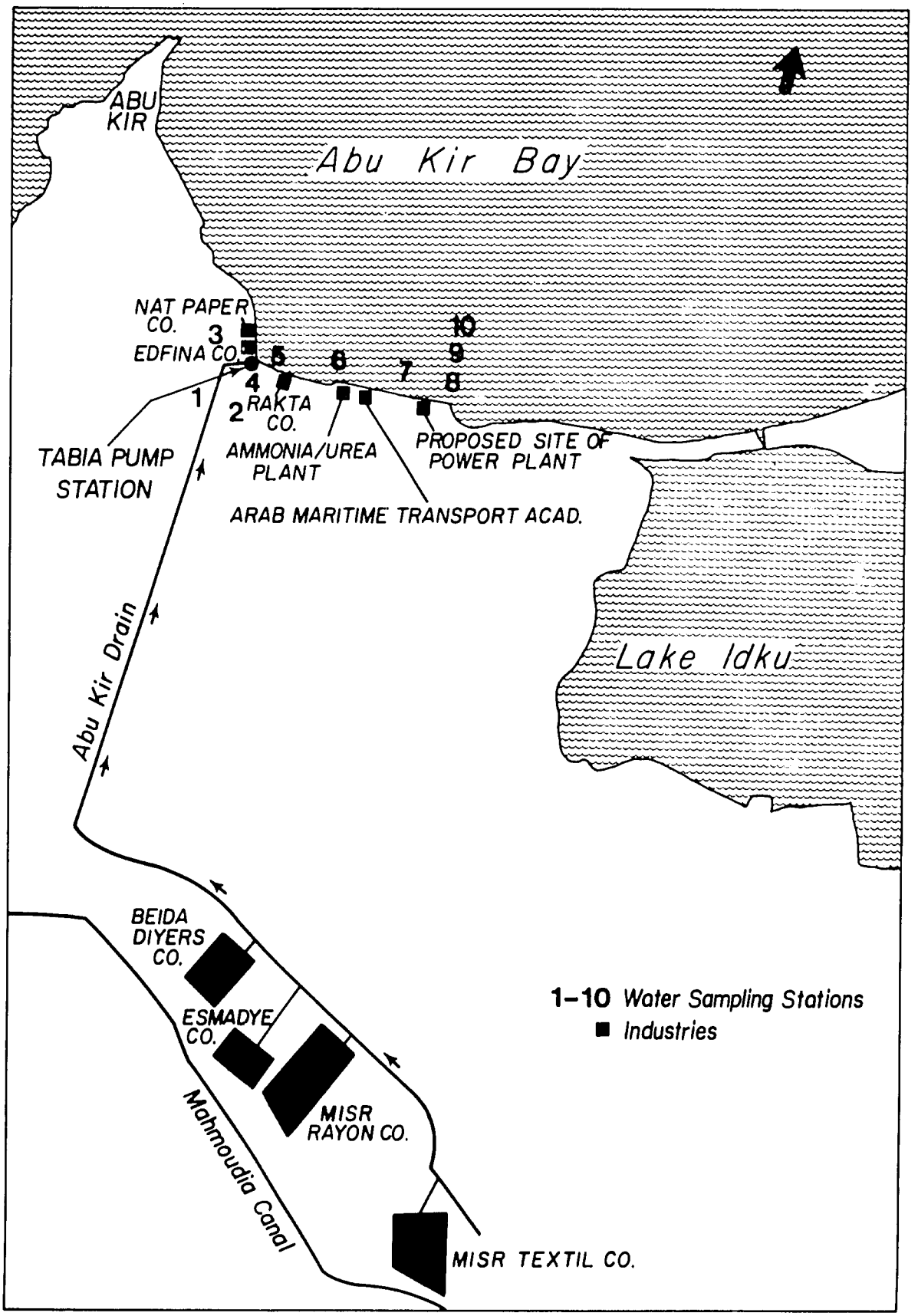


Fig.3-14 Locations of water quality stations and industries discharging into Abu Kir Bay.

TABLE 3-11.

STATISTICAL SUMMARY OF CHEMICAL ANALYSES
ABU KIR BAY WATERS

Station	pH	DO	NH_4 - N	NO_3 - N	BOD	H_2S
	pH units	←		mg/l		→
1	7.4	1.48	1.25	5.50	1,020	0.28
2	8.2	0.90	1.31	4.90	1,300	0.21
3	7.2	2.46	0.70	2.90	1,410	0.16
4	8.0	0.70	0.77	4.40	1,280	0.19
5	8.0	2.27	2.48	8.15	728	0.26
6	8.2	3.45	1.06	8.50	499	0.17
7	8.3	4.40	0.93	9.09	289	0.08
8	8.4	5.95	2.03	8.80	348	0.01
9	8.4	6.15	2.59	9.46	280	0.01
10	8.4	6.24	1.92	9.59	244	0.01

The delta lakes together represent only about 15 percent of the total commercial fishing area of Egypt, which also includes the Nile River and the contiguous portions of the Mediterranean and Red seas. However, since construction of the Aswan High Dam, which has greatly decreased the general fertility and the resulting fisheries of the Mediterranean in Egyptian coastal waters, freshwater sources and, in particular, the delta lakes have contributed 50 to 60 percent of the country's total fish landings.[22] Fig. 3-15[23] shows the relationship between Egyptian freshwater and Mediterranean fish landings for the years 1970 to 1975, the former representing some 94 percent of the total in the most recent years.

Although of relatively small size in comparison with the other delta lakes, Lakes Idku and Maryut are highly productive, as shown in Table 3-12, and together contribute a significant fraction of the total Egyptian fish landings. Fig. 3-16 illustrates the comparison of the Lake Maryut fish catches with those of the total marine landings at Alexandria for the years 1970 to 1975. Again, the lake has contributed 75 percent or more of the total for the past several years.

TABLE 3-12.

ESTIMATED FISH PRODUCTION FROM FOUR EGYPTIAN DELTA LAKES

Lake	Fish Production (kg Freshwater/ha/Year)
Manzala	162
Borullus	275
Idku	587
Maryut	1,092

Thus, the Egyptian Delta Lakes in general and Lakes Idku and Maryut in particular have an importance to food, specifically animal protein production, and to the economy of the country which far exceeds their geographical significance.

In classical historical times, Maryut, or Mareotis as it was then known, covered a considerably greater area than it does today. With rich farms on its shores, fish and waterfowl abundant in it, and serving as an important navigation basin, the lake was of considerable significance to the welfare of Alexandria until the twelfth century A.D. Mareotis was fed primarily by the Canopic branch of the Nile. By the late twelfth century, the tributary streams had become so silted up that water flow to Mareotis was considerably reduced, and the lake gradually receded to become a salty swamp.

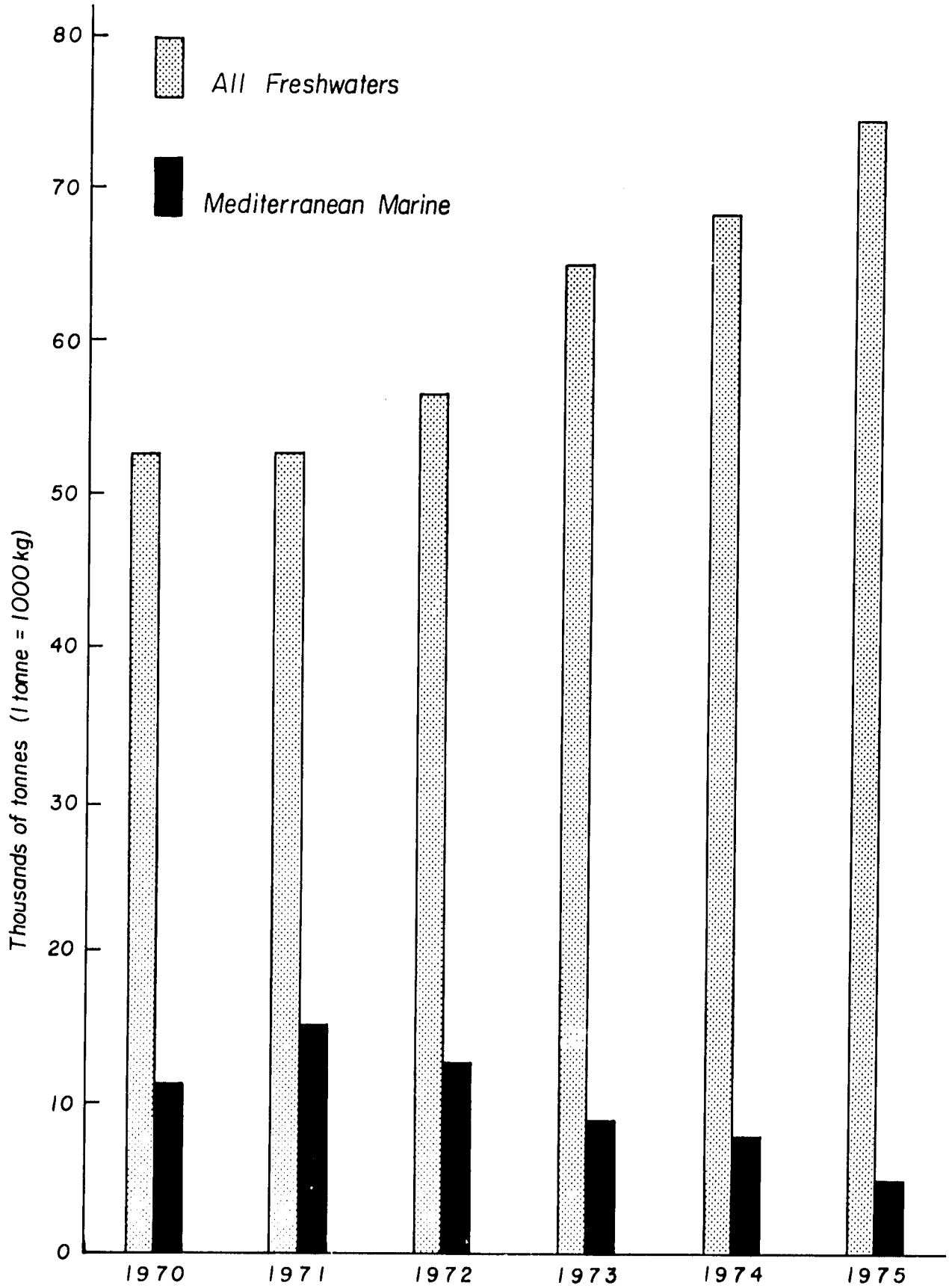


Fig. 3-15 Comparison between the Egyptian freshwater and total Mediterranean marine fish catches for the years 1970-1975

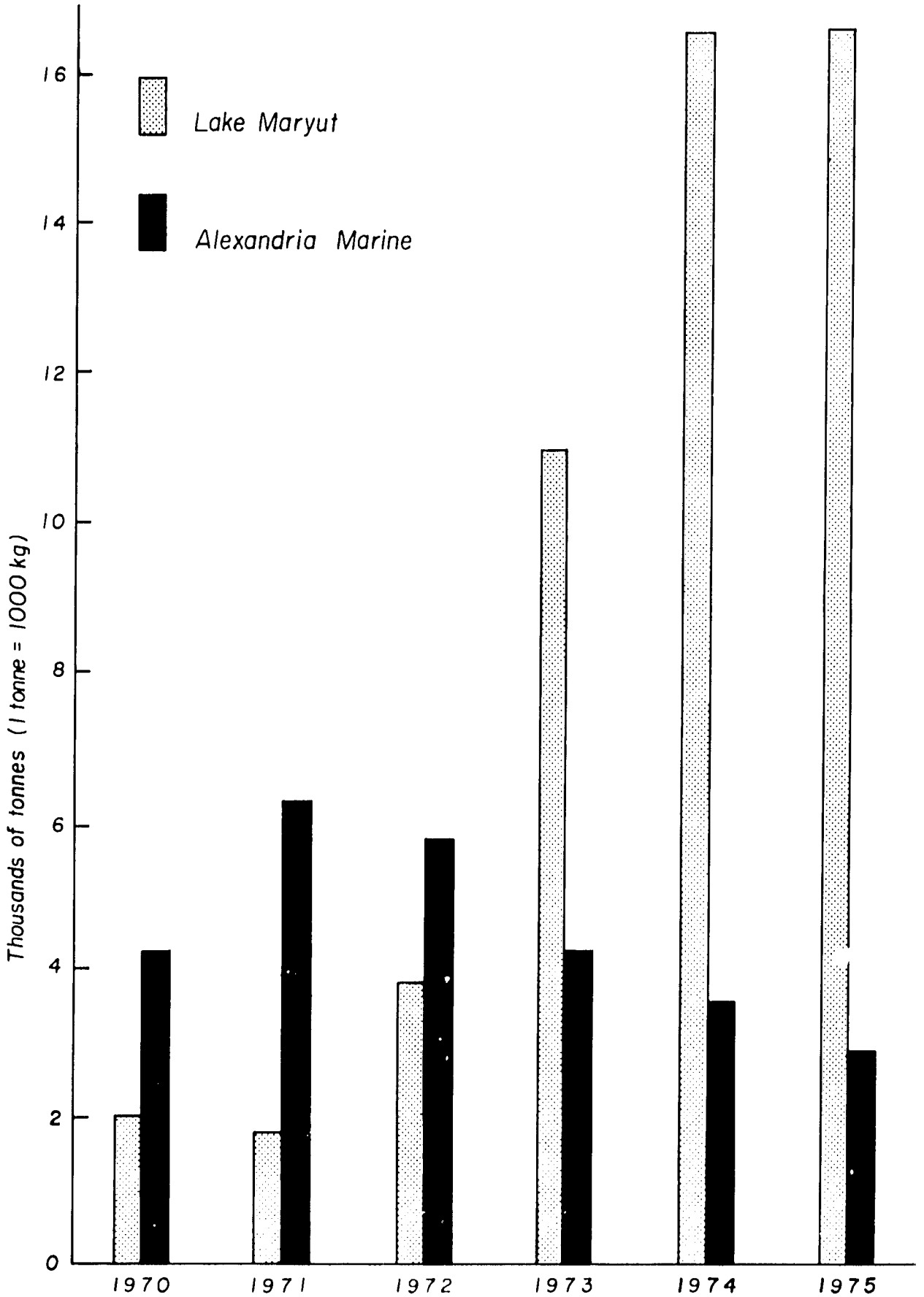


Fig.3-16 Comparison between the Lake Maryut (freshwater) and the total Alexandria marine fish catches for the years 1970-1975

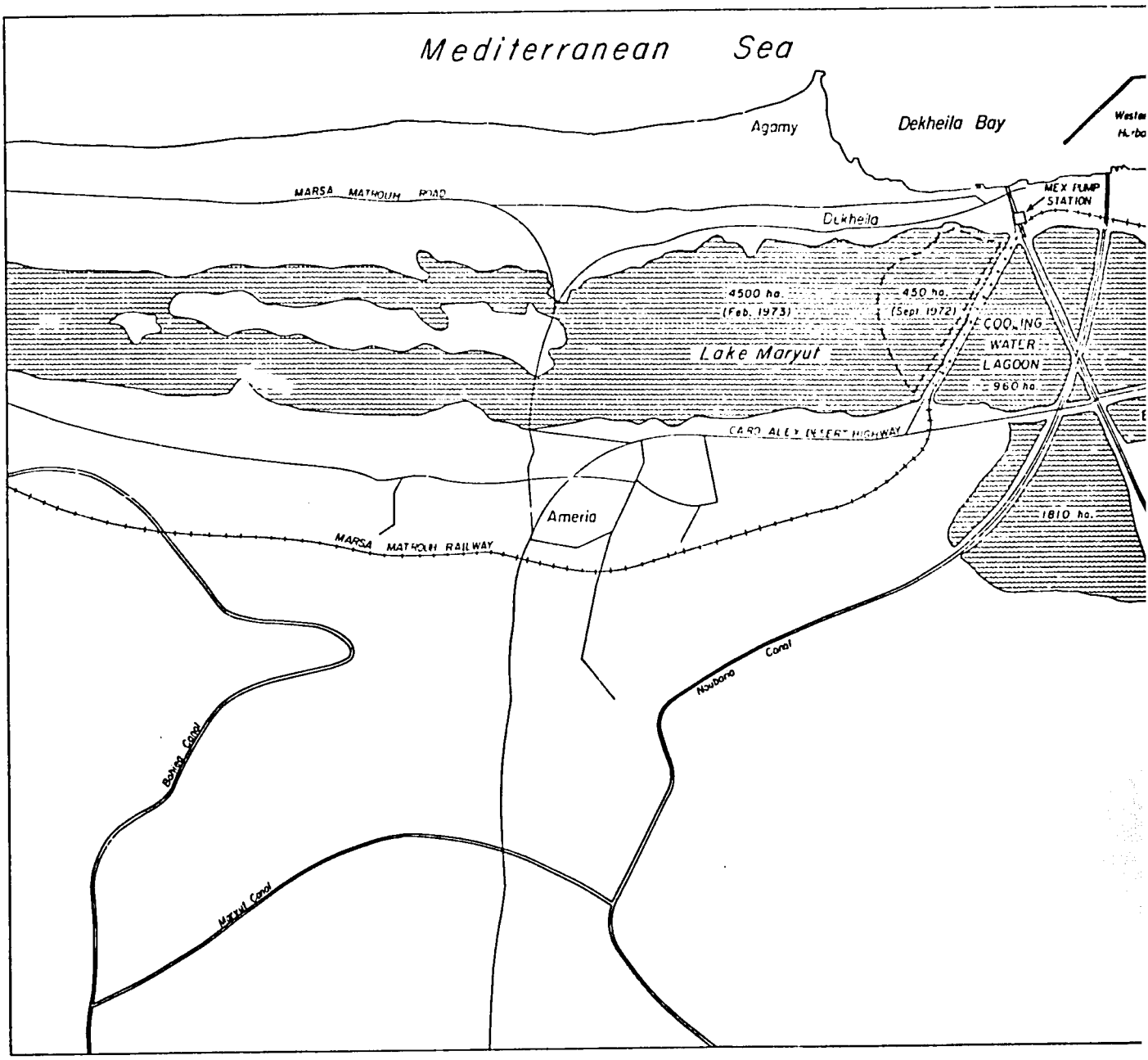
For the 700 years from the twelfth to the eighteenth century, it was almost completely dry with water entering only during the yearly Nile flood. Sometime during this period, the old channel to the sea was blocked, and the lake became a catch basin for drainage from agriculture in the Beheira Province to the southeast of Alexandria. In 1801, as part of their campaign against Napoleon, the British cut the dykes which separated the basin from the sea, thus reflooding the whole area and creating the current Lake Maryut.

In 1892, the agricultural irrigation system for the Beheira Province was reorganized, and Lake Maryut was made the catch basin for the drainage waters. Most drains in the area are thus designed to flow into it, and the Mex Pump Station was set up to maintain the lake at a level of approximately 2.8 m below sea level by discharging water from the lake directly to the sea.

Since about the turn of the century, the size of the lake has diminished considerably, partly as a result of natural siltation but mostly because of land reclamation and filling for agricultural and other purposes. The Nouzha Hydrodrome, for example, which was originally constructed as a seaplane terminal, was once a part of Maryut but is now completely isolated from it. From an area of about 20,000 ha in 1900, the lake had been reduced to about 8,000 ha in 1960. Filling continues with current plans showing conversion of an additional 600 ha of lake area to land for industrial development.

It is, however, a misnomer to refer to the current remains of Lake Maryut as a single lake. It consists, rather, of a series of isolated and semi-isolated basins, as shown in Fig. 3-17. The Main Basin, or "lake proper," of some 1,800 ha is bounded by Suez Canal Street on its northeast side and the connecting Cairo-Alexandria Desert Highway along its southeast side. A bridge on the Desert Highway spans a canal which connects the Main Basin with the East Basin (sometimes referred to as the "Experimental Fishery Lagoon") which was formerly very large but which has been reduced by reclamation to a current area of roughly 450 ha. The Kalaa Drain, which contains agricultural drainage and both treated and untreated wastewater from the eastern part of Alexandria, passes through a channel in the northeastern end of the East Basin and under the Desert Highway bridge into the Main Basin.

The western end of the Main Basin of Lake Maryut is traversed by the Noubaria Canal, a nonflowing ship channel with locks at its Mediterranean end and in the desert south of Lake Maryut, and the Umoum Drain, which receives agricultural drainage from the area south of Alexandria. The Umoum Drain siphons under the Noubaria Canal midway across the Main Basin, ending up at the Mex Pump Station on the coast. Both the Noubaria Canal and the Umoum Drain are dyked and separated from the lake basins. Between them, at the northern end of the Main Basin, is a small segregated section of 340 ha which is the area referred to above as designated for future


Mediterranean Sea
Agamy
Dekheila Bay
MARSA MATROUH ROAD
Dekheila
MEX PUMP STATION
4500 ha.
(Feb. 1973)
450 ha.
(Sept. 1972)
Lake Maryut
COOLING WATER LAGOON
960 ha.
CAIRO ALEXANDRIA DESERT HIGHWAY
Ameria
1810 ha.
MARSA MATROUH RAILWAY
Noubaria Canal
Bahig Canal
Maryut Canal

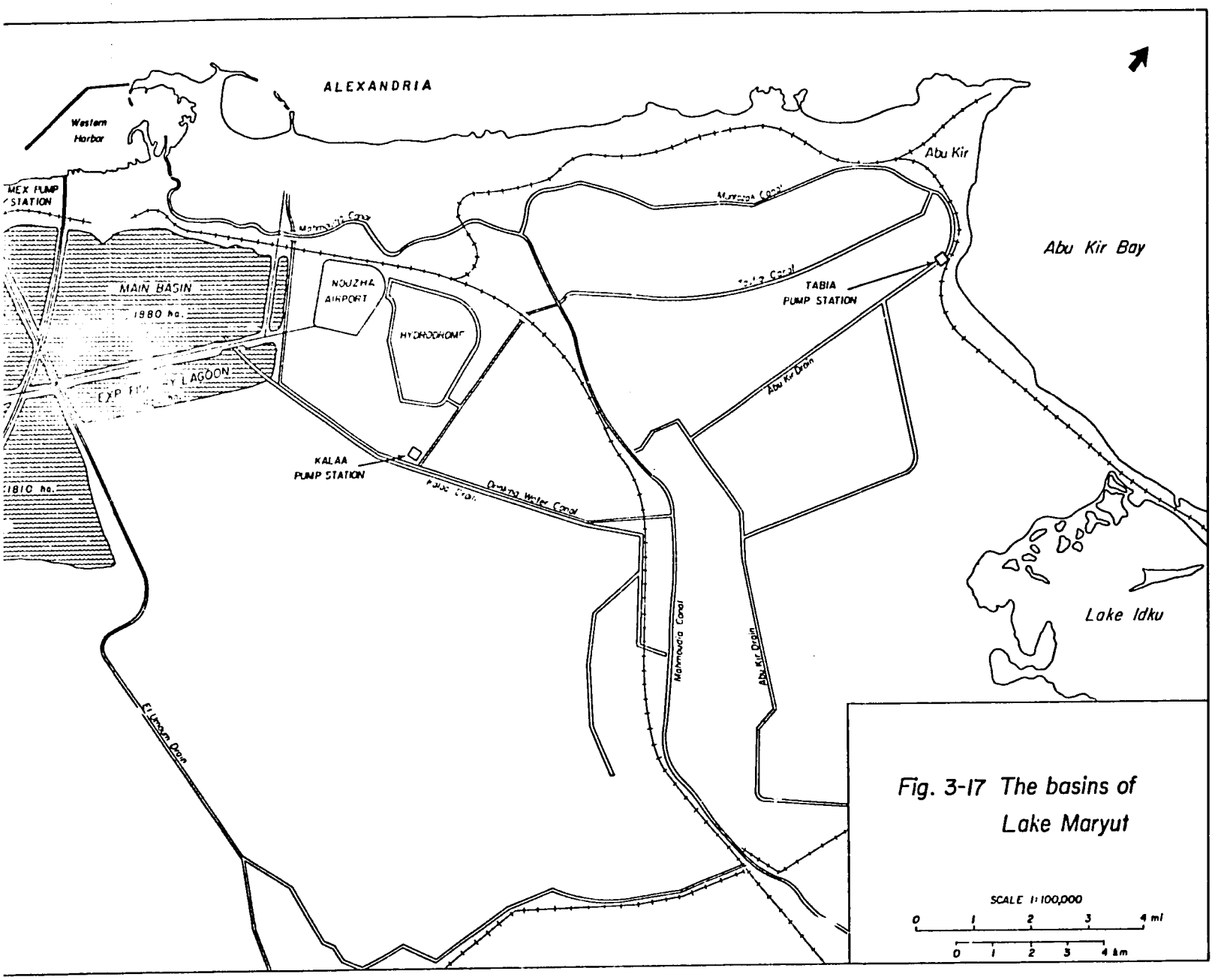


Fig. 3-17 The basins of Lake Maryut

SCALE 1:100,000

0 1 2 3 4 mi

0 1 2 3 4 km

industrial development. Farther to the west (west of the Umoum Drain) is another separate lagoon of 960 ha. This triangular basin, the Southwest Basin or "Cooling Water Lagoon," because it provides cooling water for an industrial development south of the Desert Highway, is bounded on its other two sides by that highway and the railroad. South of the Desert Highway and bounded on two sides by the Noubaria Canal and Umoum Drain is another triangular area, the Southeast Basin, which is 1,810 ha in size, about the same as the main lagoon. This also is separate from the other basins.

Finally, there is another large basin adjacent to the Southwest Basin but separated from it by the railroad and a road which runs between the Desert Highway and Mex Pump Station. This basin connects to the Mediterranean some distance west of Alexandria, and its waters are therefore saline. It varies seasonally in area from over 4,500 ha in the winter wet season to about 480 ha in summer. Parts of this large, separate basin are used for salt production.

The Umoum Drain is designed to operate at a level 40 cm below that of Lake Maryut so that excess water in the lake will flow into the drain and thence out at the Mex Pump Station. In practice, the Umoum Drain is normally above the lake level and water from the drain leaks out through numerous breaks in the dyke system and into the various basins which it traverses. In any event, the Umoum Drain and the Noubaria Canal as well as the various roads and railroads of the area effectively separate all of the basins described above except for the Main Basin and the small East Basin, connected by a canal beneath the Desert Highway. All of the basins, including the saline Western Basin at maximum flood stage, have a collective area of almost 9,940 ha. Considering seasonal variability, this is approximately the same as that given for "Lake Maryut" by Aleem and Samaan[24] for 1960. But it should be remembered that the Main Basin or "lake proper" and its connecting East Basin, comprising an area of only 2,330 ha, are the only parts of Lake Maryut which receive wastewater from greater Alexandria and are the only basins drained by the Mex Pump Station.

The Main Basin receives wastewater from four point discharges along its northeastern shore: Pump Station No. 3 west, the Gabbary and Gheit El Enab Drains, and the Industries Pump Station. Via the East Basin, it also receives effluent from the Kalaa Drain, which contains both wastewater and agricultural drainage. These latter sources enter the eastern end of the lake. Together, on an average, they consist of some 250 Ml/day of wastewater and 360 Ml/day of agricultural drainage. Table 3-13 provides a rough estimate of the daily domestic and industrial waste loads (nitrogen, phosphorus, biological and chemical oxygen demands, and suspended solids) entering Lake Maryut from these sources.

An average of 7,000 Ml/day (range 3,000 to 8,600) of water is pumped from the northwest corner of Lake Maryut (Main Basin) into Dekheila

TABLE 3-13.

ESTIMATES OF CURRENT WASTELOADS FOR LAKE MARYUT[1]

Source	Flow (10^3 m^3/day)	Nitrogen[2]	Phosphorus[3]	BOD_5	COD	SS
		← Kilograms/day →				
Kalaa Drain[4]	500	6,750	1,950	25,500	112,500	42,500
Industries Pump Station	39	466	78	42,900	127,900	43,100
Gheit El Enab Drain	47	1,727	653	25,000	58,700	30,100
Gabbary Drain	13	611	169	5,800	13,900	5,400
West Pump Station No. 3	10	410	110	5,000	9,900	5,020
Total	609	9,964	2,960	104,200	322,900	126,120

[1]From Camp Dresser & McKee File III(a)5(A), 15 November 1977.

[2]Does not include nitrate, nitrite, or organic nitrogen not measured by permanganate digestion (albuminoid N test).

[3]Does not include particulate or dissolved organic P.

[4]Includes 360 x 10^3 m^3/day agricultural drainage.

Bay and the Mediterranean via the Mex Pump Station. Most of that water flows directly through the Umoum Drain to the pump station. An indeterminate amount leaks out of both the Umoum Drain and the Noubaria Canal and thence to the pump station. The distribution of water quality parameters to be discussed later shows that inputs from the Umoum Drain and Noubaria Canal would probably not spread significantly into the eastern portion of the Main Basin, but would probably move northward directly towards the Mex Pump Station, more or less together with the main flow within the Umoum Drain. In other words, the Main Basin of the shallow (1-m deep) Lake Maryut (a volume of some 1,880 Ml) appears to be relatively stagnant, with a residence time of 31 days for the combined 600 Ml/day of wastewater and agricultural drainage entering its eastern end.

Nutrient data shown in Table 3-13, which are based on analyses made by Dr. F. Sharkawi, High Institute of Public Health, University of Alexandria, are incomplete, because nitrogen values do not include nitrate, nitrite, or a portion of the organic nitrogen (which are not measured by the albuminoid-nitrogen test). Phosphorus values do not include either dissolved or particulate organic phosphorus. Furthermore, measurements were not made in the Umoum Drain or at the Mex Pump Stations, so no mass flow of nutrients through Lake Maryut could be determined.

A single set of samples was therefore collected on 15 December 1977 and analyzed by Marine Environmental Services (Table 3-14). These data were then used to make a crude estimate of the mass flow of nutrients into and out of the Main Basin of Lake Maryut (Table 3-15). The output at Mex Pump Station is the mean value of 7,000 Ml/day given above. The Umoum Drain input of 5,000 Ml/day is the mean volume pumped into the Umoum at the various lift stations. The value for the Noubaria Canal is the difference between the output at Mex and the other known inputs. This may be greatly exaggerated because there may be a significant additional volume entering the Umoum Drain through direct land drainage. If that were the case, the mass input of nutrients to the lake and the efficiency of their removal by passage through the lake would be both considerably greater than shown in Table 3-15. That would seem doubtful, because the main flow of the Umoum Drain is directly through its channel to Mex, where there is neither time nor area for very much nutrient removal. However, the data are certainly not adequate for more than a very rough approximation and are perhaps most useful to illustrate the fact that, at least at that particular time, roughly the same quantity of nutrients was introduced to the lake by agricultural drainage as from wastewater.

TABLE 3-14.

NITROGEN AND PHOSPHORUS CONCENTRATIONS IN WASTEWATER*

	NH_4^+-N	NO_2^-+NO_3^--N	N	$PO_4^=$-P	P
	(mg/liter)				
Kalaa Drain	7.30	0.80	11.60	1.60	1.60
Gabbary Drain	27.00	1.40	37.00	4.70	6.10
Industries Pump Station	0.30	11.00	13.00	1.00	1.10
Umoum Drain	0.10	1.60	1.80	0.10	0.20
Noubaria Canal	0.02	0.60	0.80	0.01	0.02
Mex Pump Station	0.08	1.12	1.40	0.09	0.11

*Collected 15 December 1977 and analyzed by Marine Environmental Services.

TABLE 3-15.

ESTIMATED MASS BALANCE OF WATER AND NUTRIENTS THROUGH LAKE MARYUT

	Flow (10 Ml/day)	N (kg/day)	P (kg/day)
		Input	
Kalaa Drain	500	5,800	800
North Shore Drains[1]	70	2,590[2]	427[2]
Industries Pump Station	39	507	43
Umoum Drain	5,000	9,000	1,000
Noubaria Canal	2,000	1,600	40
Total	7,609	19,497	2,310
		Output	
Evaporation	100	-	-
Mex Pump Station	7,500	10,500	825
Percentage Removal by Lake Maryut	-	46	64

[1]Gheit El Enab, Gabbary. Pump Station No. 3, West.

[2]Based on analysis from Gabbary Drain only.

Another means of estimating the nutrient removal capacity of Lake Maryut (Main Basin) is from its rate of net organic productivity. This was estimated at 12 grams dry organic matter/m^2/day by Aleem and Samaan[24] for the year 1960.

Unicellular algae have a nitrogen and phosphorus content of roughly 8 percent and 0.8 percent of their dry organic weight, respectively,[25] while aquatic macrophytes contain less of these elements, about 2 percent and 0.2 percent N and P, respectively.[26] Using a mean composition of 5 percent N and 0.5 percent P for the mixed phytoplankton-macrophyte flora of Lake Maryut results in a daily photosynthetic assimilation of 11,280-kg nitrogen and 1,128-kg phosphorus over its 1,880-ha area, compared to the net uptake of 8,997-kg N and 1,485-kg P obtained by the mass flow calculations in Table 3-15. As discussed later, A.A. Salaam believes that the organic productivity of Lake Maryut is lower today than when the measurements were made in 1960 to 1962, a fact which, if true, would bring the two estimates closer together.

3.B.5.b.ii Physical Description of Lake Idku. Lake Idku (or Edku) lies east of the city of Alexandria, extending east to west parallel to Abu Kir Bay for a distance of some 19 km. In width, it averages about 6 km; it is 10 km at its widest, where two peninsulas extend into the lake from east and west, forming a semi-enclosed embayment, Lake Ghitas. Its total area is reported as 12,600 ha by Samaan,[27] and this has been confirmed by the current authors from earth satellite photographs. The lake has an average depth of 1 m and apparently has not significantly changed in depth for the past 100 years.

The lake receives its water from the Idku and Berkik Drains, the latter entering Lake Ghitas, which drain agricultural lands of Beheira Province to the south and east. The amount of water discharged into the lake from these sources ranges from about 3,000 to 9,000 Ml/day and averaged 5,800 Ml/day for the years 1969 to 1970. Assuming an area of 12,600 ha 1-m deep and a corresponding volume for Lake Idku of 12.6×10^7 m^3, the input of 5.8 x 5,800 Ml/day results in a retention time of about 22 days for water in the lake as a whole, not including tidal exchange.

The lake discharges its surplus water into the Mediterranean through a permanent inlet (Bougaz El Maaduya) located at its western extremity. Normally, the lake's level is about that of the Mediterranean and there is relatively little tidal exchange. Salinity in the lake normally ranges from about $5^o/oo$ near the inlet to $1^o/oo$ at its eastern end. However, strong northerly winds may force seawater into the lake temporarily, at which times salinities may increase to that of full seawater near the inlet and to as high as $12^o/oo$ in the center of the lake.

3.B.5.c Groundwater. The groundwater characteristics of the Alexandria region, especially as related to the study area, present a paradox. It would be more appropriate to consider this water as being a mixture of subsurface waters. That is, all water occurring below the ground surface.

Most of the definitive terminology usually applied to the description of groundwater must be used on a conditional basis because of the relatively unique hydrologic characteristics of the area. This is because of several predominant factors, all of which yield an unusual composite hydrologic effect on the so-called groundwater of the area. These are:

1. an extensive seawater infiltration into the substratum from the Mediterranean Sea

2. the lack of a true freshwater aquifer within the study area

3. the lack of an identifiable aquifer recharge area

4. the low rainfall and high evaporation rate of the area.

Therefore, for purposes of discussion, the term groundwater as used in this report is applied to that water present in the pore space matrix of the subsurface sediments, rock, and soils of the area regardless of its origin and hydrologic behavior. There is a paucity of coherent basic groundwater data for the study area. Existing data, while locally useful, is based on widely scattered and relatively shallow borings and lacks completeness as to parameter recording. This is especially true regarding the possible existence of a deepseated (i.e., in excess of 100 m or so) freshwater aquifer which may or may not exist in the subsurface of the Alexandria area.

The most recent and complete data for the areas west of the Noubaria Canal have been compiled by the FAO-UNESCO project based in Alexandria. Records for the eastern part of Alexandria are maintained by the Desert Institute Water Resources Department[29] and the Institute for Groundwater Research of the Ministry of Irrigation in Cairo. Data obtained from these sources have been used as basic references for this section of the report.

In general, the quality of groundwater in the Alexandria region is extremely poor. Analyses of currently available data on groundwater quality all bear witness to the predominance of brackish and not freshwater being contained within the subsurface soil deposits and consolidated bedrock formations of the Alexandria area. There are few, if any, occurrences of groundwater in the study area which can be considered as being freshwater, according to the normally accepted definition.

Past and current waterwell borings throughout the Alexandria area have, in general, yielded a groundwater product which is at best significantly brackish and, in a considerable number of instances, must be regarded as

being absolute brine. The persistent brackish character of the groundwater is because of the following basic reasons:

1. continuous seawater infiltration into the terrestrial substratum

2. the bedrock and many of the soils of the area are permeated with soluble marine salts and gypsum which were formed during evaporation cycles associated with the development of marine lagoons

3. the permeation of saline waters from irrigation canals into the surrounding substrata

4. the overall negligible yield of atmospheric freshwater recharge and the high evaporation rate of the area.

There are, of course, other reasons. However, the above are the principal causes of brackish groundwater conditions.

Because of the high salinity of the groundwater, drinking and irrigation water is predominantly supplied to the area by canal water flowing from the Nile.

Depth to the so-called water table, if indeed there is a true water table based on a normally accepted definition, is generally very shallow and is usually found within a few meters of the ground surface. This is chiefly because of the low topographic relief of the Alexandria area and the infiltration of seawater into the terrestrial substratum. The seawater tends to mound itself to the ground surface or near ground surface of the terrestrial soil strata and bedrock formations. This mounding effect of the saltwater floats what little, if any, freshwater is present in the invaded substratum to the ground surface or near ground surface and works against the potential formation of a structured lens of freshwater usually associated with seawater infiltration into a terrestrial substratum.

Much of the study area lies below the sea level of the Mediterranean, as shown in Sections A-A' and B-B' of Fig. 3-4, a condition which further aggravates the problems of saltwater intrusion. Groundwater data from Ras el Soda in the eastern part of the city are presented in Table 3-16. These data indicate the degree of dissolved solids contained in the groundwater of the area. In western portions of the study area, the water table has risen sharply in recent years because of the extensive irrigation networks developed for agricultural reclamation of the Noubaria Canal[30] and poses a problem of waterlogging and salinity which have plagued recent agricultural reclamation efforts in the western areas. Construction of the west Noubaria Main Drain is an attempt to reduce these problems.

TABLE 3-16.

GROUNDWATER SAMPLES TAKEN FROM RAS EL SODA IN MARCH 1977*

pH	Estimated Alkalinity in the Form of Sodium Carbonate (mg/liter)	SO_3 (mg/liter)	Sodium Chloride (mg/liter)	Total Quantity of Diluted Salts (mg/liter)	Subsurface Depth of Sample (meters)
7.70	593.6	558.4	3,627.0	5,026	0.30
7.60	678.4	1,442.6	22,815.0	27,456	0.75
7.30	593.6	1,327.4	11,641.5	15,404	0.70
7.70	636.6	5,007.4	50,895.0	68,062	0.80

*Memorandum from Hamdy, M.H., Ref. Groundwater Sampling in Ras el Soda (Alexandria), 8 March 1977.

Small amounts of fresh groundwater have been reported in some desert locations peripheral to the study area.[31] In addition, the existence of a deep-seated aquifer in the vicinity of the study area must be regarded as a possibility, according to past and recent reports.[32] However, for all practical considerations, if such an aquifer does exist proximal to the study area, it would probably not be determined within the foreseeable future; this type of study and evaluation is beyond the scope of this IEIS. It is mentioned here to focus attention on a possible valuable resource, should it be present, because the impacts of potential salt sinks within the Alexandria region, especially to the west, could have an irreversible deleterious impact should pollutants percolate to such an aquifer.

T.K. Liu[4] summarized the character of the groundwater table in the study area, according to its expected relationship with the various soil zones evaluated. In Zones I, II, and III, because of the nature of the subsoils and proximity to the sea, the groundwater table is expected to occur near that of sea level. Consequently, the depth to the water table should vary with the elevation of the ground surface. In Zone IV, ground surface elevations are low. Thus, the groundwater table should occur at or near the ground surface. In Zone V, the groundwater table is expected to be deep in the desert plain (see Fig. 3-4).

3.C Biological Elements

3.C.1 Terrestrial Ecology

The land within the study area consists of urban development, freshwater lake and marsh, irrigated agricultural land, and desert lands. The urban area lies on a low ridge along the shore of the Mediterranean. To the south of this ridge lie agricultural and lake areas which are from 2.6 to 6.5 m below sea level. This cultivated area is irrigated by canals which bring water from the Nile. Most of it is below the level of Lake Maryut and is kept drained by pump stations pumping water into drainage canals, principally the Kalaa and Umoum drains. The water from these drains crosses Lake Maryut at a level of 2.6 m (8.5 ft) below sea level and is then pumped over the ridge into the Mediterranean by the Mex pump station. Immediately to the west and south of the urban and irrigated areas are many hundreds of miles of desert. This desert is mostly barren and devoid of plant life. See land use map, Fig. 3-27 (Section 3.D.4).

Although specific records of birds using Lake Maryut and Lake Idku apparently do not exist, Heinzel et al.[33] indicate birds were found in the Nile Delta, which includes the Alexandria area. Many species of waterfowl, which breed in northern Europe, use this area for winter range. These include 14 species of ducks and at least 70 other species of water-dependent birds, such as grebes, pelicans, herons, egrets, spoonbills, flamingoes, ospreys, cranes, rails, and coots. (See Technical Appendix No 1.)

Species actually seen in or around the lakes by project personnel include surface-feeding ducks (Anas sp.), egrets (Egretta sp.), barn swallows (Hirundo rustica), the kingfisher (Alcedo atthis), and the hoopoe (Upupa epops). Other species pass through the area in the course of migration, and a few are found in the area year-round. (See Technical Appendix No. 1.)

3.C.2 Marine Ecology

The eastern basin of the Mediterranean is separated from the western basin by a sill at a 330-m depth between Sicily and North Africa. The basin is only moderately deep, with maximum depths to over 3,200 m off Mersa Matruh in western Egypt and to 4,000 m southeast of the island of Rhodes. Mean depth is around 2,000 m. The depths are reached rather abruptly, with little continental shelf and a steep continental slope. The shelves are quite narrow, usually no more than 8 km wide, but reach their greatest extent off the Nile delta where they extend 60 km offshore. The total shelf area in the eastern Mediterranean is 85,650 km^2 in the north (Greece, southern Turkey, and Cyprus) and 35,050 km^2 in the south (Syria, Lebanon, Israel, and Egypt). Of the southern continental shelf area, 28,750 km^2 (80 percent) lies in Egyptian waters. Tidal range is small, some 0.5 m, and hence the intertidal area is in general quite limited. There are a

number of very shallow brackish to hypersaline (salinity 2-50°/oo) lagoons lying along the shore. The largest by far are the Delta Lakes of Egypt, comprising the saline Lake Bardawil and the brackish Lakes Manzala, Borullus, Idku, and Maryut. The area of these last four is some 310 km^2. The first three are connected to the sea by narrow channels; but Lake Maryut, at Alexandria, is artifically maintained and discharges via a pump station.

Evaporation, at about 1,200 mm/year, exceeds precipitation in the eastern Mediterranean; and surface salinities of the sea are in excess of 39°/oo. The Nile River, formerly with an annual flow of some 62 km^3, was an important contributor of freshwater to the eastern Mediterranean; but, with the building of the Aswan High Dam, this flow has been reduced by more than 90 percent. Now, the only important freshwater input is that from the outflow of the Black Sea. This water tends westward along the coast of Greece and thus away from the eastern Mediterranean. Some partially diluted water is present in the vicinity of Rhodes, where winter cooling results in the formation of the eastern Mediterranean deep water of salinity 38°/oo and temperature 13.5°C. The currents are generally anticyclonic along the coasts and are congruent with frontal zones offshore.[34] The water is well oxygenated everywhere, with 4.5 to 6.4 mg/l in surface layers and 3.6 to 4.8 mg/l in deeper waters off Egypt.[35]

Nutrients are in very low supply in the waters of the eastern Mediterranean; consequently, it is an area of extremely low productivity. Phosphate appears to be the limiting nutrient. Typical levels off Egypt are 0.003 to 0.004 mg/l, and the standing stocks of phytoplankton are very low at less than 10 cells/ml at the surface.[36] Typical cell concentrations for the Mediterranean as a whole are 10 to 76 cells/ml,[37] and these must be considered quite low in comparison to other subtropical seas. Values in the Gulf of Mexico, for example, are about 700 cells/ml. Standing stocks of zooplankton in offshore Egyptian waters are also low, as would be expected, with values in the range of 1,000 individuals/m^3. Benthic biomass near Cyprus and in the Aegean Sea is about 1.3 to 2 gm/m^2 at shelf depths.[37]

Mediterranean fauna is on the whole very poor in species. Relative to other areas at similar latitudes, the Mediterranean would rank lowest in the absolute number recorded. There are 540 species of known fishes in the entire Mediterranean; but, in the Red Sea, for example, more than 800 species have been described and the true number probably exceeds 1,000.[38] The low number of species in the Mediterranean is attributable both to the relative isolation of the Mediterranean Basin from the rest of the world's oceans and to its relative newness geologically. The current Mediterranean was a dry basin in the Miocene and filled from the Atlantic when continental plate movements opened a gap at Gibraltar. The low nutrients, which mean that the basic food supply is not large, may also play a role in determining the number of species. Where food is limited, only so many can survive.

As would be expected from the geological history, Mediterranean fauna is derived almost entirely from the Atlantic. From this source in the west, there is a clear diminution of species in proceeding through the basins to the east. The eastern basin of the Mediterranean is the poorest in species of all. Ben-Tuvia reports a total of 285 fish species for the coast of Israel, a number only slightly more than half the total fish species known for the entire Mediterranean. Of these 285, 70 percent are species in common with the Atlantic fauna; 14 percent are found throughout the warm waters of the world; and 7 percent are endemic to the Mediterranean but are closely related to Atlantic species. Almost 9 percent come from the Red Sea and have reached the eastern Mediterranean by migration through the Suez Canal.

Communities of animals in the Mediterranean are generally characterized by some degree of dominance. In a trawl collection, for example, 20 to 40 percent of the catch might be one of a few species, while the rest of the catch would be comprised of a large number of species but all in rather low abundance. Local conditions and the nature of certain species do provide exceptions to this generality, as in pelagic sardine shoals composed entirely of one species; but, for the most part, the situation is comparable to that found in beach seine catches investigated over the years along the Egyptian Mediterranean coast, as shown in Table 3-17.[39] Here, of approximately 36 species recorded, 10 formed 80 percent of the catch and only a few of these comprised more than 10 percent. Such a pattern, one of moderate but not overwhelming dominance, is the one to be expected in warm-to-temperate water, fairly low diversity assemblages. It stands intermediate between the situation of very high dominance, low diversity, characteristic of northern assemblages, and the essentially no dominance, high diversity found on a tropical coral reef. The same pattern of dominance and abundance has been noted in the oceanic plankton populations of the eastern Mediterranean.

Egyptian waters have felt the impact of man's activities probably more than any other major region in the world. The first perturbation came with the completion of the Suez Canal in 1896. This canal made possible contact between one of the world's richest faunas, that of the Red Sea, and a relatively quite poor one, that of the eastern Mediterranean.

Because the waters of the canal vary quite a bit in temperature and salinity along its 162-km length, including the exceedingly saline Bitter Lakes and the rather fresh Lake Timsah, transit through it is not easily accomplished. Nonetheless, a number of fishes and invertebrates have made the journey and have succeeded in becoming established in a new area. The consequences of such establishment have been a subject of great interest to ecologists. The subject has recently been reviewed by Ben-Tuvia.[40]

TABLE 3-17.

BEACH SEINE CATCH COMPOSITION, TOP TEN SPECIES BY WEIGHT, FOR EGYPTIAN MEDITERRANEAN COAST IN SEVERAL YEARS[39]

Species	1928-1929 (percentage)	1959-1961 (percentage)
Sardinella maderensis	15	25
Mugil capito	36	10
Mugil cephalus	2	18
Mugil saliens	2	3
Argyrosomus regius	6	8
Umbrina cirrosa	4	1
Dicentrarchus labrax	1	4
Dicentrarchus punctatus	1	4
Pomatomus saltator	16	3
Sparus auratus	1	8

Virtually all successful migrants have moved from the Red Sea to the Mediterranean. This is to be expected. Because they come from a much richer fauna, which implies a high level of interspecific competition for resources, each of these would have been groomed by natural selection to compete very well. Encountering another species with similar ecological requirements in the Mediterranean, the Red Sea immigrant would certainly outcompete and eventually replace it. At least 30 species of fishes from the Red Sea are now established in the eastern Mediterranean. Twenty-one of these have become quite common, often at the expense of a native species; 16 appear regularly in commercial landings. As much as 21 percent of the Israeli trawl fishery, for example, is composed of such species. Red Sea species which figure in the Egyptian landings are the rabbitfishes (Siganidae), *Upeneus moluccensis* (Mullidae), a barracuda (Sphyraenidae), and the lizardfish, *Saurida undosquamis* (Synodontidae).

The introduction of a new species, particularly when it becomes abundant, is a major upheaval. Native species can be outcompeted for food, breeding areas, and specialized habitats (as in rock caves). If the new species is a predator, it can make serious inroads on a prey population.

The entire community structure, one which has taken many thousands of years to evolve, can be disrupted within the course of decades or less. Some native species go to extinction, and relative abundance can shift radically as some new community equilibrium is sought. And, of course, because the process is a biological one, once begun it can spread to involve vast areas. In the eastern Mediterranean, Red Sea fishes have been reported from Egypt, Israel, Lebanon, Turkey, Greece, Italy, Libya, and even Tunisia outside the eastern basin. Thus, the building of a shallow canal only 150 m wide in the very southeastern part of the Mediterranean has a continuing impact on the entire region, more than a million square kilometers.

The second major perturbation came with the building of the Aswan High Dam. Certainly, there have been very many benefits to Egypt from the dam, but the net result on the coastal sea has been generally deleterious. Before building the dam, the Nile produced a distinct anomaly in the otherwise unproductive Mediterranean. High nutrients (more than 0.060 mg/l phosphate) in the flood waters resulted in standing stocks of phytoplankton of 9,000 and even 10,000 cells/ml where they entered the sea.[36] These values were more than 100 times those recorded for offshore Egyptian waters outside the river's influence. A similar pattern existed in the zooplankton. Normally, in concentrations of about 1,000 individuals/m^3, concentrations of 50,000 to 80,000 individuals/m^3 occurred in the region of high production associated with the flood. Benthic biomass on the shelf off the Nile Delta was 20 gm/m^2, ten times the average for the Mediterranean. The Nile flood supplied as much as 7.5×10^{12} mg (or 7,500 metric tons) phosphate annually, making this area one of the most productive of all the warm waters of the world.[37] The resulting rich fisheries, particularly for sardines, which existed off the Nile Delta were very important for Egypt. With the cessation of flow in 1964, these fisheries rapidly declined, from as much as 20,000 metric tons/year of sardines to something around 600 metric tons/year. This was the most dramatic change, but most species of fishes were affected in some way.

Table 3-18 shows the relationship between fish catch, river flow, and fishing intensity expressed as the number of motorized boats fishing for the period of 1962 to 1970. These data suggest the strongest correlation of catch is with river flow, rather than effort, thus indicating the very major effect that the damming of the Nile has had on the marine environment.

The Institute of Oceanography and Fisheries at Alexandria has been an important agent in the scientific study of the local marine environment. There is, therefore, a good background of information from investigations conducted mostly during the 1960s and published in the Institute's bulletin. The majority of these papers concern themselves with fishes and fishing effort, particularly sardines,[41] grey and red mullets,[42] and groundfish;[43] but, there are also works dealing with the phytoplankton,[44] zooplankton,[45] and general oceanography.[46] The investigations usually took the form of oceanographic surveys with emphasis on the fish species present and their seasonal abundances. Two important areas which have not been examined are primary production and the nature of the benthos.

TABLE 3-18.

CATCHES OF COMMERCIAL FISHES ON THE MEDITERRANEAN COAST OF EGYPT IN COMPARISON WITH FISHING INTENSITY (THE NUMBER OF BOATS ENGAGED) AND NILE RIVER FLOW FOR THE PERIOD 1962 to 1970[35]

Year	Total Catch (tons)	Sardine Catch (tons)	Number of Motorized Boats	Nile Discharge (km^3)
1962	37,832	18,166	574	44.0
1963	32,909	12,981	562	43.6
1964	25,975	7,372	552	63.7
1965	24,686	7,635	548	35.9
1966	15,044	1,233	569	13.2
1967	12,212	812	546	21.5
1968	13,588	463	406	5.9
1969	8,521	600	-	3.6
1970	8,100	580	-	4.0

The usefulness of the considerable data assembled by these investigations is largely historical, for the Aswan High Dam has so changed the oceanographic regime that conditions of the 1960s no longer exist. The situation in the fisheries is obvious, and similar changes must be expected in all components of the ecosystem. They have not, however, been documented. The Soviet-Egyptian Expedition of 1970, the results of which were published in Volume 5 of the Bulletin of the Institute of Oceanography and Fisheries, had as its theme the study of post-Aswan conditions. The emphasis, however, was entirely on hydrography and fisheries; the main result was merely to provide details of the decline in fisheries noted above.

There are, therefore, no local data which describe quantitatively the current situation in the marine environment off Alexandria. Groups at the University of Alexandria, however, have recently undertaken biological work. Studies of the phyto- and zooplankton are intended to provide data comparable to that of the studies in the 1960s and follow the ear-

lier techniques. A fish market survey, including species and weights, was begun in August 1977 and will continue on a monthly basis. From a preliminary examination of the data already gathered, it is safe to assume that these studies, when finished, will provide details but no surprises. In the absence of the Nile flow, Egyptian marine waters are like those typical of the Mediterranean: low in nutrients and generally impoverished.

Because of its commercial importance, semiquantitative data on the fishery at Alexandria have been kept. As for Egypt as a whole, Alexandria depends for its fish supply on three sources - freshwater, the Mediterranean, and imports. The freshwater catch comes from Lake Maryut and Lake Idku; the Mediterranean catch is fished off the coasts in front of the city; and the imports, limited in amount, are mostly frozen hake landed directly from Soviet fishing vessels.

From an economic standpoint, the marine and freshwater catches are probably very roughly equal in value, the average price of marine fish being slightly higher than freshwater fish. Using the 1975 marine landings of 2,875 metric tons and an average price of 90 piastres/kg, these fish were worth L.E. 2.6 million. For freshwater, assuming a catch of 5,000 tons and a price of 80 piastres/kg, the value would be L.E. 4 million. The fishery's net value, then, may approach L.E. 7 million in all of Alexandria. While monetary terms provide one frame of reference for examining the value of the catch, a more proper one is merely the protein that it provides. This is, of course, a direct function of the actual weight, with no real difference between whether it comes from salt water or fresh.

The marine fishery at Alexandria is practiced offshore from small trawlers, seine boats and from small rowed boats fishing gillnets right off the beaches in only a few meters of water. The trawl fishing, on the bottom, is mostly at depths of 40 to 50 m. There is virtually no pelagic fishery. Two major areas are fished, that in front of the city with the fish landed at Alexandria and Abu Kir Bay with the landings at Abu Kir. There appear to be about 100 motorized boats in Alexandria and perhaps half to a third that number in Abu Kir. A few small trawlers and a larger number of rowed gillnetters operate out of Miami. The gillnets are generally set in the evening and hauled the next morning, the boat having spent the night anchored nearby.

Table 3-19 shows the depth distribution for the important groups taken by trawl off Alexandria in the early 1960s. Different fishes are characteristic of different depth zones, and the distributional picture does not seem to have changed much since that time. Flatfish (Soleidae) and shrimps (Penaeidae) are most important in shallow areas, less than 50 m deep. The deeper waters, 50 to 100 m, seem to be those where the greatest catches are taken; it is here where the Mullidae and Sparidae, the most important by weight of the fishes landed at Alexandria, occur in the greatest numbers. The experimental trawling data of Table 3-19 suggest

TABLE 3-19.

DISTRIBUTION BY DEPTH FOR TRAWL-CAUGHT GROUPS OFF ALEXANDRIA. ENTRIES ARE PERCENTAGE OF TOTAL WEIGHT: FAMILIES NOT INCLUDED AMOUNTED IN ALL TO LESS THAN 10 PERCENT[47]

	15 to 50 m (percentage)	50 to 100 m (percentage)	100 to 200 m (percentage)
Sharks and rays	9	11	4
Sciaenidae	3	1	2
Mullidae	11	14	19
Sparidae	1	17	-
Triglidae	4	4	5
Soleidae	9	5	-
Gadidae	-	9	22
Carangidae	-	8	11
Sphyraenidae	-	-	20
Penaeidae	34	5	-
Cephalopods	21	16	8
Mean kg/hour	38.5	41.3	49.0

that even larger stocks might exist in depths beyond 100 m, but the Soviet-Egyptian Expedition of 1970 found no important stocks in deep water.

There has been a change in the composition of the trawl catch at Alexandria over the years. For the groups where data are available, the shifts in percent composition in the 10 years from 1960 to 1970 are shown in Table 3-20. The marine Mullidae, Sparidae, and Triglidae have increased in relative importance. This could be related to the increased salinity which resulted from cessation of the Nile flow.[43] The inshore Soleidae and, in particular, the Penaeidae show declines. The Penaeidae spend a part of their lives in brackish Lake Idku; pollution from Tabia of the Maadia channel, the only inlet to that lake, could have adversely affected their numbers. The predatory sharks and rays and the Carangidae decline as well. The declining catch per unit effort and the overall decline in the entire marine catch ought to discourage the industry, but it does not seem to do so. Fishermen report that their numbers are now greater than 10 years ago and increasing, and at least half a dozen new trawlers were being built in January 1977.

The work of Hashem, of the Soviet-Egyptian Expedition, and of the market study currently in progress show that there is considerable change in the fishery over the course of the year. The winter is the poorest time to fish, both from the standpoint of weather and the generally low abundance of fishes; and the late summer is the best. Mullidae, Sparidae, and cuttlefish are relatively more abundant in colder periods; and Pomatomidae, Carangidae, Mugilidae, Sciaenidae, and Clupeidae predominate in summer. Serranidae are important at all times. Groups of increasing importance are Synodontidae and Leiograthide, both recent immigrants from the Red Sea.

Table 3-21, from the Soviet-Egyptian Expedition report, shows the catch rate and standing stocks of fishes by season for the four main fishing areas. Abu Kir includes the Alexandria region and is probably the area where the greatest pressure is exerted. Abu Kir has the lowest catch rates and the lowest standing stocks at all times. In autumn, when stocks are greatest, the biomass in the Abu Kir area is equivalent only to 0.8 gm/m^2, 10 percent of the level known for Georges Bank.

Marine populations near Alexandria are affected by the city in two ways, by fishing pressure and by pollution. Neither of these can be quantified with available data; and, in fact, their relative contributions to declining fisheries are difficult to separate. Overfishing must be considered a serious problem. The difference in catch rates shown in Table 3-20 illustrate this somewhat; but it is most evident on visiting the fish market, where the great majority of fish offered for sale are juveniles, captured before they have even had a chance to spawn. This problem was also noted by Russian experts connected with the Soviet-Egyptian Expedition. They observed particularly that the average size of sardines had decreased and that the larger species of shrimps had declined in abundance to almost insignificant levels. According to Russian fishery management practices, the maximum allowable catch for sustained yield must

TABLE 3-20.

CATCH COMPOSITION FOR GROUPS TRAWLED BETWEEN 10 AND 100 m OFF ALEXANDRIA IN DIFFERENT YEARS. ENTRIES ARE PERCENTAGE OF TOTAL WEIGHT[43]

	1960 to 1961 (percentage)	1969 to 1970 (percentage)
Sharks and rays	12	9
Mullidae	16	22
Sparidae	11	17
Triglidae	5	11
Soleidae	9	4
Gadidae	6	6
Carangidae	5	2
Penaeidae	25	8
Mean kg/hour	40.0	7.3

TABLE 3-21.

CALCULATIONS OF RELATIVE RESERVES OF BOTTOM FISH BY SEASONS AND REGIONS[35]

Region	Season	Fishing Area (km^2)	Depth (m)	Average Catch/ Trawling Operation (kg)	Standing Stock of Bottom Fish (tons)
Abu Kir	autumn	970	10 to 200	7.3	810
	winter			1.4	170
	spring			2.4	280
	summer			5.7	630
Rosetta	autumn	1,170	10 to 105	14.2	1,890
	winter			4.8	680
	spring			2.7	390
	summer			8.0	1,060
Borullos	autumn	1,120	10 to 100	8.1	1,580
	winter			4.7	980
	spring			2.6	530
	summer			6.2	1,220
Damietta	autumn	2,100	10 to 100	10.5	2,500
	winter			4.8	1,210
	spring			2.2	550
	summer			3.7	880

not exceed 30 percent of the total reserve. Using data for the Abu Kir area from Table 3-21, this rule suggests that the annual catch in 1971 should have been no more than about 600 metric tons. In fact, the total Alexandria catch for that year was recorded as 6,370 metric tons by the Institute for Oceanography and Fisheries. Even with the usual allowances for faulty data, these numbers strongly suggest that the offshore stocks are being severely overfished.

There is no evidence of pollution offshore, and the influence of pollution on the biota there must be restricted to species which during their life histories migrate inshore to polluted areas. Shrimp, grey mullets, and soles, all of which move into the shallow water of Abu Kir Bay, and even, in the case of the first two, into Lake Idku through the Maadia channel, may have been so influenced. All have registered declines, but data to firmly identify the cause are lacking. Certainly the discharge of industrial wastes from Tabia would be harmful, but so would overfishing.

Where domestic wastes enter the sea, as they do from almost every beach along the Alexandria waterfront, added nutrients can be considered beneficial. A simple calculation, assuming an annual discharge from Kait Bey, the largest point source, of $2.9 \times 10^7 m^3$ containing 11.25 mg phosphate/l, shows that the amount of this nutrient added would be about 10 percent of that provided by the Nile flood in the past. That the outfalls do enrich the area is shown by the concentrations of birds and, particularly, of fishermen around them. Whether the fish that live there are safe to eat is quite another question, but there are no data available to answer it.

3.C.3 Freshwater Ecology

3.C.3.a Ecological Description of Lake Maryut. In 1959 to 1960, a series of comprehensive studies of Lake Maryut was initiated by the staff of the Department of Oceanography, University of Alexandria, and the Institute of Oceanography and Fisheries, Alexandria. Emphasis was on the Main Basin and its connecting East Basin (which was larger than the Main Basin at the outset, but reduced to its current size by landfill soon after the studies began). The purpose of the studies was to provide baseline data against which future effects of pollution from the city of Alexandria could be evaluated. The studies included descriptions of the sediments,[48,49] physics and chemistry of the lake,[50] primary productivity,[51] zooplankton,[52] benthos,[53] and fishes.[54,55,56] The concern with biological productivity and the fishes in this work underscored the theme of the value of the fisheries to Alexandria. Several subsequent publications a decade later reflected the concern about the effects of the existing pollution of Lake Maryut on the fisheries.[57,58,59]

Lake Maryut (the Main Basin or "lake proper" and the East Basin-see Fig. 3-17) was described in the reports of the early 1960s as a shallow

body of water averaging about 1 m in depth. Its northeastern end already showed evidence of moderate to heavy pollution, presumably as a result of wastewater discharges to that part of the lake. The bottom in that area was soft, black, highly organic, smelled of H_2S, and contained few animals. In the southwestern half to three-quarters of the lake's area, the bottom was hard, bare, and consisted of a badly sorted complex type of sand-silt-clay, greyish to black grey in color with many empty shells and shell fragments of the bivalve, Cardium edule, gastropods, and the empty calcarious remains of the tube worm, Mercierella enigmatica. A third ecological habitat was an area heavily populated by the higher, rooted plant, Potamogeton sp., which occurred in the southeastern portion of the so-called "East Basin." This area was reclaimed for agriculture beginning in April 1962 and will therefore not be further discussed here.

Because of its shallow depth, the lake is nearly always well mixed vertically and seldom develops any vertical stratification. Temperatures on the average range from 12°C in winter to 29°C in summer. Salinities are lowest (average - 3.6°/oo) in the rainy season of August-December and highest (average - 13.0°/oo) in the dry season of spring and early summer, because of evaporation and the introduction of Mediterranean water from the Mex Station and/or the Noubaria Canal locks. The lake may therefore be considered brackish even though it has no permanent connection to the sea.

As would be expected, DO was found to be lowest in the polluted northeastern section of the lake, which became anoxic in midsummer with observations of floating dead fish reported. The unpolluted end of the lake, on the other hand, maintained oxygen concentrations from 3.7 mg/l in midsummer to 9.3 mg/l in late winter.

Distribution of the major nutrients, nitrogen and phosphorus, was relatively uniform throughout the lake, and their concentrations were not particularly high, ranging from undetectable levels in summer to maxima of 0.3 mg/l N and 0.1 mg/l P in winter. Presumably the high levels of primary productivity by both unicellular algae (phytoplankton) and the higher rooted plants utilize these nutrients as rapidly as they become available. It should be pointed out, however, that neither ammonia, the prevalent form of nitrogen in untreated domestic wastewater, nor the dissolved organic forms of nitrogen and phosphorus were measured.

The phytoplankton was represented by an abundant, diverse community including 35 species of bluegreen algae, 20 species of green algae, 33 species of diatoms, and four species of euglenoids. The bluegreens, mostly filimentous forms many of which formed floating mats at the water surface, were most abundant in summer. The green algae were most numerous in winter, while the diatoms flowered twice a year in spring and late fall.

In addition to the submerged, rooted macrophyte, Potamogeton pectinatus, which was most prevalent in the now extinct part of the lake, as discussed above, other higher plants mentioned were the reed grass (Phragmites

communis), most abundant in the northern part of the lake near Mex, and the cattail (Typus latifola) and water hyacinth (Eichhornia crassipes) which were largely confined to the Umoum Drain and its immediate vicinity. The low salinity tolerance of the latter two species presumably prevents their wider distribution in the lake.

Values for primary organic production (photosynthetic carbon fixation) ranged from 2.18 grams carbon/m^2 day in winter to 10.75 gC/m^2/day in the summer in the polluted, northeastern end of the lake and 0.38-10.51 gC/m^2/day for the same periods in the unpolluted "bare" area of the lake. Mean annual production for the entire lake (Main Basin) was approximately 6 gC/m^2/day, or roughly 12 g dry weight of organic matter/m^2/day. This yield is equivalent to an organic production of 44 metric tons/ha/year, or roughly 83,000 tons per year for the entire Main Basin of Lake Maryut. Judging by this standard alone, Lake Maryut must be considered a highly productive, heavily eutrophied lake. Compared with its mean annual production of 6 gC/m^2/day, the mean productivity of Lake Idku was found to be 0.6 gC/m^2/day and of the Nouzha Hydrodrome (see Fig. 3-12), 0.3 gC/m^2/day.

The bottom fauna of Lake Maryut in 1960 consisted of a euryhaline, brackish-water fauna. Other than a few ostracods (crustacea) and nematode worms, the anoxic black sediments in the polluted, northeastern end of the lake were devoid of animals. In the so-called "bare area" in the northeastern two-thirds or more of the lake, the benthic biota was characterized by an extremely abundant community of a very few species. The most important of these, in numbers and biomass, was the polychaete worm, Nereis diversicolor (49 percent of total biomass); followed by the snail, Melania tuberculata (34 percent); two species of amphipod crustacea, Corophium sp. (11 percent) and Gammarus sp. (3.4 percent); and chironomid (fly) larvae (1.2 percent). Two additional bottom organisms, which were rarer and unevenly distributed on hard bottom or on the stems of the reed grass, Phragmites, were the barnacle, Balanus improvisus, and the tube worm, Mercierella enigmatica.

In the area where these benthic organisms occurred ("the bare area"), they were present at the exceptionally high mean density of 76.5 g/m^2. In contrast, the benthic biomass of another Egyptian Delta Lake, Lake Borullus, was reported by the same investigator (A.A. Samaan) as 19 g/m^2, while that of the Nouzha Hydrodrome was reported as 6.3 g/m^2 (unpublished data, Hydrobiological Institute, Alexandria).

The zooplankton of Lake Maryut, studied during the period 1960 to 1962, was a curious mixture of freshwater holoplankton (permanent members of the plankton), present throughout the year, and marine meroplankton (larvae of benthic animals) that appeared sporadically during the animals' breeding seasons. The latter, when present, far outnumbered the former. The most abundant meroplankton were barnacle (Balanus improvisus) nauplii (a maximum of 46,000/m^3) and larvae of the small shrimp, Leander spp., with smaller numbers of polychaete (worm) and gastropod (snail) larvae. The most abundant member of the permanent holoplankton was the rotifer, Brachyonus sp., followed in importance by copepods (five species of the freshwater genus, Cyclops) and the cladoceran, Moina dubia.

Like other components of the Lake Maryut fauna, the community of fin fishes was characterized by large numbers of a very few species. Of these, three species of the ubiquitous and hardy genus, Tilapia, are by far the most important, together comprising over 90 percent of the fish population and also the commercial fishery. These are T. zillii, T. nilotica, and T. galilaea. All three species are reportedly either omnivorous, feeding either on plankton or vegetative material, or strictly herbivorus. T. zilli and T. nilotica are both used for aquatic weed control.[60] Although all three species are freshwater fishes in the normal sense of the term, all can tolerate rather high salinities, one of the facts which accounts for their presence in the brackish waters of Lake Maryut.

In addition to Tilapia, small numbers of eel (Anguilla anguilla), mullet (Mugil spp.), and catfishes (Bajrus, Clarias, and Synodontus spp.) occur in the lake. These latter fishes have declined in numbers during recent years, while Tilapia have increased their dominance.

The more recent publications by M.A.H. Saad on the pollution of Lake Maryut, written in the early 1970s, have stressed the impact that wastewater discharges at the northeastern end of the lake have had on the sediments, DO, BOD, and commercial fish catches. However, it is difficult from these reports to document changes which have occurred since the studies a decade earlier. It is claimed that the bottom "is now covered with sludge due to the deposition of decaying organic wastes. Near the wastewater discharges outfalls sludge deposition increases markedly in depth reaching the water surface. The sludge creeps away from this area of deposition to cover most of the lake bottom."[57]

However, there are no data to substantiate these statements or to show how the situation has changed with time. Anoxic conditions appear to occur over a larger area and perhaps for a longer period during the summer than was reported earlier.[50,58] Higher values of DO (10 to 15 mg/l) were found in different parts of the lake by the later report than had been shown in the earlier report, presumably because of greater photosynthetic activity of the phytoplankton and other plants.

Also emphasized in a comparison of the same reports is the decrease in total fish production from Lake Maryut from 10 x 10^6 kg in 1961 to 1.5 x 10^6 kg in 1969, also attributed to pollution but again with no evidence for a cause-and-effect relationship. In the meantime, however, the fishery appears to have recovered from its 1961 depression, and the yields for 1974 and 1975 exceeded that for 1969 by a factor of about 1.7. One difficulty in interpreting these fishery statistics, however, is that they do not show which of the basins of Lake Maryut the fish were taken from. One verbal report (Dr. A. Ezzat, University of Alexandria) indicated that 80 percent of the current catch is now taken from the Southeast Basin and only 20 percent from the Main Basin. A group of fishermen further stated that most of the fishing activity in the Main Basin now actually takes place in the Noubaria Canal or the Umoum Drain. There is, however, no comparable information available for the earlier periods pertaining to the exact locations of the fish catches.

The most recent water quality study of Lake Maryut has been carried out by Dr. F. Sharkawi of the University of Alexandria High Institute of Public Health. Measurements have been made at monthly intervals during 1975 to 1976 over a grid of 17 stations in the Main Basin and the East Basin of Lake Maryut. Samples were also taken from the Kalaa Drain and the Noubaria Canal.

Figs. 3-18 through 3-26 show the distribution of water quality parameters as presented by Dr. Sharkawi. Highest values of phosphate, ammonia-nitrogen, BOD, and sulfide and the lowest values of DO, all the parameters associated with organic pollution, are clearly highest in the northeast sector of the lake, near the wastewater discharges. These become less extreme as the water moves slowly towards the western end of the lake and the Mex Pump Station. Salinity, on the other hand, is highest in the Noubaria Canal, one of the obvious sources of saltwater to the lake.

One of the more striking differences between the tabulated 1974 to 1975 data of Dr. Sharkawi[61] and the earlier study by Aleem and Samaan[50] in 1960 is the reduction in salinity from a maximum of over 13 ^{o}/oo in 1960 to a maximum of 3 ^{o}/oo and a mean of 2 ^{o}/oo in 1975-1976. This reduction may have adversely affected some of the brackish water fauna, particularly the benthos and their plankton larvae. According to Dr. A. Ezzat (personal communication), benthic organisms have now virtually disappeared from the Main Basin of the lake.

Phosphate-phosphorus concentrations now average almost 0.4 (range 0.1 to 0.6) mg/l, four times the 1960 level. (Ammonia-nitrogen was measured by Sharkawi while nitrate was reported in the earlier survey; so no comparison of that nutrient is possible.) DO appears to have been lower or absent over a greater area in 1975 to 1976 than in 1960, the mean concentration at all stations in 1975 and 1976 being 1.27 and 1.80 mg/l, respectively. In 1960, low levels, or anoxic water, were found only at one location at the northeastern corner of the Main Basin.

Visual pollution is readily apparent around the lake proper. Particularly notable are black water discharges from the Kalaa Drain as well as water discoloration and floating organic materials along the north shore. There are strong odors around much of the perimeter of the lake proper; the Kalaa and North Shore discharges are easily recognized by their distinctive aromas.

This limited evidence suggests that pollution of the lake has become somewhat more intense and more widespread over the past 10 to 15 years. The effects of such an increase in pollution are less clear. There is no evidence that the depth of the lake has decreased in the past decade. Fish production may have been affected; but, if so, it is not clear in which direction. Verbal reports are that the benthos has virtually disappeared (see above) and that the primary production has decreased to one-third its former level (A.A. Samaan, personal communication); but these reports are not documented and, if true, could be caused by other factors (i.e., reduced salinity).

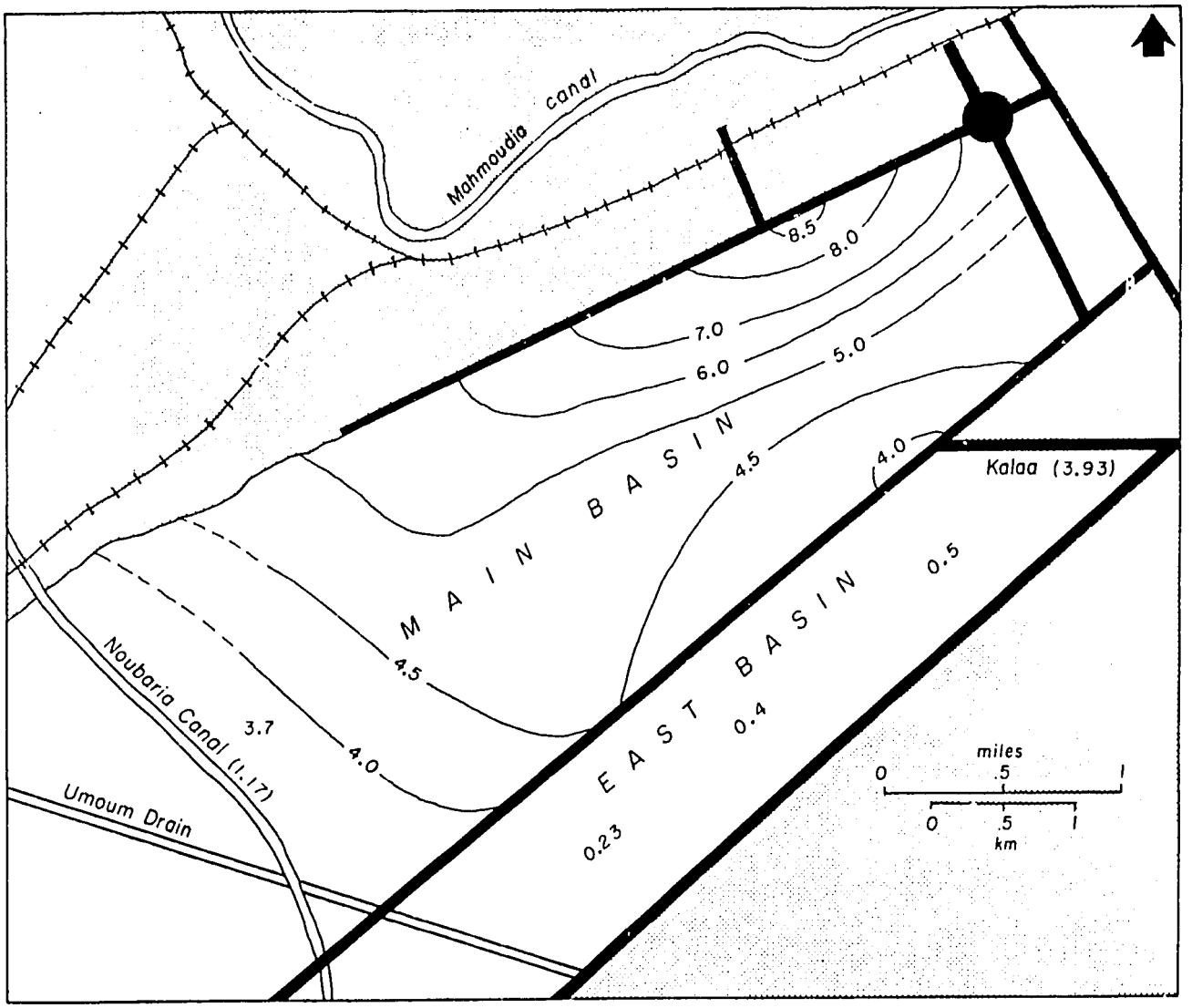


Fig.3-18 Dissolved phosphates (ppm PO_4): August, 1975 - July, 1976

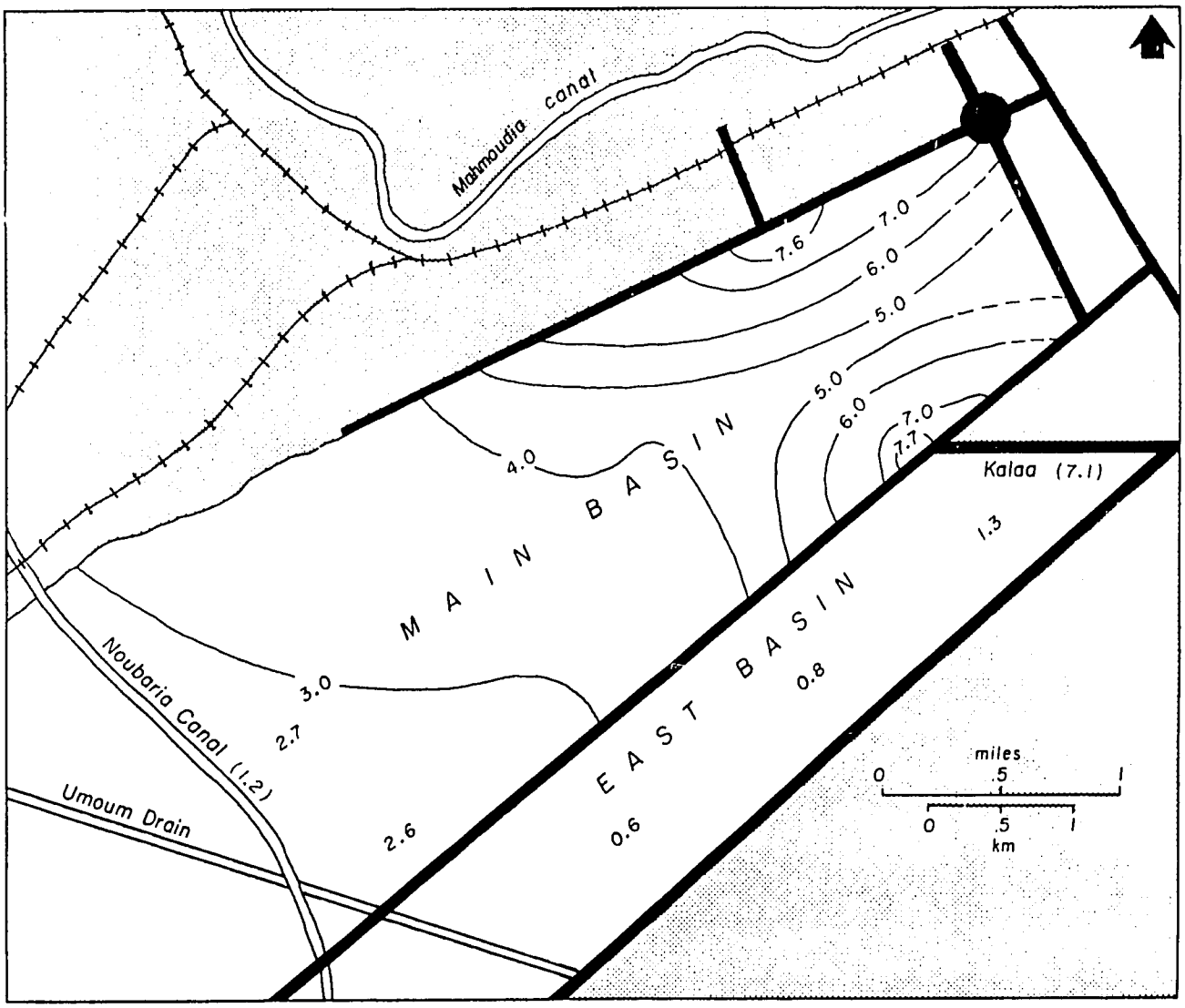


Fig.3-19 Mean ammonium - nitrogen (ppm). August, 1975 - July, 1976

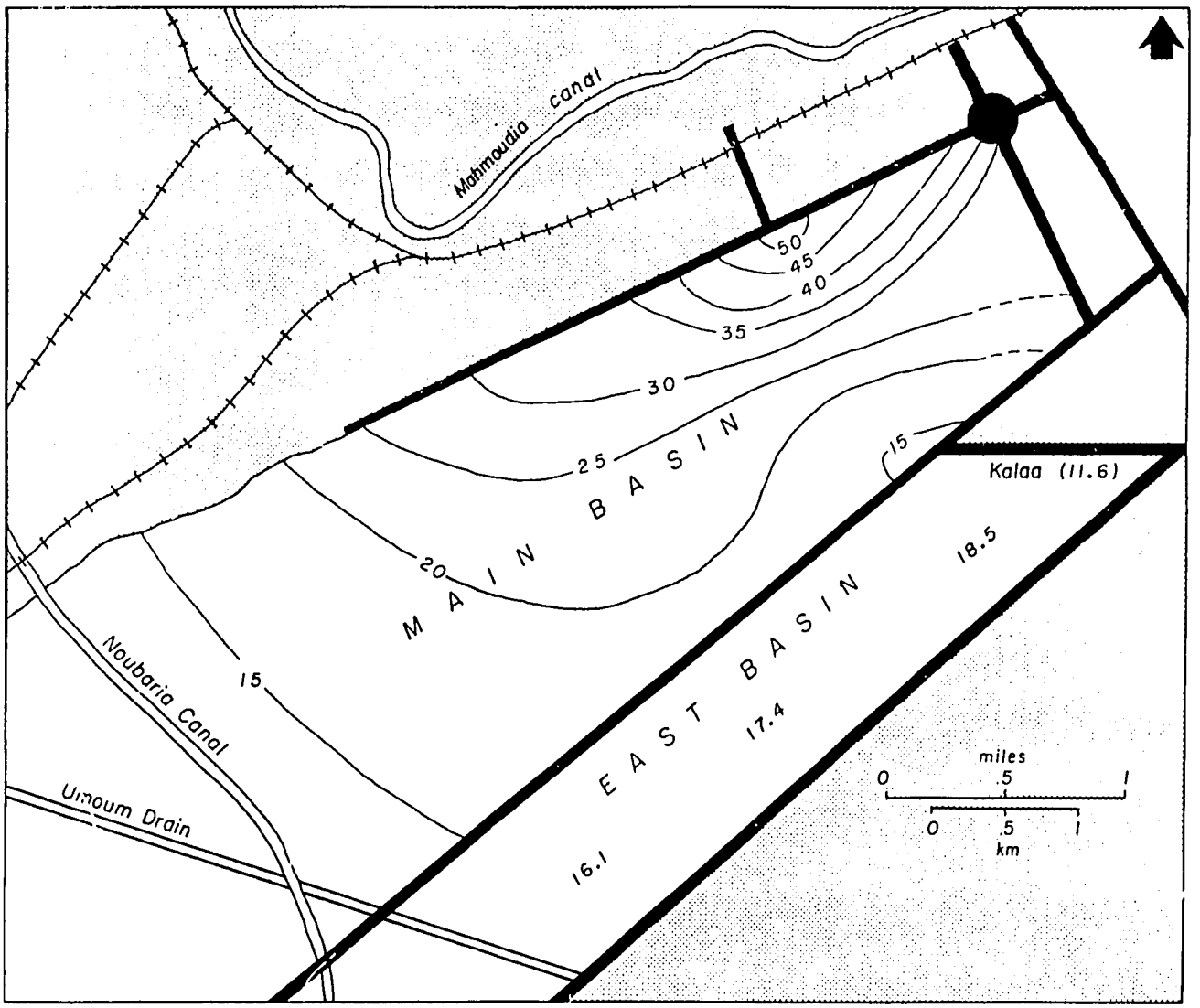


Fig.3-20 Mean BOD_5 (ppm): August, 1975 - July, 1976

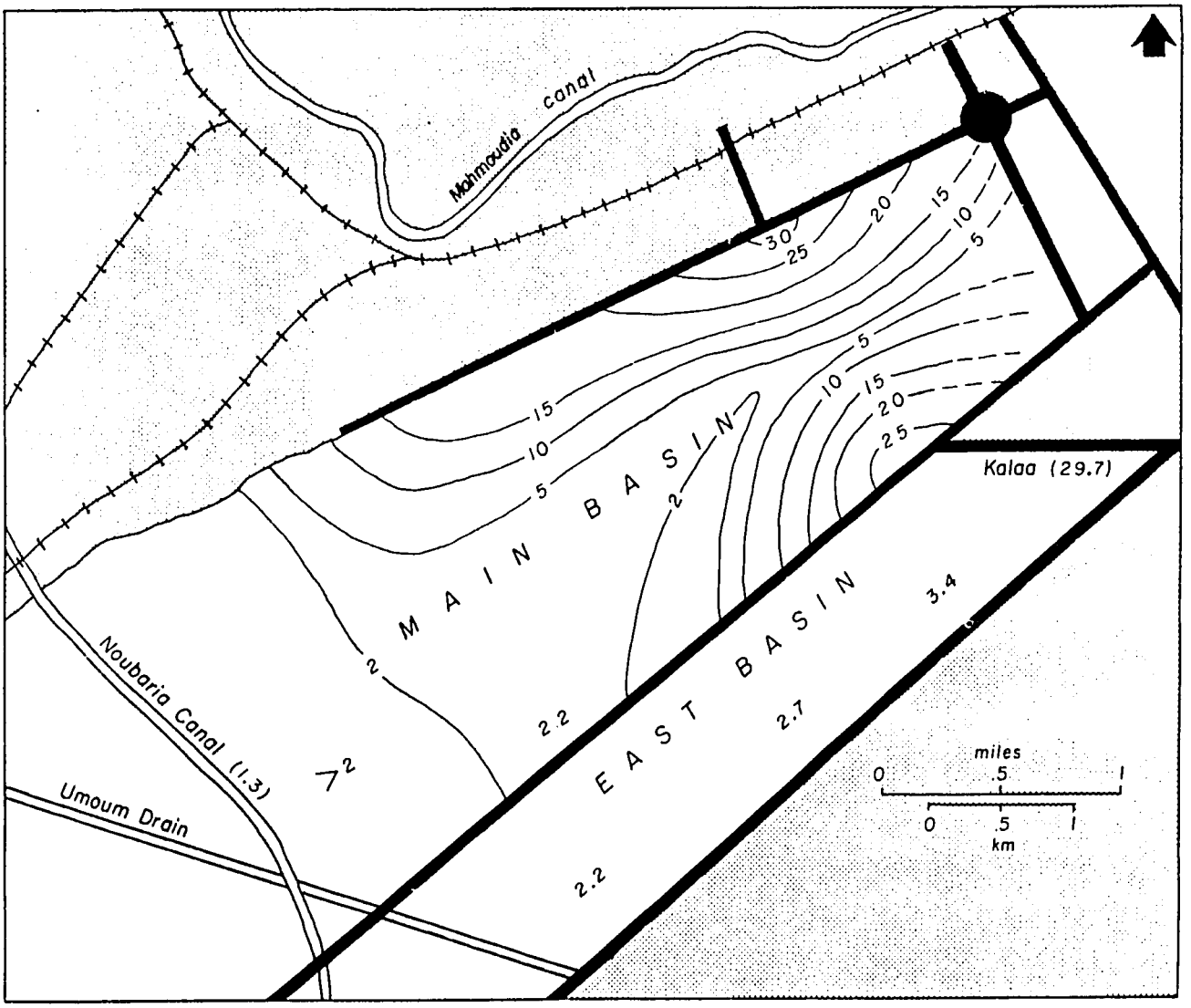


Fig.3-21 Mean dissolved sulfide (ppm). August, 1975 - July, 1976

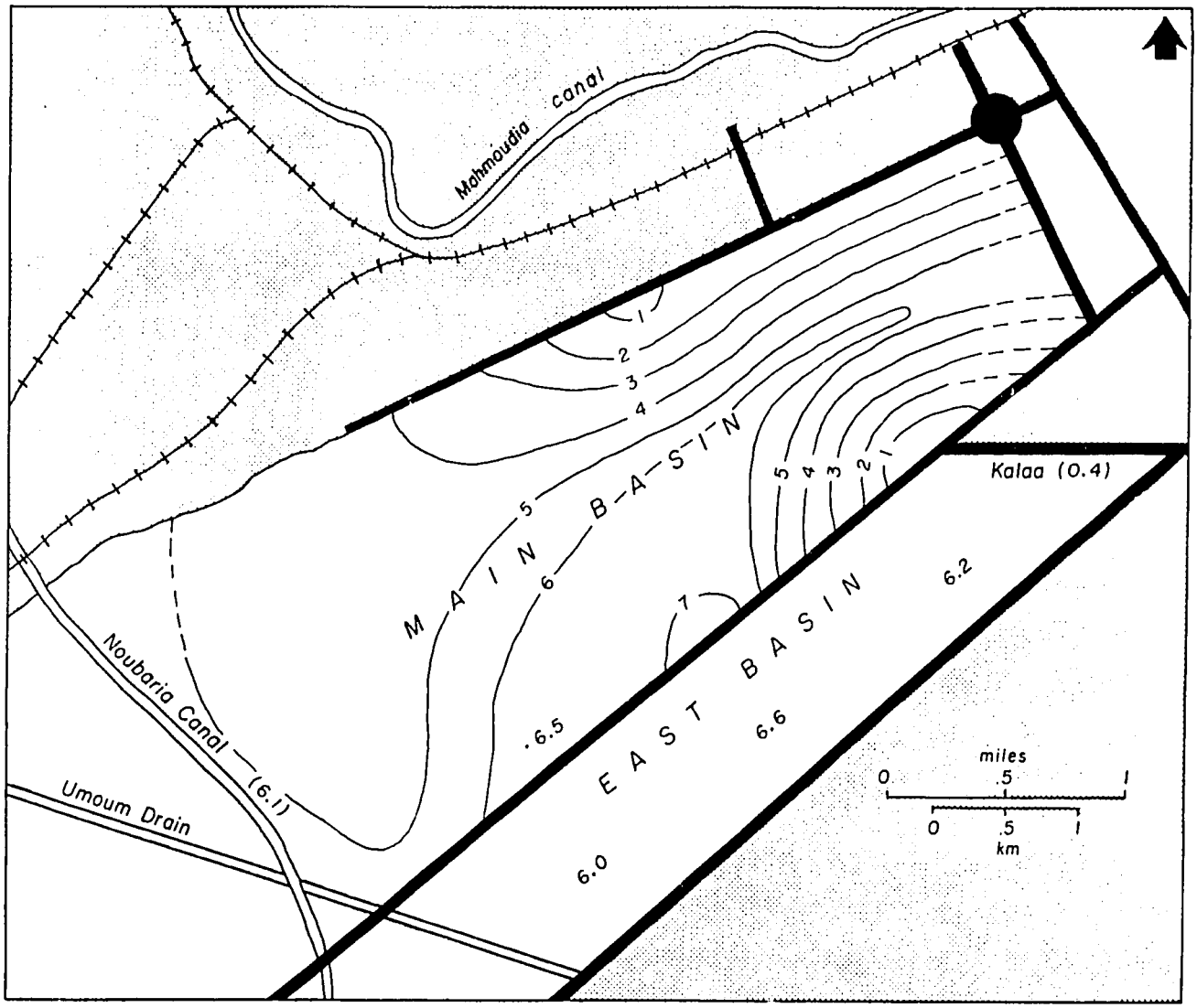


Fig.3-22 Mean dissolved oxygen (ppm): August, 1975 - July, 1976

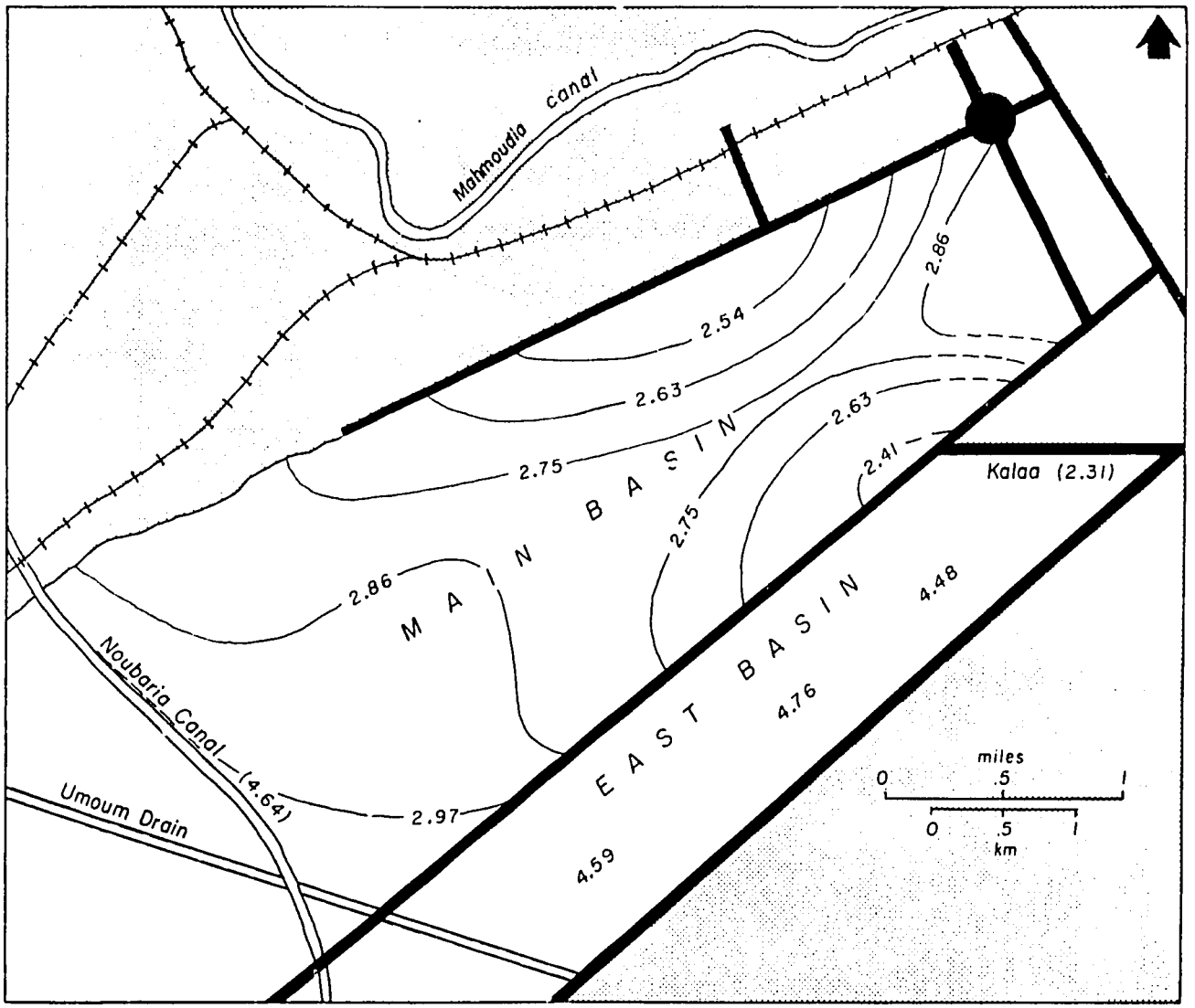


Fig.3-23 Mean salinity (‰) : August, 1975 - July, 1976

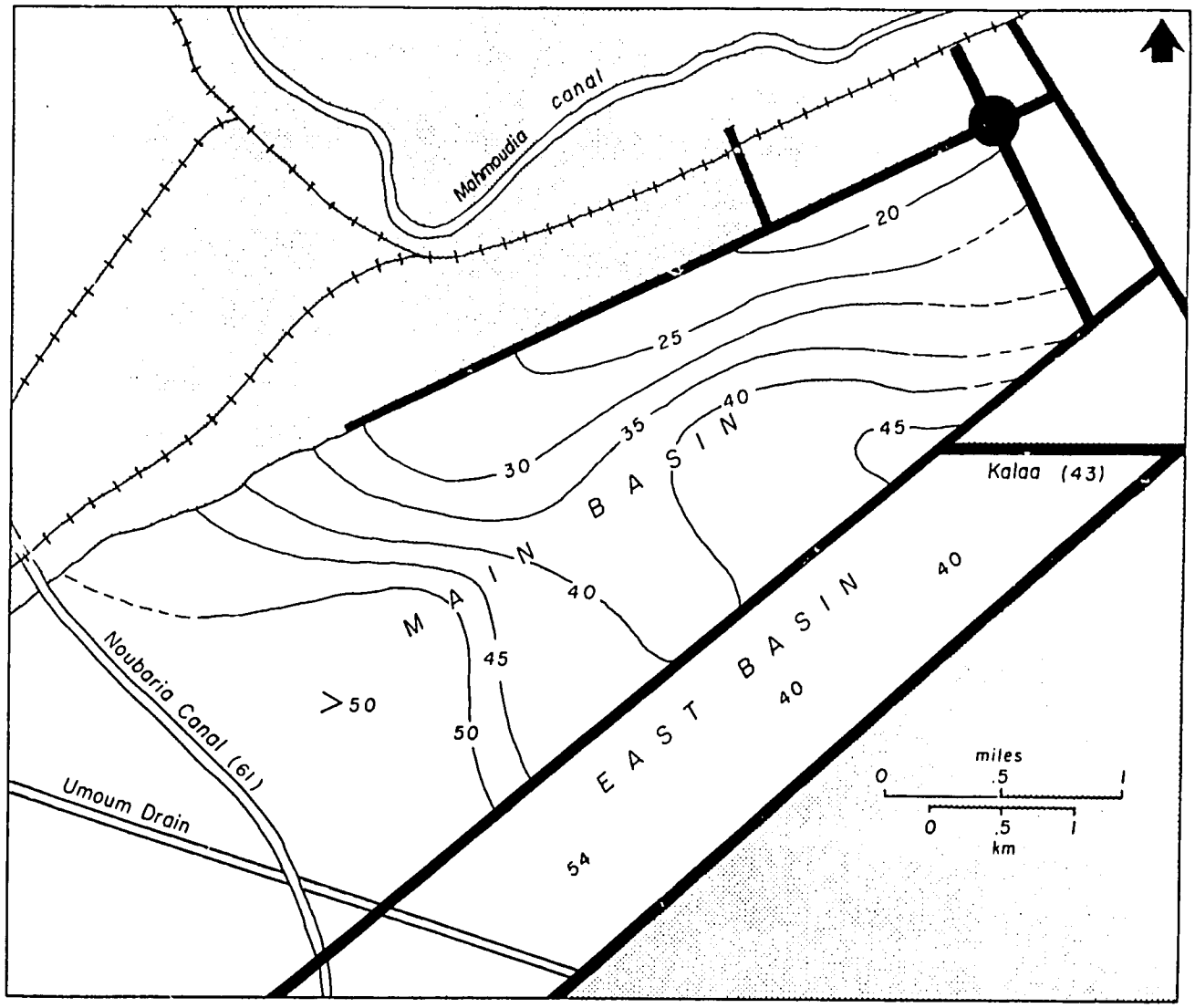


Fig. 3-24 Secchi disc readings (cm). August, 1975 - July, 1976

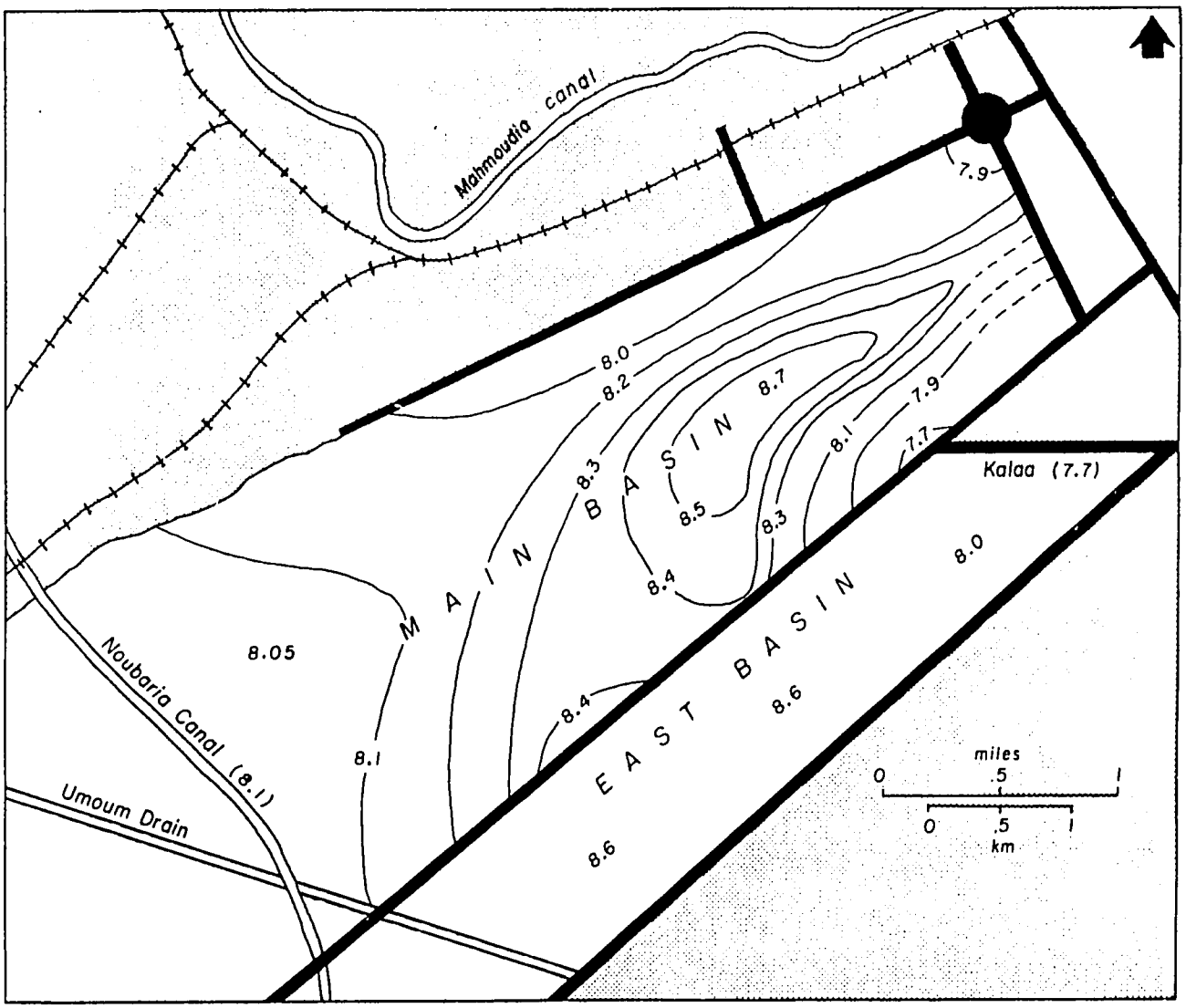


Fig.3-25 Mean pH . August, 1975 - July, 1976

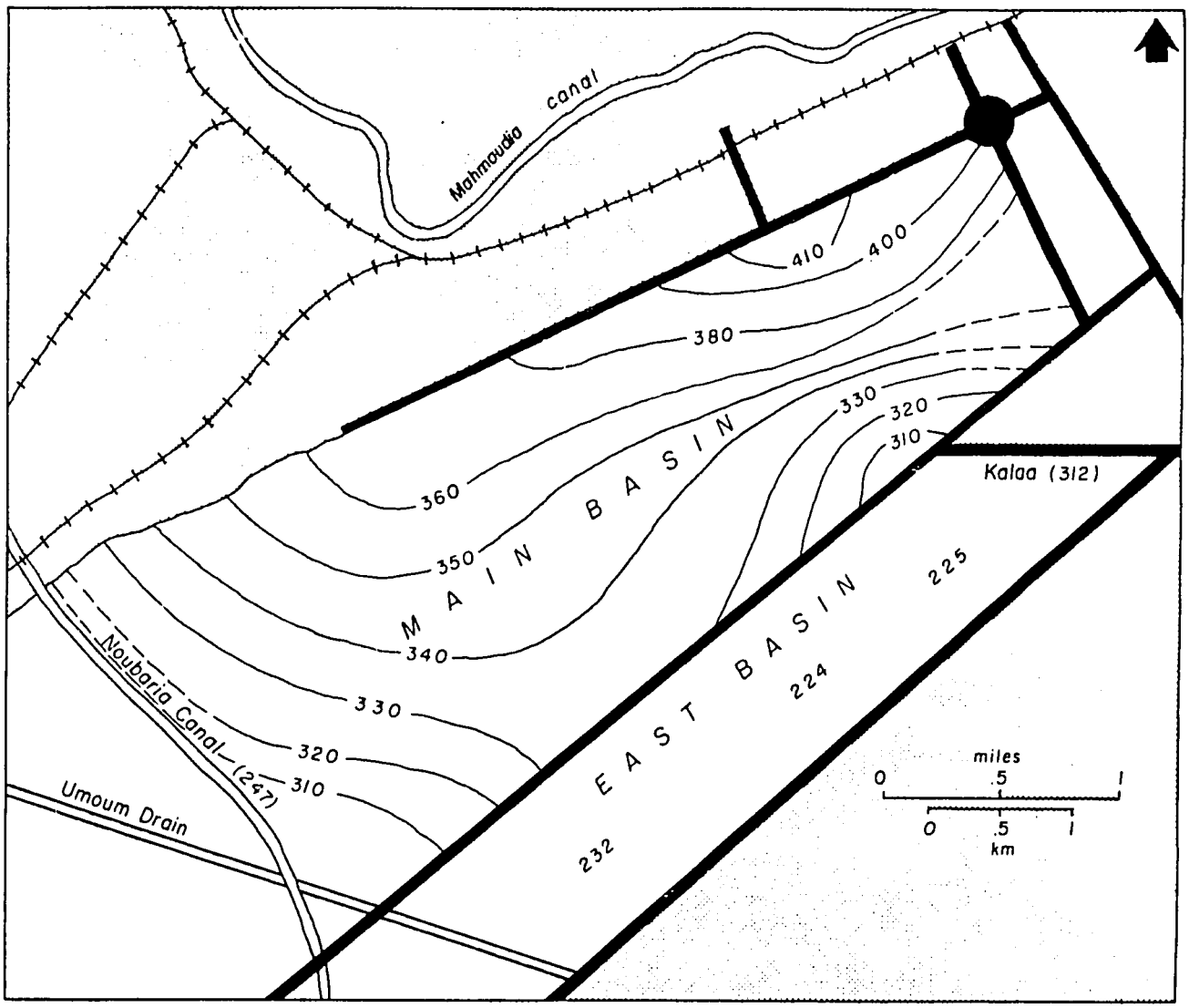


Fig.3-26 Total alkalinity (ppm $CaCO_3$): August, 1975 - July, 1976

There is no question that the Main Basin of Lake Maryut is an extremely fertile, highly productive body of water, one whose eutrophication has probably reached and exceeded its usefulness to man. The rate of change of the basin and its projected life in its current form are questions much more difficult to assess.

A collection of fish was obtained from the Lake Maryut commercial fishery on 5 December 1977. This included samples of Tilapia nilotica and T. galilaea and one specimen of the catfish Clarias sp. from the eastern, heavily polluted part of the lake (near the Gabbary Drain) and the same two species of Tilapia and a single mullet (Mugil sp.) from the western, relatively unpolluted part of the lake. The specimens were preserved in 90 percent ethyl alcohol and subsequently analyzed for heavy metals and organic trace contaminants. Analyses of heavy metals were made for both muscle and liver tissue, but there was sufficient material for only muscle tissue analyses for the organic compounds.

Samples for heavy metal analyses were dried to constant weight at 150°C, ashed at 550 C, and digested with nitric acid. Analyses were done by flame atomic absorption with dual channel background correction. Very low (trace) quantities were determined using a graphite tube atomizer with deuteruim arc background correction and method of additions. Mercury was determined using cold vapor atomic absorption.

Samples for organic trace contaminants were extracted and analyzed by gas-liquid chromatography using American Association of Analytical Chemists (AOAC) methodology.

The results which represent single analyses of only one specimen in each category are shown in Table 3-22, which also shows metal analyses for 13 species of fish taken from the Mediterranean Sea off Israel[62] and for 28 species of fish from the western North Atlantic Ocean.[63] No detectable concentrations of pesticides (eight compounds) were found. Very low concentrations (ca. 1 ppm) of dibutyl phthalate, a plasticizer used in the solvent industry, were found; but these were not significantly higher in the fish from the heavily polluted area than in those from the unpolluted end of the lake. They are not high enough in any case to be hazardous for human consumption.

Assuming fish from the Mediterranean and Atlantic contain "baseline" concentrations of heavy metals, the muscle tissue and, for the most part, the livers of the Lake Maryut fish do not contain unnatural metal levels. Only the catfish (Clarias) from the east end of the lake, containing 87.90 ppm of lead in its liver, significantly exceeded comparable baseline data. All the other analyses gave concentrations which fell within or at least were very close to the upper limit of the range of values in the baseline data. Most of the data for muscle tissue from Lake Maryut were close to the baseline means and, in several cases, the Lake Maryut fish were lower than baseline means.

TABLE 3-22.

CONCENTRATIONS OF TRACE CONTAMINANTS IN FISHES FROM LAKE MARYUT (eastern, polluted end and western, unpolluted end), THE MEDITERRANEAN SEA OFF ISRAEL, AND THE WESTERN NORTH ATLANTIC (metals, ppm, dry weight; organics, ppm wet weight)

	Cd	Co	Cr	Cu	Fe	Hg	Ni	Pb	Zn	Pesticides[1]	Plastics[2]
L. Maryut (east end)											
Tilapia nilotica											
muscle	0.07	0.02	1.75	9.55	38.80	0.01	1.40	0.29	48.60	<0.01	1.10
liver	0.36	0.02	12.40	23.80	314.00	<0.01	1.20	2.10	107.00	-	-
Tilapia galilaea											
muscle	0.25	0.07	1.24	9.50	29.80	0.01	0.45	0.12	52.10	<0.01	1.63
liver	0.64	0.50	9.02	26.60	356.00	0.02	1.00	1.15	180.00	-	-
Clarias sp.											
muscle	0.04	0.07	1.83	4.44	21.70	0.02	0.21	<0.05	25.00	<0.01	1.42
liver	4.57	2.10	25.90	47.40	7,328.00	0.02	5.20	87.9	216.0	-	-
L. Maryut (west end)											
Tilapia nilotica											
muscle	0.04	0.03	1.50	6.57	39.40	0.05	0.14	<0.05	34.70	<0.01	1.02
liver	0.21	3.30	14.60	27.3	10,070.00	0.33	11.00	1.76	157.00	-	-
Tilapai galilaea											
muscle	0.14	0.01	1.42	9.42	16.50	0.03	0.09	0.35	40.40	<0.01	0.78
liver	0.46	0.80	23.7	33.50	982.00	0.04	<0.01	5.71	268.00	-	-
Mugil sp.											
muscle	0.08	0.05	3.49	6.45	58.60	0.04	<0.01	0.21	34.10	<0.01	-
liver	0.07	0.10	3.69	4.93	419.00	0.14	0.37	0.42	169.00	-	-
Mediterranean											
muscle											
mean	0.30		2.10	4.4			1.80	1.80	27.2	-	-
range	0.10-0.70		0.60-4.10	0.90-23.5			<0.1-10.8	0.04-5.3	0.5-84.3	-	-
number	33		31	33			32	33	32	-	-
Atlantic											
muscle											
mean	0.40			5.40		1.30		2.50	41.50	-	-
range	0.10-1.60			<0.30-23.00		0.09-8.10		<0.50-8.60	7.00-397.00	-	-
number	0.26			26		24		25	26	-	-
Liver											
mean	2.00			14.10		2.00		2.10	113.00	-	-
range	0.30-3.20			3.30-35.00		0.40-4.40		1.50-2.80	30.00-210.00	-	-
number	3			3		3		2	3	-	-

[1] Pesticides include DDT, dieldren, toxophone, malathion, parathion, guthion, diazinon, and methyl parathion.

[2] Dibutyl phthalate.

3.C.3.b Ecological Description of Lake Idku. The eastern half to two-thirds of Lake Idku is covered by a dense population of rooted macrophytes, mainly Potamogeton pectinatus and, to a lesser extent, Ceratophyllum demersum; and the shoreline supports a thick fringe of the reed grass, Phragmites communis, which appears to be extending out into the lake. In the extensive Phragmites areas, water depth is no more than a few centimeters As a result, it is difficult to determine the exact boundaries of the lake.

Concentrations of inorganic nitrogen ($NO_2^- + NO_3^-$) and phosphate range from undetectable levels in spring and summer to maxima of 0.14 and 0.16 mg/l, respectively, in winter. These extremely low values probably result from nutrient assimilation by the extensive populations of macrophytes as the water passes through them.

Mean value for primary organic production of the phytoplankton is 0.6 g carbon/m^2/day, with values in the bare western end of the lake about twice those in the Potamogeton area. Estimated mean production of the hydrophytes is 1.3 $gC/m^2/day$, or twice that of the phytoplankton.[64]

The bottom of Lake Idku consists of hard sand mixed with plant detritus near the inlet, a grey mixture of sand-silt-clay with many fragments of broken shell further inside the lake in the bare, western area. The bottom fauna were surveyed in 1958 and again in 1969.[65,66] No significant differences were seen between the two studies except that a large bed of water hyacinth, present in the eastern end of the lake in 1958, has been destroyed in the intervening years and the bottom fauna in that formerly shaded area had changed from one dominated by chironomid (fly) larvae to a diverse population of molluscs and amphipods (Nassarius, Balanus, Planorbis, Corophium). In the bare area of the lake, the benthos consisted of amphipods (Gammarus, Corophum), polychaetes (Nereis diversicolor), molluscs (Corbidula), oligochaetes, and mysids in that order of abundance. In the plant area, the dominant benthic organisms were chironomid (fly) larvae, with smaller numbers of amphipods.

The fish fauna of Lake Idku are essentially the same as that of Lake Maryut, being strongly dominated by the same three species of Tilapia (T. nilotica, T.zillii, and T. galilaea) with smaller numbers of mullet (Mugil spp.), eels (Anguilla anguilla), and catfishes (Clarias sp.). Tilapia spp. make up 80 to 90 percent of the commercial fish landings.[67] Unlike Lake Maryut, which has no permanent connection to the sea, the Bouqaz inlet to Lake Idku provides ready passage for the anadromous and catadromous species (mullet, eel). Accordingly, these species are somewhat more important in the commercial fish catch of Lake Idku, but their numbers are still dwarfed by those of Tilapia.

There is also a valuable fishery for penaeid shrimp in Abu Kir Bay and the nearby coastal waters which depends upon Lake Idku for its existence. Penaeids migrate into brackish water as post-larvae, growing to maturity in such areas, and Idku is the only such habitat open to the sea in the area. However, commercial landings of these shrimp, predomi-

nantly Penaeus perathurus, have been sharply reduced in recent years, because of constriction of the inlet, formerly 15 x 5 m in cross section but reportedly much more shallow now because of siltation. Another possible cause of the reduced production of shrimp may be water pollution resulting from the industrial wastewater discharge from Tabia Pump Station, a few kilometers west of the inlet. Effluent from this station flows eastward along the coast and across the inlet, where it may become entrained with the tidal exchange of the lake.

Lake Idku was reported in 1970 to sustain an annual production of 587 kg of commercial fish landings per hectare of lake area.[67] This is roughly half the reported rate of production of Lake Maryut (1,092 kg/ha/year). However, it is not specified in that publication for what year or years those statistics apply or for what part or parts of Lake Maryut they apply. Total landings for Lake Idku apparently varied by almost tenfold from 1970 to 1975.

Using the figure 12,600 ha, given above, for the area of Lake Idku and the yield of 587 kg/ha, total landings for Lake Idku for whatever period they represent amount to 7.6×10^6 kg per year. This is intermediate between the minimum of 2×10^6 kg in 1970 and the maximum of 17×10^6 kg in 1974 to 1975 reported for Lake Maryut. According to Dr. A. Ezzat (personal communication), more fish are being landed from Lake Idku than from Lake Maryut; but reliable statistics for the former are not available. Those shown in this report for Lake Maryut are at best questionable.

3.C.4 Special Status Species

Neither the Egyptian Government nor the Alexandria Governorate list any species in the project area as having any special status.

The Fish and Wildlife Service of the U.S. Department of the Interior does not include any species likely to be found in the project area on its worldwide list of endangered and threatened wildlife and plants. The only species listed as occurring in Egypt is the slender-horned gazelle (Gazella leptoceros). It is unlikely that this desert-dwelling animal occurs in the project vicinity.

3.D Human Elements

3.D.1 Population and Housing

The governorate of Alexandria, the study area, is spread out along 60 km of Mediterranean coast over an area of 658.3 sq km. Most of the population is located in the urban area along the coast. Because of this concentration, population density figures can be misleading. The overall net density of the governorate (exclusive of warehouse and industrial space, central business districts, cemeteries, parks, and large institutional areas) is about 2,780.1 persons per sq km. The density of the urban area, about 105 km, however, ranges from over 260,000 to just under 20,000 persons per sq km.[68] The large difference in densities arises because the governorate contains up to 46 percent desert and 28 percent agricultural land.

Alexandria currently has about 2.3 million inhabitants. The annual population growth rate has declined from 2.9 percent 10 years ago to about 2.7 percent in mid-1976 (see Table 3-23). It is assumed, however, that the density of many parts of the city will continue to increase. The lower income groups who have large families and fewer resources for renting apartments are forced to live in more densely populated neighborhoods. Limited capital for new construction and laws prohibiting eviction of tenants, as well as a lack of available housing to relocate current tenants, discourage the public or private redevelopment of older, densely populated areas. The areas which have been redeveloped by the public housing authority have relatively predictable densities; current design standards restrict public housing to no more than five floors in height. Higher buildings, creating greater densities, would be less suited to families having large numbers of children requiring easy access to streets and open areas.

Wealthier people who are able to afford more space live in less densely populated neighborhoods, although new construction of high-rise buildings is tending to increase the density of middle and upper income areas as well. For an additional description of housing characteristics, see Special Report No. 3.[68]

Because of the large influx of summer-time residents and holiday visitors to Alexandria, the number of additional inhabitants (seasonal residents) on an average day during the peak summer months of July and August increases by approximately 350,000.[68] The effect on water demand and wastewater generation is equivalent to adding 15 percent to the city's permanent population. Table 3-24 shows the permanent and seasonal population by neighborhood areas called Kisms. By the year 2000, on an average day, the additional population can be expected to reach 595,000. The expected increase in summer population is in part associated with the future tourist development west of Agamy which has been designated for permanent and seasonal residential development (see Technical Appendix No. 2).

TABLE 3-23.

POPULATION OF ALEXANDRIA
1960 - 2000

Year	Population (1000s)	Growth Rate (percentage)*
1960	1,516.234	2.88
1970	2,014.539	2.77
1980	2,648.000	2.95
1990	3,540.000	2.79
2000	4,663.000	-

*Compound annual rate.

Source: Special Report No. 3.[68]

Note: CAPMAS preliminary 1976 census shows the population of Alexandria to be 2,318.655 thousand.

TABLE 3-24.

PROJECTED SEASONAL AND PERMANENT POPULATION DISTRIBUTION BY KISM[1] (1,000s)

Kism	1977	1980	1990	2000
Gomrok	143	168	169	170
Manshia	45	51	55	56
Labban	79	95	103	112
Attarine	75	82	88	93
Karmooz	214	238	244	252
Moharrem Bey	336	375	380	385
Bab Sharky	350 (119)	390 (135)	514 (165)	532 (172)
Ramleh	446 (35)	530 (40)	656 (50)	706 (54)
Montazah	310 (189)	336 (200)	723 (205)	1,345 (214)
Minet El Bassal	228	272	327	370
Dekheila	46 (7)	63 (15)	106 (70)	145 (155)
Ameria	47	50	175	500
Total permanent	2,319	2,650	3,540	4,666
Total seasonal	(350)	(390)	(490)	(595)
Combined total	2,669	3,040	4,030	5,261

[1] Values in ( ) are estimated maximum seasonal population projections.

Sources: Status Report #2;[90] 1976 Census-CAPMAS;[69] Special Report #3.[68]

Because Egypt has a limited agricultural land base and an increasing population, there are limited employment opportunities in rural areas. As a result, there has been a population shift to urban areas. After 1985, it is expected that migration to the city will increase at higher rates. The demand for labor associated with several new primary industrial projects as well as employment opportunities generated by complimentary, labor-intensive fabrication industries would encourage this immigration flow.

Despite the relatively low level of immigration (12,000 to 15,000 per year), Alexandria has a problem providing housing for all its people. According to one governorate official, there are 17,000 people living in tents on the outskirts of the city, because there are not enough housing units to accommodate them (Fouad A. El Leithy, personal communication, November 1977). In 1975, a total of 2,031 publicly financed housing units were constructed;[69] over half of these were two-bedroom units termed "economical," (i.e., having only bare walls). The average number of rooms per family in Alexandria in 1976 was 2.5 and average family size was 4.9, about the same as for other urban areas of the country and slightly lower than for the agricultural areas.[69] The vacancy rate in apartments and rooms was approximately 5 percent, excluding dwellings occupied on a seasonal basis only. If these were taken into account, the vacancy rate would be higher (see Technical Appendix No. 3).

In 1973, the crude birth rate in Alexandria was 30 per 1,000 population and approximately 43 percent of the current population is under 15 years of age. The birth rate has declined steadily from a peak of over 50 per 1,000 population in 1953, while the death rate has declined less rapidly, from a high of 22 per 1,000 population in 1953 to about 10 per 1,000 in 1973.[68]

3.D.2 Public Health Issues

Wastewater treatment facilities are built for many reasons, but the most basic one is the improvement of public health. Nowhere is the public health justification of a wastewater treatment project clearer than in Alexandria, for the current environment is an ideal setting for extensive outbreaks of disease similar to the cholera epidemic that infected the city in 1970. This portion of the report presents relevant public health statistics for Alexandria, followed by eyewitness accounts of the everyday public health hazards that are taken for granted by the people of the city.

3.D.2.a Public Health Data. Statistics alone cannot convey the meaning of public health problems faced by the people of Alexandria and Egypt, but they do allow an approximate basis for comparison with the rest of the world. Dr. Daniel A. Okun, a consultant to Camp Dresser & McKee International Inc., prepared a memorandum[70] in August 1977 showing the

extreme nature of public health problems in Alexandria and their relation to inadequate wastewater facilities. Okun's memorandum and other sources of public health data[71,72] offer some quantitative insight into the magnitude of the city's public health problems.

Health conditions in Egypt as a whole are poor. The most commonly used index of overall health quality is the infant mortality rate, defined as the death rate of children under 1 year of age; in 1973, Egypt reported 97.9 infant deaths per thousand live births, a rate of virtually one in ten. This was the seventh highest national rate in the world that year, exceeded only by four small countries in sub-Sahara Africa, an island in the Caribbean, and Pakistan (including what is now Bangladesh). Infant mortality rates in Egyptian cities are higher than the national average, presumably due in part to better reporting. As shown in Table 3-25, Alexandria's average infant mortality rate from 1963 to 1972 is slightly lower than Cairo's, but remains a grim indication of Alexandria's health problems; more than one infant died for every eight born in Alexandria during those years.

Statistics on water-related disease are the most relevant for describing existing conditions, as affected by wastewater problems. As shown in Table 3-26 average reported incidence rates of typhoid and paratyphoid, infectious hepatitis, and dysentery are markedly higher in Alexandria than in Cairo and Egypt as a whole. While these data are subject to greater reporting error than infant mortality data, they do show the unusual magnitude of sanitation problems in Alexandria.

As shown in Table 3-10, epidemiological studies performed by the High Institute of Public Health reveal a significantly higher incidence of health complaints among bathers relative to nonbathers at Alexandria's beaches, and exposure to the bacterial pollution from current onshore discharges presumably accounts for some of the difference. Increased use of Alexandria's beaches in summer may also account for some of the seasonal variation in disease incidence over a 3- to 6-year period noted in Okun's memorandum:

	Summer Season	Off-Season
Infant mortality; deaths per week	180	94
Typhoid and paratyphoid, cases/month	274	157
Infectious hepatitis, cases/month	111	92

An extremely serious aspect of the higher summer incidence rates is the likelihood that infected tourists will carry diseases from Alexandria to other parts of Egypt and the Middle East. There can be little doubt that

TABLE 3-25.

RELEVANT INFANT MORTALITY DATA*

Locations and Years(s)	Infant Deaths per 1,000 Live Births
Egypt, 1973	97.9
Libya, 1972	80.3
Iraq, 1972	28.1
Kuwait, 1973	44.1
Jordan, 1973	22.6
Syria, 1972	21.7
Pakistan, 1968	124.3
India, 1970	61.0
U.S.A., 1973	17.6
Sweden, 1973	9.9
Egypt, 1963-72	118
Cairo, 1963-72	148
Alexandria, 1963-72	131

*Sources: World Health Statistics Annual 1973-1976, World Health Organization, Vols. I and II, [71], Compendium of Vital Statistics from 1930, Pub. 01-100, February 1973, published by CAPMAS. [72]

TABLE 3-26.

WATER-RELATED DISEASES IN EGYPT*

	Governorates		
	Cairo	Alexandria	Egypt
Population, mid-1974	5,640,600	2,250,300	36,254,100
Typhoid and paratyphoid cases			
Average per year, 1970 to 1974	5,585	2,486	12,621
Average per 100,000 per year	99	110	35
Infectious hepatitis			
Average per year 1970 to 1974	2,825	2,647	22,053
Average per 100,000 per year	50	118	61
Dysentery			
Average per year 1970 to 1974	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 Sector Study, June 1977.

in either season the risks are exacerbated by the wastewater hazards described in the following section (3.D.2.b).

Among the most revealing statistics discussed by Okun are those describing cholera. (Clearly diagnosed outbreaks of cholera have never been officially recognized by the Egyptian government, which, instead, prefers the term "acute enteric summer disease." There is, however, no question about the identity of the disease.) Statistics of 1970 (Table 3-27) show that the incidence of cholera in Alexandria was four times greater than the Cairo rate and six times greater than the national average. Alexandria health department statistics for 1974 show a clear association between inadequate wastewater management and the incidence of cholera. Health district cholera incidence rates varied from "no reported cases" in some districts to a rate of 1,014 per 100,000 in a western section of the city. Gheit el Enab, Alexandria's dairy district, has the second highest incidence rate of 958 per 100,000, which reflects its notoriety for inadequate wastewater removal due to sewer blockage by cow manure; Alexandria's highest incidence was reported in Kafr Ashri, an adjacent district. Derbala, Siouf, and Hagar El Nawatia all had unusually high incidence of both cholera and typhoid, reflecting the large fraction of unsewered areas within their boundaries. The cause and effect relationship between inadequate wastewater treatment facilities and these public health problems cannot be rigorously shown on the basis of such data, but water-borne human wastes are clearly implicated in the transmission of these diseases.

3.D.2.b Public Health Hazards. This report can present no clearer description of the hazards of inadequate wastewater management than the following excerpts from Special Report No. 4 of the Alexandria Wastewater Facilities Development Program.[73]

> "Perhaps a way to convey to the reader the general state of health and sanitation in Alexandria is to describe a few of the many observations made by the writer in the course of living in Alexandria for a few months. These are:
>
> - "sewage overflowing manholes in a residential-industrial area due to overloaded conditions. The sewage flowed across the street and directly into the Montazah Canal which not only serves as the raw water supply for the Maamoura Water Treatment Plant a few kilometers away but serves as the bathing, dishwashing, laundry, and stock watering place for many squatters who inhabit the canal banks both before and after the Maamoura Plant intake. Not only did the sewage flow into the Canal, but traffic splashed through the flooded street and sprayed this raw sewage over cars and pedestrians alike. This was observed to be happening at two different times, and evidence at the site indicated that this flooding is a regular occurrence.
>
> - "sewage overflowing manholes in another location, flowing along and across the street, with heavy traffic splashing through

TABLE 3-27.

CHOLERA IN EGYPT IN 1970

Governorate*	Date of Onset	Attack Rate 100,000 in 1970
Kalyoubia	31 May 1970	27.4
Alexandria	3 June 1970	100.3
Cairo	14 June 1970	25.2
Giza	27 June 1970	21.7
Matrouh	4 July 1970	75.8
Red Sea	5 September 1970	56.1
All Egypt		16.5

*All other governorates had attack rates lower than 20 per 100,000 population.

Source: Report on the Epidemic Situation in Alexandria (1970-71) by Dr. M. H. Wahdan and M. El-Nomrousy.

and pedestrians who wished to pass having to walk through because there was no other way to get from one side to the other except to crawl up an adjacent railroad embankment.

- "sewage overflowing from septic tanks, flooding the area between adjacent houses and flowing into the door of one of the apartments. This area has no sewer system. Down the street, ducks were using a raw sewage ditch for drinking water and for doing what ducks do in water. Further down the street there was construction of a sewer, paid for by the local inhabitants who had given up having it done through formal channels. Unfortunately, the design and construction methods preclude a workable system which, if it worked, would only concentrate the problem among their downstream neighbors.

- "great ponds of wastewater lie in the low lands surrounding housing areas in Siouf Keblia and Ras el Soda. In the former area, inhabitants have constructed earthen walkways above the level of the water to gain access to their homes.

- "septage, sludge, and water pumped out of septic tanks have been observed to be dumped into the sea at several locations along the seashore. Discharge is usually into a storm drain manhole but on one occasion the discharge hose was placed over the wall for direct discharge. Discharge of septage has also been observed in the open ditches which drain agricultural lands.

- "workers who clean sewers work without protective clothing of any kind. One crew consisted of one man who went down into the sewer and used his hands to scoop up the gritty solids to fill the bucket. His colleagues at the surface hauled the full bucket up for dumping, the bucket dripping on the poor fellow below. When he emerged, he was dressed in shorts, a skivy shirt, and a scull cap and was barefooted. It is understood that in some areas septic tank cleaners actually enter the tank to bucket the contents out.

- "children have been observed swimming in the obvious plume of a combined sewage overflow in the Eastern Harbor. They would run along the top of the pipe and dive into the dirty water rather than swim in the cleaner water nearby, probably because the dirty water was warmer.

- "people were observed to be swimming on the beach adjacent to the Sporting Pump Station at a time when the pumps were not operating and the full flow was discharging to the sea less than 70 m away. They were well within the plume of dirty water that forms when these overflows discharge.

- "open channels carrying very strong sanitary sewage exist beside and between closely built houses in the Nouzha area. Children in

this low-income area play in these areas and certainly at some time they must come in direct contact with these waters. Flies abound in the area from garbage and sewage, and children can be seen with scores of flies around them, on their heads, hands, in their eyes, mouth, and ears. Similar situations have been observed in the other unsewered areas.

- "in the Gheit el Enab area, where the cows are kept in areas which are among the most densely populated, cow manure is piled in the streets until such time as it can be hauled away. Much of this material is thrown in the sewers. In the winter, the area floods and the sewers which are plugged cannot carry away the water.

- "solid wastes, paper, garbage, and all sorts of trash are placed in piles in the streets, in high- and low-income areas alike, for contract haulers to collect and haul away. These piles are ubiquitous. In the summer, each pile attracts thousands of flies and is the source of odors. Local fruit and vegetable stores attract these flies in swarms. Fruits such as grapes, pears, and plums are eaten without cooking and peeling. The necessary sanitation is impossible in this situation."

While these incidents represent an accumulation of the more dramatic situations in Alexandria, some or all of them have been observed by all personnel involved in the field work required for the preparation of this report. The conditions have to be seen to be believed.

3.D.3 Economy

The Nile River made possible one of the world's earliest cultures and centers of agriculture, and it is still the Nile and the agricultural sector which provide the largest share of Egypt's Gross Domestic Product (GDP). In 1974, 47 percent of the work force was directly involved in agricultural production on the 4 percent of Egypt's land that is arable, providing 31 percent of the GDP and gaining 80 percent of the country's foreign export earnings.[74] Counting secondary employment directly associated with agriculture, over half of the population depends on 2.4 million hectares of the Nile Valley for its livelihood. In contrast, industry in 1973 provided 23 percent of the GDP and employed 13 percent of the work force. [74]

In 1975, the civilian labor force was estimated at 10 million, of which official figures show 9.29 million employed.[75] However, some other important factors should be noted. There is considerable seasonal employment and underemployment as well as participation in the work force by children under the legal working age of 12. It is estimated that each year 185,000 new jobs are created while 300,000 persons enter the labor force, many of them college graduates. Because the government guarantees jobs to these graduates, many people end up on the government payroll with

little to do. In fact, underemployment in the public sector is believed to be as high as 30 percent, with a resulting decrease in administrative efficiency.[89] As a result, professionals have been encouraged by the government to emigrate to manpower-short areas of Africa and the Middle East.[76] Furthermore, because of a lack of employment opportunities in agriculture and a high birth rate (32.5 per thousand), there has been an influx into urban areas. In the cities, however, economic and particularly industrial expansion has not progressed sufficiently to provide jobs for all those who seek them.

As is the case with many developing nations, Egypt's economy is suffering from a severe balance of payments deficit. In 1976, for instance, exports were U.S. $2.61 billion less than imports.[77] (See Table 3-28.) The high inflation rate of nearly 30 percent in 1975, at least partially concealed by subsidies on food and some other items, has been largely responsible for the balance of payments problems and has forced Egypt to rely on foreign aid for its survival. In addition to the United States, whose aid program is nearly one billion dollars annually, which makes Egypt the largest single recipient of U.S. economic aid, several oil-producing nations of the Middle East have formed a U.S. $2-billion organization for the development of Egypt.

Alexandria is Egypt's second largest urban center, and, as such, only 4 percent of the labor force of 581,000 is involved in agriculture. Fifty-nine percent work in manufacturing, commerce, transportation, and communications; another 25 percent are in services and insurance (see Table 3-29).

Primary industrial employers are textiles, food processing, petroleum refining, paper production, and oil and soap production (see Table 3-30). Alexandria currently employs about 14 percent of Egypt's manufacturing labor force. With the proposed addition of major new industries, economic expansion is expected to continue as described in the next section (3.D.4). In addition, the national government now discourages industrial development in Cairo, in an attempt to stabilize its population. As a result, Alexandria is likely to be an attractive future alternative location for industries.

As Egypt's primary port, in the 1970s 12 to 13 million tons of cargo pass through Alexandria each year. With the planned expansion of the Dekheila port facilities, it is expected that by the late 1970s, Alexandria will be able to handle about 70 percent of the nation's maritime traffic.[78]

Technical Appendix No. 4 contains additional economic background information.

TABLE 3-28.

SELECTED KEY ECONOMIC INDICATORS - EGYPT
(in US$ millions) (L.E. 1 = US $2.56)

GDP	1974	1975	1976*
Exports (f.o.b)[1]	1,755	1,720	1,790
Imports (C.i.f)[1]	-3,750	-4,975	-4,400
Trade balance[1]	-1,995	13,255	12,610
Public revenue[2]	3,025	3,945	4,980
Public expenditure[2]	-4,845	-6,665	-6,775
Emergency fund deficit[2]	-85	-730	-640
Total deficit[2]	-1,905	13,450	12,435
External financing[2]	240	495	460
Domestic financing[2]	1,665	2,955	1,975

*Estimates.

[1] Balance of payments.

[2] Public finances.

Source: "Economic Trends Report" - Egypt USAID Unpublished Report, Cairo, May 1977.[77]

TABLE 3-29.

ALEXANDRIA LABOR FORCE TRENDS
(100s of people)

Sector	Size of Labor Force 1970	1972	1974
Manufacturing	1,801	1,817	1,927
Commerce, transportation, communication	1,277	1,352	1,487
Services and insurance	1,210	1,398	1,442
Agriculture, forestry, fishing	240	255	243
Construction	187	208	193
Gas and electricity	59	56	58
Mines-quarries	13	23	34
Other	29	119	426
Total	4,816	5,228	5,810

Source: CAPMAS, February 1977.[91]

TABLE 3-30.

VALUE OF INDUSTRIAL PRODUCTION OF SELECTED INDUSTRIES IN ALEXANDRIA
(Current L.E. 1,000)

Industry	1960	1966/7	1970/1	Growth Rate* (percentage)
Textiles	40,060	74,497	74,307	6.06
Food processing	25,077	55,949	63,035	9.2
Paper production	6,825	16,474	25,308	13.5
Chemicals	6,168	18,168	23,407	13.0
Main metals	4,901	9,809	18,167	13.3
Petro and coal products	700	2,128	7,930	26.0
Clothing and shoes	1,978	5,063	6,839	12.5
Soft drinks	2,011	2,064	2,981	3.8
All other industry	30,486	41,197	58,805	6.5
Totals (all industries)	118,206	225,348	280,779	8.6 percent

*Compound annual rate for 10.5 years.

Source: CAPMAS, Yearly Industrial Statistics, February 1977.[91]

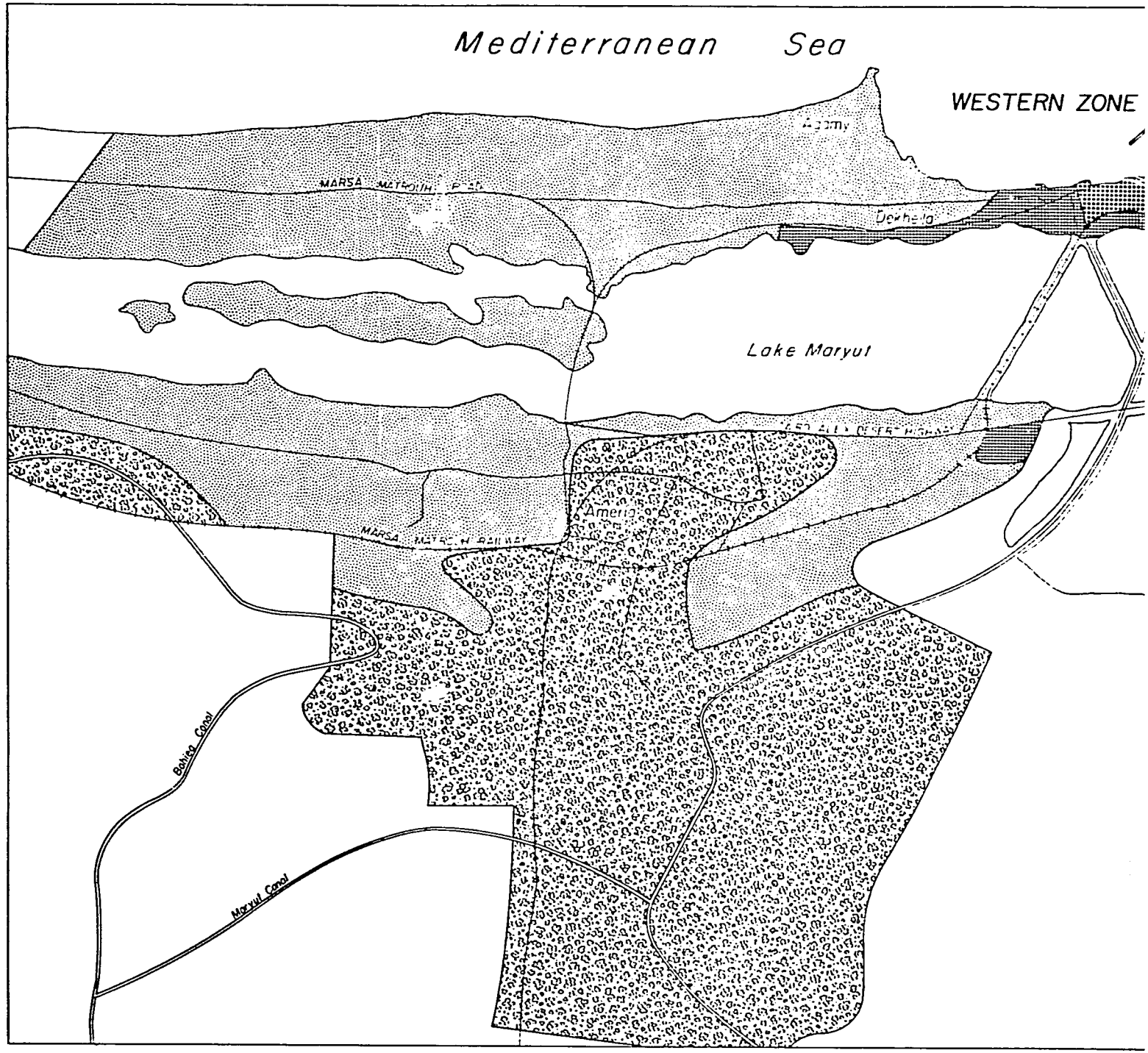
3.D.4 Land Use

The governorate of Alexandria is divided into four administrative zones--Central, Eastern, Western, and Ameria. The three urban zones, Central, Eastern, and Western, are divided into sections called kisms, which roughly designate neighborhood areas. The governorate is made up of approximately 46 percent desert, 28 percent agricultural land, and 16 percent urban development (see Fig. 3-27). Of the remaining 10 percent, Lake Maryut occupies a significant area, varying in size with the season. In winter, the rainy season, it may occupy up to 100 km^2, while in summer the lake may be 60 square km^2. The aerodrome occupies approximately 3 km^2.

3.D.4.a Desert. While the desert has been traditionally inhabited only by nomadic peoples, the current stress on agricultural land and the increasing level of industrialization in the Alexandria area have encouraged expansion of industrial and residential areas to the south and west of the main urban center. Table 3-31 shows these areas.

Currently, 55 companies have applied to locate within the Alexandria Free Zone. The first are scheduled to be established in 1978. In all, the Ameria area, including the Free Zone, has 2,100 ha zoned for industrial development. A prefabricated housing factory is under construction and building has begun on 1,000 housing units which are intended for future employees of the housing factory and workers currently engaged in area land reclamation projects. A total of 3,600 ha have been zoned for residential developments around Ameria. By the year 2000, the population of Ameria is expected to increase to over ten times its current level of 47,000.[69]

In an effort to relieve the major urban centers of the great stresses of large increases in population expected in the coming decades, the government has begun planning a series of satellite cities around the industrial zones. One plan[79] calls for development of the coastal desert area to the west of Alexandria. Currently, the coastal zone of the western desert is fairly isolated from the rest of the country and has few services (public health, utilities, education). Aside from Bedouins, the only travelers in the area are visitors to the beaches and the El Alamein war memorial. The high population density in the delta region makes it desirable to develop vacant areas of the country and provide for future living and working space. The overall plan for the western desert calls for developing 6,000 km^2 along 400 to 500 km of the Mediterranean Coast west of Alexandria to the Libyan border. According to the plan, approximately 750,000 persons can be accommodated in the area by the year 2000. There are plans for industries, irrigated agriculture, tourist facilities, free zone developments, and trade. The regional plan states that there is enough livable space to provide for another two to three million persons. Obviously, the extent and pace of development will affect Alexandria's pattern of land use, population, and economic prosperity. Hopefully, the development will take some of the pressure off of Alexandria's overtaxed facilities.


Mediterranean Sea
WESTERN ZONE
Lake Maryut
Bahrea Canal
Maryut Canal

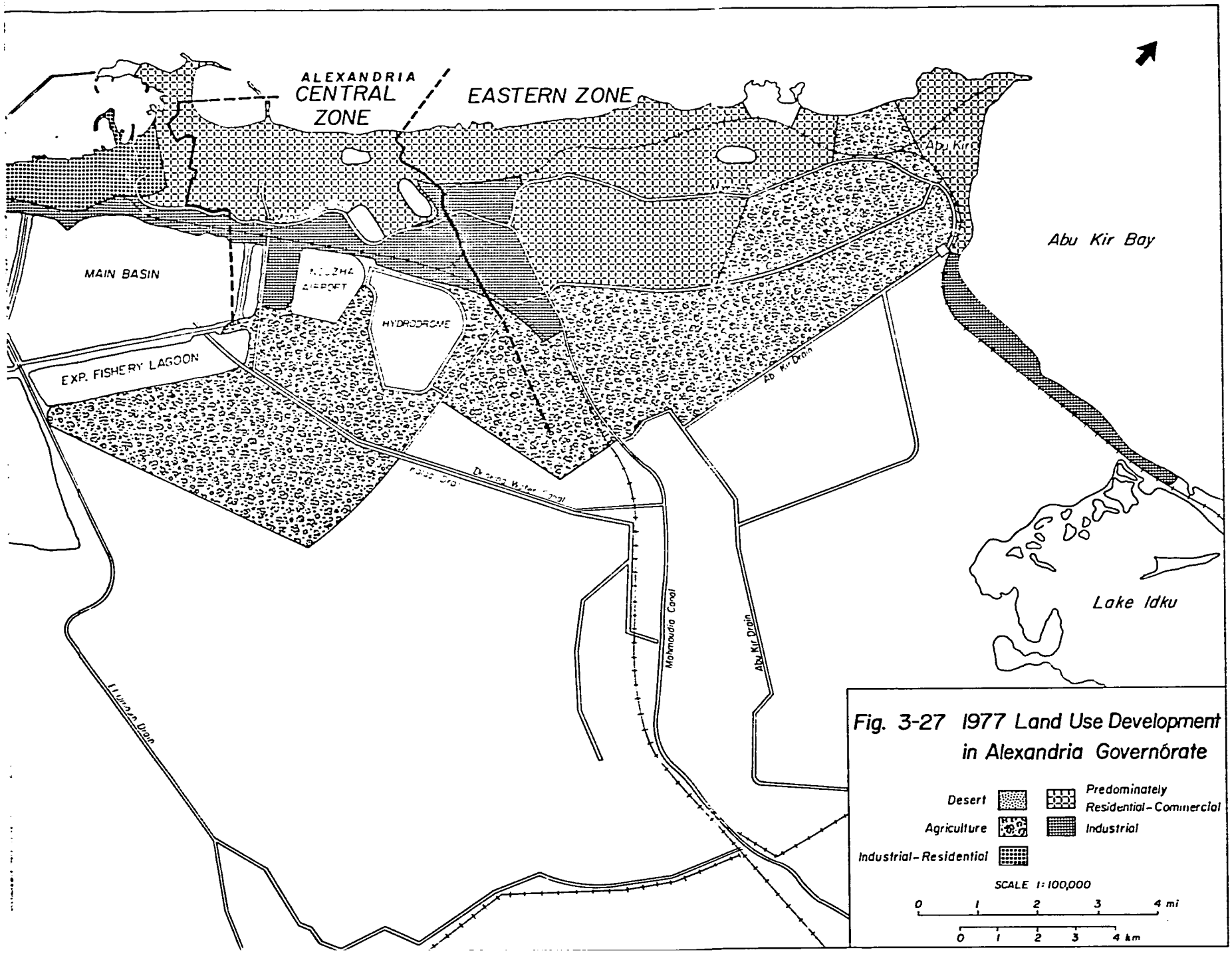


Fig. 3-27 1977 Land Use Development in Alexandria Governórate

TABLE 3-31.

CURRENT AND FUTURE AREAS OF INDUSTRIAL DEVELOPMENT
by Kism

	Currently Available		Additional Land Available for Development		Potential Total Area		Percentage Increase
	Ha	Acres	Ha	Acres	Ha	Acres	
Abu Kir	13.9	34.4	-	-	-	-	-
Abu Kir Bay	275.0	679.5	256.0	632.6	531.0	1,312.10	93
Montazah	95.3	235.4	482.0	1,191.0	577.0	1,425.80	505
Ramleh	146.0	360.9	357.8	884.1	503.8	1,244.90	245
Moharrem Bey	115.0	284.1	233.0	575.7	348.0	859.90	202
Bab Sharky	116.0	286.6	64.0	158.1	180.0	444.80	55
Karmouz	71.2	175.9	-	-	71.2	175.90	-
Minet El Bassal	17.0	42.0	-	-	17.0	42.0	-
Dekheila	82.8	204.5	3,890.0	9,612.2	3,972.8	9,816.80	4,798
Ameria	-	-	2,100	5,189.1	2,100.0	5,189.10	792
	932.2	2,303.3	7,382.8	18,242.8	8,314.7	20,545.7	

Source: Wastewater Special Report #3.

The closest satellite city to Alexandria would be that built at Ameria, southwest of central Alexandria. It is anticipated that by the year 2000, Ameria will have a population of 500,000, with the possibility of expansion to 1 million. It will occupy an area of 145 km^2, including zones for industry, tourism, and other facilities of a city. The precise location of development at Ameria is uncertain, but its most significant impact on Alexandria will be a reduction in population pressures on the central city.[80] The wastewater facility needs of Ameria are addressed in the wastewater Master Plan. See Tech. App. No. 3 for recommended location.

Expanding to the desert would deal with another land use problem; during the 25 years after independence 360,000 ha were transformed from desert to agricultural land; but, at the same time, over 240,000 ha of high quality agricultural land were lost to housing, industry, highways, airfields, and other uses. [81] Further compounding the problem is that the reclaimed land is usually less fertile than the alluvial delta soil. As a result, high quality agricultural land is increasingly valuable to the nation, and the western desert plan is, at least in part, an attempt to conserve it.

3.D.4.b Agriculture. Since 1954, 96,300 ha of land near Alexandria have been reclaimed from the desert and have been turned to agricultural production. As a result, much of the governorate land is occupied by small agricultural villages. These areas, generally to the south along the Noubaria Canal, include several large commercial farms, private farms and cooperatives, agricultural reclamation projects, and numerous chicken farms. It is expected that most of this area will continue as a rural and agricultural area. However, as with most rural areas in Egypt, the population is projected to expand at an annual rate of about 3 percent. It can be expected that as the population density increases, there will be a continuing stream of immigrants to Alexandria and other urban centers.

The pressures to convert agricultural land for urban development noted above are strong in Alexandria; a major housing project called Sadat City is planned to house 500,000 people by the year 2000 in agricultural lands southwest of Abu Kir.

3.D.4.c Urban. The city itself is difficult to classify as strictly residential, commercial, or industrial, because there is significant mixing in many areas. There are densely inhabited sections with up to 2,600 persons per ha with a jumble of apartments, shops, workshops, and houses on narrow streets and alleys. There are other sections with under 200 persons per ha with villas, broader streets, and gardens. Much of the city is a combination of small shops and residential buildings with varying densities. There is only a small amount of open space in the city, primarily the beach and a few small parks.

Most industries are located along a crescent beginning at Abu Kir Bay and running west along the Mahmoudia Canal to Mex-Dekheila. The main shop-

ping and commercial center is in the Attarine and surrounding areas. The newer section of town (mostly constructed since World War II) is to the east of the downtown area between San Stefano and Montazah. Along the coast in this area, many wealthier Egyptians have homes or flats for use during vacation periods.

3.D.5 Government Organization

3.D.5.a National Government. Regional and local government in Egypt is strongly influenced by the national government and is subject to the direction of the Ministry of Local Government. The principal features of the national government include an elected president, serving as head of state and chief executive, an extensive cabinet organization, a presidential bureau and agency system, and a large civil service.[74]

The Arab Republic of Egypt is governed through a constitution dated 11 September 1971. The constitution describes Egypt as a democratic socialist state, defines the rights, obligations, and public liberties of the population, establishes the supremacy of law and the system of government.[74] The government system is based on a unicarmeral elected legislature called the People's Assembly. There is an independent secular judiciary with a system of law derived from Islamic and French codes. The constitution specifies that citizens are equal before the law without discrimination on the basis of race or religion.

In 1975, the central government employed over a million persons in the civil service[74] and approximately 345,000 in the military.[74] In the early 1970s, the national budget allocated 90 percent of gross domestic investment and nearly 30 percent of total consumption. This trend is currently under revision with a stated effort by the president to emphasize private enterprise and a freer economy.[74]

The civil service in Egypt has been subjected to continual inefficiencies. Of the large civil service force, half are considered to be inadequately or marginally trained.[74] Progress toward reforming the civil service system has been a perpetual goal of the government. One complicating factor is the law guaranteeing employment for all college graduates, whether or not they are needed.[74]

3.D.5.b Local Government. The constitution provides for three levels of government: governorates, cities, and villages. In 1975, there were 25 governorates; of these, Cairo, Alexandria, Port Said, and Suez were classified as city governorates and combined the functions of governorate and city administrations. The executive of each governorate is appointed by the president. At each level of local government are two councils--one to control and plan, the other to implement and supervise projects.[74]

3.D.5.c Governmental Services. Services at the local level within Alexandria are provided by branches of National Ministries and through the governorate. The governorate itself has few locally derived revenues and is thus an arm of the national government. The overlapping authority between the governorate and National Ministries makes for organizational fragmentation. Table 3-32 presents the budget and number of employees for various governmental services in Alexandria. As a socialist republic, much of the employment in industry and the commercial sectors is also government controlled. Table 3-32 concentrates on services typically provided by government.

3.D.5.c.i General Organization for Sewage and Sanitary Drainage (GOSSD). GOSSD is a national level organization of the Ministry of Housing and Reconstruction. It is responsible for managing, improving, maintaining, and operating wastewater collection and disposal. In Alexandria, the GOSSD office is under the supervision of the main office in Cairo. It is the Cairo office that has the final decision on design of facilities, tendering and awarding of contracts, and other major decisions. Most routine management functions are carried out by the local staff. Currently, there is consideration of a plan to transfer the function of the Alexandria GOSSD Office to the Governorate.[82]

The organizational chart of GOSSD-Alexandria shows it to have four staff departments and five line departments. The current staff of 1,633 is broken down as follows:

Department	1977 Staff
Executive	8
Personnel and Training	18
Budget and Finance	71
Legal	9
Public Services	7
Design	7
Project Execution	52
Water Pollution Control	109
Sewer Maintenance	648
Mechanical and Electrical	704
Total	1,633

Source: Special Report No. 4, Section 4, p. 7-7.

The funding of GOSSD-Alexandria is mainly met by funding allocations from the National Ministry of Finance. Charges are made for new utility connections, the only local source of funding, but the income is reduced by a subsidy for low income housing. The budget for new projects must be approved by the Ministry of Planning. The budget and number of employees for the governmental service is shown in Table 3-32.

Several factors tend to weaken the organization's effectiveness. As discussed in Special Report No. 4, GOSSD has problems in attracting and retaining experienced personnel, at least in part because of the overall weakness of the compensation system. Also, the regulation pertaining to selection for promotions tends to program an individual's career at the very beginning, leaving few incentives for achievement or excellent performance.

Perhaps the most serious problem in Alexandria's wastewater management practices is the lack of enforcement of the 1962 Sewer Use Law. Over the last several decades the Alexandria sewer system has been grossly abused by having great masses of materials dumped into it which the system is not designed to carry. These materials are solid wastes and trash, mazout and used oils, toxic and low pH industrial wastes, septage from the pumping of septage tanks, and cow manure. In the volumes discharged, these materials cannot be carried in the sewer and the result is blockage of the lines from the additional accumulation of solids. The mazout and waste oil float on the water and accumulate in the high points in the system. These materials seriously affect operation of the treatment plants, make sewer cleaning difficult and, upon discharge, degrade water quality and represent a potential fire hazard. Problems noted in the organization of GOSSD, the technical deficiencies in the sewerage system itself, and the lack of enforcement of the sewer use law all have direct impacts on the natural environment of Alexandria and on its inhabitants.

TABLE 3-32.

BUDGET AND NUMBER OF EMPLOYEES
FOR VARIOUS GOVERNMENTAL SERVICES
IN ALEXANDRIA
1977

Service	Budget, L.E.	Number of Employees
Governorate (local government)	9,966,711	9,315
Education (primary/secondary)	14,892,650	28,849
Health	4,000,900	10,000
Social Affairs	728,583	982
Housing	534,915[2]	[1]
Food Control	253,710	550
Agriculture	345,230	632
Labor Agency	269,910	563
Water Authority	3,219,000	4,000
Transportation	[3]	9,000
Maamoura Co. for Housing and Reconstruction	[3]	180
Sanitary Drainage (GOSSD)	2,559,152	1,633

[1]Included with governorate personnel.

[2]Excludes approximately L.E. 2 million spent on industrial housing derived from a 15-percent tax on profits.

[3]Unavailable.

Source: Interviews with government officials, December 1977, Waterworks Master Plan, Special Report No. 4.

3.D.6 Community Facilities

3.D.6.a Existing Wastewater Facilities. The existing wastewater collection and disposal facilities of Alexandria are closely linked with the city's sanitary and environmental problems. Because Alexandria's wastewater currently contains human wastes from about 2 1/2 million people, its safe removal from the urban environment is of paramount importance to public health. Appropriate treatment and disposal of these wastes after their collection is also required to minimize the environmental and social costs associated with pollution. This section briefly describes the wastewater facilities of Alexandria and some of their current problems.

3.D.6.a.i Collection Facilities. The existing wastewater collection facilities serve the western, central, and eastern zones. These sewered areas contain about 85 percent of Alexandria's population, leaving only 15 percent of the city's people without public wastewater facilities. Connection to the sewer system does not, however, insure satisfactory wastewater removal. As described elsewhere in this report, raw sewage often backs into the streets from sewers blocked by trash, garbage, cow manure, and other illegally discharged solid wastes. While sanitary conditions in sewered areas are better than unsewered regions most of the time, current solid waste problems in Alexandria severely limit the usefulness of a reasonably well-designed wastewater collection system. Overloaded septic tanks in unsewered portions of town frequently overflow into the streets because of tight soils. Current wastewater facilities in Alexandria thus often fail to obtain their most basic objective of removing sanitary wastewater.

The eastern zone is the largest of the three sewered areas and its wastewater facilities are designed to convey wastewater to either Smouha Drain without treatment or the East Treatment Plant for secondary treatment. Because of the extent of the service area and its topography, several pump stations are required to convey wastewater to the East Plant. However, in the western section of the zone (Smouha area), there are no pump stations for conveyance to the treatment plant, and wastewater flows by gravity into Smouha Drain.

Often during the winter months, stations along the coastal portion of the zone do not pump wastewater to the East Plant. Some of these stations do not have gravity overflows and use separate stormwater pumps to discharge wastewater to the sea. Other coastal stations, equipped with gravity overflows and no stormwater pumps, merely do not operate. These practices conserve wastewater pump service life for the demanding operating conditions experienced in the summer months and reduce the chances of objectionable wastewater overflows. Also winter operation, maintenance, and treatment costs are lower, because about 25 percent of East Zone wastewater is discharged directly to the sea.

Reliable flow data do not exist, but current estimates of average flows to the East Plant based on population data, industrial waste surveys, per capita contributions, and infiltration are about 70 Ml/day, while an additional 125 Ml/day is discharged directly into Smouha Drain. Industrial wastes comprise about 10 and 30 percent of these totals, respectively.

Western zone wastewater facilities currently discharge an average flow of about 110 Ml/day into Lake Maryut from four locations along the northern shore. These include Pump Station No. 3 West, 10 Ml/day; Gabbary (Pump Station No. 1), 13 Ml/day; Gheit el Enab Drain, 47 Ml/day; and Industries Pump Station, 39 Ml/day. A lesser amount, about 8 Ml/day, is discharged into the Western Harbor from Pump Station No. 2 and other scattered overflows. West zone wastewater is intended to be conveyed to the new West Plant for primary treatment; however, the plant is still under construction and is not expected to be operational until 1979.

Nearly all wastewater discharged from Industries Pump Station and about 40 percent of the flow in Gheit el Enab Drain is estimated to be industrial effluent. The above flows and industrial percentages are estimates based on population data, industrial waste surveys, infiltration, per capita wastewater contributions, and flow measurements made in the summer of 1977.

Central zone wastewater facilities currently discharge an average flow of about 130 Ml/day of untreated wastewater into the Mediterranean. The majority of this flow is discharged through a 735-m-long outfall at Kait Bey with the remaining flow spilling out of various overflow pipes along the beaches and in the eastern and western harbors. The existing Kait Bey outfall is broken in several places and discharges wastewater through these random breaks. Reliable flow data do not exist, and the above estimate is based on population data, industrial waste surveys, infiltration, and per capita wastewater contributions. Industrial surveys indicate less than 20 percent of central zone wastewater is of industrial origin.

About 80 Ml/day of domestic wastewater from unsewered portions of Alexandria in the east and west (Ras el Soda, Siouf Keblia, Nouzha, Mex-Dekheila, Abu Kir, and Ameria) either seeps into the ground or runs into nearby canals and drains. Such pollution constitutes a serious threat to public health because of the use of canals for public and private water supply, bathing, and washing. The Montazah canal which contains the intake to the Maamoura water treatment plant is often grossly polluted.

About 40 percent of Alexandria's industrial wastewater is discharged to the wastewater collection system in the three major service areas described above; the other 60 percent is discharged to canals, drains, and the sea. Industrial wastewater treatment is almost

always minimal or nonexistent. Particularly notable examples of gross industrial pollution are an estimated 5 metric tons of mercury discharged to the Mediterranean by the El Misr chemical plant at Mex-Dekheila, and the heavy pollution of Abu Kir Bay from untreated pulp and paper and textile industry wastes from the Abu Kir region. The general characteristics of toxic industrial wastes are discussed in Chapter 5 (5.C.2).

3.D.6.a.ii Treatment Facilities. The East Treatment Plant has a hydraulic capacity of 100 Ml/day, but the sedimentation and biological treatment processes can only provide treatment for 50 Ml/day under ideal operating conditions. Currently, the operation of the plant is complicated by intermittent pumping from Pump Station No. 11, which sometimes delivers a high flow exceeding the plant's hydraulic capacity, or no flow at all. Seldom is a uniform influent rate received at the plant. Excess flow is routed directly to the effluent channel through a bypass pipe, to prevent plant flooding. There is little cooperation between the staff operating the East Treatment Plant and Pump Station No. 11. The resulting degree of treatment provided by the plant is at times a small fraction of what could be expected from a well-operating facility.

East Treatment Plant effluent discharges to the Hydrodrome Drain, where it is joined by raw sewage from Smouha Drain. Considerable biochemical oxidation in the Hydrodrome Drain reduces the concentrations of these wastes, and they are further diluted by the agricultural return water from Kalaa Drain before flowing into the southeast corner of Lake Maryut.

The West Treatment Plant has a hydraulic capacity of 100 Ml/day, but is nominally rated at 85 Ml/day. The plant, which is still under construction, would only provide primary treatment when completed in 1979. West zone wastewater, currently discharged into Lake Maryut from four locations, would be collected at the plant, thus eliminating pollution near existing discharge points. However, pollution loads currently distributed along the north shore of the lake would be concentrated at the plant effluent pipe. Western zone wastewater loads to the lake are about three times as great as those from the eastern zone, presumably because of high concentrations of industrial waste and the biochemical oxidation of east zone wastewater in the Hydrodrome Drain.

No treatment is provided for the central zone wastewater discharges from the Kait Bey outfall or the eastern and western harbor overflows. The coastal portions of both the eastern and western zones also discharge untreated wastewater to the Mediterranean. While there are no reliable estimates of total wastewater flows to the Alexandria coast, these discharges are clearly implicated in the bacterial pollution of the city's beaches, noted in the Water Resources section of this report, 3.B.5.a.

The wastewater facilities Master Plan along with Special Report No. 2, Inventory of Existing Facilities, contain more detailed descriptions of existing collection and treatment facilities. Specific system deficiencies are discussed in detail along with recommendations for immediate improvements. Proposed top priority projects, which are currently in the design phase, are a result of recommendations made to correct existing system deficiencies. Reference should be made to these documents for specific information.

3.D.6.b Existing Water Supply System. Alexandria has a comprehensive municipal water utility which supplies potable water on a 24-hour basis at generally adequate pressure to the vast majority of the population, commercial and industrial enterprises, and governmental institutions within its service area (Fig. 3-28). The Alexandria Water General Authority (AWGA) has expanded its physical facilities during the years to keep abreast of increased demand for water caused by the rapidly expanding population, increased summer use, and industrial demand.

Principal problems related to the existing facilities include poor operation and control of treatment processes, a generally poor quality of raw water, equipment which does not function or was not installed in the plant initially, and inadequate supervision and training of operation personnel. Maintenance of physical facilities and mechanical equipment is below normally accepted standards, resulting in the reduction of the useful life of these facilities and equipment.[85]

The Nile River is the source of raw water supply for the Alexandria water system. Water is conducted into the area by a comprehensive system of multipurpose canals, principally the Mahmoudia and Noubaria canals. The canals are used for navigation, irrigation, water supply, disposal of domestic, agricultural, and industrial wastewaters, as well as a source of raw water for the potable water supply. As the canals approach and pass through the Alexandria Urban area, quality of the canal waters deteriorates rapidly and places a heavy burden on the treatment process.

Water treatment is provided at six sites in the urban area. Treatment processes are similar at each site and consist of flocculation and coagulation of raw water by chemical addition, clarification, rapid sand filtration, and disinfection prior to distribution.

Distribution system pump stations and reservoirs have been located at major demand centers and areas of low pressures. Twenty-two distribution system pump stations have been identified and storage reservoirs have been provided at 13 sites. Total system storage, exclusive of storage provided at treatment plant sites, amounts to 85,000 cubic meters. The distribution system consists of approximately 2,050 km of cast iron, ductile iron, steel, and asbestos-cement pipe, ranging in age up to 100 years.

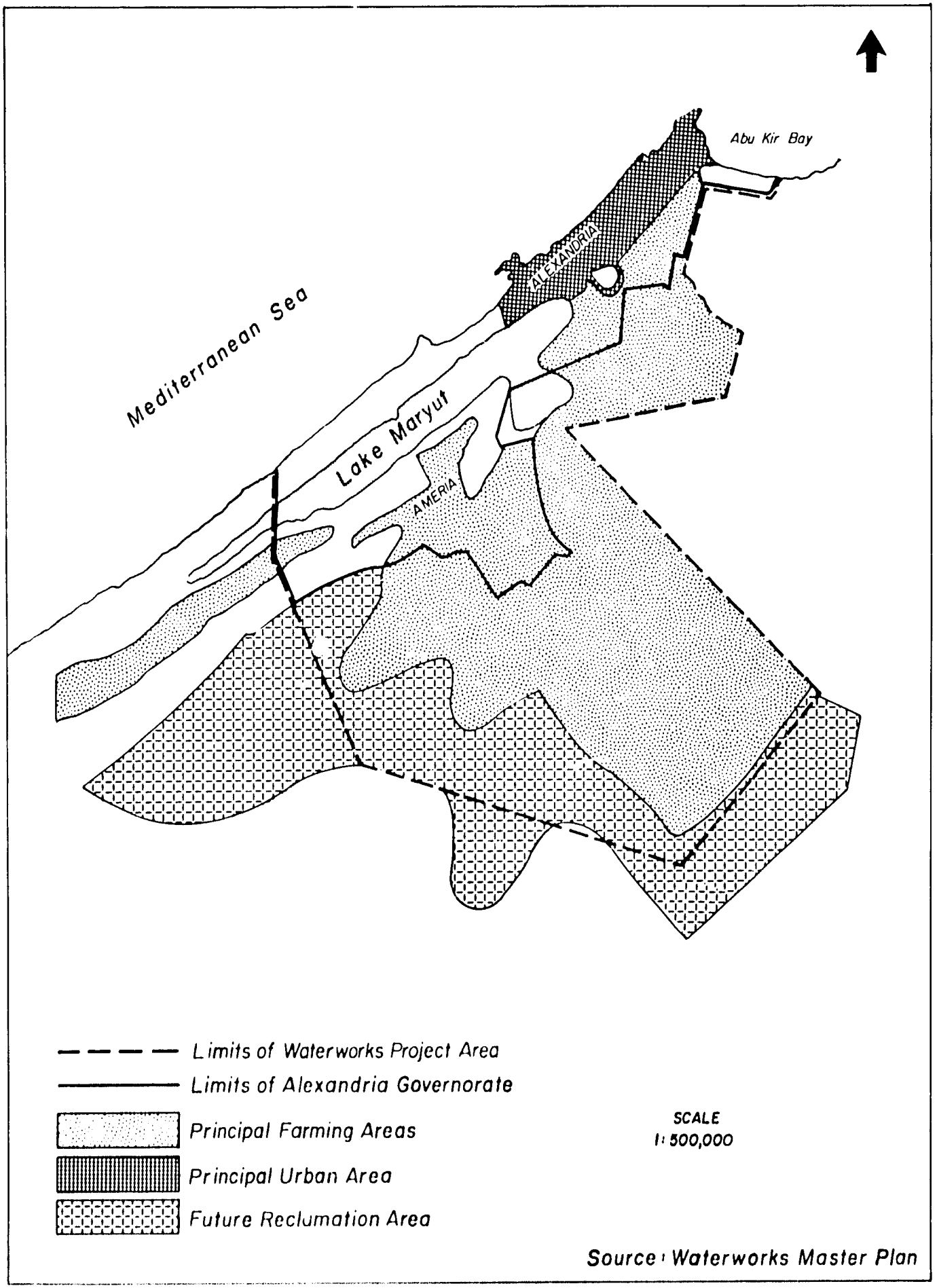


Fig. 3-28 Alexandria Waterworks Project Area (Schematic)

Subscribers are served by the system through service connections of lead, PVC, or cast iron materials. There are over 220,000 subscribers and over 99 percent of the connections are metered.[85]

In 1976, reported average daily production capacity for all six plants was 600 Ml/day and maximum daily water demand was 780 Ml/day.[85] Judging by records of subscriber billing rates, the demand for water has increased by about 5 percent per annum between 1966/67 and 1975.

Of the 600 Ml/day average demand, domestic use in 1976 was estimated to be 362 Ml/day;[70] and industrial use was estimated at 115 Ml/day; 123 Ml/day are for governmental and other uses.

Per capita water use per day ranges from 80 liters per day in low income areas, to 230 liters per day in higher income areas. The areawide average is 115 liters per day. During the summer months, the driest and hottest season, there are many tourists in Alexandria, increasing the demand for water. In Mamoura, an area that has few permanent residents, variation in water use ranges from 60 percent below annual average during the winter to 110 percent above average during the summer.[85] Permanent population served in 1976 was estimated at 2.37 million permanent and 1.10 million seasonal inhabitants.[85]

The domestic base rate for water use is 10 piastres per month for the initial 10 m^3 and 15.2 millemes for each additional m^3 consumed. There are over 40 different tariff rates which are applied in Alexandria. Industries and other establishments that are expected to consume more than 25 m^3 a month are charged 40 to 60 millemes per m^3, depending on category of use.

3.D.6.c Solid Waste Management. There is no public service in Alexandria for the collection of domestic and trade wastes. Residents in the middle and upper income groups, who might account for about 50 percent of the population, pay contractors, known as Zabaline, to collect daily from individual apartments and houses. Wastes from all other dwellings and shops are thrown in the streets. The city employs about 2,000 sweepers to clean the streets, but this number is insufficient to cope with current conditions.[86] Over 80 vehicles are usually available to collect the heaps of waste amassed by the sweepers, but these are also insufficient. Probably 400 tons per day of these wastes are never collected.[86] There are some areas where no sweepers are employed, and streets have been seen which are covered by a layer of decaying wastes up to 20 cm deep.

A sweeper can rarely collect more than 250 kg per day, and a Zabaline with his donkey cart can collect up to 750 kg per day.[86] The tools and carts provided to the sweepers are of poor design and quality, and sweepers are often observed picking up wastes with bare hands. It is customary for waste heaps to attract people who scavenge for any usable material; dogs, goats, and other animals are attracted by the scraps of edible material.

Cows are kept within the city, and manure is dumped in the streets and forced down manholes, often clogging the sewers. Shopkeepers sweep out their shops directly on the sidewalk.

About half of the total wastes collected, probably 600 tons/day, are now disposed of by the Zabaline. They use open areas of waste ground officially allocated to them for sorting and reloading the wastes. These areas are permanently polluted. The 500 tons/day collected by the governorate are dumped on marshy land or in Lake Maryut, increasing the pollution of these land and water areas and creating breeding grounds for flies and disease organisms.

As Flintoff points out,[86] Alexandria is fortunate in one respect: there is a strong demand from local farmers for crude wastes which they compost on their farms. The Zabaline sell this waste to the farmers at 1 or 2 L.E. per ton, and it is reported that about 30 percent of the wastes collected by governorate crews are unofficially sold this way.

Impact of the current solid waste problem on the sewage system in Alexandria is of major importance. As noted in the item on wastewater, the large quantity of solid wastes placed in the system, either by chance or deliberately, is one of the basic reasons for the system's lack of efficiency. The most recent and comprehensive description of the city's solid waste management problem is found in the Alexandria Excluded Wastes Management Study, prepared by CDM as an extension of the Wastewater Master Plan.*

3.D.6.d Transportation. Because of physical limitations, Alexandria has developed in a narrow strip of land along the Mediterranean. As a result, intracity traffic by automobile, bus, or train generally follows an east-west pattern. The major traffic corridors within the city are between the downtown business and commercial center and the eastern portion of the city, and these are generally congested and noisy. Other busy corridors run a relatively short distance to Dekheila and Agamy to the west and to several areas south of the city.

Recent information shows the number of vehicles registered in Alexandria:

Private autos	37,000
Taxis	13,000
Trucks and half-lorries	14,600
Buses	1,200
Horse carriages	400
Hand and donkey carts	15,500

Source: Personal contact with traffic police, December 1977.

*Alexandria Excluded Wastes Management Study, July 1978. Report prepared for the Ministry of Housing and Reconstruction, Arab Republic of Egypt, by Camp Dresser & McKee Inc., Chas. T. Main International Inc., and the Arab Technical and Economic Consulting Office.

These numbers represent only a portion of the vehicles on Alexandria's streets. Many trucks from outside the city carry cargo to and from the port and industrial sites. During the summer, many tourists drive to Alexandria, greatly increasing the number of vehicles, traffic congestion, and noise for 2 or 3 months each year.

Public transportation includes electrified streetcars and light rail vehicles (collectively called trams). In 1977, trams carried an average of 621,744 passengers per day over 146.6 km of routes. Bus lines carried 384,794 passengers per day over 522.5 km.[83] The bus lines connect the city of Alexandria with some outlying communities and are, therefore, considerably longer than the tram lines which run exclusively within the city. Another 54 km of bus lines and 62 km of tram lines are planned for development in the next few years.

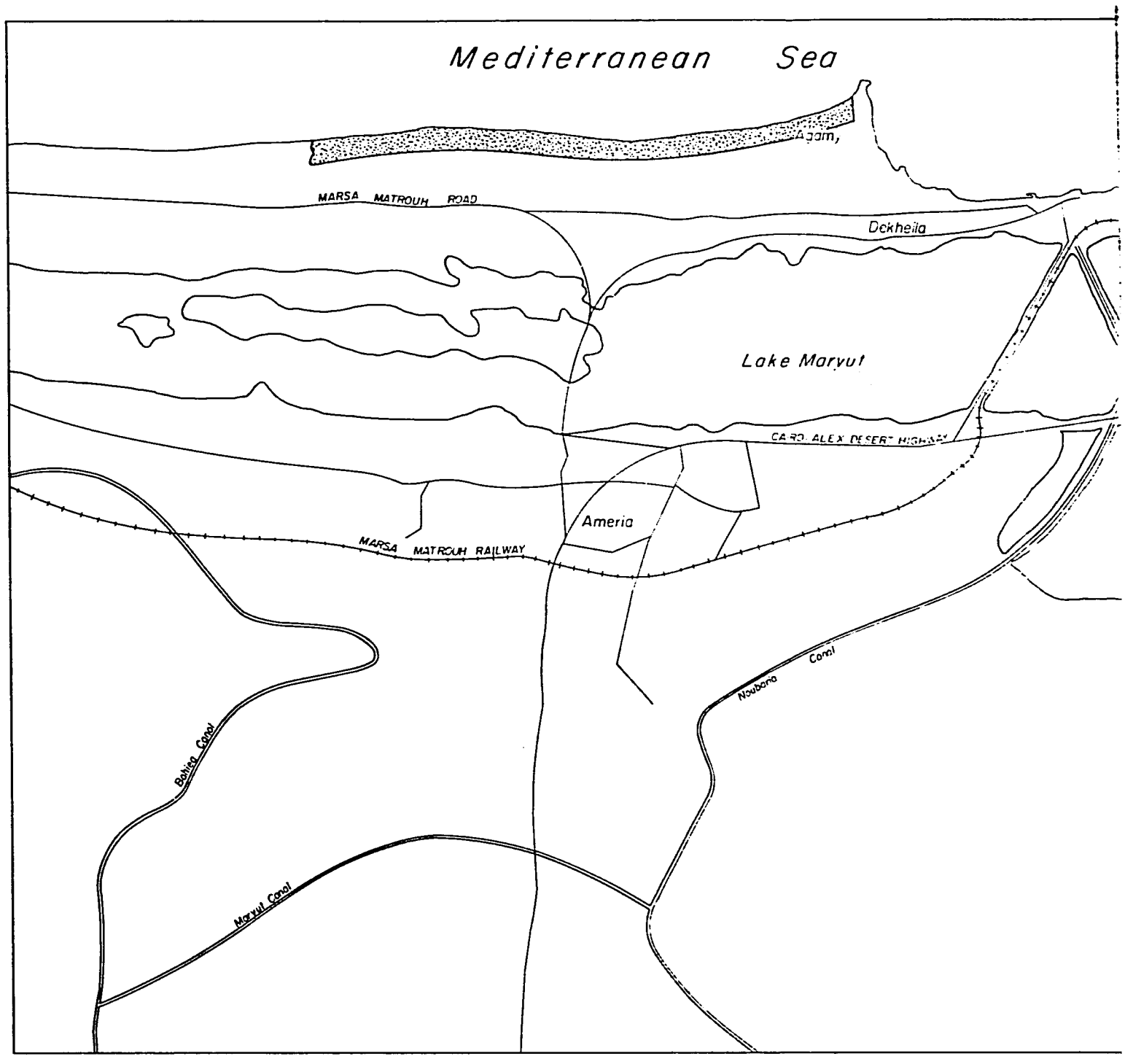
Alexandria is connected to Cairo and the southern parts of Egypt primarily by two highways--the Delta Road and the Desert Highway. The Delta Road runs close to the Nile and through many towns and villages along the way to Cairo; the Desert Highway is located farther to the west and passes through no major population centers between the metropolitan areas of Alexandria and Cairo.

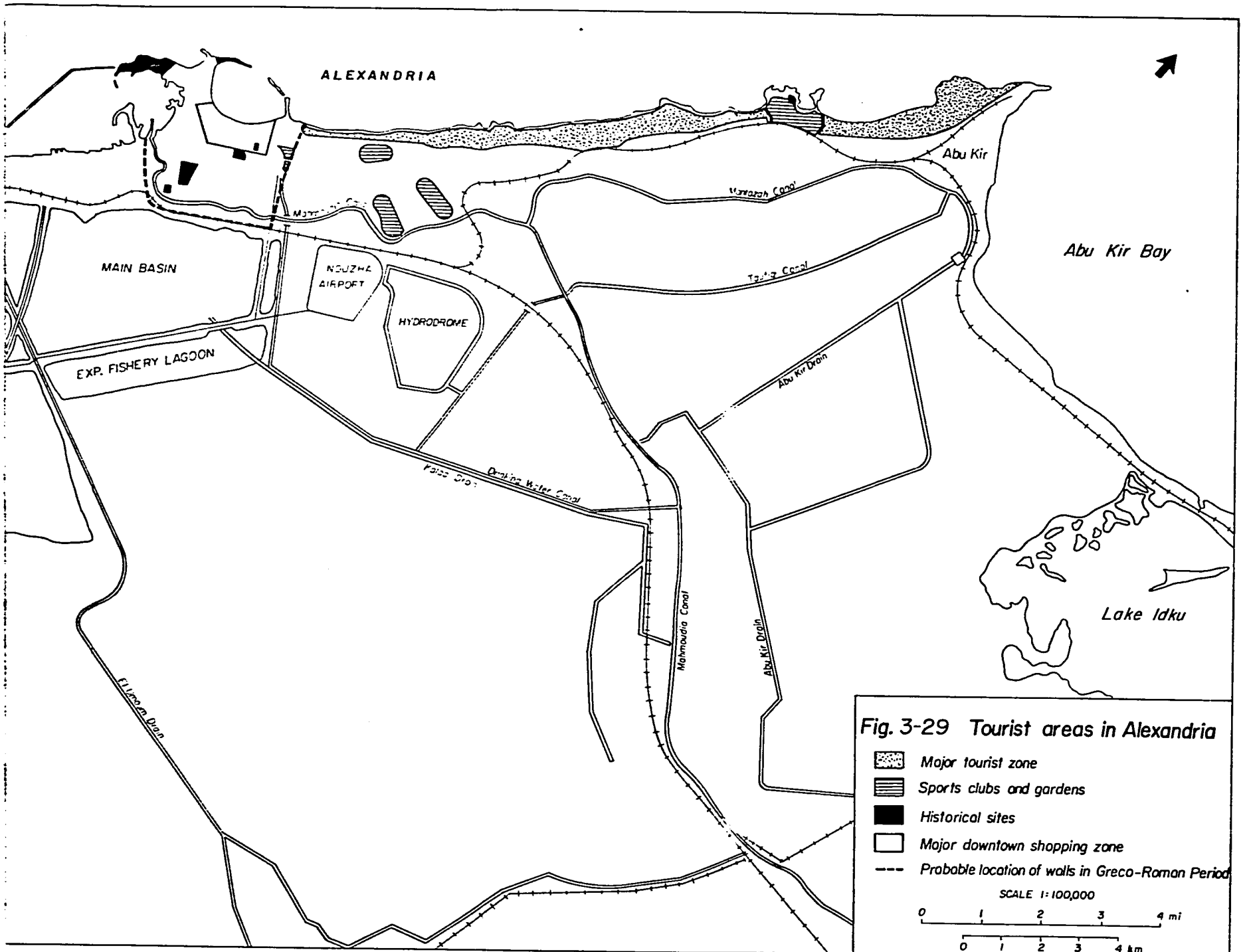
Railroad service is usually very reliable from Alexandria. There are two basic classes: first class, with reclining armchairs, air conditioning, and food service, and second and third classes with no amenities. Passengers from Alexandria can travel by train to nearly every area of the country. Long distance bus routes are also available.

While Alexandria does have an airport, its use is restricted to military and emergency use. Regularly scheduled commercial flights for travel within Egypt were available until a few years ago. There are plans for construction of a major international airport, but it is uncertain if and when they will be initiated.[84]

Being the country's major port, shipping has a major impact on the economy and the transportation system of Alexandria. The current capacity of the port is about 10 million tons per year. The latest Five Year Plan[84] estimates an increase in the port's capacity to 15 million tons by 1980, through an investment of L.E. 68.8 million. By 2000, it is estimated that the port will be able to handle up to 40 million tons per year.[85]

3.D.6.e Recreation. Alexandria's major recreation attractions are its extensive beaches which stretch almost continuously along Alexandria's coastline. Especially during the summer months, Alexandria attracts hundreds of thousands of visitors from the Arab world and from Europe. Egyptians have traditionally sought relief from the intense summer heat in Cairo, and other interior areas, by coming to Alexandria where they can be sure of a pleasant sea breeze and more moderate temperatures.


Mediterranean Sea
Agam,
MARSA MATROUH ROAD
Dekheila
Lake Maryut
CAIRO ALEX DESERT HIGHWAY
Ameria
MARSA MATROUH RAILWAY
Bahira Canal
Maryut Canal
Noubaria Canal


ALEXANDRIA
Abu Kir
Abu Kir Bay
MAIN BASIN
NOUZHA AIRPORT
HYDRODROME
EXP. FISHERY LAGOON
Abu Kir Drain
Mahmoudia Canal
Abu Kir Drain
Lake Idku
Fig. 3-29 Tourist areas in Alexandria
Major tourist zone
Sports clubs and gardens
Historical sites
Major downtown shopping zone
Probable location of walls in Greco-Roman Period
SCALE 1:100,000
0 1 2 3 4 mi
0 1 2 3 4 km

Tourism officials estimate that 1 million vacationers visit Alexandria for approximately 3 weeks during the summer months of June, July, and August.[87] This estimate is based on city water consumption and hotel records; however, little information is available on the large number of visitors who stay with relatives and friends or those who rent apartments exclusively for vacation use.

Most visitors to Alexandria are from Egypt, but an increasing number are from other Arab states. Approximately 70,000 western tourists stop in Alexandria during Mediterranean cruises. Another 100,000 foreigners stay in Alexandria hotels each year while on vacation or on business.[87]

Tourists and hotel residents are believed to have spent nearly L.E. 43 million in Alexandria in 1977. (See Technical Appendix No. 2.) The value of betting in Alexandria's casinos is unknown, but it is believed to be in the millions of pounds each year.

Despite the apparent health hazards to beach visitors (shown in Table 3-10 and discussed in 3.D.2), the future of Alexandria's tourism industry looks favorable. With few other beach resort areas in the country and continued developments at Agamy and points west, it is expected that the number of seasonal visitors to Alexandria and its beaches will double by 2000.

During the cholera outbreak of 1970-1971, it was estimated that tourism was reduced by 250,000 during the summer season.[88] Should the level of wastewater pollution increase with the growing population of the city, there is the possibility of increased health hazards and a declining attractiveness of Alexandria as a resort.

3.D.7 Cultural Resources

3.D.7.a Historical Development. Alexandria was an important center even before its founding by Alexander the Great in 332 BC. The city itself was known as Rakotis as early as 1500 BC. Alexandria became the center of learning for all of the Mediterranean basin, a focus for Hellenic and Semitic scholars as well as scientists. Under the Ptolemies, the great library and research institute museum, reportedly containing half a million volumes, was established. The Old Testament was translated into Greek here. Unfortunately, Alexandria also has been a focus of political disturbance and, in the third century AD, the main museum and library were destroyed in a civil war and an associated library was burned by Christians in 391.

Under Roman jurisdiction, Alexandria was an important political center, forming part of the route to the east. Egypt supplied large amounts of grain and other products to Rome, and Alexandria became an active port-of-call for trading vessels. Caesar and Cleopatra courted in the city. Both the Greeks and Romans built up the city and left their marks.

Under Christian influence, Alexandria became a center of church government and theology. It is believed that St. Mark made his first convert to Christianity in Alexandria in AD 45. Later under Islamic rule, the city lost its importance as Cairo (then called Fustat) was founded, and the Arabs placed a greater importance on land routes for trade. Alexandria did not rise to importance during following times except as an important stop for the spice trade from the Orient. In 1498, the Portuguese found a southern sea route to India, further reducing Alexandria's importance, and, soon after, the Turks conquered Egypt in 1517. By mid-18th century, it was a small, relatively unimportant fishing town.

Under Ottoman Viceroy Muhammed Ali Pasha in the 19th century, Alexandria experienced a rebirth. The viceroy opened the Mahmoudia Canal, built new docks, and encouraged industrial development. In 1882, England began half a century of rule by bombarding Alexandria. Under the British, Alexandria became the summer capital of Egypt, foreign commerce thrived, and industry grew.

3.D.7.b Modern Resources. The city today has only fragments of its history intact. There is the Greco-Roman Museum with a noted antiquities collection. The municipal library has about 70,000 volumes in Arabic and European languages, while the library of the University of Alexandria has 1,200,000 volumes. There are two botanical gardens, the Nouzah Gardens and Antoniadis Park. A sports stadium for 25,000 has served as the site for the Arab Olympic Games. Two sport clubs offer facilities for polo, golf, tennis, handball, and horseracing. At the former royal Montazah Palace is a casino. There are seven movie theaters and the Said Darvish Theater.

Recently, an amphitheater, probably of Roman origin, has been restored. The famous Pompey's Pillar and the remains of great buildings exist in the heart of the city. Some say Alexander the Great is buried in the city but this has never been confirmed.

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CHAPTER 4

FUTURE ENVIRONMENTAL SETTING WITHOUT IMPROVED WASTEWATER FACILITIES

4.A General

For environmental engineering projects in developing countries, the main concern for the future is the continued worsening of public health conditions, particularly in rapidly urbanizing areas such as Alexandria. The future environmental setting without improved wastewater facilities establishes the critical public health justification for the project, and also reflects the ecological damage to Lake Maryut and the Mediterranean of failure to improve wastewater management in Alexandria. For the purposes of this report, this chapter represents the environmental impacts of the "no-action" alternative.

Table 4-1 summarizes those elements of the existing environmental setting which could be expected to change without improved wastewater facilities. It is important to distinguish between two types of changes which would occur without the implementation of a project: those changes which would occur whether or not a project is implemented and those which are a result of the decision to take no action. As discussed below, this is particularly important when considering the interrelationships between population growth, economic growth, and deteriorating public health, if wastewater facilities are not improved.

4.B Enumeration of Elements Which Are Not Expected to Change

Without improved wastewater facilities, the physical characteristics of location, terrestrial and marine topography, geology, soils, climate, and groundwater in the Alexandria region are not expected to change significantly before the year 2000. Land reclamation activities would probably alter some of the soils and groundwater levels in parts of the governorate, but such changes do not significantly affect the environmental

TABLE 4-1.

CHANGES IN THE ENVIRONMENT WITHOUT IMPROVED WASTEWATER FACILITIES

Environmental Characteristic	Likely to Change	Unlikely to Change	Directly Affected by Project
Physical Elements			
Location		X	
Topography		X	
Geology and soils		X	
Climate and meteorology		X	
Marine resources		X	X
Freshwater resources	X		X
Groundwater resources		X	
Biological Elements			
Terrestrial ecology		X	
Marine ecology	X		X
Freshwater ecology	X		X
Human Elements			
Population and housing	X		X
Public health	X		X
Economy	X		
Land use	X		
Governmental organization		X	
Community facilities	X		X
Cultural resources		X	

assessment because they could occur with or without the project. Terrestrial ecology is also unlikely to change in response to the absence of improved wastewater facilities.

The oceanographic situation is unlikely to change. The waters in general would remain warm, low in nutrients, and well oxygenated. Current flow would be only moderate, generally along the coast, but sometimes with a weak onshore component. Because of the low nutrients, biological production would be low and so would the numbers of plants and animals present at any time. There is no reason over a period of 25 years to expect any great change in the fauna, although there is the continued likelihood of increases in the relative numbers of Red Sea species. Siganidae (rabbit fishes), for example, appear to be rather recent immigrants but are beginning to figure in commercial landings. The basic regime in the sea, however, would be the same in the year 2000 as the current one described in Chapter 3.

Turning to human elements of the existing environment, Table 4-1 indicates that almost all are likely to change by the year 2000, regardless of the implementation of a wastewater master plan for the city. There is no evidence that the governmental organization within Alexandria will alter over the next 20 years, and the city's rich heritage of cultural resources is unlikely to change dramatically over the life of the project.

4.C Discussion of Elements Which Might be Expected to Change

The human and biological elements of the existing environmental setting are expected to change drastically by the year 2000, if wastewater facilities are not improved. The extremely undesirable public health conditions described in Chapter 3 would deteriorate even further if the "no-action" alternative were adopted, and the ecological impacts on both Lake Maryut and Alexandria fisheries would be severe. The general trends in population growth, economics, and land use which will probably occur regardless of Alexandria's wastewater management practice will be discussed first, followed by a description of the impacts of these changes on Alexandria's public health and the ecological balance of Lake Maryut and the Mediterranean.

By 2000, the population of Alexandria is expected to reach 4,663,000, nearly double the current number of inhabitants.[1] One of the direct impacts of this increase would be an increased demand on the water supply and wastewater system. Also associated directly with the population growth would be an increasing demand for housing and land, public transportation, recreational and other facilities, and for a government able to develop, coordinate, and administer programs to meet these needs. The interrelationships of these problems are shown most clearly by the future public health hazards of overflowing sewers, if the Egyptian government fails to implement an effective solid waste management program.

By 2000, an estimated 8,300 ha of land in Alexandria may be devoted to industrial development, slightly more than 80 percent of which would be located in Dekheila and Ameria. Currently, only 932 ha are in industrial use (see Table 3-31). Major new projects are outlined in Table 4-2, and future projects in Dekheila are shown in Table 4-3.

Plans exist for other forms of development as shown on Fig. 4-1. Ameria is expected to increase to at least 500,000 inhabitants from an estimated 45,000 in 1976,[2] and other developments are scheduled along the coast further to the west. Between 1976 and 2000, Ameria's population is expected to increase about ten times, Abu Kir's over eight times, Mex-Dekheila's nearly three times, and the area south of Maamoura would change from an area of scattered agricultural population to the proposed Sadat City housing 500,000 persons.[3] These areas are all outside the limits of the existing wastewater collection system. (See Tech. App. No. 3).

Alexandria's economy, like its population, will grow to some extent regardless of the implementation of effective wastewater management. The industrial projects described in Tables 4-2 and 4-3 will not be stopped by inadequate municipal wastewater facilities, although they may be slowed by the cost of individual wastewater treatment and disposal facilities which could be required under existing laws. (Effective enforcement of such laws, however, would constitute a violation of the "no-action" assumption.) The current Five-Year Plan developed by the Ministry of Planning proposes investments of over L.E. 118 million in port and shipping facilities alone and foreign investment in the Dekheila sponge iron plant is estimated at L.E. 50 million.[4,5] West Germany has pledged 102 million marks for the Abu Kir fertilizer plant and another 24 million marks for a floating dock project in Alexandria.[5] Vigorous economic development of this nature ensures that employment opportunity and resultant immigration from rural areas will continue to grow with or without improved wastewater facilities.

Considering the inevitable population growth which will occur in Alexandria, the environmental impact of the "no-action" alternative is quite simply a public health nightmare. The conditions described in Chapter 3 will worsen as population densities increase and currently inadequate facilities are taxed even further. There is clearly some interaction between deteriorating health conditions and decreased population growth, for it is inconceivable that the proposed new cities of Ameria and Sadat City could each contain half a million persons by the year 2000 without some form of wastewater management. If current population estimates (which implicitly assume adequate wastewater management) were correct, the fraction of Alexandria's population living outside currently sewered areas would increase from 15 percent in 1977 to about 40 percent (1.8 million persons) in the year 2000;[6] under the "no-action" hypothesis, this fraction might be assumed to endure the kinds of conditions currently found in the unsewered portions of the city. While the actual population growth without improved sewerage is uncertain, the unparalleled opportunity for waterborne disease epidemics is not. Alexandria would be vulnerable to frequent outbreaks of cholera, typhoid, and hepatitis, all

TABLE 4-2.

MAJOR NEW PROJECTS

Project	Type of Project	Estimated Completion Date	Expected Direct Increase in Employment
Alexandria port	Expansion of port capacity from 10 million tons/year to 15 million tons/year	1980	1,700
Dekheila port and industrial development	6-million ton port capacity for general cargo and dry bulk	1985 (first phase)	1,500 to 2,000
	4 million tons/year for sponge iron facility		500
	30-million ton capacity, four additional industrial projects	1985 to 2000	4,000 to 5,000
Ameria free zone	600-ha industrial park	June 1977 (first phase)	Short-run employment uncertain
	Industrial park	2000	54,000 in the year 2000, assuming 90 employees/ha
Petrochemicals	Aromatics facility	1980 to 1985	2,000
	Possible Olefin facility		
Abu Kir fertilizer plant	0.5 million tons/year	1978	2,000

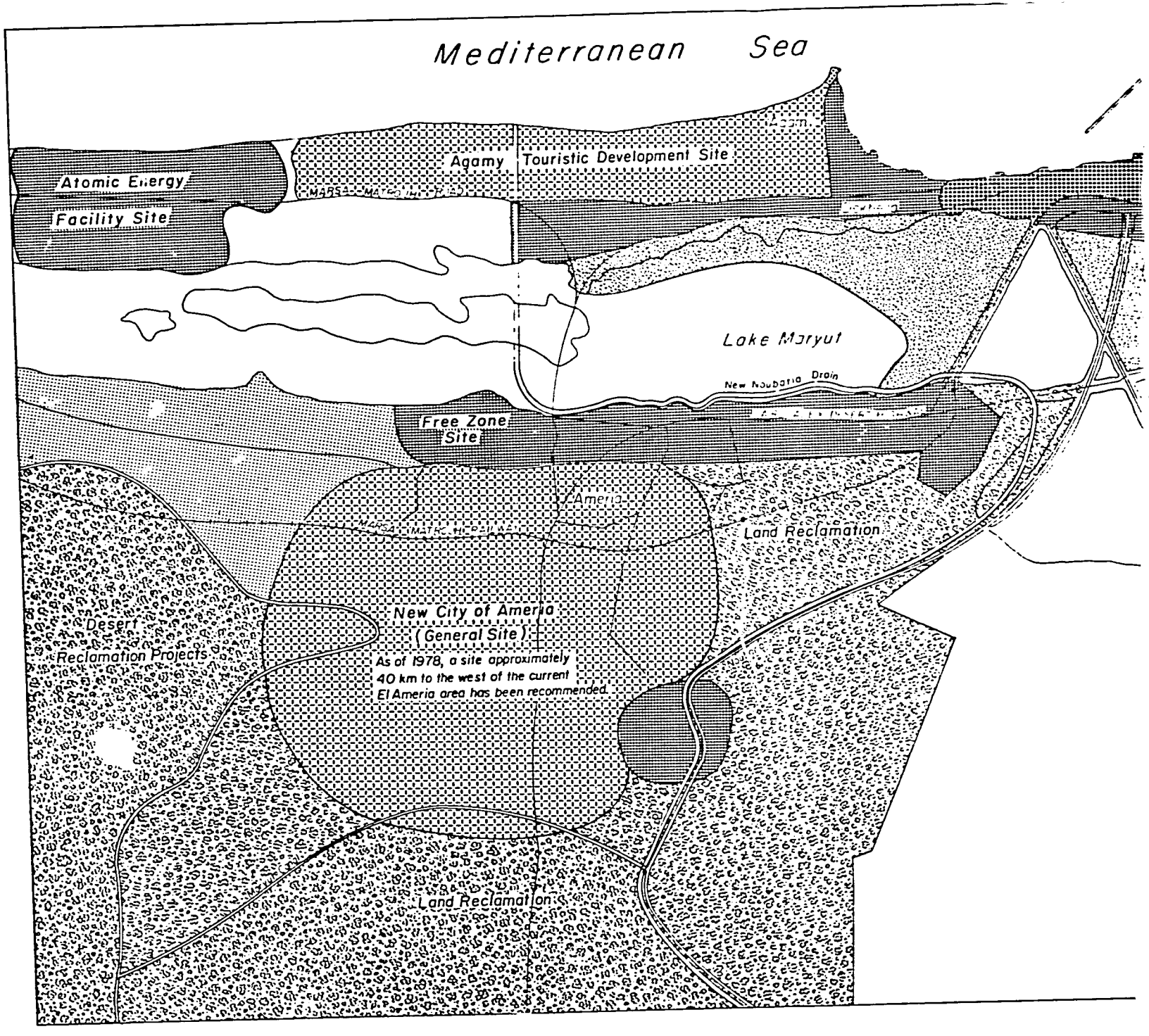
Source: Alexandria Waterworks Development Programs, August 1977.[3]

TABLE 4-3.

FUTURE PROJECTS IN DEKHEILA

	Project	Year	Employment
1.	Dekheila port	1985	1,500 to 2,000
2.	Four additional free zone industries	1985 to 1990	4,000 to 5,000
3.	Sponge iron	1985	500
4.	Iron and steel complex integrated with sponge iron facility	1985 to 1990	12,000
5.	Possible oil refinery associated with Sumed pipeline terminal	1980 to 1985	1,500 to 2,000
6.	Possible fertilizer plant associated with Sumed pipeline terminal	1980 to 1985	2,000

Source: Alexandria Waterworks Development Programs, August 1977.[3]


Mediterranean Sea
Agamy
Touristic Development Site
Atomic Energy
Facility Site
Lake Maryut
New Noubaria Drain
Free Zone
Site
Ameria
Land Reclamation
New City of Ameria
(General Site)
As of 1978, a site approximately
40 km to the west of the current
El Ameria area has been recommended.
Desert
Reclamation Projects
Land Reclamation

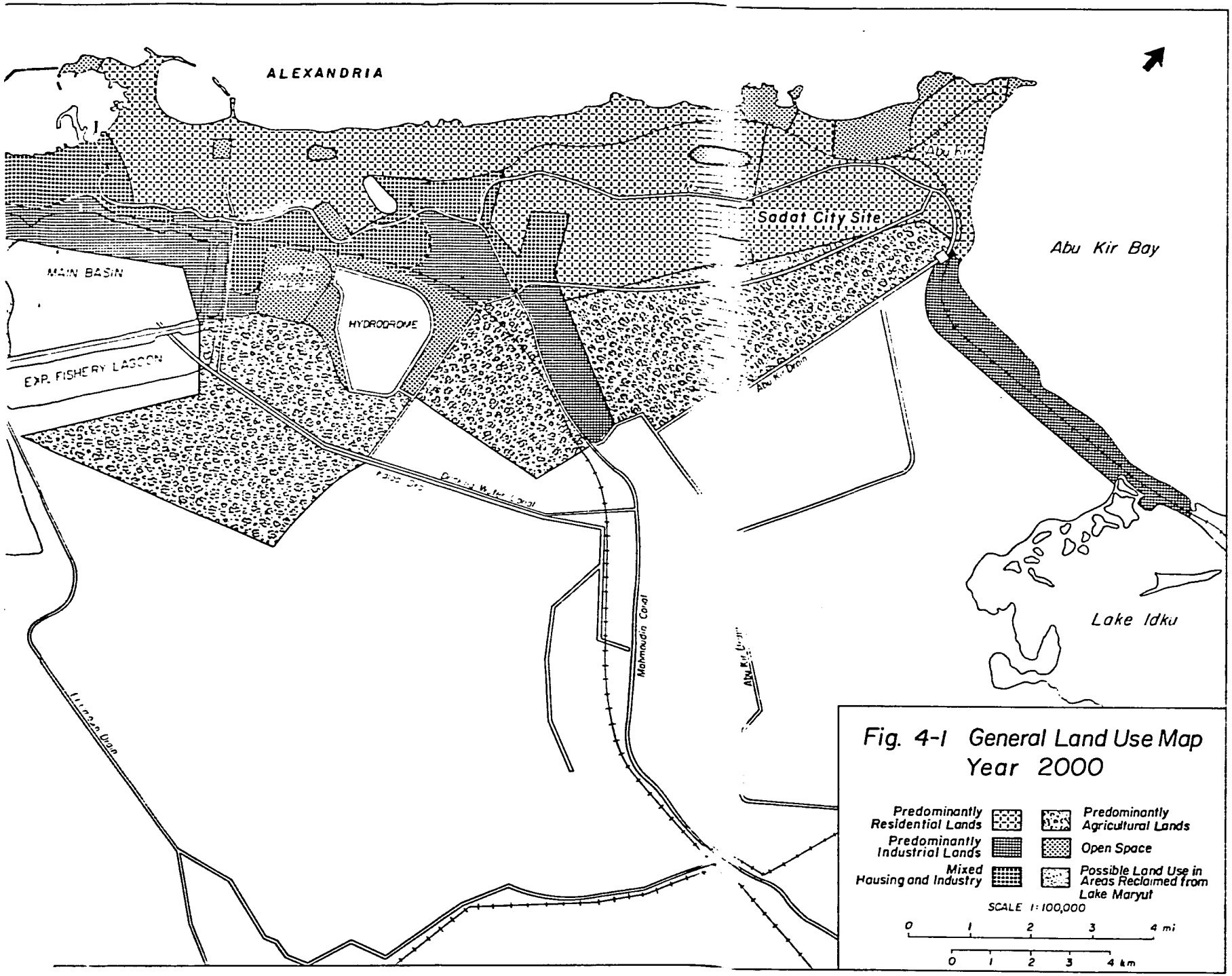


Fig. 4-1 General Land Use Map Year 2000

of which have attacked the city's people in recent years. Given Alexandria's role as a trade and travel center of Egypt and the Mediterranean, the consequences of such epidemics would spread far beyond the boundaries of the governorate. The regular passage of summer tourists provides another dangerous means of disease transmission, although one which might decrease in importance as bathing water quality deteriorated.

Pollution of the beaches of Alexandria was considered a serious problem more than 20 years ago. Since then, the problem has increased; what were intermittent flows of wastewater from storm drains then, now appear to be almost constant at the beaches. Studies by the High Institute of Public Health indicate coliform contamination of all beaches in the city, with concentrations ranging up to 1.5×10^6/100 ml. Even more significant is a recent study done for the U.S. Environmental Protection Agency concerning health problems associated with bathing at Alexandria's beaches. The incidence of vomiting or diarrhea, red eye, fever, skin lesions, ear infection, infections of the upper respiratory tract, and colics averaged 11.0 to 13.5 percent in bathers, and 1.5 to 5.0 percent in nonbathers. The rates are very high, and when one considers there is, in the local population, some degree of resistance resulting from chronic exposure, the pool of disease must be considered enormous. The doubling of the population, and the doubling of the wastewater discharge across the beaches, only means that this will increase. Furthermore, the study concerned itself only with bacterial diseases. Viruses are an even more serious matter. The rate of viral disease and potential pool in the population must be comparable to that derived from a study of the bacteria, but there are no pertinent data. Adequate data with which to assess possible health implications of uncontrolled toxic industrial waste discharges to the Mediterranean are also not currently available. The reader is referred to Chapter 5 for a more detailed discussion of toxic hazards. (Also, see Tech. App. No. 5A, 5B and 6).

Alexandria is now a very important seaside resort, and projections for the year 2000 are that tourism on this account will grow. But with the chances of becoming seriously ill by going in the water better than 1 in 10, this seems unlikely. Again, it is very difficult to cite firm numbers, but surely there is a point beyond which people will no longer take a chance. When this happens, the beaches at Alexandria will lose their appeal, and the tourist trade, considered an important part of the economy, will dwindle. Failure to do anything about the wastewater service will only hasten the day.

While the most important changes in the environment under the "no-action" hypothesis are the increased public health problems, the ecological balance of Lake Maryut will also change markedly, both with or without improved public wastewater facilities. Lake Maryut will in all probability be smaller in extent than it is today. This will primarily result from active programs of land reclamation, the major force in halving the area of the lake during this century. Excluding the highly saline

western basin, the remaining semi-isolated basins of the lake now total some 5,000 ha in area. The area of the Main Basin and the triangular section to the west of the Umoum Drain is about 2,220 ha, and of this, it is planned shortly to reclaim about 500 ha for industrial development. Even if this is the only reclamation to be done by the year 2000, and the real likelihood is that there would in fact be more, it represents a considerable reduction in lake area. The current area of the Main Basin and the experimental fishery lagoon, into which wastewaters are now discharged, is 2,670 ha. The planned industrial reclamation would reduce this by more than 20 percent.

Lake Maryut is a highly eutrophied region now, and, in addition, receives from wastewater discharges as much as 3,910 mg/l of total solids. Furthermore, its depth nowhere exceeds 1 m. In north temperate regions, such a lake would quickly fill. Rooted plants would encroach from the side, and the lake would soon be a bog. This pattern of succession, derived from studies in northern Europe and North America, may not be applicable to Lake Maryut. The lake seems to have had a rather stable configuration for long periods in its past,[12] and the rather similar Lake Idku shows no change in over 100 years.[13] The Lake of Tunis, another shallow lake along the Mediterranean Coast that receives the domestic wastewater discharge from a large city, is not mentioned as filling, although aspects of the pollution there have been discussed.[14] In the Lake of Tunis, serpulid worms have built shallow reefs here and there. The dominant serpulid, Merceriella enigmatica, also occurs in Lake Maryut; but reefs have not been reported. What the processes are that seem to keep these shallow subtropical lakes open is not known, but the rate of filling from natural and seminatural causes would appear to be slow enough that there would still be open water in Lake Maryut in the year 2000.

The question of the life expectancy for Lake Maryut under the existing environmental conditions is, nevertheless, an important issue. From the past history of the lake, which has varied from a much larger lake in classical times, to a salty swamp and finally to its current reduced state of a catch basin for agricultural and wastewater drains, it might be anticipated that its evolution will continue. As has been previously pointed out, the area of the entire Lake Maryut has diminished from about 20,000 ha in 1900 to 8,000 ha in 1960 to 6,000 ha currently. This diminution in size since the turn of the century has been mainly because of land reclamation and filling for agricultural and other purposes.

Our concern here is with the Main Basin (or Lake Proper) into which the wastewater drains empty. We are interested in ascertaining how long it would take to completely fill the lake with sediment. The area of the lake proper is about 2,000 ha, with an average depth of 1 m or a total volume of 2×10^7 m^3. The suspended sediment loads currently entering the lake proper have been summarized in Table 4-4. No values have been included for the Umoum Drain contribution. The principle suspended sediment loads are from the two wastewater discharges of Industries' Pump Station and the Gheit El Enab Drain. Although the flow in the Kalaa

TABLE 4-4.

EXISTING WASTELOAD ESTIMATES FOR LAKE MARYUT

Source	Flow-Ml/day	Suspended Sediment-kg/day
Kalaa Drain	500	42,500
Industries' Pump Station	39	43,100
Gheit El Enab Drain	47	30,100
Gabbary Drain	13	5,400
Pump Station No. 3 West	10	5,000
Total		126,100

Drain is considerably larger than that for either of the above sources, much of its suspended sediment load has been removed through the East Treatment Plant and the extensive drain system up to its outfall into the lake. Saad[15] has discussed some of the characteristics of the organic sludge deposits in the lake proper. They have high porosities in excess of 90 percent. The solid material fraction of the sedimentary deposits can be determined from these data to vary from 0.17 gm/cm^3 to 0.43 gm/cm^3.

Assuming that all the suspended sediment of the wasteloads is deposited in the lake and none is generated back into the water column, we can calculate a value of ($170\ kg/m^3 \times 2 \times 10^7\ m^3$) / ($126 \times 10^3$ kg/day x 365 days/year) = 74 years for the smaller density value and 187 years for the larger density value. Considering the various approximations in this simplified calculation, it would seem within reason, then, to consider that under existing conditions, the current Main Basin has a life expectancy on the order of 100 years.

A doubling of the discharge to the lake, and, at the same time, a reduction of at least 20 percent of its volume, means that the flushing rate would be increased by about 2.5 times. An increased flushing rate decreases sedimentation rate, thereby slowing the filling of the lake from this source. On the other hand, the increase in the discharge means that the nutrient load would be considerably greater than it is now. The rate, therefore, of primary production, already high, must increase; and organic sedimentation could be augmented. A greater density of particulate matter (in the sediment load) and of phytoplankton cells will increase the turbidity. Primary production (photosynthesis) will then only be possible in an increasingly shallow stratum of the lake water; below the level where sufficient light can penetrate, sinking plant cells will use up oxygen. Phytoplankton respiration, and their eventual death and decomposition, can contribute to an increased oxygen deficit. There are currently significant portions of Lake Maryut where oxygen is low, and anoxia has been reported.[16] Under anoxic conditions, the fishes and other animals will die.

The actual conditions in the lake in the year 2000 would then depend on the balance between flushing rate, nutrient levels, and the rate of phytoplankton growth. With a projected input of 500 Ml/day into the Kalaa Drain, and there mixed with about 350 Ml/day of agricultural drainage, total discharge to the Main Basin would be about 850 Ml/day. With a reduced volume of about $1.6 \times 10^7\ m^3$, residence time in the lake would be about 22 days. This is not much different from the residence time of approximately 31 days currently observed. But the BOD load would be much higher than now, with a mean of more than 250 metric tons/day. At this level, photosynthetic action could not keep pace, and there is a very good chance that the entire lake would go anoxic. Even if it did not, because of strong wind mixing, for example, oxygen levels in the water would always be much lower in the year 2000 than they are today.

Low oxygen limits the distribution and even survival of fish in the lake. Tilapia, the dominant fish there, and the one on which the only possible fishery is based, is extremely tolerant of low oxygen, but only up to a point. Even today, most of the fishery in the Main Basin is concentrated in about its western third, away from the low-oxygen regions associated with the wastewater drains. Were this reduced by 50 percent, and in combination with the reduction resulting from reclamation, probably no more than 300 ha would remain as a useful fishing area. At a rate of production of 1,000 kg/ha, the annual catch from this region would then be 300 metric tons, a figure one to two orders of magnitude less than the catch for the whole lake today. Remembering the poor quality of the fishery data (Chapter 3), this calculation must be approached with much caution; nonetheless, it would seem that the year 2000 would find the fish catch from Lake Maryut considerably diminished.

There is one other aspect of the problem which emerges from this exercise. Increased flushing rate, high production moved towards the outlet, and high BOD mean that the effluent from the Mex Canal to the sea will have a greater potential for polluting that area than it does today. Estimating the degree to which this would be true is difficult, but it does remain as a very real possibility.

The offshore marine fishery, trawled for the most part at depths of 40 to 50 m, currently lies outside areas polluted by Alexandria. With no change in the wastewater system, the same would be true in the year 2000. Nonetheless, conditions in the city could have a profound effect on this region. Fresh fish is in high demand in Alexandria today, and presumably would also be in the year 2000. But with a doubling of the population, and with a decline in the freshwater fishery as described above, pressure on the offshore fishery would greatly increase. But, as indicated in Chapter 3, the catch-per-unit effort declined from 40 kg/hour in the early 1960s to about 7 kg/hour in 1970, and the predominance of young fishes in the market is already indicative of severe overexploitation. Egyptian fishermen are, however, not discouraged by the prospects now and probably would not be, right up to the point when the offshore fisheries would collapse. Again, the data are imperfect, but it is probably safe to say that the offshore fisheries could not withstand the increased pressure on them that the human population increase and the decline of the lake would bring by the year 2000.

Both mullet and shrimp spend a portion of their lives in fresh water and a portion in the sea. For these two important species, access to Lake Idku through the channel at Maadia is a necessary part of their life histories. Today, the effluent plume from Tabia, containing both domestic and industrial wastes, flows across the Maadia channel, degrading it by contamination of the water and through siltation which is tending to close the passage. With a doubling of the wastewater discharge from Tabia, and with increased fishing pressure on these easily exploited species, both will probably have declined to insignificant levels by the year 2000.

One impact on future Mediterranean water quality that is particularly hard to assess is that of uncontrolled industrial wastewater discharge under the "no-action" alternative. Currently available data[1,17] are insufficient to allow an accurate estimate of future toxic waste loads, but the probable direct discharge to Dekheila Bay of 4 to 5 metric tons a year of mercury from the Misr Chemical Industries plant in Alexandria's Mex-Dekheila region is already cause for alarm. The unpredictable growth of industries and their wastes in Alexandria over the next 20 years might have far-reaching impacts on the aquatic life of the Mediterranean, if no effective pollution control is implemented. These problems could become a growing embarrassment for both the city and the Egyptian nation in light of the growing international concern over Mediterranean pollution.

In summary, both the social and ecological environment of Alexandria would be profoundly damaged by the failure to improve wastewater facilities. The precise extent of these changes is difficult to assess because of their enormity, but the deterioration of the Alexandria environment without improved wastewater facilities clearly explains the need for a project.

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[4]The Five-Year Plan: 1978-1982, Volume I, The General Strategy for Economic and Social Development, Ministry of Planning, A.R.E., August 1977.

[5]1975 Yearbook (Federation of Egyptian Industries).

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[7]Lackany, A., "The Sewage Pollution of the Sand and Air of the Alexandria Bathing Beaches," Jour. Egypt. Med. Assn., 39, 1956, pp. 537-540.

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[9]Fig. I-6 and I-7, Special Report No. 1, (Oceanographic Studies), Alexandria Wastewater Facilities Development Program, Camp Dresser & McKee, International Inc., 2 February 1977.

[10]Hakin, K.E., Study of Microbial Indicators to Health Effects at Alexandria Bathing Beaches, High Institute of Public Health, Alexandria University, Report Prepared for Environmental Protection Agency, Washington, 1977.

[11]Smit, J., "What Future for Alexandria," Geoforum, 8, 1977, pp. 135-140.

[12]El Wakeel, S.K., and Wahby, S.D., "Texture and Chemistry of Lake Maryut Sediments," Arch. Hydrobiol., 67, 1970, pp. 368-395.

[13]Samaan, A.A., "Primary Production of Lake Edku," Bull. Inst. Oceanogr. Fish. A.R.E., 4, 1974, pp. 259-317.

[14]Stirn, J., "Modifications of Some Mediterranean Communities Due to Marine Pollution," Thalassia Jugoslavica, 7, 1971, pp. 401-413.

[15]Saad, M.A.S., "Effect of Pollution on the Sediments of Lake Maryut, Egypt," Rapport Com. Int. Mer Med., 21, 1972, pp. 125-127.

References (continued)

[16]Saad, H.H., Ezzat, A., and Shabana, M.B., "Effect of Pollution on the Blood Characteristics of Tilapia zilli," Water Air and Soil Pollution, 2, 1973, pp. 171-179.

[17]Sketch of the Main Sources of Pollution from the Alexandria Industrial Area, Report prepared by A. Margola, Centrol Antinquinamento, Brescia, for United National Industrial Organization, United Nations Environment Program, Geneva, 19 April 1977.

CHAPTER 5

DESCRIPTION OF ALTERNATIVE WASTEWATER MASTER PLANS

5.A Alternative Considerations

5.A.1 General

Existing environmental conditions in Alexandria, described in the previous chapters, indicate many needs for improvement. Problems with wastewater collection, treatment and disposal systems, water supply treatment and distribution systems, solid waste disposal, air pollution control, communication, transportation, recreation, housing, education, and medical facilities all require correction to prevent further deterioration of the standard of living. While these and other problems need attention, the scope of the wastewater Master Plan is limited to those alternatives which provide adequate wastewater collection, treatment, and disposal facilities for Alexandria through the year 2000. These alternatives, their costs, and noneconomic considerations, as addressed in the Master Plan report, are discussed in detail in this chapter.

5.A.2 Disposal Alternatives

The objective of a wastewater facility system is to convey wastewater away from its source, provide adequate treatment, and dispose of the effluent, while minimizing adverse environmental impacts. In Alexandria, there are four fundamentally different alternatives for ultimate wastewater disposal. These include:

1. disposal to the Mediterranean through sea outfalls or canals and/or drains
2. disposal to Lake Maryut
3. disposal to the land for crop irrigation
4. disposal to evaporation ponds.

Theoretically, any one of these disposal alternatives or some combination of two or more can be considered in determining the most technically feasible and environmentally compatible Master Plan. However, disposal alternatives were not the only planning considerations. Several treatment, collection, and consolidation alternatives were also evaluated.

5.A.3 Treatment Alternatives

Treatment process alternatives considered in the Master Plan report included preliminary, primary, and secondary treatment and anaerobic-aerobic lagoons. Preliminary treatment facilities include flow measuring, mechanically or manually cleaned bar screens to remove coarse solids, grit removal facilities, and flotation units to remove oil and grease. Primary treatment includes preliminary treatment facilities followed by primary sedimentation basins to remove suspended solids. Optional chlorination facilities can be added after the sedimentation process for disinfection. Secondary treatment consists of primary treatment plus a biological oxidation process followed by secondary sedimentation basins. Prior to effluent disposal, chlorination facilities can again be added for disinfection. Anaerobic-aerobic lagoons combine sedimentation and biological oxidation in the same process. However, lagoons do not use mechanical equipment and require considerably more land to achieve an effluent quality equivalent to secondary treatment. Again, chlorination is a process option preceding disposal.

5.A.4 Industrial Wastewater Management Alternatives

About 50 percent of the Master Plan's design wastewater flow for the year 2000 is expected to be discharged by industry. (The design flow does not include uncontaminated flows such as cooling waters which, within certain thermal restrictions, can be discharged to the nearest appropriate surface drain or watercourse.) Of the contaminated industrial wastes included in the Master Plan design flows, approximately 70 percent cannot be accepted in conventional wastewater collection, treatment and/or disposal facilities without pretreatment because of any or all of the following characteristics:

(1) unusually high concentrations of suspended solids or grease which could clog the sewers,

(2) unusually corrosive waste constituents which could damage the sewers and/or pumping plant of the collection system,

(3) unacceptable concentrations of toxic materials which can cause severe and irreversible damage to the receiving environment if not treated prior to discharge by conventional means. These toxic wastes could include such materials as arsenic, cyanide, certain dyes, pesticides, conditioners, herbicides, oils, and certain synthetic organic chemicals.

The Wastewater Master Plan addressed two options for the control of contaminated industrial wastes. One alternative was the collection of the unusually strong wastes described above in a separate system for conveyance to an evaporation pond, while the remaining industrial wastes would be discharged to the municipal system along with the city's domestic wastes. The second alternative considered was acceptance of all industrial wastewater by the municipal system, but only after such pretreatment by industry as would be necessary to render it comparable in quality to domestic wastewater. Existing data on Alexandria's industrial wastewater, cost estimates for the separate collection alternative, and a more detailed presentation of the Master Plan's assessment of the alternatives are included in Sections 5.C.2 and Technical Appendix No. 5.

5.A.5 Sewer Service Areas

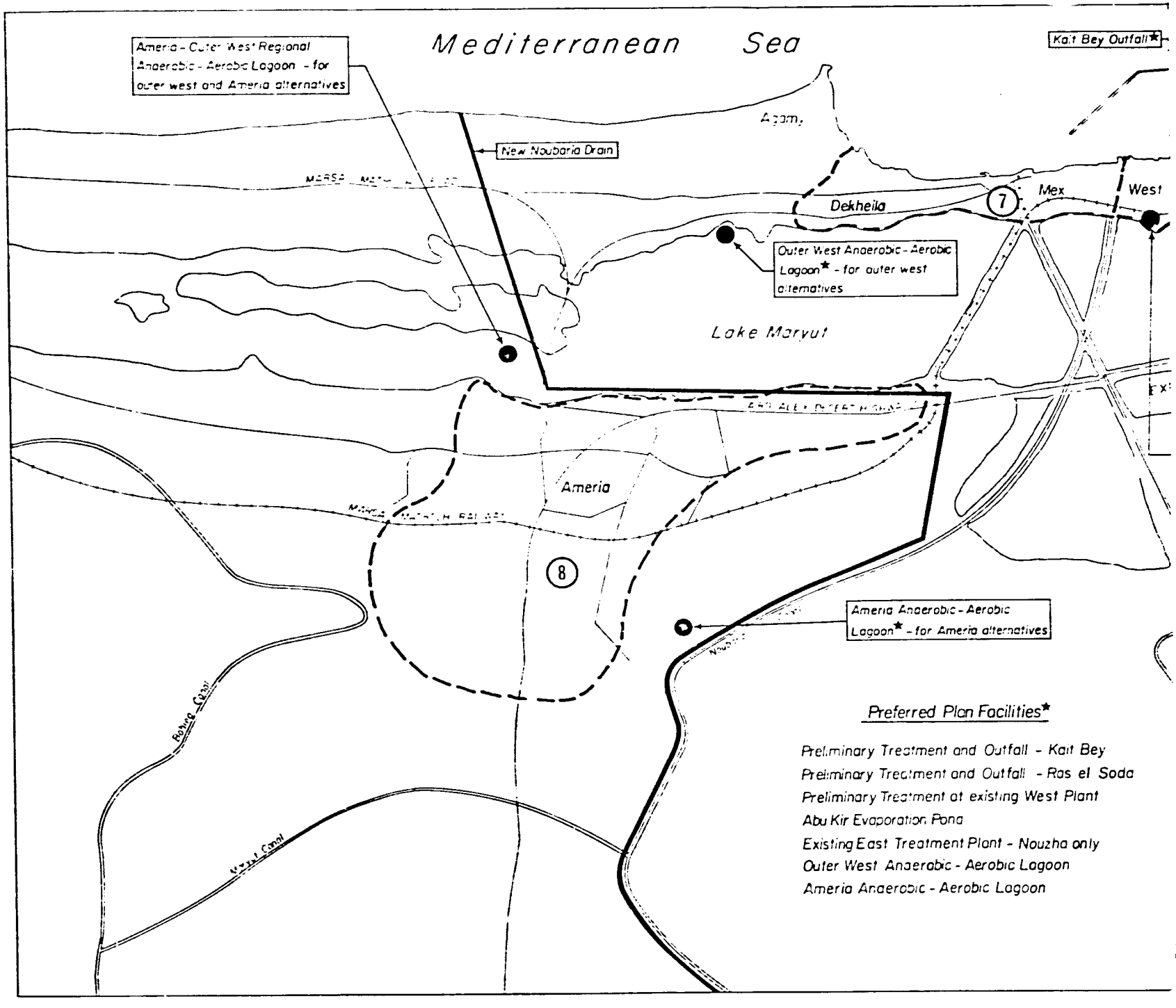
Before discussing consolidation alternatives, a brief review of the sewer service areas is appropriate. The governorate of Alexandria had been divided into ten sewer service areas which were consolidated into eight sewer service planning districts in the Master Plan report. Fig. 5-1 shows the location of these areas and the new planning districts. From east to west, they are:

- -Abu Kir
- -Outer East (Sadat City, Ras el Soda, Siouf Keblia)
- -Inner East (East Zone)
- -Nouzha
- -Central
- -Inner West (West Zone)
- -Outer West (Mex-Dekheila)
- -Ameria

Only three areas, Inner East, Central, and Inner West, are sewered. The remaining areas, expected to have complete sewer service by the year 2000, should contain about 37 percent of the city's population and generate 50 percent of the average wastewater flow. Population and flow estimates for each of these areas are shown in Table 5-1.

5.A.6 Consolidation Alternatives

Besides collection, treatment, and disposal alternatives, several planning district consolidation alternatives are possible for the planning areas mentioned above. The Master Plan report considered no consolidation, total consolidation, and partial consolidation. No consolidation would require eight separate treatment and disposal facilities, while total consolidation would reduce these to a single regional system. Partial consolidation options involving eight service areas are numerous.


Mediterranean Sea
Ameria - Outer West Regional Anaerobic - Aerobic Lagoon - for outer west and Ameria alternatives
Kait Bey Outfall★
New Noubaria Drain
Agami
Dekheila
7
Mex
West
Outer West Anaerobic - Aerobic Lagoon★ - for outer west alternatives
Lake Maryut
Ameria
8
Ameria Anaerobic - Aerobic Lagoon★ - for Ameria alternatives
Rahmania Canal
Mahmoudia Canal
Preferred Plan Facilities★
Preliminary Treatment and Outfall - Kait Bey
Preliminary Treatment and Outfall - Ras el Soda
Preliminary Treatment at existing West Plant
Abu Kir Evaporation Pond
Existing East Treatment Plant - Nouzha only
Outer West Anaerobic - Aerobic Lagoon
Ameria Anaerobic - Aerobic Lagoon

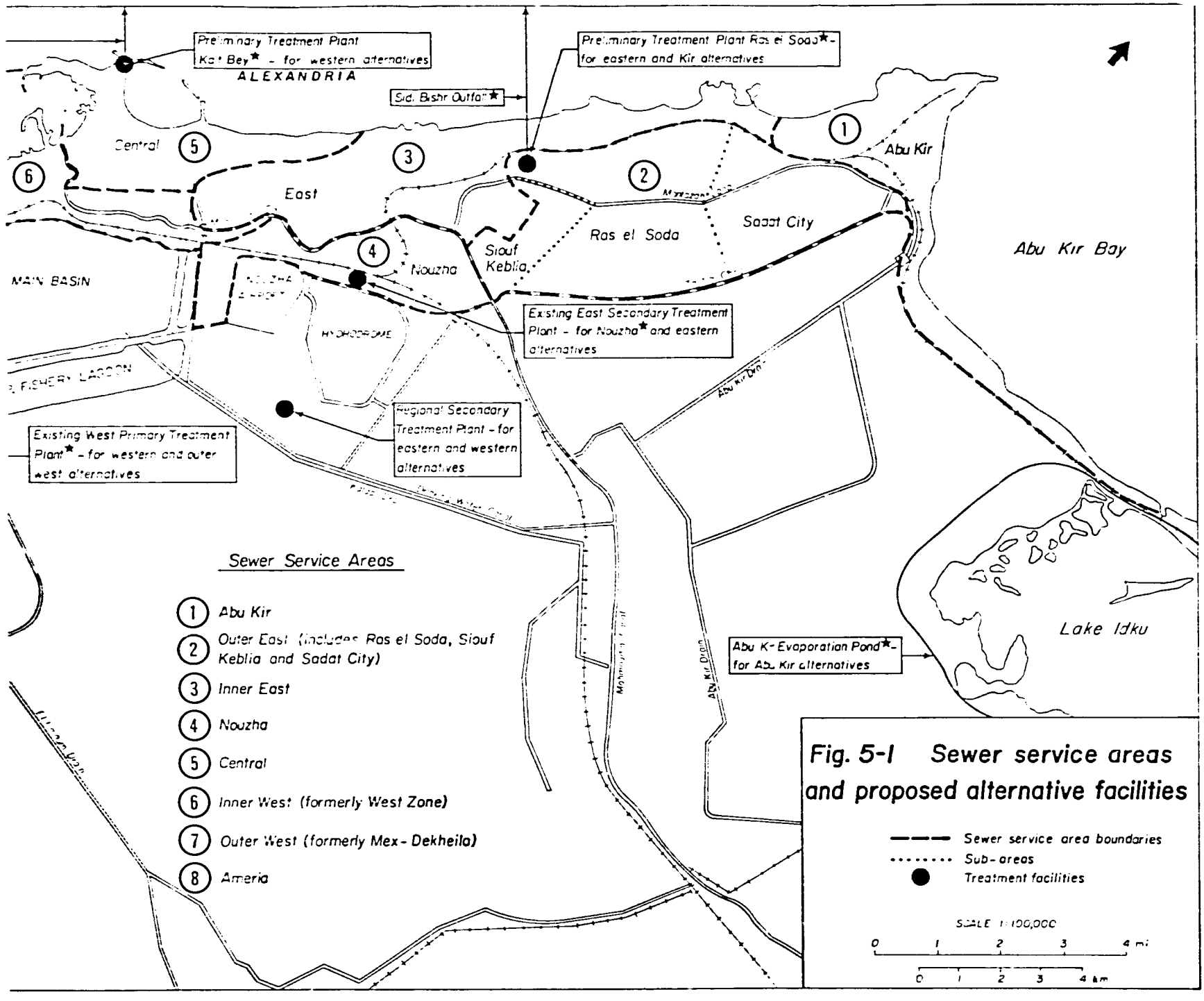


Fig. 5-1 Sewer service areas and proposed alternative facilities

TABLE 5-1.

ESTIMATED POPULATION AND FLOWS FOR SEWER SERVICE AREAS

Service Area	1980 Population	1980 Average Flow (Ml/day) Domestic	Infil.	Indus.	Total	2000 Population	2000 Average Flow (Ml/day) Domestic	Infil.	Indus.	Total
Abu Kir	45,000	4	2	113	119	185,000	20	3	150	173
Outer East	187,000	15	3	24	42	983,000	106	14	85	205
Inner East	1,045,000	125	35	43	203	1,450,000	190	38	104	332
Central	830,000	94	11	22	127	930,000	127	12	34	173
Inner West	680,000	55	9	72	136	800,000	100	9	110	219
Outer West	63,000	5	1	60	66	145,000	15	2	144	161
Ameria	60,000	6	3	23	32	500.000	68	7	62	137
Nouzha	51,000	4	1	12	17	72,000	7	2	36	45
Totals	2,961,000	308	65	369	742	5,065,000	633	87	725	1,445

5.B Evaluation Criteria

Considering the number of service areas (eight), the possible industrial waste collection alternatives (two), the possible treatment alternatives (four), the number of disposal alternatives (four), and the numerous consolidation possibilities, there are innumerable wastewater master plans. However, studying each possibility was unnecessary, because many combinations were unfeasible by observation. The Master Plan report adopted an elimination procedure beginning with a regional approach, to reduce the number of possible plans. Economic impacts and noneconomic parameters were compared and engineering judgment used to determine viable alternatives. This process of elimination continued until the analyses indicated a preferred Master Plan.

Costs for designing, constructing, and operating wastewater facilities in Alexandria were based on information from Egyptian contractors, consultants, government agencies, and material and equipment sales representatives from Egypt and throughout the world. Costs are based on July 1977 prices using an exchange rate of $1 U.S. = L.E. 0.70 Egyptian. Cost curves developed from these data and used to estimate economic impacts of various alternatives are shown in the Master Plan report, Chapter 5. The present worth and total annual cost methods were used in all cost comparisons assuming interest rates of 8, 10, and 12%, to check the sensitivity of the results to different costs for capital.

Other important criteria used in the Master Plan to evaluate alternatives were overall plan effectiveness, reliability, flexibility, and ease of implementation. The effectiveness of a proposed plan was defined as its ability to provide necessary wastewater facilities to meet the needs of Alexandria through the year 2000. Reliability was defined as the degree of assurance that the plan would continually accomplish its objectives. Flexibility was defined as the ease in which the proposed facilities could be adapted to changing land use patterns or other methods of disposal. Implementation was defined as the likelihood of plan acceptance by government agencies, the ability to construct the proposed facilities without straining logistical and financial resources, and the degree to which planning objectives could be accomplished without adverse environmental impact. Using these evaluation criteria, unsuitable alternatives were identified and eliminated from further consideration. The following pages describe the alternatives considered in the Master Plan report and how the choices were reduced to a preferred Master Plan.

5.C Master Plan Alternatives

5.C.1 Regional Alternatives

The initial screening procedure involved a comparison of four regional master plans. These plans, shown schematically on Fig. 5-2, include:

Sewer Zone	Regional Alternatives			
	A Sea Disposal	B Lake Disposal*	C Crop Irrigation	D Desert Evaporation
Abu Kir		Evp.	Evp.	Evp.
Outer East	P → Sea			
Inner East		S → Lake	S → Crop	
Nouzha				
Central				Evp.
Inner West	P → Sea	S → Lake	S → Crop	
Outer West		L → Drn.		
Ameria	L → Drn	L → Drn.	L → Drn	

P - Preliminary Treatment
L - Anaerobic - Aeorbic Lagoons
S - Secondary Treatment

Drn. - New Noubaria Drain
Evp. - Evaporation Pond
Crop - Crop Irrigation

*Note: Lake disposal is considered as an interim alternative in the Final Master Plan Study Report, as discussed in Volume I, Section II, Regional Disposal Alternatives.

Fig.5-2 Regional Alternatives

A. Discharge of preliminary treated wastewater into the sea using two outfalls, one serving the Inner West, Central, and Outer West; the other serving the Inner East, Outer East, Abu Kir, and Nouzha. Wastewater from Ameria is treated in a lagoon prior to discharge into the new Noubaria Drain.*

B. Discharge of secondary treated wastewater into Lake Maryut from two treatment plants, one serving the Outer East, Inner East, and Nouzha; the other serving the Central and Inner West. Abu Kir is served by an evaporation pond located in Lake Idku; while the Outer West and Ameria are served by lagoons discharging into the new Noubaria Drain.

C. Reusing secondary treated effluent from two treatment plants for agricultural irrigation, one serving the Inner East, Outer East and Nouzha, with the other serving the Inner West and Central zones. Abu Kir, the Outer West, and Ameria receive the same treatment a d disposal as described in Alternative B, except the Outer West and Ameria are treated in the same lagoon.

D. Discharge to a western desert evaporation pond serving all zones except Abu Kir, whose wastewater would be discharged into a separate evaporation pond located in Lake Idku.

These four regional master plans were selected from the various consolidation, collection, treatment, and disposal alternatives on the basis of engineering judgment. Knowledge of existing conditions and assessments of technical feasibility established a mental screening process to select these plans for further evaluation. These four were judged to be the most probable regional planning approaches and detailed evaluations were conducted. Costs shown in Table 5-2 indicate Alternatives A and B are more economical. Alternative A, ocean disposal, has the least present worth, with Alternative B, discharge to Lake Maryut, about 9 percent higher. The present worths of Alternatives C and D, crop irrigation and desert evaporation, are about 23 and 33 percent higher, respectively. Annual average operating costs follow a similar ranking, except desert evaporation has the second lowest followed by higher costs for lake disposal and crop irrigation.

On the basis of costs alone, crop irrigation and desert evaporation could be considered unsuitable. However, there were other noneconomic reasons for eliminating these alternatives. In Master Plan Chapter 6, reference is made to personal correspondence with Mr. Saleh Shihab, Under Secretary of the Ministry of Irrigation at Damanhour, which indicated "the cost to the (Egyptian) government for irrigation water in the lower Delta region is reported to be about L.E. 0.002 per cubic meter." Because of this low cost, the estimated availability of adequate water resources for irrigation from the Nile River basin, the potential for additional water resources through more efficient irrigation practices, and the technical problems of using more saline water for irrigation (treated effluent has a much higher total dissolved solid content), this alternative is economically unsound.

* See Tech. App. No. 7, Vol. II, this report.

TABLE 5-2.

COST-EFFECTIVENESS ANALYSIS OF REGIONAL ALTERNATIVES[1]

	Regional Alternatives			
	A	B	C	D
Capital Costs (L.E. x 10^6)	Sea Outfall	Lake Maryut	Crop Irrigation	Desert Evaporation
Conveyance facilities[2]	102	124	124	352
Treatment facilities[3]	86	191	191	23
Disposal facilities[4]	126	1	44	35
Total Capital Cost	314	316	359	410
Annual Average Operation and Maintenance Costs (L.E. X 10^6)				
Total for all facilities[5]	3.8	6.0	6.5	5.6
Total Annual Costs (L.E. x 10^6)[6]	38.3	40.8	46.0	50.7
Total Alternative Present Worth (L.E. x 10^6)[7]	228	249	280	304

[1]Table based on costs presented in Wastewater Master Plan, Table 7-1 (5 January 1978 draft report).

[2]Consists of main trunks, interceptors, pump stations, and force mains.

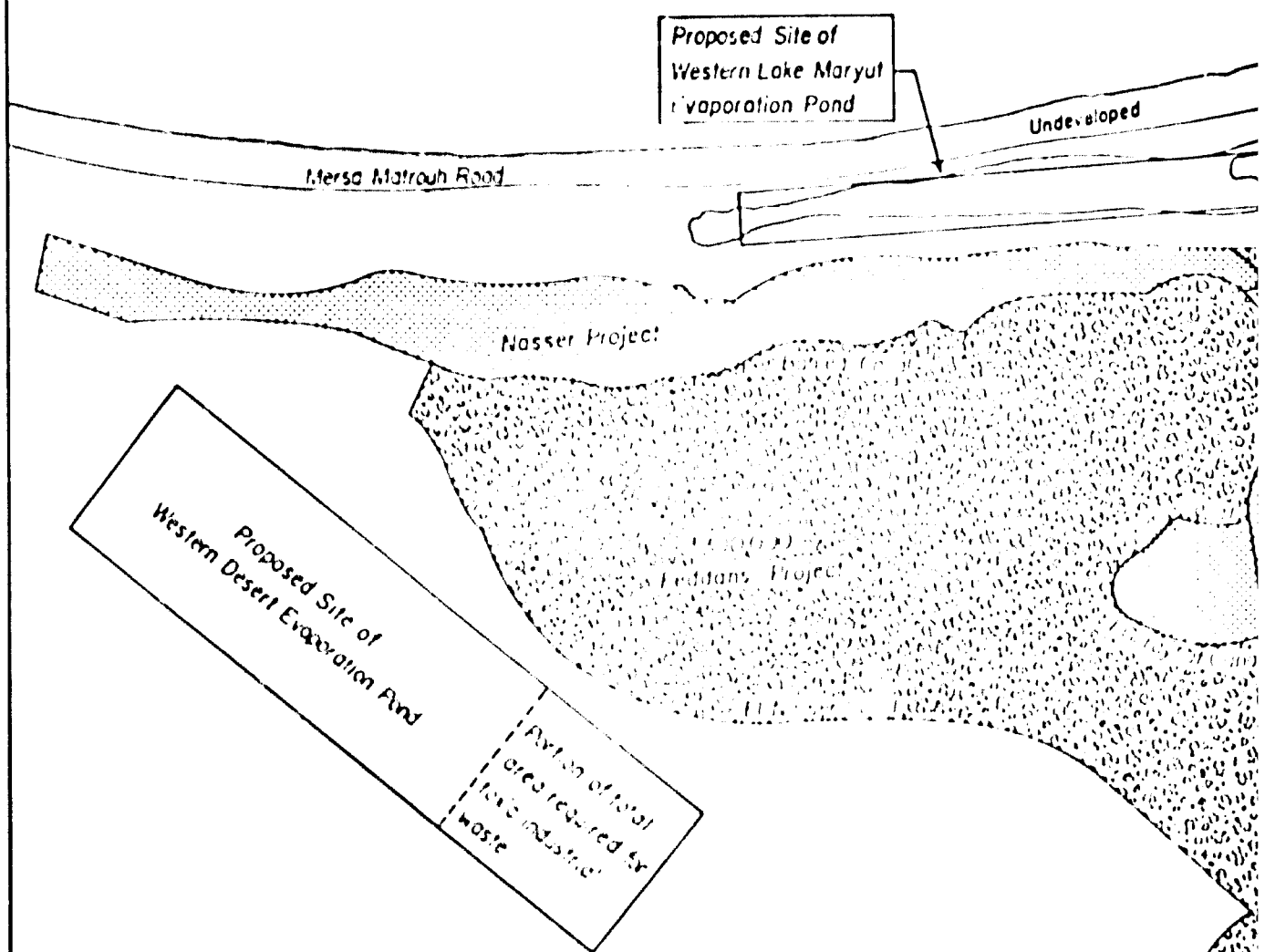
[3]Consists of wastewater treatment facilities and land requirements.

[4]Consists of effluent pump stations, force mains, evaporation ponds, and outfalls as required.

[5]Based on average year 1990 wastewater flows.

[6]Includes the cost of capital recovery and annual O&M, using an interest rate of 10%.

[7]Based on single capital payment in 1982 plus annual O&M over 23 years at 10%.



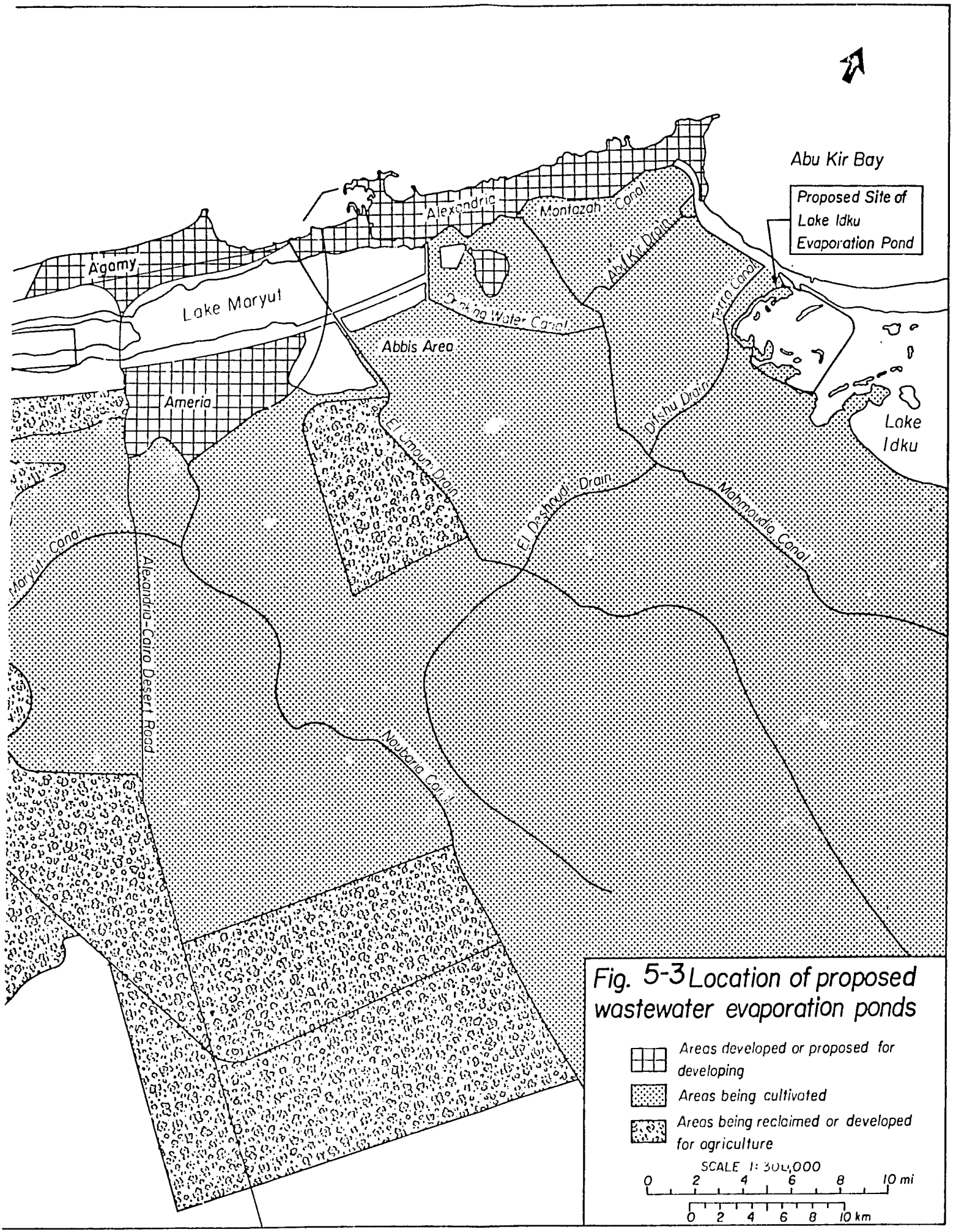
Notes:

(1) Agricultural areas based on map prepared by the Ministry of Land Reclamation of the Egyptian Land Development Organization on Agriculture Expansion along the Nasserian Canal, 1968.

(2) Proposed western desert site based on discussions with the Organization for Rehabilitation and Agricultural Projects of the Ministry of Irrigation.

(3) Western Lake Maryut evaporation pond considered for Alexandria's toxic industrial wastewaters.

(4) Lake Idku evaporation pond considered for Abu Kir's industrial wastes.


Abu Kir Bay
Proposed Site of Lake Idku Evaporation Pond
Alexandria
Montazah Canal
Agamy
Lake Maryut
Abu Kir Drain
Abbis Area
Ameria
Lake Idku
El Umoun Drain
Dikhu Drain
El Deshoudi Drain
Mahmoudia Canal
Maryut Canal
Alexandria-Cairo Desert Road
Nubaria Canal
Fig. 5-3 Location of proposed wastewater evaporation ponds
Areas developed or proposed for developing
Areas being cultivated
Areas being reclaimed or developed for agriculture
SCALE 1: 300,000
0 2 4 6 8 10 mi
0 2 4 6 8 10 km

In Alternative D, an estimated 225 km^2 of desert is required to construct a pond large enough to evaporate the estimated year 2000 average flow. Because of existing or proposed irrigation projects to the south and west and salt manufacturing operations and tourist development adjacent to western Lake Maryut (see Fig. 5-3), wastewater must be conveyed about 75 km from central Alexandria to reach such suitable space. Technical and logistical problems associated with such a long, large pipeline raised concerns over plan effectiveness and reliability. Also, the plan offers minimal flexibility because most of the city's wastewater would be conveyed to a remote location. While attractive in concept, such disadvantages, in addition to cost, eliminated this alternative from further consideration. The environmental impacts of this approach are, however, addressed in the next chapter.

In those stages of planning during which the environmental analyses of this report were performed, Alternatives C and D were not developed in detail because of their far greater cost. Reuse of highly saline effluent could not be justified, if adequate, less expensive supplies of fresh water were available; nor could desert evaporation, if Alternatives A and B satisfied planning criteria at considerably less expense. In the final stages of engineering analysis in the Master Plan Study, Alternative B was eliminated from consideration for environmental and other reasons, and only regional Alternatives A, C, and D are presented in the Final Report; technically detailed service-area alternatives for both sea disposal and reuse are also developed in the final Master Plan Report.

5.C.2 Toxic Industrial Wastewater Alternatives

Appendix C of the Wastewater Master Plan presents the results of the industrial wastewater survey performed by CDM, MAIN, and ATECO between January and June 1977. The survey revealed that the industries of Alexandria currently discharge about 870 Ml/day of wastewater; about 640 Ml/day are uncontaminated flows such as cooling waters, while the remaining 230 Ml/day carry some pollutional load. With average BODs concentratiohs of 700 mg/l, these contaminated industrial wastewaters are stronger than Alexandria's domestic wastes (500 mg/l of BOD_5), and many contain unacceptability high concentrations of suspended solids, grease, corrosive acids and bases, and toxic materials.

In describing the more serious industrial waste problems in Alexandria, Appendix C notes:

"- Higher than average organic loads are generated in the abattoir and tanning, food, beverage, paper, oil and soap, and starch and yeast industries.

- Heavy metals are contained in the discharge from chemical, electric and electronic, metal processing, printing, tanning and textile industries.

- Large cooling water flows are discharged from oil refineries, power generating stations, and oil and soap plants.

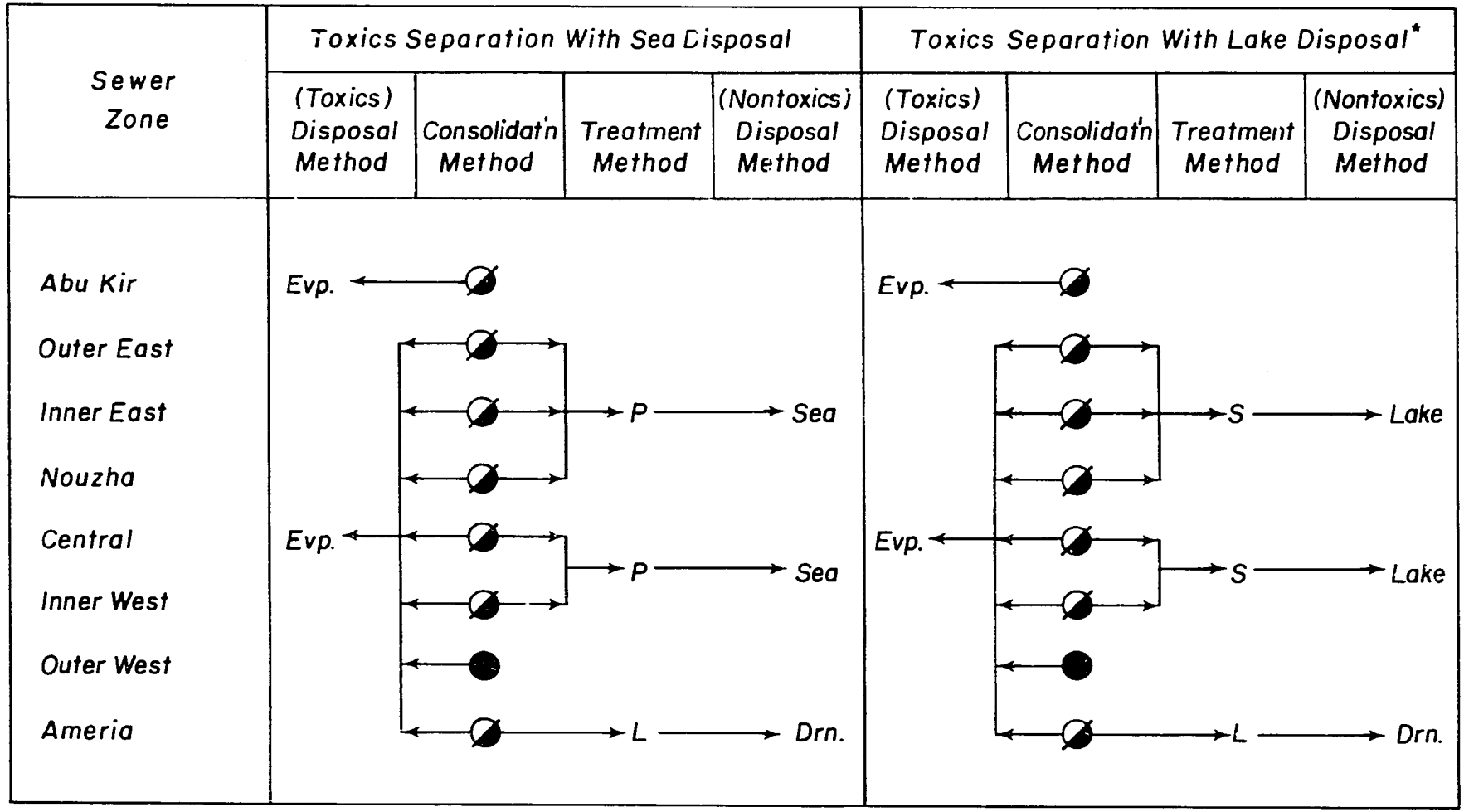
- Major industrial wastewater problem areas are: tanneries in Mex, chemical plants in Dekheila, paper mills near Abu Kir, miscellaneous strong wastewaters centered around Industries Pump Station, and discharges to the lower reach of the Mahmoudia Canal."

While the industrial waste survey made a preliminary assessment of the characteristics of about 90 percent of the city's current industrial wastewater, no planning effort can accurately predict the future composition of Alexandria's industrial wastes. Although wastewaters containing high suspended solids concentrations or unusually corrosive wastes can have a significant local impact by disrupting the operation of the collection system, this report must also focus attention on the environmental dangers associated with improper management of industrial wastewaters containing toxic materials. Mercury is one example of a toxic compound present in Alexandria's wastewater which has recently been recognized as a major health problem throughout the world. Mercury accumulates in the nervous system, impairs nervous system functioning, and can eventually cause death. In Minimata Bay, Japan, a nervous disease causing in excess of 100 human deaths was traced to mercury accumulated in fish and shellfish eaten by Minimata Bay residents. The source of the mercury was found in industrial wastes being discharged into streams entering the bay. As discussed in Chapters 4 and 6, mercury is currently being discharged into Dekheila Bay and fish are caught from these waters and eaten by Alexandrian residents.

The effects of other toxic wastes may not be as dramatic but, nevertheless, are cause for concern.* Free oil and emulsions can coat and destroy algae and other plankton and can interfere with the natural process of reaeration and photosynthesis. Oils can also affect marine animals, tainting fish and shellfish flesh. Pesticides, heavy metals, and other such potentially toxic compounds also accumulate in fish and shellfish flesh and can possibly reach concentrations harmful to man. Severely toxic substances eliminate aquatic biota, while lesser concentrations permit only more tolerant species to survive. In either case, the aquatic food chain is unnecessarily disturbed. Table 6-3 summarizes some of the observed metal concentrations at the Industries' Pump Station discharging to Lake Maryut. Although they do not exceed EPA hazard criteria, they are based on a limited sampling program and reflect only current conditions.

As noted earlier, the Master Plan considered two alternatives for the management of toxic industrial wastes: separate collection and conveyance to an evaporation pond, or pretreatment followed by discharge to the municipal sewers. Preliminary layouts for the separate collection systems shown in Fig. 5-4 were made and their costs estimated, as shown in Table 5-3. For the purpose of estimating design flows in this separate system, the Master Plan defined "toxic industrial wastewaters" as "Industrial discharges requiring pH adjustment or other pretreatment to comply with the recommended industrial waste ordinance prior to discharge to the domestic sewer system."

* See Tech. App. No. 5A and 5B, Vol. II, this report.



P - Preliminary Treatment

S - Secondary Treatment

L - Anaerobic - Aerobic Lagoon

Evp. - Evaporation Pond

Toxic Wastes ← ⊘ → Nontoxic Wastes

*Note: Lake disposal is considered as an interim alternative in the Final Master Plan Study Report.

Fig.5-4 Collection Alternatives - Toxic Industrial Wastewater Separation

TABLE 5-3.

COST-EFFECTIVENESS ANALYSIS OF INDUSTRIAL WASTEWATER COLLECTION ALTERNATIVES[1]

	Collection Alternatives							
	No Separation		Toxic Separation[2]					
			Sea Outfalls			Lake Maryut		
Capital Cost (L.E. x 10^6)	Sea Outfall	Lake Maryut	R	TI	T	R	TI	T
Conveyance[3]	102	124	91	67	158	113	67	180
Treatment[4]	86	191	70	-	70	157	-	157
Disposal[5]	126	1	107	28	135	1	28	29
Total Capital Cost	314	316	268	95	363	271	95	366
Annual Average Operation and Maintenance Costs (L.E. x 10^6)								
Total for all facilities[6]	3.8	6.0	4.3			6.2		
Total Annual Cost (L.E. x 10^6)[7]	38.3	40.8	44.2			45.6		
Total Alternative Present Worth[8] (L.E. X 10^6)	228	249	263			282		

[1]Table based on costs presented in Wastewater Master Plan, Table 7-2 (5 January 1978 draft).

[2]Remaining wastewater, TI-Toxic Industrial Wastewater; T-Total Flow.

[3]Consists of main trunks, interceptors, pump stations, and force mains.

[4]Consists of wastewater treatment facilities and land requirements.

[5]Consists of effluent pump stations, force mains, evaporation ponds, and outfalls as required.

[6]Based on average year 1990 wastewater flows.

[7]Includes the cost of capital recovery and annual O&M, using an interest rate of 10%.

[8]Based on single capital payment in 1982 plus annual O&M over 23 years at 10%.

Such a broad definition includes several wastes which are not toxic to the flora and fauna of the receiving environment, but is necessary to assess the extent of industrial waste control required. Technical Appendix No. 5 of this report is a list of industrial discharges in Alexandria which currently fit the above definition of "toxic".

Table 5-3 shows that the construction of a separate toxic industrial wastewater collection system costs approximately 45 million Egyptian Pounds (70 million U.S. dollars) more than the combined municipal system possible with pretreatment of strong industrial wastes. The total cost of the combined system alternative is, however, as yet unknown because preliminary design and cost estimation of treatment facilities for Alexandria's industries were beyond the scope of the original Master Plan contract. However, an amendment to the contract between CDM a MOHR to complete this work was signed and the resulting Toxic Industrial Waste Study addresses the costs for these facilities. As experience elsewhere indicated pretreatment within individual industries is generally the most cost-effective and practicable means of controlling toxics, the Master Plan recommended the pretreatment alternative for management of most of Alexandria's industrial wastewater.* However, the Master Plan recommended the separate conveyance of Abu Kir's industrial wastes to an evaporation pond at nearby Lake Idku, because of its lower cost in this region.

The Master Plan, therefore, recommends the strong enforcement of a sewer use ordinance to control the discharge of toxic pollutants to the municipal sewer (see Technical Appendix 6). As noted elsewhere, a sewer use law has already been on the books since 1962, and many of Alexandria's industrial waste discharges openly violate it. This report, therefore, examines to the limited extent possible the environmental implications of the discharge of untreated industrial waste to the central sewers. Chapter 6 discusses, for each of the disposal alternatives, the environmental consequences of the discharge of untreated industrial wastes with concentrations equal to those currently found in Alexandria's industrial effluents. Such untreated discharges are by no means the "most likely" case, but can in some sense be accepted as an approximation to the effects of poor enforcement of the sewer use law. Such an analysis appears to be the most reasonable possible with existing data.

5.C.3 Consolidation Alternatives

Having eliminated crop irrigation and desert evaporation as regional alternatives and separation of toxic industrial waste as a collection alternative, the Master Plan report next discussed consolidation alternatives. Without performing a rigorous economic analysis, consideration was given to three consolidation alternatives: no consolidation, partial consolidation, and total consolidation. The evaluation, based on engineering judgment and experience, reviewed probable economic and non-economic impacts.

* See Tech. App. No. 5A and 5B, Vol. II, this report.

The no consolidation approach was judged to be technically and economically impractical. Providing separate treatment plants for eight service areas denies economies-of-scale, creates numerous staff and operational problems, and generally results in an inefficient use of available resources. Implementation of such a scheme is highly unlikely, and system reliability would be difficult to maintain. The no consolidation approach was, therefore, eliminated from further consideration.

Total consolidation was also judged to be technically and economically impractical. The diameter of a single outfall large enough to accommodate projected flows approaches 4 m which would be extremely difficult if not impossible to construct. Disposal to the lake following secondary treatment would require about a 1,450-Ml/day plant, one of the largest such plants in the world. Although consolidation can generally take advantage of economies-of-scale, the two facilities described here exceed accepted limits and are judged to be technically unadvisable. On this basis, total consolidation was no longer considered a viable alternative.

Partial consolidation using either sea or lake disposal with some discharge to local canals and/or drains was selected for more rigorous analysis. While there are several possible partial consolidation schemes, engineering judgment, together with the intention of using existing collection and treatment facilities and the geography of Alexandria, eliminated many of the numerous possibilities. The resulting feasible sewer service area alternatives included in the Master Plan evaluations are discussed below.

5.D Service Area Alternatives

In the stages of Master Plan study during which environmental analyses were performed, detailed service-area alternatives were only available for the two least-cost alternatives, sea and lake disposal. These are the alternatives presented below, and provide the basis for the environmental impact analyses of sea and lake disposal presented in Chapter 6. Since that time, those service area alternatives discussed below which employ secondary treatment and lake disposal, have been replaced in the Final Master Plan Report by alternatives employing identical treatment facilities for agricultural irrigation, consistent with the Master Plan's rejection of lake disposal as an acceptable alternative. Environmental impacts of sea disposal, lake disposal, irrigation and evaporation are all addressed in detail in Chapter 6 of this report.

5.D.1 Evaluation Criteria

All existing wastewater treatment facilities are contained in the Inner West, Inner East, and Central zones. Because of the geography of Alexandria and the intent to salvage existing facilities, the Inner West and Central zones were consolidated into one planning area while the outer

east and inner east were combined to form another. These consolidations were judged to be the most preferrable engineering arrangements, and costs were developed comparing ocean and lake disposal alternatives for both. Separate studies were conducted on the remaining four peripheral areas--Abu Kir, Outer West, Ameria, and Nouzha. The alternative selected from each of these studies became part of the preferred Master Plan.

Capital and operating costs for the following comparisons were based on preliminary engineering designs of the required facilities. Master Plan Appendix L contains lists of gravity sewers, pump stations, force mains, treatment facilities, and outfall pipes required for the respective alternatives showing size, capacity, length, and other pertinent design data. The basis for these designs are those design criteria also included in the Master Plan appendices.

5.D.2 Eastern Alternatives

The eastern area consists of a sewered zone (Inner East) and three unsewered areas--Ras el Soda, Siouf Keblia, and Sadat City (Outer East). Alternatives for providing the required wastewater facilities were:

1. Convey wastewater to a secondary treatment plant serving only the eastern area and discharge treated effluent into Lake Maryut.

2. Convey wastewater to a regional secondary treatment plant which would also serve the Inner West and Central zones (western area) and discharge treated effluent into Lake Maryut.

3. Convey eastern area wastewater to a preliminary treatment plant in Ras el Soda prior to ocean disposal through an outfall at Sidi Bishr.

These alternatives are illustrated schematically on Fig. 5-5, and their costs are shown on Table 5-4. The most cost-effective alternative is No. 3, an ocean outfall. Depending on the interest rate, the present worth of Alternative 3 is from 14 to 21 percent less than Alternative 2 and 19 to 25 percent less than Alternative 1. The difference in annual average operation and maintenance cost is more pronounced. The ocean outfall alternative is about 40 percent less than Alternative 2 and 47 percent less than Alternative 1. Besides economic advantages, the outfall system only requires preliminary treatment, a much simpler process, and is therefore more reliable. The greater degree of dilution in the ocean gives a guarantee of continual satisfactory disposal not possible in Lake Maryut. Based on these factors, an ocean outfall at Sidi Bishr, with preliminary treatment in Ras el Soda, was recommended for the preferred Master Plan.

	Sewer Zone	Alternative 1 Con. Treat Dis.	Alternative 2 Con. Treat. Dis.	Alternative 3 Con. Treat. Dis.
Eastern Alternatives (537 Ml/day)	Outer East Inner East Inner West Central	S → Lake (Irr.)*	S → Lake (Irr.)*	P → Sea
Abu Kir Alternatives (173 Ml/day)	Abu Kir Outer East Inner East	Evp. P → Sea	P → Sea	Evp. P → Sea.
Western Alternatives (392 Ml/day)	Inner West Central Inner East Outer East	S → Lake (Irr.)*	S → Lake (Irr.)*	P P → Sea
Outer West Alternatives (161 Ml/day)	Ameria Outer West Inner West	L → Drn. L → Drn.	L → Drn.	L → Drn. P → Sea
Ameria Alternatives (137 Ml/day)	Ameria Outer West	L → Drn. L → Drn.	L → Drn.	

P - Preliminary Treatment
S - Secondary Treatment
L - Anaerobic-Aerobic Lagoon
Evp. - Evaporation Pond
Drn. - New Noubaria Drain
Irr. - Irrigation (Reuse)

*Note: See Volume I, Section II, Evaluation Criteria for Service Area Alternatives for discussion of Lake and Irrigation Disposal Alternatives.

Fig. 5-5 Service area alternatives

TABLE 5-4.

COST-EFFECTIVENESS ANALYSIS OF EASTERN ALTERNATIVES[1]

	1	2	3
Capital Costs (L.E. x 10^6)	Secondary Treatment Eastern Area	Share of a Regional Secondary Treatment Plant With Western Zone	Sea Outfall Eastern Area
Pipelines	51.73	51.73	38.50
Pump Stations	10.56	10.56	11.45
Treatment facilities	94.12	87.56	23.00
Disposal facilities	0.12	0.10	55.60
Land acquisition	0.54	0.55	3.84
Total Capital Cost	157.07	150.50	132.39
Annual Average Operation and Maintenance Costs (L.E. x 10^6)			
Total for all facilities[2]	2.89	2.57	1.52
Total Annual Cost[3]	22.16	21.03	17.42
Total Alternative Present Worth (L.E. x 10^6)			
Interest rate 8%	133	126	108
Interest rate 10%	121	114	98
Interest rate 12%	110	104	82
			Preferred Plan

[1] Table based on costs presented in Wastewater Master Plan, Table 7-4 (5 January 1978 draft).

[2] Based on average year 1990 wastewater flows.

[3] Includes the cost of capital recovery and annual O&M, using an interest rate of 10%.

[4] Based on single capital payment in 1982 plus annual O&M over 23 years.

5.D.3 Abu Kir Alternatives

There are no wastewater facilities in Abu Kir. Based on existing and projected development, the Master Plan Report considered three alternatives to provide sewer service. These were:

1. Convey all wastewater to an evaporation pond located along the northern shore of Lake Idku.

2. Convey all wastewater to the preliminary treatment plant in Ras el Soda prior to ocean disposal through the outfall at Sidi Bishr.

3. Convey domestic wastewater to Ras el Soda while pumping industrial wastewater from the vicinity of Tabia Pump Station south to the Lake Idku evaporation pond.

These alternatives are shown schematically on Fig. 5-5 and Table 5-5 lists their costs. The cost comparison favors Alternative 3; however, because the difference between this cost and the amount shown for Alternative 1 is negligible, these two alternatives are judged to be economically equivalent. Alternative 2, conveying everything to the outfall, is considerably more expensive and was eliminated from further consideration.

The decision to select Alternative 3 for the preferred Master Plan was based on flexibility and implementation. The two wastewater facility systems in Alternative 3 were judged to be more responsive to future land use changes and more adaptable to a construction staging program. Both alternatives were considered to be equally reliable and effective. Because costs alone did not indicate a clear advantage, the recommendation of Alternative 3 as part of the preferred Master Plan was based on these noneconomic factors.

5.D.4 Western Alternatives

The western area consists of the Inner West and Central zones and each has existing wastewater facilities. These areas are essentially fully developed and completely sewered and were considered as one area for planning purposes. Alternatives considered for the treatment and disposal of wastewater were:

1. Convey wastewater to a secondary treatment plant serving only the western area and discharge treated effluent into Lake Maryut.

2. Convey wastewater to a regional secondary treatment plant, which would also serve the eastern area, and discharge treated effluent into Lake Maryut.

3. Convey Inner West wastewater to the existing west treatment plant which would be converted into a preliminary treatment facility.

TABLE 5-5.

COST-EFFECTIVENESS ANALYSIS OF ABU KIR ALTERNATIVES[1]

	1	2	3
Capital Costs (L.E. x 10^6)	All Wastewater To Evaporation Pond	All Wastewater to Ras el Soda - Share in Cost of Preliminary Plant and Sea Outfall	Industrial Waste to Evaporation Pond-Domestic to Sea Outfall
Pipelines	7.37	8.25	7.88
Pump stations	4.09	5.54	3.86
Treatment facilities	18.90	6.50	16.32
Disposal facilities	-	26.88	2.20
Land acquisition	3.51	0.98	3.12
Total Capital Cost	33.87	48.15	33.38
Average Annual Operation and Maintenance Costs (L.E. x 10^6)			
Total for all facilities[2]	0.24	0.64	0.21
Total Annual Cost[3]	4.32	6.46	4.27
Total Alternative Present Worth[4] (L.E. x 10^6)			
Interest rate 8%	25	40	24
Interest rate 10%	23	37	22
Interest rate 12%	21	34	20
			Preferred Plan

[1]Table based on costs presented in Wastewater Master Plan, Table 7-5 (5 January 1978 draft).

[2]Based on average year 1990 wastewater flows.

[3]Includes the cost of capital recovery and annual O&M, using an interest rate of 10%.

[4]Based on single capital payment in 1982 plus annual O&M over 23 years.

Construct another preliminary treatment facility at Kait Bey for the central zone. Pump treated effluent from the Inner West zone to an ocean outfall at Kait Bey which would also convey Central Zone effluent into the sea.

These alternatives are illustrated schematically on Fig. 5-5, and Table 5-6 presents their costs. The most cost-effective alternative is No. 3, an ocean outfall. Depending on the interest rate, the present worth of Alternative 3 is from 8 to 10 percent less than Alternative 2, and 14 to 18 percent less than Alternative 1. Because Alternative 2, a regional treatment facility serving the eastern and western areas, was eliminated from consideration in the eastern alternative analysis and because it would also cost more when studied from the western area perspective, it was eliminated from any further evaluation. Alternative 1 was also eliminated for economic reasons.

Additional noneconomic advantages of Alternative 3 include use of an existing wastewater treatment facility still under construction. Because of economic problems, the Egyptian government has not been able to complete the existing west plant on schedule, and it is now estimated to be ready for operation in 1979. With proper modification, this facility could serve a useful purpose in the preferred plan. Other advantages include the reliability of using a simpler preliminary treatment process and the continued dilution guaranteed by ocean disposal. This system would also provide collection and conveyance flexibility to adapt to future agricultural reuse schemes, should effluent reuse be required. Based on all these economic and noneconomic considerations, an ocean outfall was recommended for the preferred Master Plan.

5.D.5 Outer West Alternatives

The Outer West, formerly called Mex-Dekheila, does not have wastewater facilities. Based on existing and projected development, the Master Plan report considered three alternatives to provide sewer service. These were:

1. Collect and convey wastewater to an anaerobic-aerobic lagoon located along the northern shore of western Lake Maryut and discharge treated effluent into the new Noubaria Drain.

2. Collect and convey wastewater to a regional lagoon (located near the Ameria-Agamy road) serving the Outer West zone and Ameria and discharge treated effluent into the new Noubaria Drain.

3. Collect and convey wastewater to the existing West Treatment Plant where a regional preliminary treatment facility serving the outer and inner west zones would be constructed. Treated effluent would be pumped to the Kait Bey outfall for ocean disposal.

TABLE 5-6.

COST-EFFECTIVENESS ANALYSIS OF WESTERN ALTERNATIVES[1]

	1	2	3
Capital Costs (L.E. x 10^6)	Secondary Treatment Western Zone	Share of a Regional Secondary Treatment Plant With Eastern Zone	Sea Outfall Western Zone
Pipelines	16.65	18.02	13.50
Pump stations	5.35	6.77	4.24
Treatment facilities	71.87	63.40	17.50
Disposal facilities	0.12	0.08	42.59
Land acquisition	0.39	0.39	1.20
Total Capital Cost	94.38	88.66	79.03
Average Annual Operation and Maintenance Costs (L.E. x 10^6)			
Total for all facilities[2]	2.32	1.77	1.61
Total Annual Cost (L.E. x 10^6)[3]	13.96	12.69	11.15
Total Alternative Present Worth (L.E. x 10^6)[4]			
Interest rate 8%	86	79	72
Interest rate 10%	78	71	64
Interest rate 12%	70	65	60
			Preferred Plan

[1]Table based on costs presented in Wastewater Master Plan, Table 7-6 (5 January 1978 draft).

[2]Based on average year 1990 wastewater flows.

[3]Includes the cost of capital recovery and annual O&M, using an interest rate of 10%.

[4]Based on single capital payment in 1982 plus annual O&M over 23 years.

These alternatives are shown schematically on Fig. 5-5, and Table 5-7 lists their costs. The most cost-effective alternative is No. 1, conveyance to an anaerobic-aerobic lagoon along the northern shore of western Lake Maryut with discharge of treated effluent into the new Noubaria Drain. Depending on the interest rate, the present worth of Alternative 1 is from 32 to 37 percent less than Alternative 2 and 54 to 58 percent less than Alternative 3. While there is essentially no difference in annual average operating costs between Alternatives 1 and 2, Alternative 1 is about half the operating cost of Alternative 3. Based on this analysis, Alternatives 2 and 3 were judged to be less cost effective and were eliminated from further consideration.

Besides less cost, Alternative 1 offers process simplicity, construction flexibility, and an ease of implementation not offered in Alternative 3. Although Alternative 2 has these same advantages, a regional approach in an area where future development is not clearly defined, reduces future flexibility. Therefore, these advantages, in addition to least cost, favored Alternative 1, and it was recommended as part of the preferred Master Plan.

5.D.6 Ameria Alternatives

Ameria, a rapidly developing area located southwest of Alexandria, is currently unsewered. The Master Plan report considered two alternatives to provide wastewater facilities:

1. Collect and convey wastewater to an anaerobic-aerobic lagoon located in the eastern portion of Ameria and discharge treated effluent into the new Noubaria Drain.

2. Collect and convey wastewater to a regional lagoon, located west of the Ameria-Agamy road and discharge treated effluent into the new Noubaria Drain.

Because of the distance, alternatives involving conveyance to either the Kait Bey outfall or a secondary treatment plant along the shores of Lake Maryut were considered unfeasible.

Alternatives 1 and 2 are illustrated schematically on Fig. 5-5, and their costs are shown on Table 5-8. Because of topography and additional conveyance facilities, Ameria's share in the cost of a regional system is greater than a separate lagoon, and depending on the interest rate, the present worth of Alternative 1 is about 15 to 18 percent less than Alternative 2. Also, the additional conveyance facilities required for a regional system would result in about a 30-percent higher annual average operating and maintenance cost. These factors indicated the regional approach was not cost effective.

TABLE 5-7.

COST-EFFECTIVENESS ANALYSIS OF OUTER WEST ALTERNATIVES[1]

	1	2	3
Capital Costs (L.E. x 10^6)	Anaerobic-Aerobic Lagoon For Outer West Zone	Share of a Regional Anaerobic-Aerobic Lagoon With Ameria	Share of Preliminary Plant w/Inner West and Sea Outfall With Inner West and Central
Pipelines	5.07	8.89	7.27
Pump stations	3.19	3.19	0.26
Treatment facilities	8.83	8.87	8.25
Disposal facilities	2.88	2.33	15.82
Land acquisition	1.39	1.33	1.20
Total Capital Cost	21.36	24.61	32.80
Average Annual Operation and Maintenance Costs (L.E. x 10^6)			
Total for all facilities[2]	0.23	0.24	0.47
Total Annual Cost (L.E. x 10^6)[3]	2.85	3.24	4.44
Total Alternative Present Worth[4] (L.E. x 10^6)			
Interest rate 8%	13	19	28
Interest rate 10%	11	17	26
Interest rate 12%	10	16	24
	Preferred Plan		

[1] Table based on costs presented in Wastewater Master Plan, Table 7-7 (5 January 1978 draft).

[2] Based on average year 1990 wastewater flows.

[3] Includes cost of capital recovery and annual O&M, using an interest rate of 10%.

[4] Based on single capital payment in 1982 plus annual O&M over 23 years.

TABLE 5-8.

COST-EFFECTIVENESS ANALYSIS OF AMERIA ALTERNATIVES[1]

	1 Anaerobic-Aerobic Lagoon for Ameria	2 Share of Regional Anaerobic-Aerobic Lagoon With Outer West
Capital Costs (L.E. x 10^6)		
Pipelines	11.83	13.37
Pump stations	1.12	2.55
Treatment facilities	7.60	7.55
Disposal facilities	1.01	1.99
Land acquisition	1.18	1.14
Total Capital Cost	22.74	22.60
Average Annual Operation and Maintenance Costs (L.E. x 10^6)		
Total for all facilities[2]	0.17	0.22
Total Annual Cost (L.E. x 10^6)[3]	2.91	3.42
Total Alternative Present Worth[4] (L.E. x 10^6)		
Interest rate 8%	17	20
Interest rate 10%	15	18
Interest rate 12%	14	17
	Preferred Plan	

[1]Table based on costs presented in Wastewater Master Plan, Table 7-8 (5 January 1978 draft).

[2]Based on average 1990 wastewater flows.

[3]Includes the cost of capital recovery and annual O&M, using an interest rate of 10%.

[4]Based on single capital payment in 1982 plus annual O&M over 23 years.

Besides cost advantage, Alternative 1 offers greater flexibility to adapt to changing land use patterns which is an important consideration in an area where future development is not clearly defined. Implementation and construction flexibility were other advantages and, when considered with lower costs, they clearly favored a separate facility. Therefore, Alternative 1 was recommended as part of the preferred Master Plan.

5.D.7 Nouzha Alternatives

Alternatives for the treatment and disposal of wastewater from Nouzha were not considered in the Master Plan. Nouzha, which is an unsewered area, is adjacent to the existing East Treatment Plant. This plant, which only began operation in 1975, currently serves the Inner East Zone and discharges treated effluent into Lake Maryut. When East Zone wastewater is diverted to the proposed ocean outfall, all plant capacity would be available for Nouzha. Because these existing facilities are new and projected wastewater flows and loads from Nouzha are less than the existing plant capacity, continued use for Nouzha was recommended as part of the preferred Master Plan.

5.E The Preferred Plan

5.E.1 Plan Description

Analyses of the previous alternatives resulted in the recommendation of a preferred Master Plan for the city of Alexandria. This plan, shown schematically on Fig. 5-6, consists of the following components:

1. Discharge preliminary treated domestic and industrial wastewater into the Mediterranean Sea through two outfalls. One outfall, at Kait Bey, would serve the Central and Inner West Zones with preliminary treatment facilities at Kait Bey for the Central Zone and at the existing west plant for the Inner West Zone. The other outfall at Sidi Bishr would serve the Inner East, Outer East, and domestic wastewater from Abu Kir. Preliminary treatment facilities for this outfall would be built in Ras el Soda.

2. Convey Abu Kir industrial wastewater to an evaporation pond located along the northern shore of Lake Idku.

3. Convey domestic and industrial wastewater from Nouzha to the existing East Treatment Plant and discharge treated effluent into Lake Maryut.

4. Convey domestic and industrial wastewater from the Outer West Zone to an anaerobic-aerobic lagoon located along the northern shore of western Lake Maryut and discharge treated effluent into the new Noubaria Drain.

Sewer Zone	Consolidation Method	Treatment Method	Disposal Method	Comments
Abu Kir			(150 Ml/day) → Evp.	Industrial Waste to Evaporation Pond in Lake Idku.
Outer East		P	(560 Ml/day) → Sea (Sidi Bishr)	Preliminary Treatment Plant in Ras el Soda Outfall at Sidi Bishr Discharge Domestic and Industrial Wastewater to Sea.
Inner East				
Nouzha		S	(45 Ml/day) → Lake	Modify Existing East Treatment Plant
Central		P	(392 Ml/day) → Sea (Kait Bey)	Preliminary Treatment Plant at Kait Bey for Central, at Existing West Plant for Inner West. Both Plants Discharge to Sea Through One Outfall.
Inner West		P		
Outer West		L	(161 Ml/day) → Drn	Discharge From Lagoon to New Noubaria Drain
Ameria		L	(137 Ml/day) → Drn	Discharge From Lagoon to New Noubaria Drain

P - Preliminary Treatment
S - Secondary Treatment
Drn - New Noubaria Drain
L - Anaerobic - Aerobic Lagoon
Evp. - Evaporation Pond

Note: This Figure Based on Wastewater Master Plan Figure 7-5.

Fig. 5-6 Preferred Master Plan

5. Convey domestic and industrial wastewater from Ameria to an anaerobic-aerobic lagoon located in Ameria and discharge treated effluent into the new Noubaria Drain.

In addition to the above, the Master Plan report recognized the potential adverse impact from discharging toxic industrial wastewater into the ocean and recommended the enforcement of an industrial waste ordinance. The costs of compliance and enforcement are addressed in the Toxic Industrial Waste Study.

5.F Summary

The environmental impacts of all alternatives discussed in this chapter are addressed in Chapter 6. The impacts of the no-action alternative have already been discussed in Chapter 4. Additional information on Master Plan alternatives is contained in Chapter 7 of the Wastewater Facilities Master Plan Report.

Reference

[1] Appendix C of the Alexandria Wastewater Master Plan Study Final Report, July 1977. Report prepared for the Ministry of Housing and Reconstruction, Arab Republic of Egypt, by Camp Dresser and McKee Inc., Chas. T. Main International Inc., and the Arab Technical and Economical Consulting Office.

[2] Alexandria Wastewater Facilities Development Program, Status Report Number 2, 8 November 1977. Report prepared for the Ministry of Housing and Reconstruction, Arab Republic of Egypt, by Camp Dresser and McKee International Inc., Chas. T. Main International Inc., and the Arab Technical and Economical Consulting Office.

CHAPTER 6

ENVIRONMENTAL IMPACTS OF ALTERNATIVES

6.A General

The fundamental purpose of this report is to describe the environmental consequences of alternative wastewater management schemes for the Alexandria region. To achieve this purpose, it has been necessary to describe the framework of existing environmental conditions (Chapter 3) and the alternatives presented in the Wastewater Master Plan (Chapter 5). The environmental consequences of doing nothing to improve wastewater facilities in Alexandria have been described in Chapter 4; the current chapter, however, represents the heart of the report, for it describes the environmental impacts of the wastewater management alternatives presented in the Master Plan.

The detail with which environmental impacts can be determined depends to a large extent on the completeness of available data describing the alternatives. The environmental impacts of agricultural reuse and evaporation, for example, are of necessity discussed in more general terms than those of ocean and lake disposal, because the former were not developed to the same level of detail in the course of the Master Plan study. The salient environmental issues associated with each alternative are, however, discussed in sufficient detail to allow the reader to understand those impacts which can be predicted with currently available information.

Impacts of ocean and lake disposal, evaporation, and agricultural reuse are discussed at length in the body of this chapter, while construction and operation related impacts of the alternatives are discussed in closing.

6.B Primary Impacts

6.B.1 Ocean Disposal

6.B.1.a Ocean Outfall Assimilation Characteristics. For the ocean disposal alternatives considered for the eastern and western areas, the ultimate disposal of the main portion of Alexandria wastes is to be from two ocean outfalls, one along the Kait Bey alignment and the other along the Sidi Bishr alignment. Both outfalls would extend to a distance of about 10 km offshore with diffusers at their outer ends oriented normal to the dominant coastwise currents. The depth of water at 10 km offshore on the Kait Bey alignment is 56 m and that on the Sidi Bishr alignment is 52 m. If industrial wastewaters are combined with domestic wastewater, the projected dry-weather flows are 392 Ml/day (4.5 m^3/sec) at Kait Bey and 560 Ml/day (6.5 m^3/sec) at Sidi Bishr. If industrial wastes are excluded, the flows would be somewhat less.

Fortunately, there is substantial experience with the operation and performance of outfalls of this type from the Pacific coast of the United States. A great deal of theoretical, laboratory, and field experience has evolved over the years so that prediction of wastewater outfall and diffuser performances can be made with some degree of certainty. Of particular note are the continuing theoretical and laboratory investigations by personnel at the W.H. Keck Laboratory of the California Institute of Technology and the field investigations by the Southern California Coastal Water Research Project. A summary of the characteristics of the major Pacific Ocean outfalls, as taken from Koh and Brooks, is given in Table 6-1.

The latest, and most definitive, description of offshore wastewater diffuser performance in a coastwise current has been given by Roberts.[2] The minimum dilution at the surface, or initial dilution, D, is given by the simple expression,

$$D = 0.58 \frac{ubh}{q} \qquad (1)$$

where u is the coastal current, b the length of diffuser, h the water depth, and q the wastewater flow, provided that the Froude number, F, defined by the relation,

$$F = \frac{u^3}{\frac{\Delta\rho}{\rho} g \frac{q}{b}} \qquad (2)$$

is greater than 0.1. In equation (2), the quantity $\alpha\rho$ is the density difference between sea water and sewage water, 0 is the density of sewage water, and g the acceleration resulting from gravity. The first equation is simply an expression for the dilution of an outfall flow, q, by the coastwise current which it intercepts, ubh, as corrected for the fact that the whole water column does not participate in the dilution.

TABLE 6-1.

SUMMARY OF CHARACTERISTICS OF MAJOR PACIFIC OCEAN OUTFALLS

Location	Year Operation Began	Distance Offshore (km)	Length of Diffuser (m)	Depth of Water (m)	Design Average Flow (m^3/sec)
Sanitation districts of Los Angeles County, Whites Point No. 3	1956	2.4	730	63	6.6
City of Los Angeles at Hyperion	1960	8.4	2,420	59	18.4
San Diego	1963	3.5	820	63	10.3
Sanitation districts of Los Angeles County, Whites Point No. 4	1965	2.3	1,350	54	9.7
Metropolitan Seattle, West Point	1965	0.9	180	69	5.5
Sanitation districts of Orange County	1971	6.5	1,830	56	12.7
Honolulu, Sand Island	1975	2.8	1,030	69	4.6

Using a nominal value for the diffuser length of 500 m for each of the Alexandria outfalls, a coastwise current value of 15 cm/sec as observed 10 km offshore, and the observed density difference of 0.026 for summer conditions, we obtain initial, minimum, dilution values of 540 for the Kait Bey outfall and 350 for the Sidi Bishr outfall. The Froude number values for these conditions are, respectively, 1.5 and 1.0.

It is also of interest to calculate the initial dilution at the surface over the diffuser for the case where there is no current. We can do this from the following relation, also taken from the Roberts report,

$$D = 0.42\left(\frac{\Delta\rho}{\rho}\, g\right)^{1/3} h\left(\frac{q}{b}\right)^{-2/3} \qquad (3)$$

We obtain values of 340 for the Kait Bey outfall and 250 for the Sidi Bishr outfall.

As the wastewater field progresses away from the diffuser, there will be a secondary dilution related to the natural dispersion characteristics of the ocean waters. This additional dilution can be calculated in a number of ways, all of which give much the same result. We shall follow Brooks, using the 4/3 power diffusion law. Taking the above characteristics for the flow and diffuser length and Brooks' relation for the diffusion coefficient, we obtain an additional dilution by a factor of 4 at a distance of 10 km in the direction of the current from either outfall.

Details of outfall planning, design, and assimilation characteristics described in the Marine Studies Report, Chapter 5, Vol. IV, of the Master Plan Study are presented in Volume I Section III, and Technical Appendix No. 8 of this volume.

6.B.1.b Environmental Effects of Ocean Outfalls for the Eastern and Western Areas. The BOD of the wastewaters to be supplied to the two outfalls is estimated to be 530 mg/l. With the initial dilutions, the BOD in the receiving waters would be 1.0 mg/l for Kait Bey and 1.5 mg/l for Sidi Bishr. With the time constant measured in days for oxidation of the waste materials and the additional, secondary dilution as the wastes are dispersed by coastal currents away from the outfall locations, there will be a negligible effect on the DO concentrations of the receiving, ocean waters.

Nutrient values for the wastewaters are estimated at 33 mg/l for ammonia nitrogen, 40 mg/l for total nitrogen, 11 mg/l for dissolved phosphate, and 12 mg/l for total phosphorus. With the initial dilutions at each outfall, the estimated nutrient values above background in the receiving waters would be as given in Table 6-2. Such additional nutrient concentrations would not have a detrimental effect on the ocean waters. If anything, they would enhance the productivity of the generally impoverished eastern Mediterranean waters in the vicinity of the outfalls.

TABLE 6-2.

ESTIMATED WATER QUALITY VALUES ABOVE BACKGROUND AT THE OUTFALLS WITH INITIAL DILUTION

Outfall	BOD	NH_4 - N	Total N	PO_4 - P	Total P
	all units mg/l				
Kait Bey	1.0	0.061	0.085	0.020	0.026
Sidi Bishr	1.5	0.094	0.131	0.031	0.040

The bacterial concentrations of total coliforms at the existing Kait Bey outfall have been observed to be in the range of 10^7-10^9 per 100 ml. Typical standards for total coliform counts for bathing beach purposes are 1,000/100 ml and for shellfishing 100/100 ml. The current system at 10 km offshore is dominantly a coastwise current in either the northeast or southwest direction. Onshore currents have been observed for only 9 percent of the time at 10 km offshore and for only 2 to 7 percent of the time 2.5 km offshore. In addition, onshore currents, when they do occur, are of smaller magnitude than coastwise currents, being 7 to 8 cm/sec at 10 km offshore and 3 to 4 cm/sec at 2.5 km offshore. Furthermore, the duration of the onshore currents is limited to periods of a day or less; and from drogue measurements onshore currents only occur for the surface waters. All of this information indicates that there is little chance for bacterial pollution at the beaches from wastes discharged at a diffuser 10 km offshore in water depths of 50 m or so.

Nevertheless, it is of interest to determine whether bacterial pollution of the beaches could occur under the most adverse conditions. Initial and secondary dilutions would reduce bacterial concentrations by a factor of at least 10^3, reducing a wastewater value of 10^9/100 ml to 10^6/100 ml. The observed bacterial die-off rate is 1 hour for a reduction by a factor of 10 under daylight conditions. This would then require a residence time of 3 hours to reduce bacterial concentrations by an additional factor of 10^3 to 10^3/100 ml. For an onshore current velocity of 15 cm/sec, travel time to the beach would be 19 hours. Presuming negligible die-off occurs during night conditions, there is still ample time in transit from 10 km offshore to reduce the bacterial concentrations to levels below that for bathing beach standards. No disinfection of wastewaters at their source would appear to be needed.

If industrial wastewater is combined with domestic wastewater, these industrial wastes would be 61 Ml/day out of a total wastewater flow of 392 Ml/day for the Kait Bey outfall and 85 Ml/day out of a total 560 Ml/day for the Sidi Bishr outfall. This, then, gives a preliminary dilution of industrial wastes with municipal wastewaters by a factor of 6.4 and 6.6, respectively, prior to discharge at each outfall. The initial dilution

for each diffuser outfall for the industrial components would then be 540 x 6.4 = 3,500 and 350 x 6.6 = 2,300, respectively.

One of the possible toxic metal concerns for the city of Alexandria is that related to mercury wastes discharged from the Misr Chemical Industries plant, located on the Mediterranean coast west of Kait Bey.

Currently, these wastes are discharged directly to the Mediterranean from a shore outfall. This industrial pollution source as well as that of other industries in Alexandria has been covered in a report by A. Margola.[4] The mercury waste discharges are estimated by Margola to be 4 to 5 metric tons/year. This is not a measured value but rather a calculation from the plant input and product output. Presuming that this industrial waste would be included in the Kait Bey collection system and using the Kait Bey flow rate of 392 Ml/day gives a mercury concentration in the Kait Bey wastewaters of 0.032 mg/l. For the ocean diffuser outfall, this wastewater effluent would undergo an initial dilution of 540 with seawater. A characteristic value for the mercury concentration in seawater is 0.1 ug/l;[5] the resulting concentration of the wastewater and seawater mixture would then be 0.16 ug/l. For mercury, a value in excess of 0.1 ug/l[5] might constitute a hazard. While ocean discharge of Mex-Dekheila's industrial wastewater through the Kait Bey outfall was one of the alternatives considered in the Master Plan, those flows are treated by anaerobic-aerobic lagoons and then discharged to the new Noubaria Main Drain in the recommended plan. Insufficient data are currently available on both the Drain and the future industrial wasteload, to assess the impact of these discharges if the industrial waste ordinance is violated. Under all alternatives in which domestic and industrial wastewaters are combined, the Master Plan calls for industrial pretreatment to keep such toxics from the environment.

Pretreatment of industrial wastes should insure that heavy metals and toxics are kept from the outfall system. It is nevertheless useful to examine the possible consequences of failure to implement industrial waste control, as an approximate form of "worst case" analysis. Future industrial waste characteristics are uncertain, and projections can only be made on the basis of relatively few observations of concentrations for the existing Alexandria industrial wastewaters. Some values are given in the report by Margola for a dyestuff plant waste discharge in the Abu Kir industrial area and by F. Sharkawi[6] of the High Institute of Public Health for the industrial waste discharges along the north shore of Lake Maryut. These latter waste discharges are from a group of salt, match, yarn, starch, yeast, and paper plants. These values have been summarized in Table 6-3. Presuming that these types of industrial wastes were to be discharged through the Sidi Bishr outfall with a total preliminary and initial dilution of 2300, the metal concentrations in the ocean, taking the larger of the North Shore or Abu Kir industries and using the characteristic seawater values as given in column four of the table, gives the results shown in column five. For comparison, the suggested levels for these metals which might constitute an environmental hazard have also been included in the table.

TABLE 6-3.*

OBSERVED METAL CONCENTRATIONS FOR ALEXANDRIA INDUSTRIAL WASTES, CHARACTERISTIC SEAWATER CONCENTRATIONS, CALCULATED CONCENTRATIONS FOR DISPOSAL IN THE OCEAN, AND EPA HAZARD CRITERIA CONCENTRATIONS

Metal	North Shore Industries	Abu Kir Industries	Seawater	Sidi Bishr Outfall	EPA Hazard Criteria
			all units ug/l		
Cadmium	0.4	-	0.02	0.02	10
Chromium	1	300	0.04	0.17	100
Copper	3	150	1	1.1	5
Iron	1,500	-	10	10.1	300
Lead	180	150	0.02	0.10	50
Manganese	400	-	2	2.2	100
Nickel	0.8	-	7	7.0	100
Zinc	600	150	2	2.3	100

An additional item of concern is the sludge deposit which would be expected to build up adjacent to the Kait Bey and Sidi Bishr ocean outfalls from the deposition of suspended solids in the waste loads and the possible effect of this sludge deposit on the environment. Only grit and floatables would be removed before discharge to the ocean, if preliminary treatment were used. The suspended particulate matter loading for municipal wastes has been estimated to be about 500 mg/l and that for industrial wastes 1,100 mg/l. Preliminary treatment would probably reduce these concentrations by about 10 percent. The characteristics, then, of the suspended particulate matter loading for ocean discharge of combined industrial and domestic wastes after only preliminary treatment would be as shown in Table 6-4.

The continuing investigations of the Southern California Coastal Water Research Project have provided useful information on sludge deposits associated with ocean outfalls. The bathymetry and coastal current system off southern California are similar to those found off Alexandria. They have investigated in some detail the sludge deposit related to the Hyperion 7-mile outfall off Santa Monica, California. This outfall has been in operation since 1960 and discharges a mixture of plant sludges and secondary effluent. For 1974, the total solids emission rate was 55,000 tons/year, which is comparable to that of the proposed Kait Bey and Sidi Bishr outfalls.

*See also Technical Appendices No. 5A and 5B.

TABLE 6-4.

CHARACTERISTICS OF SUSPENDED SEDIMENT LOADING AFTER PRELIMINARY TREATMENT FOR OCEAN OUTFALLS

Constituent	Kait Bey Outfall	Sidi Bishr Outfall
Flow, total	392 Ml/day	560 Ml/day
Flow, municipal wastes	331	475
Flow, industrial wastes	61	85
Suspended solids concentration, municipal wastes	450 mg/l	450 mg/l
Suspended solids concentration, industrial wastes	990	990
Suspended solids emission rate	209 metric tons/day	298 metric tons/day
Suspended solids emission rate	76,000 metric tons/year	109,000 metric tons/year

Mitchell and Schafer[7] investigated the characteristics of this sludge deposit with the following findings. There is a rapid decline in the organic content and other measured properties of the settling particles with increasing distance from the outfall, which is because of dilution of the effluent solids by natural marine particulates rather than to any actual changes in effluent particle characteristics in the water column through dissolution or decay. Contaminant levels are high close to the outfall and decrease rapidly with distance for the first 3 km and thereafter decline more gradually with distance. More than 90 percent of the possible metal pollutants discharged through the Hyperion 7-mile pipeline are associated with particulate matter, and the association of these pollutants with the particulates is essentially unchanged by mixing with seawater. The current rate of discharge of particulate matter represents 20 percent of the total (effluent plus natural) particulate matter settling to the bottom in the Santa Monica Submarine Canyon study area (69 km^2). The rate of decomposition of organic matter in the sediments is substantially greater than the rate of trace metal mobilization. A layer of (primarily) sludge particulates exists on the canyon floor in the immediate vicinity of the outfall. This layer is approximately 25 cm deep and covers an area of about 2 km^2. Comparison with 1971 data indicates that this layer of sludge is not moving and that surface sediment quality has not changed noticeably between 1971 and 1974. They further concluded that 70 percent of the total metals discharged since commencement of operation of the outfall may be accounted for in these sediments.

Schafer and Bascom[8] continued these investigations. They reaffirmed that the principal sludge deposit occupied an area of 2 km^2 with a thickness of 25 cm. They found that this material is not moving as a body in

any direction and that the situation is stable, apparently not having changed for at least the previous 5 years. They also found that the sludge deposit has changed the ecology of the immediate area by increasing the abundance of fish and benthic animals but decreasing the number of species of benthic animals.

We conclude that a similar sludge deposit would build up at the Kait Bey and Sidi Bishr discharge sites and that the deposit would be confined to an area of about 4 km^2 around each site. Considering the other possible alternatives for the ultimate disposal of this undesirable solid waste material, the ocean alternative would appear to be reasonable and to have a minimal effect on the environment of the city of Alexandria and vicinity.

Suspended solids emission rates to the ocean could be reduced by about 55 percent, if primary treatment were used instead of preliminary treatment. This would reduce the suspended solids emission rate in Table 6-4 to 31,000 metric tons/year for the Kait Bey outfall and to around 54,000 metric tons/year for the Sidi Bishr outfall.

In addition, since most of the metals are associated with the particulate phase, the metal concentrations shown in column five of Table 6-3 would be reduced still further by about 10 percent with preliminary treatment and 55 percent with primary treatment.

6.B.1.c Additional Waste Disposal Through Ocean Outfalls From Outer West and Abu Kir Areas. Some consideration has been given to the disposal of additional wastes from the Mex-Dekheila industrial area to the proposed Kait Bey outfall and from the Abu Kir industrial area to the Sidi Bishr outfall. The environmental effects of this additional waste loading will be considered in this section.

For the Kait Bey outfall, the suggested additional waste loading would consist of 17 Ml/day of domestic wastes and 144 Ml/day of industrial wastes from the Mex-Dekheila industrial area. This would increase projected dry-weather flows for the Kait Bey outfall to 348 Ml/day of domestic wastes and 205 Ml/day of industrial wastes, or a total of 553 Ml/day (6.4 m^3/sec).

For the Sidi Bishr outfall, the suggested additional waste loading would consist of 23 Ml/day of domestic wastes and 150 Ml/day of industrial wastes from the Abu Kir industrial area. This would increase projected dry-weather flows for the Sidi Bishr outfall to 498 Ml/day of domestic wastes and 235 Ml/day of industrial wastes, or a total of 733 Ml/day (8.5 m^3/sec).

Following the same calculations for dilution at the outfalls related to the diffuser and the coastal currents, we obtain initial, minimum, dilution values of 380 for the Kait Bey outfall and 270 for the Sidi Bishr outfall.

Because of the increased industrial component, the BOD of the wastewaters to be supplied to the two outfalls would be increased to 570 mg/l. With the initial dilutions, the BOD in the receiving waters would be 1.5 mg/l and 2.1 mg/l, respectively, for the two outfalls. The corresponding values for the nitrogen and phosphorus concentrations in the receiving waters are summarized in Table 6-5. No adverse environmental effects would be anticipated for the additional loading.

TABLE 6-5.

ESTIMATED WATER QUALITY VALUES AT THE OUTFALLS WITH INITIAL DILUTION AND INCREASED LOADING

Outfall	BOD	NH - N	Total N	PO - P	Total P
	all units mg/l				
Kait Bey	1.5	0.066	0.092	0.021	0.024
Sidi Bishr	2.1	0.093	0.133	0.030	0.033

For industrial waste components, the combined dilution with the domestic component and with the diffuser and coastal current action would now have a total dilution value of 2.6 x 380 = 990 for the Kait Bey outfall and 3.1 x 270 = 840 for the Sidi Bishr outfall. Metal concentrations in the receiving waters at each outfall would be increased by approximately an order of magnitude if pretreatment were not implemented and industrial waste metals concentrations were the same as those listed in Table 6-3.

With additional industrial wastes, there would be a substantial increase in the suspended sediment loading. Following the same calculation procedures as before, the suspended sediment loading is estimated to be 131,000 metric tons/year for the Kait Bey outfall and 170,000 metric tons/year for the Sidi Bishr outfall, or an overall increase of 60 percent over the values given in Table 6-4.

6.B.1.d Environmental Effects of Mex Discharge on Dekheila Bay. In addition to the environmental effects of the proposed ocean outfalls, we must also consider the effect of the discharge from Lake Maryut to the ocean. In the next section of this report (6.B.2), we shall consider the effects under the various alternatives of discharging wastewater to Lake Maryut and, in turn, the effects of Lake Maryut on the wastewater. Here, we consider the effects of discharging these subsequent effluents through the Mex Canal to the Mediterranean.

The effluent is discharged via the Mex Pump Station and Mex Canal to Dekheila Bay on the Mediterranean coast. The Mex Canal is about 1 km in length and has a width of 22 m and a depth of 4 m at the Mex Pump Station,

increasing to 5 m nearer the sea. El Awady and Ghanem[9] report flows of 1,000 to 3,700 Ml/day through the Mex Canal, and Rafail and Hamid[10] report comparable flows of 2,000 to 3,800 Ml/day. More recent information indicates that the current flow through the Mex Canal is about 7,000 Ml/day.

The nature of the flow from the Mex Canal into Dekheila Bay would be determined in large part by the magnitude of densimetric Froude number, defined by the relation:

$$F = \frac{u^2}{\frac{g\Delta\rho}{\rho} d} \qquad (4)$$

where u is the current in the canal, g the acceleration because of gravity, $\Delta\rho$ the density difference between seawater and the effluent water, ρ the density of the effluent water, and d the canal depth. For the higher flow value of 7,000 Ml/day, F will be 0.83 and, for a lower flow value of 3,800 Ml/day, F will be 0.25. Under these conditions of low densimetric Froude numbers, less than unity, the flow from the Mex Canal into Dekheila Bay would resemble that of a well defined, brackish water river plume, such as that described by Garvine[11] for the flow of the Connecticut River plume into Long Island Sound or that described by Bowman[12] for the flow of the Hudson River plume into the New York Bight. In this sense, the discharge would have much the same physical characteristics as the current discharge from the Tabia Pump Station into Abu Kir Bay, as described in Chapter 3 (3.B.5). It is anticipated, then, that the flow would consist of a surface plume of 2 to 4 m thickness, whose configuration would principally depend on the nearshore currents, and that there would be little mixing of effluent waters with receiving waters within the confines of the plume.

The receiving body of water into which the Mex effluent is discharged, Dekheila Bay, is a relatively enclosed bay on the Mediterranean coast in the western portion of Alexandria. As shown on U.S. Hydrographic Office chart 56100, it is bounded on its seaward side by a series of shoals with limited access to the Mediterranean. It encloses an area of approximately 1,800 ha with an average depth of 10 m. The western harbor of Alexandria is located in the northeastern portion of Dekheila Bay, and the western harbor itself is defined by a breakwater that extends from the Kait Bey peninsula around to near the Mex discharge. The residence time for the effluent plume, should it occupy the whole of Dekheila Bay, would be 10 days for a flow of 7,000 Ml/day and 19 days for a flow of 3,800 Ml/day with a 4-m thick plume.

As has been stated in Chapter 3 (3.B.5), there is a paucity of information on existing physical and water quality conditions in Dekheila Bay. There is, however, some information on conditions in the western harbor, as given by El Awady and Ghanem,[9] which shall be discussed here. The western harbor is supplied with an effluent from the Mahmoudia Canal at its innermost, northeastern end and from the Mex Pump Station through the breakwater entrance at its southwestern end. These effluents within the

western harbor are of comparable magnitude with the Mahmoudia discharge being dominant during the summer months. The salinity distribution shows a 2 to 4-m brackish water layer overlying deeper waters of normal oceanic salinity. During the summer, the deeper waters within the western harbor are anoxic. The anoxic condition is attributed to a eutrophic effect in which the surface waters of both the Mahmoudia and Mex discharges, being rich in nutrients, support a dense planktonic population. This sinks to bottom waters and in its respiration uses all of the available oxygen in these deeper waters. Because of the constriction of the breakwater, these deeper waters have a relatively slow exchange with coastal Mediterranean waters.

Waters in the Mex Canal, which consist of the discharges from Lake Maryut and the Umoum Drain, are described by Ezzat and El Serafy[13] as being generally well oxygenated with values varying from 8.6 mg/l in the winter to 5.6 mg/l in the summer. Attention here will then be focused principally on possible eutrophication effects which might be expected to ensue under the various alternatives for discharge to Lake Maryut in addition to the organic oxidation which may be anticipated under both the local and regional treatment plant alternatives. Understandably, this assessment must be quite general because of both the lack of knowledge of existing conditions in Dekheila Bay and the relative uncertainties in the conditions of the waters to be discharged through the Mex Pump Station.

Under current conditions, the estimates of Table 3-15 indicate 46 percent removal of nitrogen and 63 percent removal of phosphorus for the combined Lake Maryut and Umoum Drain system. We do not know what the percentage removals are separately for the lake and drain waters. Our estimate is that under current conditions of wastewater loading and retention times, the Lake Proper removes about 50 percent of the nutrients and retains them within the lake system as algae and aquatic weeds. Nevertheless, this leaves a significant nutrient load discharged to Dekheila Bay with nutrient concentrations of 1.40 mg/l nitrogen and 0.11 mg/l phosphorus, as shown in Table 3-14. This current loading, along with that from the Mahmoudia Canal, is the cause of the eutrophication which currently exists in the western harbor.

If only Nouzha's wastes are discharged to Lake Maryut, the Main Basin would be an oxidation and assimilation pond of approximately the right size. The only nutrient contribution to the Mex discharge would be from the Umoum Drain. Conditions within Dekheila Bay should be improved, and any continuing eutrophication effects in the western harbor would be because of the Mahmoudia Canal discharge only.

With two new treatment plants for the eastern and western areas, the wastewater discharge into Lake Maryut would be increased to 955 Ml/day from the 395 Ml/day when only Nouzha's wastes are discharged to the lake, with corresponding increases in nitrogen, phosphorus, BOD, and suspended solids, as shown in Table 6-6. As shown in Table 6-7, the loading of the

Mex discharge would be increased to 3.0 mg/l nitrogen and 0.8 mg/l phosphorus with a BOD loading, in addition, of 18.4 mg/l. A substantial portion of this additional loading is attributable to the proposed West Treatment Plant, which would essentially discharge directly to Dekheila Bay via the Mex Pump Station with minimal dilution, oxidation, and nutrient assimilation within the lake system. Under these conditions, the plume waters would probably still remain reasonably well oxygenated with the photosynthetic oxygen production offsetting organic BOD oxidation. However, the eutrophic effects in the western harbor would be intensified and would spread to other, isolated portions of Dekheila Bay, if they do not already exist there. Depending on the circulation, mixing, and retention time effects for the deeper waters of Dekheila Bay, which are unknown factors but which may be restrictive because of the shoals on the seaward side of the bay, the eutrophication might extend to encompass the whole bay.

Under the regional plant alternative, all the wastewater from the eastern and western areas would be discharged to the eastern end of Lake Maryut and would pass through the Lake Proper before reaching the Mex Pump Station. Again, we are not able to estimate the quantitative effects of this loading. As discussed in more detail in this chapter (6.B.2), there would be little assimilation of this loading by the lake system; it can only be anticipated that there would be substantial detrimental effects within Dekheila Bay and that the plume itself would begin to resemble that in Abu Kir Bay from the existing Tabia Pump Station, which has been discussed in Chapter 3 (3.B.5).

6.B.2 Lake Disposal

6.B.2.a Introduction. Disposal to Lake Maryut was considered a viable alternative by the engineering staff of the Wastewater Master Plan Study during the course of our environmental analyses, and the impacts of lake disposal are presented below. Partly as a result of our findings, lake disposal was ruled out as an unacceptable long-term solution for the management of Alexandria's wastewater in the final report of the Master Plan, and is not presented as an acceptable alternative therein.

In considering the impact of various alternatives which involve discharging wastewater to Lake Maryut, one must consider both the effect of the wastewater on the environment of Lake Maryut and the effect of Lake Maryut on the wastewater, because any flows into the lake will sooner or later be discharged from it to the Mediterranean via the Mex Pump Station, and their subsequent impact on the Mediterranean must also be evaluated. Generally, Lake Maryut may be considered as a wastewater oxidation lagoon, the effectiveness of which would depend on wastewater loadings, the rate of circulation of wastewater and other inputs (agricultural drainage) through the lake, and several other factors including the lake's general state of health and its level of eutrophication. The effect of these discharges on the lake itself would depend on much the same set of variables.

The more slowly wastewater passes through the lake, the more completely would the suspended sediment load in the wastewater be removed by sedimentation. At the same time, however, a new burden of suspended organic matter would develop in the form of unicellular algae (phytoplankton) the density of which would be inversely proportional to the rate of flushing of the lake. At long retention times, this secondary load of suspended solids would also settle to the bottom and further increase the rate of organic sedimentation.

The secondary loading of suspended solids (the phytoplankton) produces oxygen by photosynthesis in sunlight but it removes oxygen at night, in deep water and on the bottom, thereby contributing directly to BOD. The phytoplankton removes nitrogen and phosphorus while it is growing but liberates these nutrients when the cells die and decompose. If the rates of respiration and decomposition of the phytoplankton exceed their rate of photosynthesis, oxygen depletion, anoxia, and mass mortality of animals may occur. On balance, then, the development of a dense phytoplankton population, usually referred to as "eutrophication," would lead to ecological instability, reduced animal productivity including that of the fisheries, and a shortening of the life of the lake. Generally, this is descriptive of the situation which now exists in Lake Maryut.

The ecological condition of Lake Maryut can, of course, be improved by reducing or eliminating the input of wastewater. It can also be improved by increasing the rate of flushing (or decreasing retention time) of water passing through the lake, because if flushing is rapid enough, a dense secondary loading of phytoplankton would not have sufficient time to develop. Paradoxically, however, more rapid flushing would also result in less effective treatment of wastewater within the lake and the discharge of essentially untreated wastewater to the Mediterranean.

In discussing the assimilation of nutrients by aquatic plants in Lake Maryut, it is impossible to differentiate between the uptake and subsequent growth and organic production of the suspended, unicellular algae (phytoplankton) and the larger aquatic or macrophytes such as the rooted, submerged species, Potamogeton pectinatus, the emergent reed grasses (e.g., Phragmites communis), and the floating water hyacinth (Eichornia crassipes). No data are available concerning the relative importance of these two kinds of plants with respect to their current biomass or rate of growth, and no projection can be made for the future. Unfortunately, both the effectiveness of the lake in treating wastewater and the ecological health and longevity of the lake itself will depend very much on the interrelationship between these different forms of vegetation. These uncertainties, together with the general lack of information about the ecology of Lake Maryut in its current condition, render it impossible to make any reliable quantitative assessment of the impact of proposed future wastewater discharges to the lake. The following projections are therefore largely qualitative and those computations which have been made should be treated as no more than rough estimates.

6.B.2.b Environmental Effects of the Nouzha Discharge. If Lake Maryut does not receive the wastewaters of the eastern and western areas, the only wastewater which would enter Lake Maryut would be that from the Nouzha area which would receive secondary treatment at the existing East Treatment Plant and enter the southeastern end of the lake, as currently in the Kalaa Drain via the Hydrodrome Drain. This flow, consisting of 38 Ml/day of domestic wastewater and 7 Ml/day of industrial wastewater or the domestic component only (if industrial wastes are excluded) will be combined with 350 Ml/day of agricultural drainage in the Kalaa Drain before entering Lake Maryut. (The latter is assumed to be the same as the current agricultural drainage flow.)

Wastewater flows would be 18 percent and 15 percent and total flows 66 percent and 65 percent of current flows for the Nouzha discharge with and without industrial wastes, respectively. These flows and accompanying wasteloads are shown in Table 6-6. The latter are exaggerated in that they do not reflect water quality improvement in the passage of wastewater through the Hydrodrome and Kalaa drains prior to its entering Lake Maryut.

Roughly 26 percent and 16 percent, respectively, of the current wastewater nitrogen and phosphorus loadings would enter the lake under these alternatives. Their concentrations would average about 6 mg N/l and 1 mg P/l. The loadings of BOD and suspended solids, on the other hand, would be reduced to at most 5 percent of their current levels, but more likely about half of that value, because these are the parameters which would be most affected by retention in the Hydrodrome and Kalaa drains. Water entering the lake would, therefore, carry no more than about 2.5 tons/day of BOD and suspended solids with mean concentrations of about 6 mg/l.

The flows of 388 to 395 Ml/day into the 18,800 Ml of the main basin of Lake Maryut would result in a residence time of about 48 days less whatever flushing might result from leakage into the lake from the Umoum Drain and the Noubaria Canal. The latter is quantitatively and geographically unpredictable but is believed to affect no more than the western end of the Main Basin. The remainder of the lake would be relatively stagnant and still highly eutrophic, because the nutrient loading would still support a rate or organic productivity of about 4 grams dry wt/m^2/day, exactly the estimated current level of plant production in Lake Maryut (A.A. Samaan, personal communication).

Organic sedimentation and depletion of DO from the water resulting from wastewater effluent per se would be sharply reduced. However, the increased retention time, one and one-half times the current rate resulting from the decrease in flow by one-third, would result in greater accumulation of photosynthetically produced organic matter which, in turn, would increase its rate of sedimentation. DO levels would be supersaturated, and pH levels would be in the 9 to 10 range over most of the lake during the day, but both would decrease sharply at night, and several days of cloudy weather could cause widespread anoxia and mass mortality of the biota. Ecological stability would not significantly improve over current

TABLE 6-6.

ALTERNATIVE EASTERN LAKE MARYUT WASTEWATER FLOWS (Ml/DAY) AND LOADING (TONS/DAY), CURRENT AND PROJECTED

Current:	Flow	N	P	BOD	Suspended Solids
Wastewater	200	9.4	2.93	104	126
Agricultural	350	0.6	0.07	-	-
Projected Alternative Flows:	(2000 A.D. wastewater + current agricultural)				
(A)	395	2.6	0.47	6	7
(B)	388	2.6	0.47	5	5
(C)	955	13.6	5.07	88	104
(D)	863	12.6	5.07	70	75
(E)	1,347	21.6	8.07	145	171
(F)	1,194	20.6	8.07	115	123

(A) Combined domestic and industrial wastes from Nouzha after treatment at the existing East Treatment Plant.

(B) As in (A), except without industrial wastes.

(C) Combined industrial and domestic wastes from (1) Nouzha, after treatment at the existing East Treatment Plant, and (2) the eastern area, after treatment at a proposed local secondary treatment plant.

(D) As in (C), except without industrial wastes.

(E) Combined industrial and domestic wastes from (1) Nouzha after treatment at the existing East Treatment Plant, and (2) the eastern and western areas after treatment at a proposed regional secondary treatment plant.

(F) As in (E), except without industrial wastes.

conditions. Fish production might increase to some extent but would continue to be subjected to large fluctuations and periodic depressions because of the aforementioned anoxia.

The only significant improvement in water quality would be seen at Mex Station and in the water pumped to the Mediterranean, because the net flow of nutrients from the wastewater input would be tied up in the plankton, much of which would settle out before reaching Mex. In short, if the only wastewater discharge to the lake were from Nouzha via the East Treatment Plant, the Main Basin of Lake Maryut would effectively serve as an oxidation pond of just about the proper size.

The above conditions would, however, be complicated by inputs from the Umoum Drain and Noubaria Canal which together dilute the wastewater effluent, after its passage through the lake, by a factor of nearly 20-fold prior to its discharge to the sea. At the same time, however, waters from these sources contribute a total daily loading of 10.6 tons of nitrogen and 1.2 tons of phosphorus to the Mediterranean out at Mex, albeit in a highly diluted form (see Table 3-15).[14]

A rather different set of conditions would result if the combined wastewater-agricultural drainage now proposed to enter Lake Maryut via the Kalaa Drain were instead mixed with the water of the Umoum Drain where the latter crosses the Desert Highway and begins to cross the lake. This would be true particularly if the Umoum Drain, rather than being channeled across Lake Maryut to the Mex Pump Station, were deflected into the lake towards its southeastern end in such a way that the combined flows ($\sim$5,390 Ml/day) would circulate in a counter-clockwise direction before reaching Mex. Complete circulation of that flow through the 1,880-ha Main Basin of Lake Maryut would result in a retention time of about 3.5 days in contrast to the 48 days resulting from the input of the Kalaa Drain alone (see above).

The combined Umoum and Kalaa Drain flows would carry nitrogen and phosphorus loadings of 11.6 and 1.5 tons/day, respectively. These nutrients would support an average rate of organic productivity of 12 grams dry wt/m^2/day, the same as reported by Aleem and Salaam in 1960 to 1961.[15] That level of organic production would convert all of the nitrogen and 80 percent of the phosphorus to plant biomass, unicellular algae, and the larger macrophytes (water hyacinth, reed grass, etc.). Because of the more rapid flushing rate, high concentrations of organic matter (e.g., unicellular algae) would not accumulate in the water nor would this material have time to settle to the bottom, but a relatively dilute suspension of organisms would instead be discharged into the Mediterranean via Mex. The advantages of this treatment would be that organic sedimentation would be reduced to about 10 percent of its rate with the current configuration (i.e., with respect to the Kalaa and Umoum drains and the proposed discharge via the Kalaa Drain), and the life of the lake would accordingly be prolonged by some tenfold. Furthermore, the water quality and, more importantly, the ecological stability of the lake would be markedly improved, with little or no danger of anoxia and the accompanying mortalities. Fish production should increase and stabilize at levels substantially

higher than current catches, although it is not possible to forecast quantitative yields, because it cannot be predicted what fraction of organic production would be utilized by the fishes, what fraction would go into unedible macrophytes, and what fraction would be flushed out of the lake at Mex.

6.B.2.c Environmental Effects of Lake Maryut Discharges From Two Additional Treatment Plants. Under one lake disposal alternative for the eastern area, 475 Ml/day of domestic and 85 Ml/day of industrial wastewater would receive secondary treatment at a proposed local secondary treatment plant. Effluent from the new plant, combined with the 38 Ml/day of domestic and 7 Ml/day of industrial wastewater from Nouzha, receiving secondary treatment at the existing East Treatment Plant and the 350 Ml/day of agricultural drainage - a total of 955 Ml/day would flow into the southeastern end of Lake Maryut via the Kalaa Drain. This wastewater flow would have a daily loading of 13.6 tons of nitrogen, 5.07 tons of phosphorus, 88 tons of BOD, and 104 tons of suspended solids (Table 6-6).

The flow of 955 Ml/day would result in a retention time in the Main Basin of roughly 20 days as compared to the current 31 days. That and the fact that BOD and suspended solid loadings would both be somewhat lower than (85 percent and 83 percent, respectively) current levels would result in somewhat improved conditions over most of the lake. However, nutrient loadings would be significantly higher than currently, with 1.4 times as much nitrogen and 1.7 times as much phosphorus entering the eastern end of the lake. If phytoplankton growth is not inhabited, the increased nutrient loading and clearer water (resulting from less suspended solids) would enhance photosynthetic plant production, thereby producing a secondary organic loading which would increase sedimentation rate, BOD, oxygen depletion at night and in cloudy weather, and the hazards of anoxiz, ecological instability, and mass mortalities. The nutrients supply would be capable of supporting a mean annual rate of organic production over the entire lake in excess of 14 grams dry wt/m^2/day, although that is probably in excess of the light-limiting rate of photosynthesis. Such a rate of organic production, accumulating for 20 days, would result in a particulate organic loading of 289 mg/l which would either settle to the bottom or contribute to the BOD of the water when photosynthesis cannot take place (i.e., in the dark).

If, on the other hand, toxicity or light limitation result in lower rates of organic production, a surplus of nitrogen and phosphorus would remain dissolved in the water and leave the lake via Mex Station to contribute to eutrophication of the Mediterranean coastal waters.

In short, conditions in Lake Maryut resulting alone from wastewater effluent from the new and existing East Treatment Plants discharged to its eastern end via the Kalaa Drain, not even considering the effects of discharging effluent for the proposed West Treatment Plant into the northwest end of the lake, would be, at best, no better than the current, highly eutrophic, heavily polluted condition of the Main Basin.

Secondary effluent from the new West Treatment Plant, 331 Ml/day of domestic and 61 Ml/day of industrial wastewater from the western area, should be discharged into Lake Maryut on its North Shore just east of the Noubaria Canal. There is no way to predict the exact course or rate of flow of that discharge through the lake, but the net direction must be to the west, and through breaks in the Noubaria Canal and Umoum Drain, to the Mex Pump Station from which it would be discharged to the Mediterranean. The main impact of this wastewater would therefore be felt not in the Main Basin of Lake Maryut, but in the small (340 ha), triangular basin formed by and lying north of the intersection of the Noubaria Canal and the Umoum Drain and designated for reclamation for future industrial development.

Nothing is known about the existing water quality or ecology of this small basin or its significance in contributing to the commercial fishery catch of the lake as a whole. However, because of the many breaks in the dykes of the Noubaria Canal and Umoum Drain at their northern ends (creating in effect a myriad of small islets through which water from the Main Basin passes freely to the Mex Pump Station), water in that basin is probably a mixture from the Main Basin, the Noubaria Canal, and the Umoum Drain. This water is circulated through the area and pumped out at Mex Station at a rate of about 8,000 Ml/day, 7,000 from the Umoum and Noubaria (Table 3-15) and 955 from the Kalaa Drain (Table 6-6). To this would be added the 392 Ml/day effluent from the West Treatment Plant, which must presumably be diluted 20-fold and quickly (0.4 day retention) pumped out to the Mediterranean. Such a quick passage would be too rapid to be modified within the lake system, or in turn to affect it; and, therefore, other than dilution, the West Treatment Plant effluent would probably be discharged to the Mediterranean essentially unchanged.

Total estimated flows and loadings to the Mediterranean from Lake Maryut via the Mex Pump Station, if two secondary treatment plants are built for the eastern and western areas, are shown in Table 6-7.

Other than eliminating any possible detrimental effects of toxic components of industrial wastewaters on the environment and its biota, the separate disposal of industrial wastewater would reduce wastewater flows and loadings, as shown in Table 6-6. However, that reduction is so small (about 10 to 25 percent) as to be insignificant compared to uncertainties in the environmental impact assessment which result from lack of other data. Other than effects of toxic trace contaminants, discussed separately, the impact of wastewater discharges with or without industrial waste to Lake Maryut and, indirectly, to the Mediterranean are, therefore, assumed to be the same.

Environmental conditions in the Main Basin would again be improved if wastewater effluents from the existing and proposed new east treatment plants, together with the agricultural drainage scheduled to enter the lake via the Kalaa Drain, were instead all combined with input from the Umoum Drain and the total flow diverted out of the existing dyked channel and directed to flow around the basin counter-clockwise to the Mex Pump Station. The total flow of 5,955 Ml/day (including industrial wastes) or

TABLE 6-7.

PROJECTED WASTEWATER FLOWS (Ml/DAY) AND LOADINGS (TONS/DAY) FROM LAKE MARYUT TO THE MEDITERRANEAN VIA MEX PUMP STATION WITH TWO NEW LOCAL TREATMENT PLANTS

Source	Flow	N	P	BOD	Suspended Solids
East Treatment Plants[1]	955	6.8[2]	2.5[2]	88[3]	104[3]
Umoum Drain[4]	5,000	9.0	1.0	-	-
Noubaria Canal[4]	2,000	1.6	0.04	-	-
West Treatment Plant	392	8.0	3.0	57	67
Total	8,347	25.4	6.54	145	171
Concentration (mg/l)	-	3.0	0.8	18.4	20.5

[1] Kalaa Drain and Main Basin.
[2] 50 percent removal in Main Basin.
[3] 100 percent replacement of original loading with phytoplankton.
[4] Assuming the same flows as currently.

5,863 Ml/day (without industrial wastes) would have a residence time of just over 3 days. Assuming that the 12-gram dry wt/m^2/day rate of organic production reported by Aleem and Salaam[15] approximates the maximum, light-limited mean rate of photosynthesis which could occur in that area throughout the year,[16] the entire Main Basin could assimilate no more than about 11 tons of nitrogen and 1 ton of phosphorus per day, only 50 percent and 18 percent of total daily loadings of these nutrients to the lake from combined wastewater and agricultural drainage flows. But, again, the rapid flushing would prevent the buildup of a dense algal population, greatly decrease sedimentation rate, prolong the life of the lake, and significantly improve its water quality, ecological stability, and fish production.

The problem is that roughly half the nitrogen and phosphorus and probably most of the initial BOD and suspended solids load would still be present in the water when it was pumped out to the Mediterranean at Mex Dekheila, as with the alternative of the two new treatment plants, discussed above. Lake Maryut would be improved but subsequent pollution of the Mediterranean would not.

The only way to improve the water quality of the final effluent prior to its discharge to the sea would be to circulate the combined wastewater-agricultural drainage (i.e., Kalaa and Umoum Drain inputs) through both the Main and Southeast basins, roughly doubling the area of effective photosynthesis. In that event, the water ultimately discharged to the

Mediterranean would contain twice the concentration of phytoplankton (ca. 72 mg/l less whatever is consumed by animals) but no dissolved nitrogen or phosphorus and probably none of the original loading of BOD or suspended solids. Both basins would then be assured of good water quality and increased and sustained fish production, while the only subsequent pollution of the Mediterranean would come from the West Treatment Plant and its more or less direct passage to Mex.

6.B.2.d Environmental Effects of a New Regional Treatment Plant. Under the other lake disposal alternative considered, wastes from both the eastern and western areas would be treated at a proposed new secondary treatment plant located south of the hydrodrome, the effluent from which, consisting of 1,194 Ml/day of domestic and 153 Ml/day of industrial wastewater would be discharged to the eastern end of Lake Maryut via the Hydrodrome and Kalaa drains. Wastewater loadings would consist of 21.6, 8.07, 145, and 171 tons/day of N, P, BOD, and suspended solids, respectively, if industrial wastes are included, and 20.6, 8.07, 115, and 123 tons/day, if industrial wastes are excluded.[17]

Assuming that these flows became evenly mixed in the Main Basin of Lake Maryut, as was done for the other alternatives, mean residence time in the lake would be approximately 14 days. The mean BOD accumulated over that time period, about 100 mg/l, would be sufficient to turn the entire lake anoxic. However, if mean organic productivity were able to proceed at its assumed maximum potential rate of 12 grams dry wt/m^2/day (see above) and the 1-meter depth of water were kept well mixed by wind action, the photosynthetic production of 20 mg/l/day or 280 mg/l for the 14-day retention time would more than satisfy the accumulated BOD. As explained above, however, the photosynthetically-produced organic matter, if all in the form of phytoplankton, would represent a new BOD loading which would actually be higher (168 mg/l over 14-days retention minus any amount consumed by animals or lost to sedimentation in that time) than the original. Respiration of phytoplankton at night together with reduced photosynthesis during the day (i.e., during a series of cloudy days in winter) could result in complete anoxia of the lake and mass mortality of its biota.

Again, the situation would be very different if a significant fraction of the nutrients were assimilated by macrophytes such as water hyacinth and reed grasses, particularly if the latter were to form a dense marsh in front of the Kalaa Drain area through which effluent were to pass before entering the lake proper.

The suspended sediment input, if evenly spread over the Main Basin, would represent a loading of nearly 1 gram/m^2/day, enough to fill in the entire basin in a year or less, if it were all inorganic or refractory and were all to sediment in the 14-day retention time. However, nothing is known about the quality, density, or composition of the suspended solids or how rapidly their organic fraction may decompose in the water or sediments; therefore, their impact cannot be accurately forecast.

Actually, however, future waste loads to Lake Maryut from a regional treatment plant treating both domestic and industrial wastes would not be very different from those currently occurring with respect to BOD and suspended solids. Projected BOD and suspended solids loadings are about 1.4 times current loadings. That, together with the fact that residence time would be a little less than half the current time (14 vs. 31 days), means that the impact on the lake from those factors would be of little, if any, difference.

Nutrient loadings, however, would be greater by a factor of about tenfold for nitrogen and 2.7-fold for phosphorus. The projected maximum rate of photosynthetic production discussed above, however it were partitioned in the phytoplankton or macrophytes, could utilize no more than about half of the nitrogen and only 14 percent of the phosphorus. The remainder, together with unknown quantities of nitrogen and phosphorus regenerated from decomposition of sediments, macrophytes, and dead phytoplankton plus that contained in the phytoplankton itself and in the wastewater-derived suspended solids not consumed or sedimented, would leave the lake via the Mex Pump Station.

Again, the water quality, ecological stability, longevity, and fish production of the lake would be improved if the wastewater were combined with the agricultural drainage in the Umoum Drain and the combined flow circulated through the Main Basin. The retention time of 3 days, about the same as with the local treatment plants, would result in the same conditions in the lake and essentially the same loadings to the Mediterranean from the Mex Pump Station.

Combined nutrient loadings from waste treatment plant effluents and agricultural drainage, which are the same for both local and regional treatment plant alternatives, would be 30.6 tons/day of nitrogen and 9.07 tons/day of phosphorus. Utilization of all of the nitrogen by photosynthetic plant production would require a minimum area of 5,000 ha, nearly the combined areas of the five separate basins of Lake Maryut (5,440 ha). Only about one-third of the phosphorus would be removed, however, because it is excessive relative to nitrogen, based on the ratio with which these elements are utilized by plants. However, phosphorus alone without nitrogen would have no environmental impact.

The total flows of wastewater and agricultural drainage of 6,347 Ml/day would pass through the 5,440-ha five basins of Lake Maryut in 8.6 days. This would not be long enough to permit the series of basins to function with peak efficiency as aerobic waste treatment lagoons, but some sedimentation of initial suspended solids would occur. The initial BOD loading would be replaced by phytoplankton; the latter should not exceed 100 mg/l and would be significantly less than that if a substantial part of the nutrients were taken up by a growing population of macrophytes and if secondary production of herbivorous or omnivorous animals were sufficient to keep the unicellular algae grazed down. Water quality and fish production throughout the five basins of Lake Maryut would be markedly enhanced, and the impact on the Mediterranean would be minimized by such a procedure.

6.B.2.e The Impact of Toxic Industrial Wastes on Lake Maryut. According to the draft final report of the Alexandria Wastewater Facilities Development Program (p. 2-6),[18] "There are two basic means by which toxic industrial wastewaters can be handled: exclusion from the sewerage system by means of a separate collection system; and acceptance in the sewer system after the specific industrial toxicant materials have been neutralized, properly treated, or removed in-plant so that the effluent stream is of a compatible nature with domestic sewage."*

One set of disposal alternatives calls for separate collection and disposal of industrial wastes, those from the Abu Kir district to an evaporation pond constructed from a part of Lake Idku and those from other industrial areas of the city to an evaporation pond in the far Western Basin of Lake Maryut. The latter is the saline area described in Chapter 3 (Section B.5) which varies in size seasonally from 4,500 ha (winter) to 480 ha (summer). The seasonally dry area to the far west would be used for this purpose, not involving the eastern section of that basin which is now used for salt production nor the five fresh-to-brackish basins of Lake Maryut which together total 5,440 ha.

Under all alternatives which accept industrial wastes into the city's sewers, these wastes would receive pretreatment at their source to remove or neutralize toxic elements and render them comparable to domestic wastes with respect to their toxicity to the environment and its biota (see above). To the extent that this policy is successfully implemented, industrial wastes would have no environmental impact beyond their contribution to the nutrient, BOD, and suspended solid waste loading, the effects of which have been previously discussed.*

Should pretreatment or separate disposal of toxic industrial wastes not be accomplished, it is difficult to assess their impact on Lake Maryut if they are discharged there, because neither their exact quality or quantity in the year 2000 is now known. However, the draft final report of the Alexandria Wastewater Facilities Development Program, p. 2-4,[18] states that, "the strength of future domestic and industrial wastewaters will remain at much the same level as is present today....." Heavy metal concentrations in the combined industrial pump station which now discharges into eastern Lake Maryut have been reported by Dr. F. Sharkawi [19] and are shown in Table 6-8.*

All alternatives for Lake Maryut wastewater disposal call for activated sludge, secondary treatment prior to lake discharge. For many of the heavy metals found in industrial wastewater, including cadmium, chromium, copper, iron, lead, and zinc, about 90 percent is found associated with the particulate fraction.[20] The secondary treatment process, assuming that it can take place in the presence of toxic industrial wastes if no pretreatment occurs, removes anywhere from 50 percent to 90 percent of the suspended solids load, depending on the efficiency of the treatment. Assuming a 70 percent removal of suspended solids, the remaining concentration of metals in the Alexandria industrial wastewater (e.g., Sharkawi's data) after secondary treatment is also shown in Table 6-8.

*Also see Technical Appendices No. 5A, 5B and 6, this volume.

TABLE 6-8.

ESTIMATED CONCENTRATIONS OF HEAVY METALS IN INDUSTRIAL WASTEWATER,[1] IN SECONDARY EFFLUENT,[2] AND IN FINAL EFFLUENT ENTERING LAKE MARYUT[3]

(all concentrations in ug/l)

Metal	Industrial Wastewater	2° Effluent	Existing ETP Only	Input to Lake Maryut: Proposed Local Plants ETP	Input to Lake Maryut: Proposed Local Plants WTP	Input to Lake Maryut: Proposed Regional Plant
Ni	0.6	0.2	<0.01	0.02	0.03	0.02
Fe	1,448.0	420.0	7.6	40.3	63.0	46.2
Zn	537.0	156.0	2.8	15.0	23.4	17.2
Cu	2.5	0.7	0.01	0.07	0.1	0.08
Mn	322.0	93.4	0.11	9.0	14.0	10.3
Cr	0.2	0.06	<0.01	<0.01	0.01	0.01
Pb	171.0	49.6	0.06	4.8	7.4	5.5
Cd	0.2	0.06	<0.01	<0.01	0.01	0.01

[1]Sharkawi, F., "Mean Concentrations at Combined Industries Pump Stations," Study on Lake Maryut Water Pollution Resulting from Wastewater and Industrial Waste Outfalls (Unpublished Report).

[2]Assuming heavy metals all associated with suspended solids.

[3]After dilution with domestic wastewater and agricultural drainage and assuming zero concentrations in those sources.

Assuming that the strength and composition of industrial wastewater in 2000 would be "much the same as today," as discussed above, the concentrations of metals entering Lake Maryut under the various alternatives, even with no pretreatment and removal at the source, is shown in Table 6-8.

Values in each case were obtained by multiplying the assumed concentration of each metal in the secondary effluent by the appropriate dilution factor for the accompanying domestic wastewater and agricultural drainage (including only that entering by the Kalaa Drain and not that of the Umoum Drain), and also assuming no significant concentration of heavy metals in the diluting sources.

Should inputs from the Kalaa Drain in the various alternatives be further diluted by inflow of the Umoum Drain, as has been suggested above, the concentrations shown in Table 6-8 would be further decreased, roughly by another order of magnitude. Even without the latter, projected concentrations of the eight heavy metals considered, in all of the alternatives, would be lower than those stated by the U.S. Environmental Protection Agency to be hazardous to the environment (see Table 6-8), by at least one and, in most cases, by several orders of magnitude. Predicted concentrations of heavy metals entering Lake Maryut are also comparable to or lower than natural concentrations found in coastal Mediterranean waters off Israel (Table 6-9). However, all these predictions are based on existing industrial wastewater data.

Untreated and undiluted industrial wastewater is now entering Lake Maryut at the concentrations shown in Table 6-3. A sample of the commercial fish catch taken in the immediate vicinity of that outfall showed no unusual or hazardous concentration of heavy metals (Table 3-22). This would indicate that if proposed wastewater discharges to Lake Maryut maintain similar characteristics (even with no pretreatment or separate disposal of industrial wastewater), they would have no harmful effects on the lake ecosystem.

6.B.3 Wastewater Irrigation

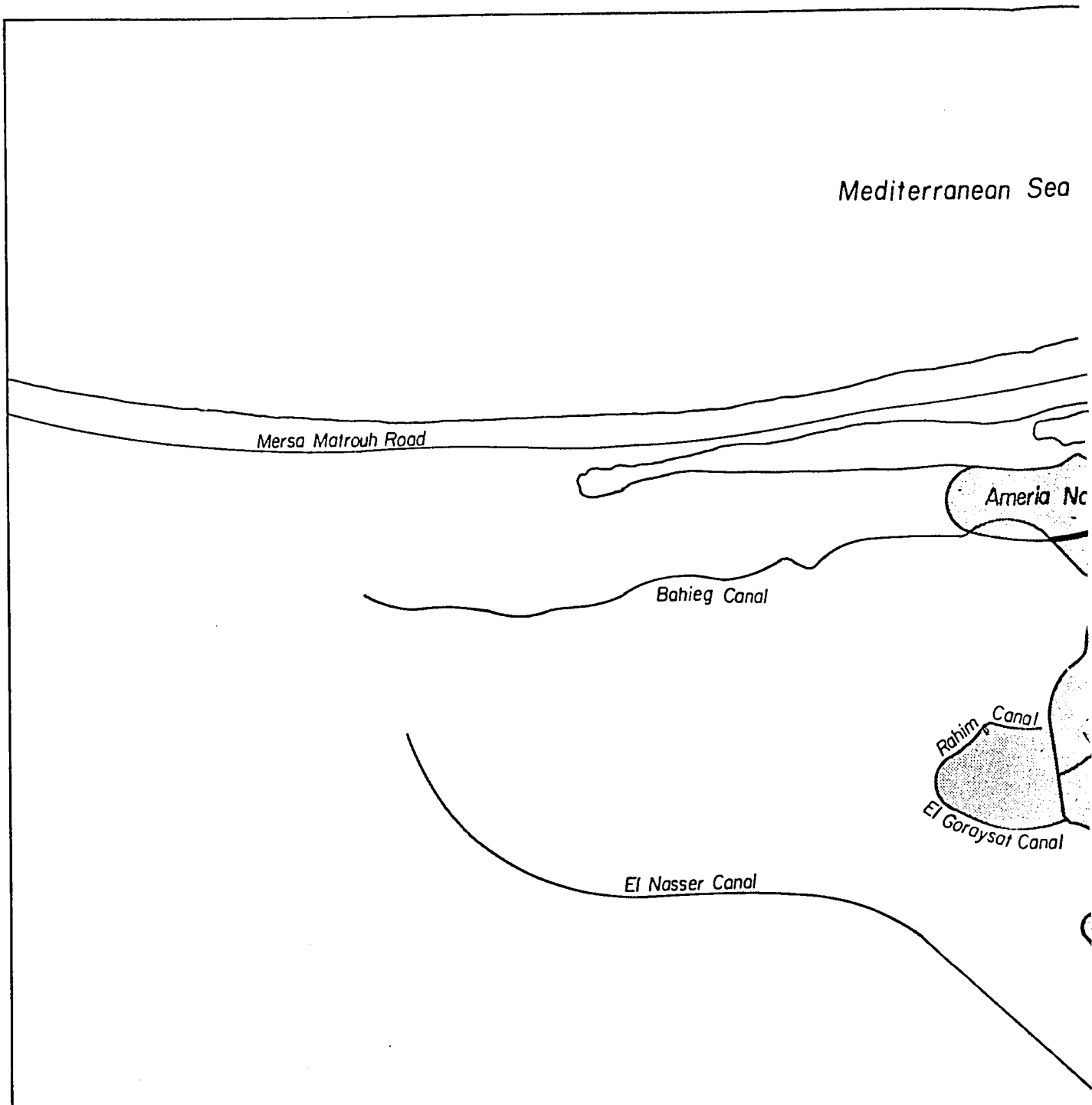
Alexandria's wastewater could be reused for agricultural irrigation after appropriate treatment, and the feasibility of this alternative was investigated early in the preparation of the Master Plan. John Bailey, an a report[21] for CDM in June 1977 to examine the agricultural potential for wastewater reuse in Alexandria. The service areas he considered most feasible are described below, followed by a discussion of the relationship between public health and the level of wastewater treatment provided. The viability and environmental impact of the irrigation alternative depend to a large measure on the high strength of Alexandria's wastewater and the dilution required before reuse; these issues are briefly addressed below. Finally, an economic comparison is made between wastewater reuse and more conventional means of irrigation.

TABLE 6-9.

CONCENTRATIONS OF TRACE METALS IN WATER SAMPLES FROM THREE COASTAL MEDITERRANEAN STATIONS OFF ISRAEL, 20 OCTOBER-11 NOVEMBER 1974 (μ grams/liter)[1]

	Acre					Kiryat Yam					Haifa				
	Cd	Pb	Cu	Zn	Ni	Cd	Pb	Cu	Zn	Ni	Cd	Pb	Cu	Zn	Ni
20 October	0.8	8.3	2.5	87.2	3.8	1.5	9.3	3.7	24.4	5.0	0.6	6.7	1.5	52.9	2.6
21 October	0.7	6.9	1.6	86.5	3.4	0.7	7.6	3.2	24.6	3.6	0.5	5.9	1.8	57.4	2.3
22 October	0.6	7.9	2.3	13.4	3.2	0.9	7.5	2.9	17.3	3.7	0.7	8.0	3.2	48.8	3.1
23 October	0.6	5.5	1.6	8.9	2.7	0.6	6.7	1.9	67.6	3.1	0.8	6.2	1.9	17.3	3.0
25 October	0.7	7.5	2.3	33.3	3.1	0.7	5.8	2.3	17.5	2.7	0.8	6.2	1.8	32.4	2.8
5 November	-	-	-	-	-	-	-	-	-	-	0.8	7.7	2.1	15.9	3.0
10 November	0.8	7.3	2.0	32.1	3.5	-	-	-	-	-	-	-	-	-	-
Mean	0.7	7.2	2.0	-	3.3	0.9	7.4	2.8	30.3	3.6	0.7	6.8	2.1	37.5	2.8
Minimum	0.6	5.5	1.6	8.9	2.7	0.6	5.8	1.9	17.3	2.7	0.5	5.9	1.5	15.9	2.3
Maximum	0.8	8.3	2.5	87.2	3.8	1.5	9.3	3.7	67.6	5.0	0.8	8.0	3.2	57.4	3.1
Minimum:Maximum	1.3	1.5	1.6	9.8	1.4	2.5	1.6	2.0	3.9	1.9	1.6	1.4	2.1	3.6	1.3

[1] Roth, I., and Hornung, H., "Heavy Metal Concentrations in Water, Sediments, and Fish From the Mediterranean Coastal Area, Israel," Env. Sci. and Tech., 11, 1977, pp. 265 269.



Reference: Potential Reuse of Sewage Water for Irrigation of Land Near Alexandria and Amerio by John Bailey, (Bookman-Edmonston Engineering, 1977).

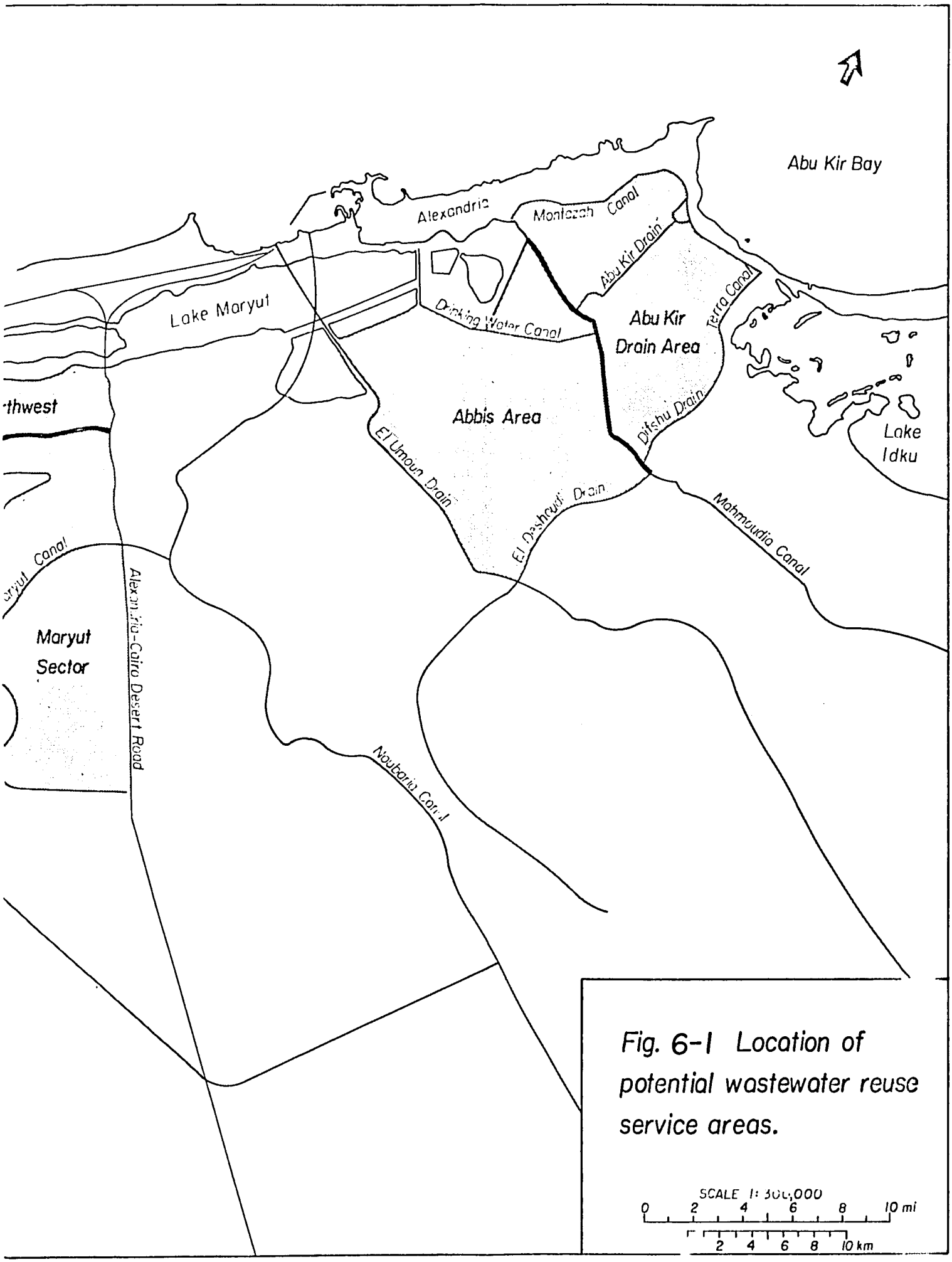


Fig. 6-1 Location of potential wastewater reuse service areas.

6.B.3.a Wastewater Irrigation Service Areas. Bailey's report indicates that there are four regions near Alexandria which are particularly appropriate for irrigation by sewage. These areas, shown on Fig. 6-1, are called the Abu Kir Drain area, Abbis area, Maryut sector, and Ameria Northwest. Costs for the agricultural reuse alternative developed by the CDM Engineering Staff in Alexandria are based on treated wastewater transport to these areas. Farther regions could also be irrigated but only with disproportionately higher transmission costs.

6.B.3.a.i Abu Kir Drain Area. The total area considered comprises approximately 13,200 ha, all of which currently receive adequate irrigation from the Mahmoudia Canal. The agricultural benefits from wastewater irrigation in this area would, therefore, come from increased yields attributable to nutrients in the wastewater and, indirectly, from the irrigation of new land made possible by conservation of Nile River water. Boundaries used by Bailey for this region were the Mahmoudia Canal on the south, the Montazah Canal on the west, the El Teraa Canal and Difshu Drain on the east, and Abu Kir Bay on the north. The eastern boundary could be extended or withdrawn without significant changes in yield per unit area.

6.B.3.a.ii Abbis Area. The Abbis region contains 10,100 ha which receive adequate irrigation from the Mahmoudia, Maryut, Beida, and Abbis canals. As with Abu Kir, the benefits of wastewater reuse would stem from nutrients in the wastewater and from the conservation of Nile River water. The Abbis area is bounded by the Mahmoudia Canal on the north, Lake Maryut and the Hydrodrome on the west, the Umoum Drain on the southwest, and the El Dishudi Drain on the southeast. This area could be expanded past the southeast border without reducing yield per unit area.

6.B.3.a.iii Maryut Sector. This region contains 17,200 ha, of which only 9,200 ha are irrigated. Because of water shortages, large areas are idle in the summer, and wastewater reuse, therefore, offers both water to irrigate new lands and nutrient benefits. The area is currently irrigated largely by the Maryut Canal, in which dissolved solids concentrations are undesirably high. The region is bounded by the Rahim, Horriat, and Bahig canals on the south; the Abu Massoud Canal on the east; the Alex-Cairo Desert Road on the north; and the Mersa-Matrouh Railroad on the northwest.

6.B.3.a.iv Ameria Northwest. This sector contains 2,100 ha of which 1,800 ha are suitable for agriculture. There is currently no irrigation, so wastewater offers benefits both as irrigation water and fertilizer. The region is bounded by the Mersa-Matrouh railroad on the south, the Cairo-Alex Desert Road on the east, and nonirrigable lands to the north and west.

6.B.3.a.v Cropping Patterns. Cropping patterns in the four areas were described by Bailey as follows:

Due to the favorable climate, year-long cropping occurs in all areas. Most extensive are field crops and vegetables, with fruit in certain areas.

The principal winter crops are berseem, wheat, or in some areas barley, broad beans, and winter vegetables. Cotton is extensive to the south, but little cotton is grown near Alexandria, due to the high demand for vegetables.

In the Abbis area, records show that the above described cropping pattern predominates, with mostly barley instead of wheat, and that no fruit is grown. Crop growth varies from excellent to poor, and reported yields are below average.

In the Abu Kir area, a diversified pattern of field crops and vegetables is grown, with about 20 percent in fruits--mainly citrus, but including some pears and apples. Crop growth ranges from excellent, near Abu Kir Drain, to poor in areas near Montazah.

In Maryut Sector, the crop pattern is largely field crops and vegetables, with extensive areas of grapes. Reported yields are below average, largely due to limited water supplies. The better lands should have a potentially high productivity with adequate water and good management.

In Ameria Northwest, cropping is limited to a few olive and almond orchards irrigated by windmills.

6.B.3.b Wastewater Treatment Level and Public Health. The Master Plan specifies a secondary level of wastewater treatment (either activated sludge or anaerobic-aerobic lagoons) for the agricultural reuse alternative. Secondary treatment is specified to minimize public health risks and because "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 used."[22]

Cohen et al[23] and Shuval[24] traced outbreaks of cholera in Jerusalem and Gaza to the use of raw sewage for agricultural reuse, but the effect of wastewater treatment on the etiology of such outbreaks has not been documented. Hoadley and Goyal[25] note that primary treatment removes only 30 to 40 percent of "indicator" bacteria (such as E. coli), while secondary treatment removes 85 to 99 percent of them. On the basis of similar evidence, the report of a 1971 WHO conference on treatment of water for reuse[26] describes secondary treatment as "essential" to meet suggested health criteria for irrigation of crops intended for human consumption. Even secondary treatment does not provide complete protection, for

Hoadley and Goyal[25] observe that, "A wide variety of pathogens including typhoid bacilli, cholera vibrios, tubercle bacilli, and coxsackie, polio, and echoviruses have been isolated from secondary effluents." The relationship between the presence of such pathogens in irrigation water and human disease is currently unknown. There is similar uncertainty about the possible long-term effects of any heavy metals that might remain in treated wastewater used for irrigation should industrial pretreatment not be implemented.

Greater protection could be assured by effluent chlorination in addition to whatever other treatment processes are used. Should there be no chlorination, either by governmental policy or equipment failure, secondary biological treatment affords considerably greater protection from pathogens than does primary treatment. For the purposes of environmental impact assessment, therefore, this report will assume a level of secondary treatment for the agricultural reuse alternative.

6.B.3.c Relevant Wastewater Quality Characteristics. Alexandria's wastewater has high concentrations of total dissolved solids (TDS), nitrogen, and phosphorus, all of which affect the suitability of the wastewater for agricultural irrigation. High TDS values limit the ability of irrigation water to flush damaging salts from the soils around the roots of crops, and nitrogen and phosphorus nutrients can improve crop yields. The mixture of wastewater with canal water would reduce both TDS and nutrient concentrations, both of which would improve water quality for irrigation purposes.

The sensitivity of crop yields to TDS varies with such factors as the crops themselves, the soil, the sodium fraction of the TDS, and the quality of drainage; in general, the yields of crops in the four service areas examined by Bailey[21] can be expected to diminish when TDS exceed 500 to 800 mg/l. Results cited in Status Report No. 2[27] indicate that TDS in Alexandria's wastewater, varying between 1,080 and 1,600 mg/l, is twice that considered acceptable by Bailey and other authorities[28,29] for unrestricted irrigation. Conventional wastewater treatment processes do not affect TDS concentrations, and the costs of desalination are prohibitive. Effective use of Alexandria's wastewater for agricultural irrigation, therefore, requires substantial mixing with low TDS canal water.

Nitrogen and phosphorus are vital to crop growth, and the large quantities found in Alexandria's wastewater are potentially valuable resources. The high concentrations of these nutrients could, however, result in their inefficient application, if no dilution were employed. Irrigation by undiluted Alexandria wastewater would apply 3.3 times the average nitrogen application and 2.7 times the average phosphorus application to Egyptian agricultural land in 1975.[21] Higher nutrient loads do not provide correspondingly higher yields,[30] and, in fact, excess nutrients in wastewater irrigation can actually decrease crop yields.[31] Dilution of wastewater before irrigation to reduce salinity problems may, therefore, actually increase the nutrient benefits from the agricultural reuse of wastewater.

6.B.3.d Wastewater Flows and Dilution. The quantity of wastewater generated by Alexandria in the year 2000, and the agricultural land area it requires for absorbtion, also limit the viability of the reuse alternative. The four agricultural service areas described by Bailey[21] contain approximately 42,000 ha, of which only 9,800 are not currently irrigated. Bailey recommended wastewater flows to each of the four service areas on the basis of preliminary TDS estimates which were significantly lower than the measured values now available. Table 6-10 shows the flows and TDS concentrations assumed by Bailey, and the TDS concentrations expected from these flows on the basis of measurements made in the summer of 1977. Under Bailey's optimistic TDS assumptions, only half of Alexandria's 1,445 Ml/day of wastewater can be absorbed by the service areas; if the higher TDS measurements are considered, the fraction may be even smaller.

The reuse alternative considered in the Master Plan discharges 952 Ml/day of activated sludge treatment plant effluent to canals which irrigate the four service regions, while the remaining flow is either discharged to an evaporation pond at Lake Idku, or to the New Noubaria Main Drain after anaerobic-aerobic lagoon treatment. This latter flow could be transported to irrigate new lands farther south, but only at a higher unit cost than the wastewater used in Bailey's service areas.[21]

Although the Master Plan discusses tne general problem of TDS, it does not describe what would happen to wastewater flow from the 952-Ml/day treatment facility which could not be reused either because of excessive TDS or because wastewater peak flows exceeded agricultural demands. The alternative considered in the Master Plan can thus reuse only two-thirds of Alexandria's year 2000 wastewater at best, while operational problems of TDS control may further reduce the flow which can be reused. A modified alternative by which all of Alexandria's wastewater could be reused was not explicitly considered in the Master Plan, for its economic viability is lower than that of the "limited reuse" alternative considered in the plan and discussed below.

6.B.3.e Economic Aspects of the Reuse Alternative. Agricultural reuse of wastewater can supply both irrigation and fertilizer benefits to lands near Alexandria. This section compares the costs of obtaining these benefits by wastewater reuse with those of more conventional methods, such as increased Nile River irrigation and the use of conventional fertilizer. In making such a comparison, costs of wastewater reuse are not those of the entire wastewater system, but rather the difference in cost between the reuse alternative and other roughly comparable ways of disposing of Alexandria's wastewater. This is because the major portion of cost is attributable to the collection and disposal of Alexandria's wastewater, and not to its reuse. Qualitative differences between the reuse alternative and conventional irrigation will also be discussed.

For coarse screening purposes, the Master Plan analyzed four regional alternatives, described in Chapter 5 of this report. Although these do not correspond exactly to the more detailed alternatives considered in

TABLE 6-10.

FLOWS AND TDS VALUES FOR WASTEWATER REUSE IN AGRICULTURAL LANDS NEAR ALEXANDRIA, EGYPT

Service Region Units	Approximate Agricultural Land Area, Hectares	Agricultural Land In Need Of New Irrigation, Hectares	Bailey's Recommended Dilution (% wastewater: % canal water)	Bailey's Assumed TDS of Mixture (mg/l)	Actual TDS Based on 1977 Measurements (mg/l)	Wastewater Flow Used (Ml/day)
Abu Kir	13,200	-	50:50	500	770	300*
Abbis	10,100	-	50:50	500	770	230*
Maryut	17,200	8,000	14:86	630	680	110
Ameria	1,800	1,800	100:0	850	1,190	82
Total	42,300	9,800	-	-	-	722

*Replaces existing canal irrigation water.

Source: "Potential for Sewage Disposal by Agricultural Irrigation in Alexandria," Memo by Peter Kolsky 12/2/77 - EIS MRF "Agricultural Irrigation" File.

the final selection of a recommended Master Plan, the regional alternatives provide a reasonable framework for economic comparison of ocean, lake, agricultural, and desert disposal options. The present worth cost, at a 10-percent discount rate, of the regional reuse alternative is L.E. 52 million greater than that of the regional ocean disposal alternative and L.E. 31 million more than disposal to Lake Maryut.[22] Based on these figures, the agricultural reuse alternative supplies irrigation water and nutrients at a cost of L.E. 0.015 to 0.022 per m^3. (This assumes that all of the 952 Ml/day of secondary effluent transported to irrigation canals can be reused, an assumption which may not be justified.) The current cost of irrigation water in the delta region, as estimated by the Ministry of Irrigation,[27] is 0.002 L.E. per m^3, based on Egypt's Aswan Dam development expenditure and costs of downstream distribution and control. Bailey estimates that structural improvements to prevent spillage could save 10 percent of current irrigation flows at a cost of only L.E. 0.0014 per m^3, less than 10 percent of the cost of water obtained for reuse. Bailey's report also indicates that the value of fertilizer saved by wastewater irrigation is approximately L.E. 0.0027 per m^3. Thus, wastewater reuse, under favorable assumptions, costs three to five times as much as conventional irrigation and fertilizer application, to obtain equivalent benefits.

The assumptions used in the above analysis are biased in favor of reuse. The analysis assumed that all of the wastewater intended for reuse could, in fact, be used, but this is unlikely because of TDS limitations noted earlier. The four service areas considered in the reuse alternative can only use an average of about 722 Ml/day, under generous assumptions, while the reuse alternative presented discharges an average of 952 Ml/day into their canals. There are three possible consequences of this difference: a TDS increase in irrigation canals above acceptable limits for agricultural purposes, a partial bypass of treatment plant effluent to Lake Maryut (given the main treatment plant's location on the Kalaa Drain), or an increase in Nile River irrigation flows to the same canals, to dilute the Alexandria wastewater load. This problem is exacerbated by the lack of storage facilities in the regional alternative as presented in the Master Plan, because peak wastewater flows do not match peak agricultural demands. Storage could ease the situation, but only with a corresponding increase in cost above that considered for the Master Plan reuse alternative. The economic analysis has also equated nutrient benefits of wastewater and fertilizer by weight, when, in fact, farmers have far greater control of nutrient application by fertilizer as opposed to wastewater irrigation.

In summary, agricultural reuse of the majority of Alexandria's wastewater involves technical and economic problems which drastically limit the viability of the alternative. Agricultural reuse of wastewater from some of the outlying areas such as Ameria and Mex-Dekheila might be economically and environmentally desirable at a future date--a possibility which weighs in favor of some form of secondary treatment at these locations.

6.B.4 Evaporation Ponds

Three sites have been considered for the evaporation of wastewater in the development of the Alexandria Wastewater Master Plan: the saline portion of Lake Maryut west of the Ameria-Agamy Road, the northern portions of Lake Idku, and the Western Desert. The engineering staff preparing the Master Plan restricted their attention to these areas because, as indicated on Fig. 5-3, almost all other land in the Alexandria region has the current or intended use of agricultural reclamation, urban housing, or industrial development.

The importance of agricultural reclamation to the Egyptian economy has been described in Chapter 3; because the fraction of Egypt's total land area which has been or will be reclaimed for agriculture in the near future is so small and its role in the Egyptian economy so significant, the value of such land to Egypt is high. The Master Plan rejects use of potential agricultural lands for the evaporation of Alexandria's wastewater (with or without toxic industrial wastes) as an essentially irreversible and irretrievable commitment of these resources. Environmental impacts of wastewater evaporation at the three sites considered by the Master Plan are discussed below.

6.B.4.a Western Lake Maryut. The western highly saline portion of Lake Maryut was considered as a potential evaporation site for toxic industrial wastewaters early in the planning process. The site consists of a shallow natural depression between Agamy and Ameria containing a pond varying seasonally in surface area between 480 and 4,500 ha. Minimal dyking would be required to enclose the site, and the area is near Alexandria and adjacent to the Ameria Free Zone, a center of future industrial growth.

Significant adverse environmental impacts from the use of the site as a wastewater evaporation pond consist of disrupting the salt manufacturing operations of El Nasr Salines Co., aesthetic degradation of the proposed Agamy touristic development, and possible contamination of a deep-seated freshwater aquifer. The Salines Co. claims jurisdiction over the site[32] and does not currently allow industrial waste discharges to it. The company plans to expand its salt production from 600,000 tons per year to 1 million tons per year, of which 200 to 300,000 tons per year would be supplied from salt beds located in the proposed wastewater evaporation site. If, in fact, the company does have jurisdiction over western Lake Maryut, consent to utilize the area for wastewater evaporation would be difficult to obtain; even if the land could be obtained, the economic impact of the loss of the salt bed would be substantial.

The magnitude of adverse aesthetic impacts is far less certain. As noted in Chapter 3, a tourist development for 100,000 persons is planned at Agamy, 1.5 km north of the pond site. While the plans for development are at best uncertain, and the precise boundaries of the development are unknown, the disposal of large quantities of wastewater in the near vicin-

ity could cause odor and other aesthetic problems which would limit the potential of the development.

Existing data[33] on groundwater in the area indicate that its salinity is far too high to be considered as a reasonable source of water supply, although the data are not sufficiently complete to rule out the existence of freshwater lenses in the area. Protection of such an aquifer currently seems of little environmental importance, but could be obtained by sealing the base of the pond with an impermeable layer, if natural clogging from wastewater solids appeared inadequate.

The use of the western portion of Lake Maryut as an evaporation site does not constitute a significant loss of habitat for terrestrial species, given the sparseness of animal population there and the vast adjacent areas of similar habitat.

6.B.4.b Lake Idku. The evaporation pond designated for the Abu Kir industrial waste disposal occupies an area of 4,000 ha in Lake Idku, about one-third of the lake, and is located in the only portion of the lake which is clear of vegetation, relatively deep, and accessible to fishing. Most of the 5 to 10,000-ton annual commercial fish catch of the lake comes from that area. It should, therefore, be avoided in the construction of the evaporation pond. Rather, from both an environmental and resource conservation viewpoint, the northeastern section of Lake Idku should be utilized for that purpose. That section, adjacent to an area which has been recently reclaimed for aquaculture, is very shallow, heavily overgrown with submerged vegetation (*Potamogeton*, *Ceratophyllum*) and fringed with a dense stand of reed grass (*Phragmites*) and other emergent vegetation which appears to be rapidly encroaching on the lake itself (see Chapter 3 (3.B.5)). In short, that area, which is relatively unproductive with respect to fish and other animals, appears to be rapidly eutrophying to a marsh and, eventually, to dry land, so that its conversion to an evaporation pond would represent no great sacrifice of an aquatic resource. Should that be done, it would be necessary to divert the entrance of the Idku Drain from the eastern end of the lake to a more central or western location, perhaps combining it with the Bersik Drain, which enters at the southern embayment known as Lake Ghitas.

Construction of an evaporation pond at Lake Idku will reduce, but not eliminate, the bird habitat of the area; two-thirds of the lake and the surrounding land will be unaffected.

6.B.4.c Western Desert. Because use of the Western Desert south of the El Nasr Canal was ruled out early in the Master Plan's development on the basis of economic considerations, little specific information on possible sites is available. The proposed sites shown in Fig. 5-3 have not been ruled out for agricultural reclamation by the Ministry of Irrigation,[34]

but are currently low priority lands because of relatively poor soil quality. If the land cannot be effectively used for agricultural purposes, then the physical and biological environmental impacts of wastewater disposal at this site appear minimal. The socioeconomic impacts of the additional cost of wastewater disposal at this site are substantial. Disposal of Alexandria's total wastewater flow at this site has a present worth cost which is L.E. 76 million more than the preferred plan; when expressed on a per capita basis of current population, this is L.E. 32 per person additional cost for the Western Desert disposal alternative.[22] If a smaller fraction of Alexandria's wastewater is evaporated at the Western Desert, then the total cost would be lower but the cost per unit of evaporated flow would be higher, because many component costs would not decrease with flow.

6.B.5 Disposal to the New Noubaria Drain

The alternatives considered for the Ameria and Outer West Regions include the treatment of their wastewater by anaerobic-aerobic lagoons followed by discharge to the New Noubaria Drain now under construction. Ameria's lagoons would be located approximately 26 km upstream of the Mediterranean while Outer West's would be only 2-3 km from the sea.(see Fig. 5-1). This section will examine within the limits of available information the possible impacts of these lagoons upon the water quality of both the Drain and the future tourist resort beaches at Agamy near the mouth of the Drain.

The new Noubaria Drain is currently being built by the Ministry of Irrigation to drain land reclamation projects west of the Noubaria Canal. Although future flows are not accurately known, the Ministry of Irrigation's drainage design criteria provide a basis for approximate flow estimation. The Drain will serve an estimated 76,000 ha (180,000 feddans), and the Ministry's design criterion of 20 m^3/day/feddan indicates that the Drain will be designed with a capacity of 3,600 Ml/day. This is not the average flow but rather the ultimate capacity of the Drain; a reasonable estimate of average flow would be one half of this design capacity, or 1,800 Ml/day.

The average year 2000 wastewater flow is estimated to be 161 Ml/day for Outer West and 137 Ml/day for Ameria. Evaporation in the proposed lagoons, which provide 30 days detention, will reduce these discharges to 139 and 118 Ml/day, respectively. Treated effluent will thus constitute approximately 7 percent of the Drain's average flow downstream of Ameria, and 12 percent of the Drain's average flow downstream of the Outer West.

Water quality in the Drain is expected to be poor because the only flow in the drain besides the treated wastewater from Ameria and the Outer West will be agricultural drainage, which is rich in organic material and nutrients. The Kalaa Drain, an existing agricultural drain discharging into Lake Maryut, was sampled in August 1977, and the BOD_5 was 15 mg/l (Table 4-7 of reference 27.) Although this is a value obtained from a single grab sample, it does provide some indication of the probable strength of the organic matter found in existing agricultural drains.

Preliminary calculations[A1] based on estimated dilutions in the Noubaria Drain and treatment efficiencies in the lagoons show that the Ameria discharge would increase the BOD_5 in the drain by only 0.6 mg/l. The Outer West discharge would increase the Drain's BOD_5 concentration of 15 mg/l, the resultant concentration in the Drain after receiving both lagoon discharges would be 16.2 mg/l or about an 8 percent increase. Such a small increase is not likely to have any significant environmental impact on water quality in either the Drain or the Mediterranean.

A similar analysis for nutrients is less meaningful because of the great fluctuations in nutrient concentrations of agricultural drainage due to seasonal variations in both fertilizer application and rainfall. Calculations[A1] based on estimated lagoon effluent quality, and assumed flows in the Drain show that the expected discharge from Ameria would measure the nitrogen concentration by less than 1.5 mg/l and the phosphorus concentration by less than 0.4 mg/l. A similar increase in nutrient concentrations can be anticipated towards the mouth of the Drain downstream of the Outer West discharge, where calculations indicate increases of less than 0.9 mg/l nitrogen, and 0.2 mg/l phosphorus. The precise significance of such increases cannot be assessed without knowing the quality of the agricultural drainage, but it is likely that the nutrient concentrations in the Drain will be high enough that these additions will have little added impact. Any environmental changes related to high nutrient loadings will be primarily due to the concentrations in the agricultural drainage with or without the addition of treated effluent.

Another environmental impact associated with the Ameria and Outer West discharges is the possible bacterial contamination of the beaches at Agamy which are intended to become a major seaside resort. Assessment of this risk is complicated by the wide range of estimates for both bacterial concentrations in raw wastewater, and for their removal by stabilization ponds. Concentrations of the indicator organism E. coli can vary by three orders of magnitude in raw wastewater from 10^7-10^{10} organisms/100 ml,[A2] and estimated bacterial count reductions vary between two to four orders of magnitude in stabilization pond systems with detention times, layouts and climatological conditions analogous to those presented in the anaerobic-aerobic lagoon alternative of the Master Plan.[A3] Other processes would also tend to reduce bacterial concentrations besides those of the lagoon system. Dilution in the Drain will decrease concentrations by at least one order of magnitude, and further dilution in the Mediterranean before the flow can reach the beaches should also decrease bacteria counts. Bacterial die-away in the Drain will play an important role in reducing concentrations from the Ameria discharge, albeit a lesser one for the Outer West's lagoon effluent. Finally, the observed die-off rate of one order of magnitude per daylight hour in the Mediterranean (as discussed in Section 3.B.5.a) would reduce the counts still further before contact with bathers could occur.

Technical Appendix No. 7, prepared by Dr. George Grantham, project manager of the Alexandria Wastewater Master Plan, addresses the question of bacterial pollution of the beaches at the mouth of the Noubaria Drain. Evidence

presented in this memorandum indicates that accepted bathing water quality standards would not be violated near the mouth of the Drain, even if effluent chlorination were not practiced at the Ameria and Outer West discharges. The uncertainties noted above, however, concerning raw wastewater bacterial concentrations, lagoon treatment efficiencies, and future Drain flows require the consideration of effluent chlorination as a possible mitigation measure to protect bathing water quality if beach development is as extensive as currently planned (see Section 7.E.3).

Finally, the question of toxic contaminants in the Drain must be addressed. Toxic industrial wastewater management under all alternatives is either by pretreatment at the source, or else by separate collection and conveyance to an evaporation pond. The Master Plan recommends the first alternative, and enforcement of adequate sewer use controls is particularly important for the operation of the anaerobic-aerobic lagoon because of the biological nature of the process; failure to enforce the law effectively could reduce the process treatment efficiency significantly. However, even if toxic pollutants were present in the effluent to the lagoons, their concentrations would be substantially reduced before discharge as noted in Technical Appendix No. 7.

The lagoon effluents are not, however, the only potential sources of toxic contaminants; as noted in the Marine Studies data (Tech. App. No. 8) agricultural pesticides may be found in water draining agricultural lands. The report states that gas chromatograph tests on water collected from the Mex Bight and off Anfushi showed no evidence of endrin, aldrin, dieldrin, DDE and DDT, but suggests that periodic monitoring of fish flesh for pesticides is advisable to stay abreast of any change in the situation. The quality of agricultural drainage per se is beyond the scope of the Alexandria Wastewater Master Plan, and will not be affected by the selection of alternatives.

6.C Construction and Operation Impacts

6.C.1 Collection Facilities

Collection facilities consist of house connections, lateral trunk and interceptor sewers, as well as pump stations and force mains. By the year 2000, an estimated 92,000 connections using 150-mm pipe would be required to provide sewer service to unsewered dwellings. An estimated 1,200 km of lateral sewers, sized from 200 to 500 mm, are also required. These building connections and lateral sewers are common to all wastewater disposal alternatives. In addition, about 64 km of force main, sized from 250 to 1,400 mm, 73 km of main trunks and intercepting sewers, sized from 200 to 2,300 mm, and 20 to 25 wastewater pump stations, with capacities from 5 to 325 Ml/day would be needed to collect and convey wastewater to treatment and disposal facilities identified in the sea and lake disposal alternatives. Crop irrigation and desert disposal alternatives would

require extensions to these facilities, to convey wastewater to outlying disposal sites.

According to the Master Plan implementation program, construction of these facilities would continue throughout the 20-year planning period, with the majority of the work planned for the first 10 years. Because of the magnitude of this program, construction projects would affect virtually every one within the governorate of Alexandria. Understanding typical construction procedures and identifying potential impacts can help mitigate short-term adverse consequences. The following sections discuss construction procedures associated with the collection, treatment, and disposal facilities proposed in the various Master Plan alternatives. However, citing impacts related to specific sites or alignments for pump stations and pipelines were not appropriate at this stage of planning.

6.C.1.a Construction Impacts. All sewer construction projects begin with construction surveys to establish baselines and benchmarks for alignment and elevation control. Most of the proposed collection and conveyance facilities would be built in heavily populated and densely-developed areas, and survey crews would temporarily disrupt local traffic. (In Alexandria, local traffic is a mixture of animal-drawn carts, bicycles, donkeys, horses, goats, cows, taxis, buses, trucks, trolleys, assorted animals, and numerous pedestrians.) Following surveys, site preparation begins which can consist of clearing brush or debris, removing unsuitable soil, modifying or improving local drainage, finding, protecting, and possibly relocating existing utilities, cutting pavement, and constructing access roads or detours. These procedures involve additional equipment and personnel and can further aggravate traffic problems in crowded areas.

Actual pipeline and foundation construction would probably be open-cut excavation, except for occasional tunneling to avoid interference with major arteries, canals, or trolley tracks. Depending on the site location, trench width, and excavation depth, the excavation may require dewatering facilities with provisions for drainage, wood or steel sheeting and bracing, and piles to support pipes or structures. Construction equipment, personnel, and materials must be brought to the site and construction waste hauled away. Such operations could virtually paralyze crowded areas. During the summer months, when population increases from 250,000 to 500,000 are common, streets are sometimes impassible without any construction activity. Creating traffic congestion, causing personal inconveniences, and bringing added noise, dust, and debris into city neighborhoods are potentially adverse impacts of pipeline and pump station construction.

Additional concerns to be addressed during construction are pedestrian safety, skilled labor shortages, construction materials and equipment shortages, and damage to archaeological artifacts. Open excavations attract people, especially children. Because of the abundance of adults and children in densely-populated neighborhoods, there is considerable

potential for accidents. The demand for skilled labor would create shortages, aggravating the local economy, because such personnel are frequently lured by higher salaries to neighboring oil-producing countries and to government-related projects along the Suez Canal. Such a large construction effort would demand more construction materials than are currently locally available. Additional imported supplies would have to pass through the western harbor which already is severely overcrowded. Such logistical problems might delay key projects and interfere with the timely completion of related facilities. Excavations would occur throughout the city and would undoubtedly uncover archaeological artifacts. Delays to investigate uncovered ruins can prolong the short-term adverse impacts associated with open excavation.

Extending conveyance facilities to irrigated areas or desert evaporation sites would temporarily interfere with irrigation procedures and crop production, in addition to the impacts mentioned above. Specific pipeline alignments or pump station sites for irrigation or evaporation alternatives have not been addressed in the Master Plan.

6.C.1.b Operational Impacts. Because of the lack of suitable solid waste collection and disposal, persons in Alexandria routinely dispose refuse into the sewer system. Expanding the sewer system without providing solid waste disposal alternatives would increase the number of unsuitable refuse collection points. Resulting sewer blockages can lead to sewer surcharging and eventual wastewater spillage into the streets. Also, wastewater out of contact with the air can produce hydrogen sulfide. This gas, when it escapes to the air, causes odors, blackens lead-base paint, and can create a lethal atmosphere for sewer maintenance personnel. When oxidized on the moist walls of sewer pipes, manholes, or pump station wet wells, it can form sulfuric acid which can corrode concrete, asbestos cement, or metal.

6.C.2 Treatment Facilities

Many of the impacts associated with constructing pipelines and pump stations can generally be applied to the construction of treatment facilities. However, in some cases, specific treatment plant sites can be addressed, because they are fixed by existing conditions. Essentially, construction procedures follow the same pattern of site survey, site preparation, and excavation.

Treatment facilities addressed in the Master Plan report consist of preliminary treatment plants at Ras el Soda and Kait Bey, secondary treatment plants at the sites of existing east and west plants, a regional secondary plant south of the Nouzha Hydrodrome, and anaerobic-aerobic lagoons in the outer west zone and Ameria.

6.C.2.a Construction Impacts. The proposed Ras el Soda preliminary treatment plant is on a narrow site located in a densely populated neighborhood. The site was chosen for its central location which enables maximum use of existing inner east wastewater collection facilities while minimizing conveyance costs to serve the unsewered outer east. Traffic congestion, personal inconveniences, added noise, dust and debris, and all other adverse impacts associated with pipeline and pump station construction apply at this site. However, unlike pipeline construction, which moves along its alignment, these impacts would affect this particular neighborhood for an estimated 2-year period. An additional concern is aesthetics, which, if negative, would have a long-term adverse impact. Relocation of adjacent housing, while not apparently necessary to fit the proposed facilities, might be considered to create a buffer zone.

The Kait Bey facility is located on the periphery of a highly developed peninsula at the site of an existing wastewater outfall. This site was fixed by the existing central zone collection system which converges at this location. Traffic congestion at the site is not likely to be a major concern; however, access roads are crowded and temporary problems could develop during equipment and materials deliveries. Failure to maintain operation of the existing outfall during construction would further aggravate shoreline pollution. (The existing outfall is only 750 m long and broken in several places.) Because the site is small, additional land might be required from adjacent military and commercial property or by reclaiming land from the sea. Should land reclamation be chosen, additional temporary shoreline pollution is possible. Other impacts previously identified are also applicable and would affect this area for a 2-year construction period.

New secondary treatment plants were proposed at the sites of the existing east and west plants. These sites are located on the periphery of development south of Alexandria and were used because they serve as collection points for existing wastewater conveyance facilities. Impacts, such as traffic congestion, personal inconveniences, noise, dust, and construction debris are not as significant in these locations. However, because access roads are generally inadequate, temporary congestion could develop during deliveries. These sites are generally beyond most public vision, and aesthetics would not be as great a concern as in Ras el Soda. Also, pedestrian safety hazards and damages to archaeological artifacts are less likely to occur in these areas. However, other impacts such as skilled labor and material shortages are still valid.

Construction of a regional secondary treatment plant located south of the hydrodrome would have similar impacts. In addition, because the proposed site occupies an area which is being used for agricultural production, construction at this location would permanently change land use. Construction impacts would affect all secondary treatment plant sites for an estimated 3 to 5-year project period.

New anaerobic-aerobic lagoons are proposed for the outer west and Ameria. Because these areas do not have sewers, the lagoon sites are not fixed

and impacts are more difficult to assess. In general, the proposed sites in the Master Plan report are undeveloped and do not displace agricultural land. However, the outer west lagoon, estimated to require 370 ha, would displace a portion of western Lake Maryut currently used for salt production. However, because the site is not fixed, specific impacts on the salt manufacturing process cannot be addressed. The Ameria lagoon would occupy about 315 ha in an area zoned for industrial development. Construction of this facility would preclude use of this area for any industrial purpose. No other site conflicts are known at this time.

The construction procedure would also involve site survey and preparation but probably little excavation. Wastewater would probably be contained in the lagoons by dikes, taking advantage of natural topography where appropriate. Construction impacts such as traffic congestion, personal inconvenience, additional noise, dust, and debris are lesser concerns in these undeveloped areas. However, children seem to appear virtually everywhere, and safety hazards to them and others are important considerations. Impacts such as skilled labor shortages, equipment and supply shortages, and damage to archaeological artifacts also continue to apply.

6.C.2.b Operational Impacts. Primary concerns with preliminary treatment plants proposed in Alexandria are airborne pollutants such as odors, aerosols, particulates and gases, noise from process equipment, and disposal of screenings and skimmings. Although the treatment process is not complicated, these plants, especially the Ras el Soda facility, are in highly-developed areas. Airborne pollutants and noise are potentially long-term impacts. Equipment failure in Ras el Soda could result in serious flooding with associated public health problems. Failures at Kait Bey would result in shoreline pollution. The Master Plan report recommends removing screenings and skimmings by vehicle to a sanitary landfill. Drippings from such vehicles through crowded residential streets would present an additional health hazard.

Because of their locations, these problems are not as pronounced at the secondary treatment plant or lagoon sites. However, the secondary treatment process is considerably more complex, and the current lack of skilled plant operation and maintenance personnel could result in poor plant performance and the continued pollution of Lake Maryut. Treated sludge would be conveyed to a sanitary landfill which may require some trucking on residential streets. (The site of a proposed sanitary landfill has not been selected.) Lagoons offer the least operational problems and do not generate screenings or sludge for disposal. However, odors are a potential operational problem and they could become an adverse impact, if the lagoons are located near developed areas.

6.C.3 Disposal Facilities-Construction Impacts

Disposal facilities consist of sea outfalls and evaporation ponds. Onshore preparations for sea outfalls would create the same adverse impacts

associated with other construction. Once at sea, temporary water pollution and interference with shipping and fishing are potential adverse impacts. Uncovering and damaging archaeological artifacts is also possible along the outfall alignment. Potential impacts during the construction of evaporation ponds are similar to considerations discussed for lagoons. Table 6-11 summarizes all the construction and operation impacts discussed in this section. Impacts associated with disposal of treated effluent into the Mediterranean Sea and Lake Maryut for agricultural reuse to evaporation ponds and into the new Noubaria Drain have been addressed earlier in this chapter.

6.C.4 Energy Requirements of Alternatives

Preliminary calculations on the energy requirements of alternatives have been made, and they indicate that energy consumption is not a major factor in the selection of alternatives. Of the four disposal alternatives considered, ocean disposal requires by far the least energy, despite the pumping requirements for the two outfalls. Lake disposal requires at least twice as much power as ocean disposal because of the aeration and process equipment used in secondary treatment. Evaporation in the western desert requires about the same energy as lake disposal; while evaporation requires virtually no treatment processes, the wastewater must be pumped 75 kilometers to a suitable site. Finally, agricultural reuse requires the most power because of both the secondary treatment requirement and the need for effluent pumping to appropriate canals. These comparisons do not include the pumping requirements for the collection system, which would be common to all alternatives. The fact that energy represents only approximately 10 percent of the annual operation and maintenance cost of the preferred plan shown in Table 8-11 of the Master Plan Report indicates the relatively minor role of energy costs in wastewater planning in Alexandria.

6.D Secondary Environmental Impacts

Secondary impacts are defined by the U.S. Environmental Protection Agency as "(1) indirect or induced changes in population and economic growth and land use, and (2) other environmental effects resulting from these changes in land use, population and economic growth." While these may be appropriate environmental concerns in the suburban or rural United States where wastewater facilities planning is a de facto surrogate for land-use planning, they do not represent significant issues in Alexandria where industrial development and employment opportunities are the growth-limiting factors. As described in Chapter 4, people from rural areas of Egypt will migrate to Alexandria whether or not wastewater facilities are improved, in search of jobs, education for their children, better health care, and a better life. The role of adequate wastewater facilities in these migrants' attraction to Alexandria is uncertain, but the wastewater

TABLE 6-11.

SUMMARY OF PRIMARY ADVERSE CONSTRUCTION AND OPERATIONAL IMPACTS OF ALTERNATIVES

Construction Impacts	Short Term	Long Term	Reversible	Irreversible
Increased traffic congestion	X		X	
Inconvenience to people and businesses	X		X	
Additional noise and dust at job site	X		X	
Litter from construction waste	X		X	
Public safety hazards	X		X	
Skilled labor shortages	X		X	
Construction equipment and material shortages	X		X	
Damage to archaeological artifacts	X	X		X
Negative aesthetics		X		X
Interference with crop irrigation	X		X	
Interference with crop production	X		X	
Interference with boating	X		X	
and fishing	X		X	
Relocation of housing		X		X
Land use changes		X		X
Construction-related water and air pollution	X		X	
Damage to street utilities	X		X	
Operational Impacts				
Use of new sewers for solid waste disposal	X	X	X	
Hydrogen sulfide generation		X	X	
Airborne pollutants (odors, aerosols, etc.)		X	X	
Noise		X	X	
Wastewater flooding due to equipment failure	X		X	
Improper screenings and/or sludge disposal		X	X	
Equipment damage from corrosive industrial waste		X	X	
Continued pollution of Lake Maryut		X	X	

flooding in Ras el Soda and Gheit el Enab has not yet stopped immigrants from moving there.

According to EPA Guidance Memorandum Number 50[A8] on the subject of secondary impacts, the critical determination is whether or not any potential secondary impacts "will result in contravention of any existing Federal, State, or local environmental law or regulation, or any plan or standard required by such laws or regulations." Precise determination of secondary impacts is difficult in the U.S., but next to impossible in Alexandria given the uncertainty of growth patterns and socioeconomic data; "induced" growth is unlikely, however, as all of the service areas considered already expect extensive development. To the best of our knowledge, however, no violations of U.S. or Egyptian environmental laws could be attributed to growth induced by improvement of Alexandria's wastewater facilities.

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CHAPTER 7

ENVIRONMENTAL IMPACTS OF THE PREFERRED ALTERNATIVE

7.A General

The process and values by which the components of the preferred alternative were selected in the Wastewater Master Plan have been described in detail in Chapter 5; this chapter will summarize the main issues of plan selection and describe the impacts of the preferred plan in greater detail. Mitigation measures which could reduce some of the adverse impacts of the preferred plan will also be addressed.

The significance of a value in the selection of a preferred alternative is essentially a product of two factors: the relative importance of the value to the decision maker and the extent to which alternatives differ when compared on the basis of that value. For example, urban land use and housing in the study area are important considerations in environmental assessment, but will be of little significance in plan selection, because all alternatives affect these factors to the same degree. Similarly, preservation of groundwater quality is of little concern in differentiating alternatives, because the existing resources are of such low quality. Taking account of both the significance of the values and the extent to which they distinguish alternatives, the preferred plan has been selected largely on the basis of the following five interrelated criteria:

- economics,
- ecological impact,
- reliability,
- flexibility, and
- social acceptability (both domestic and international).

The issues associated with each value and their bearing on plan selection are discussed below.

7.B Selection

The major environmentally significant feature of the recommended Master Plan is the discharge of two-thirds of Alexandria's wastewater to the Mediterranean, and this section will discuss ocean disposal in light of the five values noted above. Disposal of the remaining flow by lagoons and evaporation ponds will also be discussed.

7.B.1 Economics

Economic feasibility is of the utmost importance in assessing an environmental project in a developing economy such as Egypt's. A wastewater disposal alternative which costs more than the government and people of Egypt are willing to pay would not be implemented, no matter how environmentally sound it may be. The approximate economic analyses of regional disposal alternatives in the Master Plan make a clear distinction between the ocean and lake disposal alternatives on the one hand and agricultural reuse and evaporation ponds on the other. While disposal of the bulk of Alexandria's wastewater by agricultural reuse and evaporation ponds offers some advantages outside an economic context, they are not sufficient to overcome the severe economic disadvantages noted in Chapters 5 and 6. Detailed present worth analyses for the central portions of Alexandria favor ocean discharge over Lake Maryut disposal by from L.E. 23 million to L.E. 39 million, depending on the number of treatment plants proposed. Although this saving is significant, the ocean and lake alternatives must be compared on the basis of the other values to select a preferred means of disposal.

7.B.2 Ecological Impacts

Ecological impacts of the alternatives have been described in detail in Chapter 6. In describing ocean disposal for the central regions, the following points were noted:

1. There would be a negligible effect on the DO concentrations of the receiving ocean waters.

2. Nutrient concentrations would not have a detrimental effect on ocean waters and might enhance their marine resources and productivity.

3. No disinfection of wastewaters at their source would appear to be needed to protect bathing water quality.

4. If the recommendations of the Master Plan and supplemental studies pertaining to pretreatment and control of industrial wastes are implemented and enforced, then, toxic and other deleterious wastes should present no problem. (See Tech. App. No. 5A, 5B and 6, Vol. II, this report.)

5. Sludge deposits, with a thickness of about 25 cm, could be anticipated within a 4-km^2 area around each outfall. Such deposits would increase benthic abundance but decrease the variety of benthic species.

6. Ocean disposal implies a potential loss of nutrients for agricultural reuse.

The discussion of Lake Maryut disposal alternatives in Chapter 6 noted the following points:

1. Lake Maryut cannot be considered as a closed system for environmental impact analysis; wastewater discharged to the lake would eventually flow to the Mediterranean via the Mex Pump Station, albeit after varying degrees of dilution and biological activity within the lake.

2. Environmental impacts of wastewater discharges to the lake depend on both pollutant loadings and flushing action. If less wastewater is discharged to the lake, benefits resulting from the decreased pollutant load can be substantially offset by the decrease in flushing.

3. Water quality within the lake is unlikely to improve significantly under any alternative, including that by which only Nouzha's wastes are discharged from the existing East Treatment Plant. The quality of the Mex Pump Station discharge to Dekheila Bay and the Mediterranean does, however, vary with the quantity of wastewater discharged to the lake.

The relative magnitudes of the environmental impacts of the two alternatives are hard to assess, given the relative insensitivity of Lake Maryut water quality to pollutant loading and the uncertain impacts on Dekheila Bay and the Mediterranean of the Mex Pump Station discharge. These impacts have been determined on the assumption of reliable operation of both treatment and treatment disposal facilities, an assumption which is more valid for some alternatives than for others.

Possible adverse ecological impacts of agricultural reuse associated with the salinity of Alexandria's wastewater could be eliminated with adequate dilution, and the alternative offers beneficial impacts associated with wastewater nutrients serving as fertilizer. Similarly, no direct adverse ecological impacts were associated with evaporation in the Western Desert, although such a plan does preclude agricultural land reclamation at such a site.

7.B.3 Reliability

The reliability of wastewater treatment and disposal facilities and the consequences of their possible failure must be considered in assessing environmental impacts. The simplest and most reliable treatment and disposal facilities are those required for evaporation ponds, where the only concerns are the removal of coarse obstructions and the continuous operation of the pumping facilities. The ocean disposal alternative also uses only simple preliminary treatment facilities, because natural dilution and dispersion processes in the marine environment bring waste concentrations down to an acceptable level without requiring complex artificial treatment. Both evaporation ponds and ocean disposal require such little treatment that no significant adverse impact can be associated with the temporary failure of the treatment facilities, for pollutant loads would remain essentially the same.

Secondary treatment facilities required for lake disposal and agricultural reuse are far more complicated than the preliminary treatment processes of the ocean and desert disposal alternatives. Activated sludge facilities obtain high waste treatment efficiency through the use of sophisticated equipment and complex artificially-controlled biological processes. The complexity of the system makes it vulnerable to failure, and the resultant sharp decrease in treatment efficiency could have a severe impact on the environment. If bypass of an activated sludge plant became necessary, for example, effluent BOD_5 would increase 500 to 1,000 percent, and effluent bacterial counts would increase 10 or 20-fold. By way of comparison, bypass of preliminary treatment facilities for ocean discharge would increase effluent BOD_5 and bacterial counts by 10 or 20 percent.

Effective operation of large secondary treatment plants requires the existence of an institutional and economic infrastructure which is not present in Alexandria. Problems of inexperienced plant operators, poor laboratory facilities, unreliable supplies of chemicals and spare parts (many of which must be imported), and grossly inadequate maintenance and repair programs have plagued the East Treatment Plant since its startup in 1974. The fact that construction of the East Plant took 10 years, while the West Treatment Plant is still incomplete after a decade of construction, is indicative of severe economic and institutional constraints which hinder wastewater management in Alexandria. These problems can and probably will be overcome in time, but an honest assessment of alternative impacts must recognize the advantages of projects with low treatment requirements, given the current operational difficulties in Alexandria.

Other issues of reliability which affect plan selection are the likelihood of sewer use law enforcement and the nature of Alexandria's future industrial waste loads. The Master Plan calls for strict enforcement of a strong sewer use law which would eliminate the current problems of sewer clogging and corrosion, treatment process upsets, and the discharge of toxics to the environment. Most of these problems could be eliminated

by strong enforcement of Egyptian Law No. 93/162, which, although on the books for the past 15 years, is openly violated by both public and private sectors in Alexandria. The collection systems of all alternatives presented are equally vulnerable to the gross problems of clogging from illegally discharged solid wastes, but the continued discharge of toxics to the wastewater facility system can have different impacts with different disposal alternatives.

As a way of assessing vulnerability to future sewer use law violations, Chapter 6 examined the environmental impact of the ocean and lake disposal alternatives both with and without inplant toxics removal. Assuming the toxic strength of Alexandria's industrial wastewaters remains essentially the same, no significant adverse impacts are directly associated with the discharge of these toxics to either the ocean or Lake Maryut under the alternatives considered in the Master Plan. However, this conclusion is based on the limited information available on current industrial wastewater characteristics. If toxic loads were to increase drastically, and if sewer use laws continued to be ignored, the environmental impacts of the alternatives could become adverse. The biological secondary treatment process required for lake discharge could be disrupted by a heavy dose of toxics, resulting in a sharp decrease in treatment efficiency and a sharp increase in pollutant loadings to both Lake Maryut and, indirectly, the Mediterranean. The environmental impacts of ocean discharge would also be sensitive to sharp increases in untreated toxic wastes, although in most categories, current loads produce concentrations orders of magnitude less than those considered hazardous. The impact of toxics in agricultural irrigation is uncertain, although at the very least the secondary treatment processes would probably be disrupted. The environmental impacts of disposal by evaporation are less sensitive to wastewater toxicity than those of any other alternative. The subject of toxic industrial wastewater control is specifically addressed in Section 7.E.4, Toxic Industrial Waste Mitigation.*

7.B.4 Flexibility

Both the means of disposal and the level of consolidation chosen for the Master Plan involve issues of flexibility. Flexibility is also related to the economic issues discussed above, for low-cost alternatives represent flexibility in the commitment of economic resources.

The major issue of disposal flexibility is the ease with which wastewater could be reused for agricultural irrigation in the future, if future conditions so warranted. Secondary treatment and disposal of wastewater to Lake Maryut could be more easily converted to agricultural reuse than either ocean disposal or evaporation facilities, because the appropriate treatment facilities would already be built. Evaporation facilities are more flexible than those for ocean disposal, because the pipelines required to transport wastewater to the Western Desert facilitate conversion to agricultural reuse to the south of Alexandria; however, this

* Also, See Tech. App. No. 5A, 5B, and 6.

advantage is largely offset by the cost savings of ocean disposal which could be applied to reuse conversion.

The partial consolidation approach of the recommended plan is adopted for reasons of flexibility. The uncertainty of future development patterns favors the partial consolidation approach so that facilities for Ameria, Mex-Dekheila, and Abu Kir can be altered without affecting downstream facilities in a centralized system. In addition, the effluent from Ameria and Mex-Dekheila's lagoons can be reused for agriculture in the future with the simple addition of transmission facilities from the lagoons to appropriate irrigation canals.

7.B.5 Social Acceptability

Major issues of social acceptability affecting the Master Plan are:

- the perceived impact of the recommended Master Plan on the international waters of the Mediterranean
- the impact of the recommended plan on tourism
- the value to the Egyptian people of water conservation for agricultural purposes
- the economic cost of the plan.

It is difficult to gauge how the Mediterranean community will perceive the impacts of ocean discharge, regardless of the findings of this report. Secondary treatment and discharge to Lake Maryut of Alexandria's wastewater would not arouse as much concern over Mediterranean pollution, although Chapter 6 indicates that the water quality of the lake has a profound impact on the Mex discharge to Dekheila Bay and the sea. Western Desert evaporation and agricultural reuse are the alternatives least likely to arouse international or local environmental concern.

Similarly, the perceived impact of ocean discharge on bathing water quality may differ from any measured impact regardless of the technical arguments presented in Chapter 6, assuming the conservation of bathing water quality with properly designed ocean outfalls, there might well be tourists who would shun Alexandria's beaches because of the use of ocean outfalls for wastewater disposal. Alexandria's current tourist industry does not apparently suffer from the pollution of the short broken outfall at Kait Bey, so that soundly designed and built outfalls which are several kilometers in length might well present no such problem. Lake, desert, and irrigation disposal of Alexandria's wastewater are not perceived to affect tourism to any significant degree.

The high value attached to water conservation in Egypt favors agricultural reuse and lake disposal over both evaporation and ocean disposal. As with other issues of social acceptability, there may well be a painful difference between the public perception and the reality of the alternatives' impacts. Chapter 6 documents the technical problems of agricultural reuse of Alexandria's wastewater, but these problems might not be well understood by the Egyptian public. Discharge to Lake Maryut may also appear to "conserve" wastewater, when, in fact, it is merely rerouted to Dekheila Bay and the sea via Mex.

In practice, the acceptability of a plan to the Egyptian government probably depends more on economics than on any other factor. While agricultural reuse and evaporation may well be socially acceptable to the Egyptian public as a means of wastewater disposal, their extra costs of L.E. 60 to 80 million are probably not. Of all the values addressed, social acceptability is perhaps the hardest to assess.

7.B.6 Weighting of Values

The ranking of alternatives differs under different values, and the process of plan selection requires subjective value judgments on the part of those involved. Ocean disposal of the majority of Alexandria's wastes, with secondary treatment or evaporation of the remaining flow, emerges as a preferred plan, if one places a relatively high weight on values of economy, minimal adverse ecological impacts, reliability, and flexibility. The agricultural reuse alternative would emerge as the preferred plan, if social acceptability, devoid of economic considerations, were the only value considered; lake disposal and evaporation could be chosen as preferred plans under a different weighting of values. Therefore, after 6 months of study and appropriate consideration of the issues discussed above, we agree with the preferred alternative as recommended in the Master Plan. Environmental impacts of the recommended plan and proposed mitigation measures for the adverse impacts are discussed below.

7.C Beneficial Impacts

The major beneficial impact which justifies the implementation of a wastewater master plan is the resultant improvement in public health, the importance of which is discussed at length in Chapters 3 and 4. This beneficial impact is common to all the proposed master plans and does not distinguish the preferred plan from other alternatives. Similar benefits common to all alternatives are the enhancement of Alexandria's bathing water quality and the city's attractiveness as a tourist center, and the stimulation to employment and the local economy from the project's investment.

Beneficial impacts which distinguish alternatives are those associated with food production and Lake Maryut water quality. Chapter 6 shows that the apparent beneficial impact of increased crop yields and food supplies associated with agricultural reuse is in fact minimized by the crop-damaging salinity of Alexandria's wastewater; agricultural productivity can be improved far more effectively and economically through the use of Nile River water and fertilizer. While the nutrients in Alexandria's wastewater cannot be used effectively for food production in neighboring farmlands, they can improve food production in the marine environment.

Chapter 3 describes the decline in marine fish catches associated with loss of the Nile's nutrients. The discharge of Alexandria's wastewater to the nutrient-poor Mediterranean may well improve the area's fisheries. Another beneficial impact associated with the preferred plan is the reduction in organic pollution of Lake Maryut and the resultant improvement in water quality; this benefit is also associated with the agricultural reuse and desert evaporation alternatives.

7.D Adverse Impacts Which Cannot be Avoided

Proposed collection and conveyance facilities in the preferred Master Plan consist of about 92,000 house connections, 1,200 km of lateral sewers, 64 km of force main, 73 km of main trunk and intercepting sewers, and 25 pump stations. Proposed treatment facilities consist of two preliminary treatment plants and two anaerobic-aerobic lagoons. Disposal facilities consist of two sea outfalls and an evaporation pond. Adverse impacts generally associated with the construction and operation of such facilities have been discussed in Chapter 6. Those adverse impacts which specifically apply to the construction of preferred Master Plan facilities include:

- increased traffic congestion
- inconveniences to people and businesses
- additional noise and dust in the vicinity of the job site
- additional street litter from construction debris
- public safety hazards from open excavations and other construction activities
- skilled labor shortages
- construction equipment and material shortages
- damage to archaeological artifacts

-negative aesthetics

-interference with boating and fishing

-relocation of housing

-land use changes

-construction-related water and air pollution

-damage to street utilities.

Possible adverse impacts which specifically apply to the operation of recommended facilities, including the continued operation of the existing East Treatment Plant, are:

-if solid waste management is not improved

-use of new sewers for solid waste disposal

-hydrogen sulfide generation in sewers as a result of blockages

-airborne pollutants from treatment plant operations such as odors, aerosols, gases, and particulates

-noise

-wastewater flooding resulting from equipment failure

-improper screenings disposal

-equipment damage from corrosive industrial waste.

Adverse impacts associated with effluent disposal from the recommended facilities include:

-sludge bank formation at the end of the sea outfalls and reduction of benthic species

-possible bacterial pollution along the beaches at Agamy from lagoon discharges into the new Noubaria Drain

-possible bacterial pollution along the remaining Alexandria coastline from sea outfall discharges

-possible aquatic food chain contamination from toxic industrial wastes

-irreversible land use change resulting from the construction of an evaporation pond in Lake Idku and possible loss of bird habitat

-possible seepage from lagoons or evaporation ponds into underground or neighboring surface waters.

Although the adverse consequences of these impacts cannot be eliminated, they can be mitigated. The following section discusses such mitigation measures.

7.E Mitigation Measures

7.E.1 Construction Impacts

Constructing these proposed facilities would undoubtedly cause adverse impacts. However, several measures can be taken to mitigate their effects. Anticipating problems and developing plans which address them are important considerations. The Master Plan report could not address the construction impacts associated with specific pipeline alignments or pump station sites. However, preliminary design reports can and should consider among the technical comparisons, the differences in construction impacts. Such problem identification is a necessary beginning in planning mitigation measures.

A lack of planning can create unnecessary adverse impacts. An example occurred during construction of a 900-mm diameter water main along a major street in central Alexandria (El Horreya Avenue) in the fall of 1977. The pipe was stored along its proposed alignment, either on the sidewalk or along the curb, before construction began. These pipes were formidable obstacles for pedestrians and shoppers, interfered with traffic and parking, and, in general, created unnecessary inconveniences for everyone along the route. Such impacts could have been mitigated by providing a suitable storage place and coordinating delivery with installation. Other more general examples of such practices include the routine storing of construction materials such as sand, gravel, bricks, wood, and reinforcing bars on streets or sidewalks near the work site. In some cases, such haphazard storage completely blocks city streets. Because of the magnitude of construction proposed in the Master Plan, it is imperative that central storage and coordinated deliveries become established construction procedure.

Besides preconstruction planning, detailed control and supervision would also be important. Adequate qualified personnel are needed at each job site to ensure public safety, monitor progress, ensure conformance with design plans and specifications, and facilitate traffic movement. Traffic controllers and construction site monitors, to ensure safety, and resident engineers for technical supervision could ensure that planned mitigation objectives are accomplished. Unforeseen problems could immediately be reported to an overall construction management group for resolution.

Mitigation of skilled labor shortages and construction equipment and supply shortages would be another construction management planning task. Because of demand from neighboring oil-producing countries and government projects along the Suez Canal, skilled Egyptian labor is scarce. Construction managers should identify skills and numbers of personnel to determine their availability from local sources. Anticipated shortages can be mitigated through training centers for the various trades required. However, salaries must be competitive with other employment opportunities or new trainees may not remain in Alexandria. The same procedures should be followed to mitigate construction equipment and supply shortages: anticipate needs, survey local availability, and plan to either import the additional material or expand local capabilities to meet projected demands. Because the western harbor is inadequate to handle existing shipping traffic, construction schedules should allow for delivery delays on imported items.

The need to relocate housing is uncertain; however, it is a distinct possibility. Existing development in unsewered areas is often chaotic, with narrow or nonexistent streets. Pipeline alignments may require some building demolition, but such drastic procedures can be identified during the design phase. Once proposed alignments or sites are fixed, the land or easements should be purchased and identified for its intended use. Housing construction in poorer sections is currently uncontrolled, and land vacant during design may not be undeveloped when construction begins. Families to be relocated should be given early warning and assistance in moving to other housing.

Other specific impacts such as construction-related air, noise, and water pollution, damage to street utilities, and interference with boating and fishing during outfall construction can also be mitigated by problem anticipation, identification, and corrective action. With the cooperation of the designers, contractors, government personnel, and construction managers, construction impacts can be kept to a minimum and isolated to specific job sites.

7.E.2 Operational Impacts

Because of the lack of solid waste disposal alternatives, refuse is frequently dumped into sewer manholes. Extending the sewer system without providing proper solid waste disposal alternatives invites additional sewer misuse and increased maintenance problems. Resulting sewer blockages and possible wastewater flooding into the streets would recreate sanitation problems which the sewers are intended to resolve. A proper solid waste disposal system is an important mitigation measure for preventing these problems implemented prior to sewer construction.

Sewer systems can be designed to minimize potential for hydrogen sulfide generation. However, maintaining free-flowing sewers and self-cleaning velocities are essential design assumptions. If the refuse problem is

not resolved, surcharged sewers could develop conditions suited to hydrogen sulfide production. The resulting maintenance problems and potentially lethal working environment for sewer cleaning personnel are impacts which cannot be avoided.

Airborne pollutants are an unfortunate part of wastewater treatment. Odors, noise, aerosols, and gases would be present in the air at both preliminary treatment plants. Because these are in developed areas, the Master Plan proposes enclosures for the flotation units. The screens and grit removal facilities would be outdoors. Because preliminary treatment is brief and without much mechanical equipment, noise, odors, and aerosols should not present problems. Screenings would cause odors; however, if they are stored in closed containers and frequently removed to a suitable disposal site, a potentially adverse impact can be mitigated. Screenings and grit should be transported in water-tight vehicles to prevent dripping wastewater on city streets. The alternative of onsite screenings incineration should be investigated during the design phase. The proposed sites for the lagoons and evaporation pond are located in undeveloped areas. Final site selections should consider the best available information on future development, to minimize effects of airborne pollutants on neighboring areas.

Portions of the existing sewerage system convey corrosive industrial wastes. Facilities proposed in highly industrial areas should be designed to withstand corrosion in spite of a proposed industrial waste ordinance. Although the ordinance is, in theory, an effective mitigation measure, occasional discharges of corrosive wastes should be anticipated, and important equipment should be designed to operate under these adverse conditions.

Power failures are common in Alexandria. The damage and health hazard to adjacent areas from major equipment failures at the proposed wastewater treatment facilities can be avoided by providing standby equipment and power. Such design criteria are recommended in the Master Plan report for all treatment plants and pump stations.

7.E.3 Disposal Impacts

Sludge deposits at the ends of outfall pipes cannot be avoided. Their formation and effects are documented in Chapter 6. These deposits and their effects on the aquatic environment should be monitored after outfall operation begins. Should future impact studies identify a need to reduce solids loadings, primary treatment facilities can be installed at Kait Bey and Ras el Soda. Preliminary Master Plan layouts have considered this expansion at both preliminary plants, and the proposed site plans allow space for future primary sedimentation units.

Bacterial pollution can be mitigated by the installation of wastewater disinfection facilities. The most common mitigating measure is chlorination prior to effluent disposal. However, chlorinating preliminary treated effluent is expensive. The proposed outfall length and the dilutions available from disposal at sea should virtually eliminate any possibility of shoreline bacterial pollution. However, under certain environmental conditions, it is theoretically possible for sufficient numbers of indicator organisms to reach the beaches (see Chapter 6). Continued water quality monitoring would identify such occurrences, and, based on frequency and time of year, decisions can be made about disinfection installation. Plans and specifications should be prepared during preliminary treatment design, to permit the addition of disinfection facilities in an efficient manner.

As noted in Section 6.B.5, bacterial pollution from the proposed discharges at Ameria and the Outer West may be a problem if future tourist developments near Agamy are as extensive as planned. As with the outfalls, effluent chlorination can be employed as an effective mitigation measure if deemed necessary after completion of the facilities, the Drain, and more detailed planning of the tourist development. These needs can best be assessed by future bacteriological analyses at the beaches, the mouth of the Drain, and upstream and downstream of the effluent discharges to determine the fraction of bacterial pollution attributable to the lagoon effluents. (As noted in 6.B.5, the water quality of the Drain will be poor regardless of the proposed discharges, and it may be that bacterial concentrations in the agricultural drainage will be greater than those of the effluent. If this is the case, effluent chlorination may not substantially reduce total bacterial concentrations, but should still reduce the concentrations of any pathogens associated with lagoon effluents.) As with the outfalls, preliminary design of chlorination facilities is appropriate, and plant layout should include flexibility to allow for their incorporation.

Because future industrial waste characteristics cannot be predicted with accuracy, their impacts on the aquatic environment cannot be specifically addressed. The Master Plan recognized the danger of ocean outfalls with respect to abuse by local industries. An industrial waste ordinance would prohibit the discharge of toxic industrial wastes. However, enforcement and surveillance would be expensive and difficult. The question of industrial waste is a problem which must be faced by the Alexandria government. An industrial waste ordinance could only be an effective mitigating measure, if it is enforced.

Construction of an evaporation pond in Lake Idku or lagoons in the Outer West zone and Ameria would permanently change current land use, and there are no mitigating measures. Seepage from these facilities could be prevented by lining them with impermeable barriers; these suggestions are included in the Master Plan report.

7.E.4 Toxic Industrial Waste Mitigation

The analyses presented in Chapters 3, 4, and 6 show that in terms of both public health issues and conventional pollution problems, the preferred plan represents a tremendous improvement in the quality of life for the residents of Alexandria. Such analyses have, however, assumed a realistic degree of control over the discharge of toxic industrial waste to the municipal sewer, the worst case considered being the discharge of untreated industrial wastes of no greater strength than those currently measured in Alexandria. The city's industry is growing rapidly, however and the nature of its waste may change sharply with the growth, as industrialization in other countries has proven.

Suggested mitigation measures as proposed in the Master Plan include the recommended sewer use ordinance in Appendix L* and the industrial pretreatment facilities which are described in the Toxic Industrial Waste Study.* Article 4, sections 4.12 through 4.21 and section 4.24 of the sewer use ordinance describe procedures for industry to follow to maintain existing discharges or to make new connections to the municipal sewer system. Article 5 addresses allowable and excluded wastewater characteristics and Article 7 lists the penalties for noncompliance The Toxic Industrial Waste Study describes recommended pretreatment facilities for those industries with discharges which violate the recommended ordinance. However, assurance that these mitigation measures will be implemented and maintained poses a special problem. Present governmental authorities have not successfully enforced existing sewer use laws and there is currently no guarantee they will enforce the proposed mitigation measures described above.*

This report presents the control of toxic industrial wastes as an issue of major environmental significance. As has been noted throughout this report and the Master Plan, the magnitude of the environmental threat posed by the discharge of toxic wastes to the Mediterranean depends directly upon the efficiency of sewer use law enforcement and industrial pretreatment. If industrial wastes are effectively treated before discharge to the sewers, we see no major environmental hazard presented by the recommended plan. If they are not effectively treated, the benefits to be gained by the construction of the facilities in the recommended plan will be compromised and we can offer no assurance of its environmental acceptability. It will be the responsibility of the Egyptian Government to ensure implementation of these mitigation measures.

*See Tech. App. No. 5A, 5B and 6, Vol. II, this report.

7.F Short-Term Uses vs. Long-Term Productivity

The previous sections have addressed the adverse environmental impacts associated with constructing wastewater treatment facilities recommended in the Master Plan. Most of these impacts are of a short-term duration and are reversible on completion of construction. The remaining impacts such as land use and water quality changes have long-term implications. Mitigation measures to reduce the effect of these impacts have been previously addressed.

The short- and long-term losses associated with these impacts are insignificant when compared to the long-term benefits to be gained by adequate wastewater treatment facilities. A review of the existing health conditions (Chapter 3) and the future environment with no action (Chapter 4) clearly indicates the long-term loss of human productivity which would result from the degradation of existing sanitation and health problems. Although inadequate wastewater treatment facilities are only one of many deficient municipal services in Alexandria, existing conditions demand immediate action. Improvement in the quality of life for the people of Alexandria is an objective which should not be compromised.

7.G Irreversible and Irretrievable Commitment of Resources

Materials used in construction of the recommended Master Plan facilities represent a commitment of resources not likely to be reclaimed. Manpower and energy requirements also represent irreversible and irretrievable commitments. However, construction skills taught to Egyptians are retrievable for future projects. Pump station, treatment plant, and evaporation pond sites are not likely to be used for other purposes, and project costs and continued operation and maintenance costs require irretrievable financial resources. The disposal of wastewater to the sea also represents a potential loss of nutrients for agricultural reuse.

References

[1]Program Requirements Memorandum 75-62, U.S. Environmental Protection Agency, 6 June 1975.

CHAPTER 8

GLOSSARY, ACRONYMS AND CONVERSION UNITS

Acronyms - A list of acronyms follows this glossary section.

Activated Sludge - Sludge flox produced in raw or settled wastewater by the growth of zoogleal bacteria and other organisms in the presence of dissolved oxygen and accumulated insuficient concentration by returning floc previously formed.

Activated Sludge Process - A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.

Adverse Land Use - A use of land that is not in conformity with the planning or social requirements of the municipality.

Aeration - Artifically accelerated transfer of oxygen to water from air, e.g. bubbling air through the liquid or spraying the liquid in air.

Aeration, Extended - Modification of the activated sludge process which provides for aerobic sludge digestion within the aeration system.

Aeration, Step - Procedure for adding increments of settled sewage along the line of flow in the aeration tanks of an activated sludge sewage treatment plant.

Aerobic - (1) containing oxygen and (2) requiring the presence of oxygen or air to live.

Aesthetics - Evaluations and considerations concerned with the sensory quality of resources (sight, sound, smell, taste, and touch) and especially with respect to judgement about their pleasurable qualities.

Alternative - The different means by which objectives or goals can be attained. They need not be substitutes for one another or perform the same function.

Anaerobic - (1) devoid of oxygen and (2) requiring the absence of oxygen or air to live.

Anaerobic-Aerobic Pond or Lagoon - As used in this report, a stabilization pond where wastewater treatment is accomplished in two stages; the first stage, where suspended solids settle and undergo anaerobic decomposition,

and the second stage, where further wastewater treatment is accomplished by aerobic oxidation.

Anoxia - Absence of oxygen.

Aquifer - A geologic formation which contains water and transmits it from one point to another through a subsurface permeable soil or rock matrix.

Assimilate - (1) To take in and appropriate as nourishment, (2) absorb into the system.

Assimilation - The incorporation or conversion of nutrients into protoplasm that in animals follows digestion and absorption and in higher plants involves both photosynthesis and root absorption.

Assimilative Capacity - The capacity of a natural body of water to receive:

(a) wastewater without deleterious effects;

(b) toxic materials without damage to aquatic life or humans who utilize the water;

(c) BOD, within prescribed dissolved oxygen limits.

Benthos - Organisms living on the bottom of water bodies.

Biological Oxidation - The process whereby living organisms such as bacteria convert the organic matter in wastewater and water bodies in the presence of oxygen into a more stable or mineral form. Synonymous with biochemical oxidation and aerobic stabilization.

BOD - Biochemical Oxygen Demand:

(1) The quantity of oxygen mold in the biochemical oxidation of organic matter in a specified form, at a specified temperature, and under specified conditions;

(2) A standard test used in assessing wastewater strength.

The quantity of dissolved oxygen used in the aerobic stabilization of organic matter contained in a certain water body or wastewater. The quantity is determined by a standard test at a specified temperature, conditions, and time, usually 5 days. It is reported in mg/l.

Chlorination - The application of chlorine to water or wastewater generally for the purpose of disinfection.

Chlorine Stabilization - The application of chlorine to sludge to oxidize compounds and inhibit bacteria activity for the purpose of stabilization.

Coliform Organisms - A group of harmless bacteria commonly inhabiting the intestines of warm-blooded animals including humans. They are excreted along with any pathogenic organisms. Coliform concentrations in wastewater and water bodies are easily determined and used as an indicator for the presence of pathogenic organisms which are difficult to isolate. The presence of coliform organisms is taken as an indication that pathogenic organisms could be present.

Combined Sewer - A sewer which receives both wastewater and stormwater.

COD - Chemical Oxygen Demand - The oxygen equivalent of the organic matter which can be chemically oxidized. The COD of wastewater is generally higher than the BOD as more compounds can be chemically oxidized than can be biochemically oxidized.

Digestion, Aerobic - Decomposition of organic matter for stabilization in the presence of elemental oxygen.

Digestion, Anaerobic - Decomposition of organic matter for stabilization resulting in gasification, liquification, and mineralization through the action of microorganisms in the absence of elemental oxygen.

Discharge - The release of water-borne pollutants to a receiving stream directly or indirectly or to a sewerage system.

DO - Dissolved Oxygen - The oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation.

Drogue - A device used to determine the direction and velocity of water currents. They are usually submerged, to a predetermined depth, and are tethered to an identifiable surface float in order that their movement may be recorded by observers.

Eutrophic - A designation of a body of water rich in nutrients.

Force Main - A pipe which carries wastewater under pressure from a pump station.

GOSSD General Organization for Sewerage and Sanitary Drainage. A national level organization of the Ministry of Housing and Reconstruction (A.R.E.) which is responsible for managing, improving, maintaining, and operating wastewater collection treatment and disposal facilities.

Governorate - A political unit or area in the Arab Republic of Egypt administered by a council acting under the guidance of a Governor.

Hazardous Waste - Any waste or combination of wastes which poses a substantial present or potential hazard to human health or living organisms because such wastes are non-degradable or persistent in nature or because they may otherwise cause or tend to cause detrimental cumulative effects. It shall include waste material that is toxic, carcinogenic, corrosive, irritating or sensitizing, explosive or flammable. The following are not considered hazardous wastes: (1) municipal waste originating in a community and consisting of household waste from private residences, (2) commerical waste which originates in wholesale, retail or service establishments, (3) dry sewage sludge, (4) bulky waste, (5) dry non-hazardous chemical waste, (6) vegetative waste, (7) animal or food processing waste, (8) non-chemical industrial waste, (9) bulk liquid and semi-liquid waste, (10) septic tank clean-out waste, and (11) liquid sewage sludge.

Hectare (ha) - A metric unit of area equal to 10,000 square meters and 2.471 acres.

Hydrodrome - The Nouzha Hydrodrome was used as a landing area for seaplanes.

Infiltration - The groundwater that leaks into pipes and appurtenances such as manholes through joints, porous walls, or breaks.

Inflow - Surface runoff which enters sewers through direct connections such as roof drains and catch drains.

Lagoon - (1) A shallow pond, sound, or channel near or communicating with a larger body of water; (2) a body of brackish water, especially one separated from the sea by sandbars, coral reefs, etc.; and (3) (sanitary engineering) a pond containing untreated or partially treated wastewater in which aerobic or anaerobic stabilization occurs.

Lift Station - Same as Pump Station

L.E. - Egyptian pounds, L.E. 0.7 = U.S. $1.00. (See technical appendix No. 4.)

Metric Units - A listing of metric and American units and conversions is presented at the end of this glossary section.

Outfall - As used in this report, a long section of pipe for the transport and disposal of wastewater in the marine environment. Modern outfalls include a diffuser section to insure rapid initial dilution of the wastewater by seawater.

Overflow - The excess water which exceeds the capacity of a sewer or drain and is discharged from the system at an overflow structure.

Pathogen - A specific agent (generally a bacteria or virus), that causes disease.

Pelagic - Living in open seas rather than close to shore or inland.

Phytoplankton - Minute floating aquatic plants.

pH - The scale, whose numbers range from 0-14, is based on the negative logarithm of the hydrogen-ion concentration. Neutrality is represented by 7, acidity is indicated by values less than 7, and alkalinity as greater than 7.

Pollution - The presence in the environment of conditions or contaminants in quantities or characteristics which are or may be injurious to human, plant, or marine life; wildlife or other animal life; or property; or which unreasonably interfere with the comfortable enjoyment of life and property throughout such areas as it may affect.

Preliminary Treatment - Includes flow measuring, mechanically or manually cleaned bar screens to remove worse solids, grit removal facilities, and flotation units to remove oil and grease.

Pretreatment - Conditioning of a waste at its source before discharge to to remove or neutralize substances injurious to sewers and treatment processes or to effect a partial reduction in load on the treatment process. The term generally applies to the conditioning of industrial wastes before discharge to municipal sewerage systems.

Primary Treatment - Sedimentation of untreated or preliminary treated wastewater.

Pump Stations - Facilities containing pumps to life wastewater from low areas. They discharge the wastewater into force mains.

Residue - All of the solids that remain after completion of thermal processing, including bottom ash, fly ash, and grate siftings.

Screening - The removal of floating and suspended solids in sewage by straining through racks or screens.

Secondary Treatment - Treatment of wastewater by biological processes, such as activated sludge, following primary treatment.

Sedimentation - The process of subsidence and deposition of the suspended matter in sewage by gravity, usually accomplished by reducing the velocity of the sewage below the point at which it can carry suspended matter. Primary sedimentation occurs in a complete sewage treatment process before biological or chemical treatment; secondary sedimentation occurs after such treatment.

Septic Tanks - An individual subsurface fisposal process for wastewater generally from homes or small institutions. The solids settle to the bottom

and the organics decompose through anaerobic processes. The supernatant is discharged to a subsurface drain field which distributes the flow over a wide area where it percolates into the ground. The remaining solids and floating scum and grease must be removed occasionally.

Sewage - The spend water of a community consisting of a combination of liquid and water-carried wastes from residences, commercial buildings, industrial plants and institutions, together with any groundwater, surface water or storm water which may be unintentionally present (also known as wastewater.)

Sewerage System - A system of piping, treatment facilities, and appurtenances for collecting, conveying and treating wastewater.

Skimmings - Grease, solids, liquid and scum skimmed from wastewater settling tanks.

Sludge - (1) The accumulated solids separated from liquids such as water or wastewater, during processing; (2) the precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater.

Solid Wastes - Garbage, refuse, sludge from a wastewater or water supply treatment plant, or other waste in a solid form.

SS - Suspended solids . Solids that either float on the surface of or are in suspension in water, wastewater or other liquids.

Stabilization Pond - A relatively shallow body of water designed for the purpose of wastewater treatment. (See Lagoon).

Supernatant - The liquid standing above a sediment or precipitate.

TDS - Total dissolved solids. Total solids in water, wastewater or other liquids. It includes the suspended solids (largely removable by filter paper) and the filterable solids (those which pass through filter paper).

Units of Measurement - A listing of measurement units used in this report is presented at the end of this glossary section.

WHO - World Health Organization

ACRONYMS

A list of acronyms used in this report follows:

ATECO: Arab Technical and Economical Consulting Office

A.R.E.: Arab Republic of Egypt

CDM: Camp Dresser & McKee Inc.

GOSSD: General Organization for Sewerage and Sanitary Drainage (A.R.E.)

IGPM: Intergovernmental Meeting on the Protection of the Mediterranean* (Barcelona, 28 January-4 February 1975)

*Algeria, Egypt, France, Greece, Israel, Italy, Lebanon, Libyan Arab Jamahiniya, Malta, Monaco, Morocco, Spain, Syrian Arab Republic, Tunisia, Turkey, Yugoslavia.

IOC: Intergovernmental Oceanographic Commission of UNESCO (Paris, France)

IRM-MCS: Intergovernmental Review Meeting of Mediterranean Coastal States on the Mediterranean Action Plan (Monaco 9-14 January 1978) (Re. IGPM)

MAIN: Chas. T. Main International, Inc.

MAP: Mediterranean Action Plan (Re. IGPM/MED-POL)

MCS: Mediterranean Coastal States (Re. IGPM)

MED-POL: Co-ordinated Mediterranean Pollution Monitoring and Research Programme (Re. IGPM)

MOHR: Ministry of Housing and Reconstruction (A.R.E.)

MPS: Master Plan Study - Alexandria Wastewater Project

PAC/RS: Project Activities Center/Regional Seas (UNEP, Geneva, Switzerland)

UNEP: United Nations Environmental Programme, Geneva, Switzerland

USAID: United States Agency for International Development

METRIC AND AMERICAN UNITS AND CONVERSIONS

All conversions given to three significant figures unless denoted otherwise.

Length

1 kilometer (km) = 0.621 miles (mi) 1 mi = 1.61 km

1 meter (m) = 1.09 yard (yd) = 3.28 feet (ft) 1 yd = 0.914 m = 91.4 cm

1 centimeter (cm) = 0.394 inches (in.) 1 ft = 0.305 m = 30.5 cm

1 millimeter (mm) = 0.0394 in. 1 in. = 2.54 cm = 25.4 mm

1 km = 1,000 m (exactly) 1 mi = 1,760 yd = 5,280 ft (exactly)

1 m = 100 cm = 1,000 mm (exactly)

Area

1 square kilometer (km^2) = 0.386 square miles (mi^2)

1 hectare (ha) = 2.47 acres = 2.38 Egyptian feddans

1 square meter (m^2) = 10.8 square feet (ft^2) = 1.20 square yards (yd^2)

1 mi^2 = 2.59 km^2

1 acre = 0.405 ha = 0.963 Egyptian feddans

1 yd^2 = 0.836 m^2

Area (continued)

1 ft^2 = 0.0929 m^2 = 929 cm^2

1 km^2 = 100 ha = 10^6 m^2 (exactly)

1 ha = 10,000 m^2 (exactly)

1 mi^2 = 640 acres = 2.79 x 10^7 ft^2

1 acre = 43,560 ft^2 (exactly)

1 yd^2 = 9 ft^2 (exactly)

Volume

1 cubic meter (m^3) = 1.31 cubic yards (yd^3) = 35.3 cubic feet (ft^3) = 264 U.S. gallons (U.S. gal)

1 megaliter (Ml) = 0.264 x 10^6 U.S. gal = 35,300 ft^3

1 liter (l) = 0.264 U.S. gal = 0.0353 ft^3 = 61.0 cubic inches ($in.^3$)

1 yd^3 = 0.765 m^3 = 765 l

1 ft^3 = 0.0283 m^3 = 28.3 l

1 U.S. gal = 3.79 l

1 Ml = 1,000 m^3 = 10^6l (exactly)

1 yd^3= 27 ft^3 = 202 U.S. gal

1 ft^3 = 7.48 U.S. gal

Mass

1 kilogram (kg) = 2.205 pounds (lb)

1 lb = 0.454 kg =454 gm

1 metric ton (tonne) = 1.10 U.S. tons = 2,205 lb

1 U.S. ton = 0.907 tonnes = 907 kg

Mass (continued)

1 tonne = 1,000 kg = 10^6 gm

1 U.S. ton = 2,000 lb (exactly)

1 milligram (mg) = 10^{-3} gm

Flow

1 Megaliter per day (Ml/day) = 0.264 million U.S. gallons per day (mgd)
= 0.409 cubic feet per second (cfs)
= 184 U.S. gallons per minute (gpm)

1 mgd = 3.78 Ml/day

1 cfs = 2.45 Ml/day

1 gpm = 0.00543 Ml/day

1 Ml/day = 1,000 cubic meters per day (m^3/day), exactly = 11.6 liters per second (lps)

1 mgd = 1.55 cfs = 694 gpm

1 cfs = 0.646 mgd = 449 gpm

1 gpm = 0.00144 mgd (exactly) = 0.00223 cfs

Concentrations

1 milligram per liter (mg/l) = 1 part per million (ppm) = 8.34 pounds per million U.S. gallons

1 microgram per liter (ug/l) = 0.001 mg/l (exactly)

1 microgram per cubic meter (ug/m^3) = 10^{-6} mg/l (exactly)

1 part per thousand (°/oo) = 1,000 mg/l (exactly)

Biological Productivity

1 gram carbon per square meter per day ($gC/m^2/day$) = 1.84×10^{-3} pounds carbon per square yard per day ($lb\ C/yd^2/day$)

1 $lb\ C/yd^2/day$ = 543 $gC/m^2/day$

Biological Abundance

1 gram per square meter (gm/m^2) = 1.84×10^{-3} pounds per square yard (lb/yd^2)

1 lb/yd^2 = 543 gm/m^2

Dust Fall

1 metric $ton/km^2/month$ = 2.85 U.S. $tons/mi^2/month$

Temperature

Temperature in degrees Celsius (°C) = (Temperature in degrees Fahrenheit (°F)-32°F)/1.8

Temperature in °F = 32°F + 1.8 x (temperature in °C)

CHAPTER 9

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CHAPTER 10

TECHNICAL APPENDICES

TECHNICAL APPENDIX NO. 1

TABLE OF

BIRDS OF THE ALEXANDRIA AREA ASSOCIATED WITH FRESH AND BRACKISH WATER[1]

English Name	Scientific Name	Period of Occurrence		
		Winter	Migrant	Summer
Great crested grebe	Podiceps cristatus	X		X
Black-necked grebe	Podiceps nigricollis	X		
Little grebe	Tachybaptus ruficollis	X		X
While pelican	Pelecanus onocrotalus	X		X
Dalmatian pelican	Pelecanus crispus	X		
Cormorant	Phalacrocorax carbo	X		
Grey heron	Ardea cinerea		X	
Purple heron	Ardea purpurea		X	
Great white egret	Egretta alba	X		
Little egret	Egretta garzetta	X		X
Squacco heron	Ardeola ralloides			X
Night heron	Nycticorax nycticorax			X
Little bittern	Ixobrychus minutus			X
Bittern	Botaurus stellaris		X	
Spoonbill	Platalea leucoroidea	X		
Glossy ibis	Plegadis falcinellus	X		X

[1] Taken from Heinzel, H., Fitter, R., and Parslow, J., The Birds of Britain and Europe with North Africa and the Middle East, J. B. Lippincott Co., 1972.

APPENDIX TABLE (Continued)

English Name	Scientific Name	Period of Occurrence		
		Winter	Migrant	Summer
White stork	Ciconia ciconia		X	
Black stork	Ciconia nigra	X		
Greater flamingo	Phoenicopterus ruber	X		
White-fronted goose	Anser albifrons	X		
Ruddy shelduck	Tadorna ferruginea	X		
Egyptian goose	Alapochen aegyptiacus	X		X
Mallard	Anas platyrhynchos	X		
Gadwall	Anas strepera	X		
Wigeon	Anas penelope	X		
Teal	Anas crecca	X		
Garganey	Anas querquedula		X	
Pintail	Anas acuta	X		
Shoveler	Anas clypeata	X		
Marbled teal	Anas angustirostris	X		
Red-crested pochard	Netta rufina	X		
Tufted duck	Aythya fuligula	X		
Pochard	Aythya ferina	X		
Ferruginous duck	Aythya nyroca	X		

AFPENDIX TABLE (Continued)

English Name	Scientific Name	Period of Occurrence		
		Winter	Migrant	Summer
Osprey	Pandion haliaetus	X		
Black kite	Milvus migrans	X		X
Marsh harrier	Circus aeruginosus		X	
Crane	Grus grus	X		
Water rail	Rallus aquaticus	X		X
Spotted crake	Porzana porzana	X		
Little crake	Porzana parva		X	
Baillon's crake	Porzana pusilla			X
Moorhen	Gallinula chloropus	X		X
Purple gallinule	Porphyrio porphyrio	X		X
Coot	Fulica atra	X		X
Black-winged stilt	Himantopus himantopus	X		X
Avocet	Recurvirostra avosetta	X		X
Ringed plover	Charadrius hiaticula	X		
Little ringed plover	Charadrius dubius	X		X
Greater sandplover	Charadrius leschenaultii	X		
Kentish plover	Charadrius alexandrinus	X		X
Kittlitz's sandplover	Charadrius pecuarius	X		X

APPENDIX TABLE (Continued)

English Name	Scientific Name	Period of Occurrence		
		Winter	Migrant	Summer
Golden plover	Pluvialis apricaria	X		
Grey plover	Pluvialis squatarola	X		
Dotterel	Eudromias morinellus	X		
Turnstone	Arenaria interpres	X		
Lapwing	Vanellus vanellus	X		
White-tailed plover	Vanellus leucurus	X		
Spur-winged plover	Vanellus spinosus	X		X
Sociable plover	Vanellus gregarius	X		
Broad-billed sandpiper	Limnicola falcinellus		X	
Curlew sandpiper	Calidris ferruginea		X	
Dumlin	Calidris alpina	X		
Temminck's stint	Calidris temmincki		X	
Little stint	Calidris minuta	X		
Redshank	Tringa totanus	X		
Spotted redshank	Tringa erythropus	X		
Greenshank	Tringa nebularia	X		
Marsh sandpiper	Tringa stagnatilis	X		X
Common sandpiper	Tringa hypoleucos	X		

APPENDIX TABLE (Continued)

English Name	Scientific Name	Period of Occurrence		
		Winter	Migrant	Summer
Wood sandpiper	*Tringa glareola*		X	
Green sandpiper	*Tringa orchropus*	X		
Ruff	*Philomachus pugnax*		X	
Snipe	*Gallinago gallinago*	X		
Painted snipe	*Rostratula benghalensis*	X		X
Black-headed gull	*Larus ridibundus*	X		
Herring gull	*Larus argentatus*	X		
Lesser black-back	*Larus fuscus*	X		
Common tern	*Sterna hirundo*		X	
Black tern	*Chlidonias niger*		X	
White-winged black tern	*Chlidonias leucopterus*		X	
European kingfisher	*Alcedo atthis*	X		
Lesser pied kingfisher	*Ceryle rudis*	X		X
Hoopoe	*Upupa epops*	X		X

TECHNICAL APPENDIX NO. 2

ALEXANDRIA'S TOURISM INDUSTRY

Prime reasons for the growth of Alexandria into a major urban area have been its attractive beaches and mild summer climate. During the early 20th century, the King of Egypt utilized Alexandria as a summer residence. This encouraged a large number of attendant government officials and other wealthy elite seeking influence to also relocate in Alexandria. Throughout the twentieth century, Egypt's growing middle class from the country's interior (especially urban centers such as Cairo) have also sought relief from the summer heat in Alexandria.

Tourism officials estimate that over a million vacationers now visit Alexandria for approximately 3 weeks during the months of June, July, and August (personal interview).[1] Based on city water consumption records, this is believed to be a valid estimate. Few statistics are available on the vast majority of vacationers who vist Alexandria and stay with relatives or rent apartments.

Physical Aspects

Alexandria is blessed with over 40 km of shoreline, most of which are beautiful white sandy Mediterranean beaches. The weather in Alexandria is sunny and mild from April to November with cool stormy periods from November to March.

The major zone of existing tourist facilities is along the shoreline east of the Eastern Harbor (see Fig. 3-29). Generally, the lower class hotels and beaches are located close to downtown, and hotel costs increase farther east, toward the higher class resorts of Montazah and Maamoura. A

[1]El Leithy, F., Tourism Advisor to the Alexandria Governorate.

new area of tourism development is occurring west of Alexandria at Agamy. This is expected to be a major tourist growth area during the rest of the century, but its size is yet to be determined.

Origin of Tourists

Most of the vacationers who visit Alexandria are from Egypt but a growing number come from oil-rich Arabian Gulf states. Approximately 70,000 western tourists stop in Alexandria during Mediterranean cruises. Another 100,000 foreigners register in Alexandria hotels for vacations and business.[2] The national government is encouraging the use of Alexandrian hotels for conferences to ease the current overcrowded conditions in Cairo. Currently, access to Alexandria by foreign visitors is difficult because of the lack of commercial airport facilities; the nearest such airport is in Cairo.

Tourist Activities

In addition to enjoying the sun during the day, vacationers may enjoy the many restaurants, casinos, sports club, horse races, downtown markets, gardens, movie theaters, and historical areas in Alexandria. The location of some of the major tourist activity areas are shown on Fig. 3-29.

Western vacationers who visit Alexandria by boat usually stop in Alexandria for 2 days. One of those days is normally spent for a trip to Cairo and the pyramids, while the other day may be spent touring historical sites in Alexandria.

Current Tourism Expenditures

An estimate of 1977 expenditures by seasonal visitors and hotel residents is presented in Table 1. This estimate was prepared from interviews with tourism officials, published hotel statistics from previous years, and a recent tourism study for the Western Desert region.[3]

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[2]Ministry of Tourism, Statistical Research Bulletin, 1977.

[3]Regional Plan for the Coastal Zone of the Western Desert, Final Report, Vol. I (of five) - Main Report, Pof. Dr. Ismail, H., & Partners, ILACO, for the A.R.E. Ministry of Housing and Reconstruction, August 1976.

TABLE 1.*

ESTIMATED EXPENDITURES IN ALEXANDRIA BY TOURISTS AND HOTEL RESIDENTS-1977

		Seasonal Apartments	Domestic Hotel Residents	Foreign Hotel Residents	Foreigners on Boat Cruises
1.	Number of persons	1,000,000	500,000	100,000	70,000
2.	Average length of stay (days)	20	2.3	3	1
3.	Number of tourist/ hotel days	20,000,000	1,150,000	300,000	70,000
4.	Expenses, L.E./person-day	1.7	4.0	13.0	6.0
4a.	Accommodations	0.7	2.0	6.0	-
4b.	Food	0.75	1.5	3.5	2.5
4c.	Miscellaneous	0.25	0.5	3.5	3.5
5.	Total expenditures, L.E.	34,000,000	4,600,000	3,900,000	400,000
6.	Total expenditures for all tourists and hotel residents = $42,900,000 L.E.				

*Sources discussed in text.

(Tech. App. No. 2 cont'd)

The vast majority of Egyptian summer vacationers, according to vacation-days, are those renting apartments, staying with relatives, or owning a seasonal apartment in Alexandria. No statistics have ever been collected on this last category, the largest group of Alexandrian vacationers, nor have surveys been made of their expenditures. The only supporting data on the size of this group are water-use records from the Water Authority. Apartment rentals cost between L.E. 80 and L.E. 350 a month during the summer, and it has been estimated that these vacationers eat most meals at their apartments. The cost of vacationing in Alexandria has been rising steadily, according to tourism officials. For this reason, they estimate the length of stay affordable by the average Egyptian vacationer is declining (personal interview).[4]

The estimate of hotel residents, both domestic and foreign, includes those traveling for business purposes. Expenses were based on costs of lower class accommodations for domestic vacationers and upper class accommodations for foreign visitors. Expenses of tourists from Mediterranean cruises were based on the number of arrivals and expected expenses for 1 day of touring and shopping in Alexandria.

As can be expected, the significantly greater daily expenditures of upper class hotel residents and foreigners increase their proportional contribution to the total tourism industry income. Miscellaneous expenses in Table 1 represent spending for souvenirs, gifts, local transportation, excursions, admission tickets, beach rentals, and snacks. It does not include earnings from betting at Alexandria's casinos. The net income of the casinos is not known but may be in the millions of pounds.

Residents of Alexandria frequently use their local beaches and other nearby recreational facilities all year. Their expenditures and, more importantly, the value they place on living near the coast is immeasurable.

Current Environmental Conditions at Alexandria Beaches

The major resort area to the east from the downtown area to Abu Kir is a fairly straight narrow beach interrupted by headlands of rock jutting into the sea. Parallel to the beach on the seaward side is a roadway along which are intermittent beach cabins, hotels, and restaurants, while to the landward side are three- to 12-story apartment buildings. During the summer season, the best beaches are so crowded it is difficult to see anything but umbrellas and people from the road.

All the beaches have traces of oil and debris, requiring continual cleaning during the busy summer season. The water is typically a blue/green

[4] Ibrahim, N., Director of Alexandria Office of the Ministry of Tourism.

clear color. Wastewater discharges are located intermittently along the eastern beaches. These discharges were originally designed for combined wastewater only during periods of rain. However, they now discharge raw wastewater nearly continuously into the Mediterranean close to shore and thereby heavily pollute many beaches. The main wastewater discharge at Kait Bey extends only several hundred meters into the Mediteranean, and its effluent plume is carried to the eastern beaches by winds and currents. Effluent plumes from all discharges are both visible and odorous. People have been observed swimming near these untreated wastewater discharges, increasing their own risk of illness.

The Future of Tourism in Alexandria

The future of the tourism industry in Alexandria appears bright. With few other developed beach resort areas in the country, and its close proximity to the major settled areas of Egypt, Alexandria should remain the prime beach resort of domestic vacationers. The tourism projection for the Water Supply and Wastewater Master Plans were based on a doubling of seasonal visitors by the year 2000, approximately a 3 percent growth rate. This rapid growth is probable because Egypt's urban population growth is estimated to be near this figure.

Distribution of Tourists

A new touristic development zone has been identified by the government for the beaches west of Agamy. Because population pressures at the existing eastern beaches are increasing, a large portion of new tourism is planned to be located in the Agamy area. Seasonal population projections in the preliminary Water Supply Master Plan exemplify the probable increase in tourism activities for different districts.

	Equivalent Year-Round Population of Tourists			
Districts	1977*	1980	1990	2000
Bab Sharky	119	135	165	172
Ramleh	35	40	50	54
Montazah	189	200	205	214
Dekheila	7	15	70	155

*Estimate.

Source: Part 1 - Immediate Phase Waterworks Master Plan Reports - Preliminary, Alexandria Waterworks Development Programs, Camp Dresser & McKee International Inc., August 1977.

Adjacent Tourism Activity

A recent plan for the coastal zone along the Western Desert[5] calls for the rapid expansion of tourism in the most amicable areas. It is expected that primarily foreign and not domestic tourism will be the main focus of this expansion and, therefore, will not noticeably affect Alexandria's tourism. However, an expansion of domestic holiday visitors to this area from 100,000 to 339,000 in the year 2000 is expected, while foreign tourists are expected to number a million by the year 2000. In any case, the new resort areas should offer a different setting. The quiet secluded beaches and rural holiday setting planned for the Western Desert vacationers is exactly the opposite of the hustle and bustle of a major urban area like Alexandria during the summer. The Western Desert beaches and Alexandria resorts will, therefore, compliment each other and provide vacationers a chance to enjoy various settings.

New Developments

A major hindrance to international tourism in Alexandria is the absence of an international airport. Current plans call for the use of a military air base west of Alexandria for commercial airline service; however, these plans have not been finalized. With good air facilities, an Alexandria beach vacation could be more practical to combine with tours of the antiquities in Upper Egypt. Regional Arab tourism could also be expected to increase with easier accessibility. Foreseeing these possibilities, two large five-star deluxe hotels are being constructed in Alexandria. One is a Saudi-Egyptian venture near the Montazah Palace and the other is a Kuwaiti-Egyptian venture at Sidi Gaber. Both hotels are planning for Swiss or American management.

Economic Aspects

The tourism industry is very important to Alexandria with tens of thousands of employees in hotels, restaurants, and concessions, and thousands more in construction, retailing, transportation, and other services. It is important, therefore, to insure that environmental degradation of Alexandria's beaches does not occur to an extent which would jeopardize the earnings of this large industry.

Based on estimated current expenditures of tourists presented in Table 1 and various assumed growth rates in tourism expenditures, Table 2 was

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[5] Regional Plan for the Coastal Zone of the Western Desert, op. cit.

prepared showing the present worth of spending from 1977 to 2000 at different discount rates.

TABLE 2.

PRESENT WORTH OF TOURIST SPENDING IN ALEXANDRIA
1977-2000 (Millions L.E.)

Discount Rate (percentage)	Growth Rate of Spending (percentage) 2	4	6	8
8	539	652	799	991
10	453	540	651	795
12	387	455	540	649
14	336	389	456	540

Total expenditures at a 4 percent rate would total over L.E. 1,700 million and, with a discount rate of 12 percent, would have a present worth of L.E. 455 million. A 4 percent growth rate is probable considering a 3 percent growth in tourism and a 1 percent growth in real expenditures per tourist.

The cholera epidemic of 1970-1971 was estimated to have reduced tourism by 250,000 during the summer season.[6] If such situations recur, the possibility of a decline in tourism is real. In addition, many vacationers and residents of Alexandria remember when the beaches and water were much cleaner and consider the situation to be deteriorating rapidly. If the upper tolerance of various vacationers to pollution levels is met, it would gradually drive a larger share of tourists from Alexandria.

[6]Wahdan, M.H., and El Nomrousy, M., Report on the Epidemic Situation in Alexandria (1970-1971), High Institute of Public Health, Alexandria, Egypt, 1971.

TECHNICAL APPENDIX NO. 3

THE VALIDITY OF POPULATION PROJECTIONS

Introduction

Long-range planning in Egypt presents special problems and uncertainties compared with the more steady growth stage and fairly constant institutional framework of the U.S. Annual population growth in Egypt has averaged 2.5 percent since 1952, compared with approximately 1.4 percent in the U.S. over the same period. Decision making and planning is highly centralized and, therefore, likely to make sharper changes in current trends. Institutions which are taken for granted in the U.S. sometimes do not exist or are currently inoperable. It is important for the reader to recognize the inherent uncertainties in the basic population predictions used in developing the Master Plan. This appendix attempts to present and quantify some of these uncertainties.

Population Projection and Distribution

Population projections used in the Master Plan were made using standard demographic methods projecting and estimating future trends based on the best data available. Egypt's population is estimated to increase by approximately 30 million between 1975-2000. One of Egypt's major problems for the rest of the century is how to best distribute this increase in population.

Most of this increase would probably be absorbed in urban centers. As one observer noted, "Programmes to slow down rural to urban migration might well result in unnecessary loss of productive land as villages expand into their fields."[1]

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[1]Smit, J., "Which Future for Alexandria?" Geoforum, Vol. 8, 1977, pp. 135-140.

During the last quarter century while 360,000 ha were reclaimed in the desert, an increase in irrigable land of approximately one-sixth, over 240,000 ha of better agricultural land was lost to housing, industry, highways, airfield, and other nonagricultural uses. Approximately two-thirds of the current urban population, 8 million, is located in Greater Cairo, and 2 1/2 million live in Greater Alexandria. The government is proposing several new cities of roughly half a million each to relieve the population pressures on Cairo and Alexandria. Still, a large segment of the increased population, 5 to 10 million, is unaccounted for in current policy guidelines. Failures to develop alternatives for this segment of the population or failure of the development plans for new cities could induce significant migration to Alexandria beyond that indicated by the Master Plan.

New Ameria City

Most current industrial expansion in Alexandria is occurring in an area south of Lake Maryut, where an industrial development zone, including a free zone site, has been established. This is adjacent to the existing town of El Ameria whose approximate population is 40,000. The Master Plan estimates that by the year 2000 a community of 500,000 people would be residing in this area. The structure of a community of this size requires extensive planning. The Egyptian government has embarked on a program to plan a new city near the Alexandria Governorate called New Ameria City. However, their consultants' first status report, completed after the Master Plan estimates, recommended a site approximately 40 km west of the current El Ameria. This site is outside the current boundary of the governorate.

The effect on the governorate, if this site is chosen and developed, would be to reduce population pressures. However, it could also inhibit funds to develop the existing El Ameria area. This area would continue to grow in population because of employment opportunities in adjacent industrial sites. How much growth would depend on the location of the proposed new city.

Building Codes and Other Regulations

Building codes and zoning regulations limit the density of neighborhoods which in turn affects the wastewater collection system. Building codes also regulate the applicability of wastewater disposal methods. Currently, it is envisioned that population densities within the current urbanized area would increase nominally as undeveloped land is filled and building heights reach restrictive levels. To accommodate estimated

population increases, considerable planning is currently underway for new industry and housing development outside the current urbanized area.

Building codes limit the height of structures to 1.5 times the width of the street. There are some exceptions to this regulation where buildings have frontage on large open spaces. Lower income housing as currently constructed by the public housing authority is limited to five floors. Higher buildings, creating higher densities, would be relatively more capital intensive and would be less suited to families having large numbers of children requiring easy access to streets and open areas. Publicly planned projects also generally have lower population densities than private sector housing, because more open space is included in the project design. Limited capital for new construction, laws prohibiting the eviction of tenants, as well as the lack of available housing to relocate current tenants, discourage the public or private redevelopment of older, densely populated areas. Together, these laws and standards would help limit population growth in already developed areas to moderate urban densities and would force development of vacant land.

Alexandria does not have good control of development practices. Large outlying areas have been developed without authorization or permits. In these areas, development has occurred without attention to providing adequate rights-of-way or wastewater disposal. The following examples are cited for the reader:

1. Ras el Soda, a relatively new, intensely developed, low-lying residential area is without sewers. Pools of standing sewage are ubiquitous to the extent that access to many shops and houses is possible only by wading through it. Because food handling establishments abound in the area, understandably, high disease rates exist.

2. Siouf Keblia and Hagar el Nawatia exhibit high disease rates and incorporate extensive unsewered areas as well as low-lying sewered areas where the sewers are overflowing.

3. The former quarry area south of Mersa Matruh Highway in Dekheila and south of Agamy has gross surface irregularities, making it nearly impossible to sewer. If housing construction is allowed to continue, providing wastewater facilities would either require the eventual destruction of the housing, or construction of expensive, extraordinarily deep sewers and pump stations.

Conclusions

Population projections used in the Master Plan were developed with the best information available but with considerable uncertainties. These uncertainties are greater than most planning work done in a developed

country. For example, in a recent World Bank study, a population of 6.6 million in the year 2000 was used for the city of Alexandria.[2] This may be compared with the 4.7 mllion population developed for the Master Plan. For this reason, it is important for decisions made using large capital investments to have a large degree of flexibility in solving future problems.

The plan selected should be capable of modification, such that accelerated or slowed population growth can be matched by rephasing plans in future years.

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[2]Arab Republic of Egypt, Water Supply and Sewerage Sector Study, World Health Organization/World Bank Cooperative Programme, June 1977.

TECHNICAL APPENDIX NO. 4

ECONOMIC BACKGROUND INFORMATION

Exchange Rates

In 1949, Egyptian authorities fixed the par value of the Egyptian pound (L.E.) at U.S. $2.87 with the International Monetary Fund (IMF), but exchanges do not take place based on this par value. At the beginning of February 1973, the pound was kept constant in terms of IMF special drawing rights (L.E. 1 equals SDR 2.118) which effectively appreciated the pound against the U.S. dollar to L.E. 1 equals U.S. $2.56. This has been the official exchange rate since 1975. Since 1969, however, premiums have been applied to the official exchange rate for an expanding range of transactions in the "parallel market." The parallel market exchange rate was U.S. $1.70 between 1969 and 1975 and is currently $1.45. This rate applies to tourist expenditures and a wide range of import and export transactions.[1]

Currently, there are three exchange rates: the official rate of L.E. 1= $2.56; the tourist rate of about $1.45; and the black market rate, about 20 percent below that. The government has also expressed its intention to allow a controlled float of the pound, but as yet that has not happened.

The "Open Door" Policy-Law 43

As part of President Sadat's effort to encourage private enterprise and economic development, he inaugurated the "Open Door" Policy in 1974 to encourage foreign investment and industrial development. The hope was to

[1] Nyrop, R.F., et al, Area Handbook For Egypt, Third Edition, U.S. Government Printing Office, Washington, D.C., 1976.

induce foreign companies to establish industries in Egypt and allow them to import raw materials and export finished products duty free.

Law 43 dealt with Arab and other foreign investments, joint ventures, and free zones. The law was amended in 1977 to correct a number of problems which arose for foreign investors. Among other things, it now provides a guarantee that profits may be repatriated at the highest prevailing rates and permits exports without a license. Profits and earnings are exempt from taxation, and materials imported to begin projects are exempt from import duties.

Several industrial free zones were established, and investors were encouraged to visit the sites. What they found was not encouraging. Often there was no electricity or water available, limited or no accommodations for families and offices, and no reliable telegraphic communication. Egyptian authorities apparently recognize these shortcomings and are starting to address them.

International Monetary Fund

In March 1977, Egypt signed a letter of intent with the IMF, agreeing to carry out a number of actions designed to strengthen Egypt's management of its economy. These included reform of the exchange rate policy, the international debt sector, budget and fiscal policy, short-term debt, and internal credit levels.

TECHNICAL APPENDIX NO. 5-A

INDUSTRIAL WASTE STUDIES

Master Plan Volume III*, Appendix C contains a summary report on the Industrial Wastewater Survey carried out during the initial six months of the Master Plan Study. The introduction, summary, conclusions and recommendations from this appendix are included below.

Introduction

The industrial areas of Alexandria are widely distributed but tend mainly to be located along the Mahmoudia Canal, near the Cairo-Alexandria railroad and highway and near the port. Industrial development is taking place to the west along the north and south shores of western Lake Maryut, near Ameria, in Nouzha, and to the east along Abu Kir Bay. Continued industrial development will occur in these areas as well as along the Mahoudia Canal upstream of the city and along the corridor of the railroad and delta highway. Thus, the industrial areas of Alexandria will occupy much of the long, narrow space bordering the Lake Maryut - Lake Idku marine lagoons inland from the city and seashore.

All types of industry exist, from very heavy iron and steel fabricating to very light electronic components manufacture. Factories of all sizes are found from large textile mills which employ thousands of workers to local shops and street-side stalls. The most widespread industries include textile mills, tanning, paper, oil refining, and food processing. A broad range of industrial products is manufactured.

Water for industrial use is derived from several sources. The basic supply is surface water from the Mahmoudia Canal. Much of the cooling water and poor quality fresh water is taken directly from the Mahmoudia Canal. Potable and treated water is purchased from the Alexandria Water General Authority (AWGA). Limited water supply is available from privately owned ground water sources. Very little use is made of the saline waters of the sea and agricultural drainage water; both of which are abundant in the area. Large diversions from Mahmoudia Canal and purchases from the Authority are expected to meet future water demand. Increased industrial use of Noubaria Canal water is expected to take place as the Ameria industrial areas develop.

The number of water-using industries in Alexandria is in excess of 200. Water use by industrial plants varies from more than 40,000 m /day to less than 25 m /day. Data from industries and from the AWGA on water use afford the best information available on wastewater production as few industries have the means or the need to determine the volume of wastewater discharged.

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*Source: Alexandria Wastewater Master Plan Study, Vol. III, Appendices, Camp Dresser & McKee Inc., International Division, May 1978.

The industrial waste survey information provided a basis for assessment of the scope of Alexandria's wastewater problem. A comprehensive survey of the major industrial plants was performed, and as many of the smaller, predominantly "wet" industries were included as time and study funds permitted, in order to collect the most comprehensive data possible.

Industrial Survey Methods

A preliminary study of industry in Alexandria indicated that time and funds did not permit a complete survey to be made in any of the plants.* Priority was given to those industries which produced large quantities of strong wastewater. The information to be obtained was limited to the quantity and characteristics of overall plant discharge. Accordingly, the survey was limited to those industries having water use greater than 25 m /day except where the nature of the industry would make it likely, or even suspect, that its wastewater might contain toxic materials, heavy metals, pesticides or other toxic organics. Therefore, the initial survey did not include an assessment of such factors as ease of in-plant separation of wastewater streams, area and existing facilities available for in-plant pretreatment, and possible modifications to plant processes and methods to reduce wastewater or to facilitate pretreatment.

An inventory of all major water-using industries was made during the survey. Plants accounting for 90 percent of the contaminated industrial wastewater produced in Alexandria were included. The summary, conclusions and recommendations based on this initial survey are listed below.

Summary and Conclusions

1. An industrial wastewater survey of the Alexandria industries was conducted as a part of the Alexandria Wastewater Master Plan Study. The survey was conducted during the period January through June 1977.

2. The industries actually visitied were those discharging about 90 percent of the industrial wastewaters generated in Alexandria. Descriptions of each industrial plant visited, summaries of wastewater sampling analyses, and estimates of pollutional loads discharged as industrial wastewaters are contained in this Appendix.

3. The industries of Alexandria discharge about 870 ML/day of wastewater of which about 226 ML/day carry a pollutional load. The latter wastewaters are termed "contaminated".

4. The estimated pollutional load from the industries of Alexandria is 160 tonnes/day BOD and 315 tonnes/day COD. Concentrations of BOD and COD in contaminated wastewaters are 700 mg/L and 14000 mg/L, respectively.

*See additional Toxic Industrial Waste Study (6/30/78) information on pp. 10-25 -- 10-26 and Table 2 p. 10-30.

5. Higher than average organic loads are generated in the abattoir and tanning, food, beverage, paper, oil and soap, and starch and yeast industries.

6. Heavy metals are contained in the discharges form chemical, electric and electronic, metal processing, printing, tanning, and textile industries.

7. Large cooling water flows are discharged from oil refineries, power generating stations, and oil and soap plants.

8. Major industrial wastewater problem areas are: tanneries in Mex, chemical plants in Dekheila, paper mills near Abu Kir, miscellaneous strong wastewaters centered around Industries Pump Station, and discharges to the lower reach of the Mahmoudia Canal.

9. Projections indicate that contaminated wastewater volume will increase to about 647 ML/day by the year 2000 and the loading will be about 440 tonnes/day BOD , an increase of about 280 percent.

10. Discharge of contaminated industrial wastewaters should be to the public sewerage system, after in-plant pretreatment in compliance with sewer use regulations, for final disposal. Uncontaminated wastewater should be kept segregated and disposed of to the nearest appropriate surface drain.

11. A landfill/evaporation pond site should be established to receive and dispose of solid and low-volume liquid toxic materials generated in in-plant pretreatment works and in industrial operations.

12. A program should be instituted to encourage industries to segregate wastewater streams and to recycle and reuse water in cascading fashion for water conservation.

Recommendations

1. It is recommended that wherever capacity exists in the public sewerage system or wherever capacity can be provided at a reasonable cost, industrial wastes should be discharged to the public sewerage system. Such discharges should be regulated by a new sewer ordinance. Where necessary, in order to meet requirements of a new ordinance, industry must provide suitable pretreatment of its wastes prior to discharge.

2. It is recommended that a sewer use law containing the elements of the ordinance as noted in Tech. App. No. 6 be adopted and enforced by government authority. The longer adoption and enforcement are delayed, the more difficult and expensive it will become to implement. Cost for providing wastewater treatment or control in a new factory is a small portion of the construction

cost of the factory (usuallly less than 5 percent in the United States), whereas cost to provide such treatment or control in an existing factory may have much greater adverse economic implications on plant operation and production costs.

3. Government action should be taken to encourage water conservation and reuse by industry. Water should be priced near the cost of production as an incentive. Sewer use charges should be established based on flow rate. Through such charges, industries conserving water would be rewarded, while those wasting water would be penalized.

4. A hazardous material disposal site should be established. High strength, low volume wastes containing toxic metals should be collected and trucked to a disposal area. Final disposal of the liquid portion would be by evaporation. Net evaporation for Alexandria is about 2000 mm per year. Wastewater which could be treated in this manner would include: concentrated chrome tanning solutions, chrome dyeing solutions, iron acid pickling wastes, concentrated wastes from copper refining by electolysis, and metal plating wastes.

5. It is recommended that the following minimum pretreatment requirements and other in-plant operations be imposed on the type of industries listed below:

   - Beverages: Concentrated caustic bottle washing solutions should be equalized and/or neutralized before discharge to the sewer system.

   - Metal Processing: Acid pickling wastes and wastes from copper refining should not be discharged to the sewer system. These wastes should be recovered for use or trucked to a hazardous material disposal area. Studies are required to develop methods to minimize water use and wastewater production.

   - Chemicals: A reduction in water consumption is required. The highest standards of housekeeping are required to avoid contamination of wastewater streams. Suspended solids and pH control will also be necessary if contamination cannot be reduced by in-plant changes.

   - Electrical and Electronics: Cooling water use must be controlled. Wastewaters containing fluorides and mercury should be segregated for special treatment.

   - Food: Food processing wastes should be fine screened through 3 mm slots. Some plants with high levels of suspended solids may require sedimentation. Oil and floating solid traps should be installed at some plants. Whey recovery is necessary at dairies. In all food plants improved housekeeping can reduce waste loads.

- Paper: Paper mill wastewaters should be fine screened (with less than 0.4 mm slots) and adequately setttled. Systems for water re-use should be investigated.

- Petroleum Refining: All wastewaters from refineries should pass through gravity oil separators. Oil spill prevention and cleanup plans should be established. Maintenance and housekeeping should also be improved to reduce leakage and spillage of oil.

- Electric Power Generation: Thermal discharges should be within prescribed limits. Boiler blowdown should not be discharged to the canal and should be within allowable temperature limits before discharge to the sewer system. Leakage or discharge of oil or naphtha should also be prevented.

- Printing: Rinse water from the production of printing plates should not be discharged to the sewer system. Such wastes should be trucked to a hazardous material disposal site. Gasoline or solvents used for cleaning must not be allowed to enter the sewer system. Disposal by incineration is recommended.

- Plastic, Glass and Rubber: Studies should be conducted to reduce water consumption and wastewater production. Glass particles should be caught in trays. Spills of solvents should be prevented. Lead from battery plants should be collected for disposal at the hazardous material disposal site.

- Oil and Soap: Traps for collection of floating solids and oil should be installed and cleaned regularly to limit oils escaping to the sewers. Cooling water use should be studied. Contaminated wastes should be collected and discharged to the sewers. Non-contaminated cooling waters should be excluded from the sewers although, if discharged to the canal, allowable temperature limits should not be exceeded.

- Starch and Yeast: The wastewater from starch units should receive sedimentation to reduce settleable solids. Solids from sedimentation basins must be removed regularly to ensure best operation of the system. Solids should be dewatered and recovered or disposed of appropriately. Contaminated wastes must be segregated from cooling water. Cooling water use should be minimized.

- Tanneries: Chrome tanning solutions and first rinse water should be segregated from the other wastewaters. These chrome tanning solutions must be treated separately prior to discharge to the sewer. All other wastewaters should be fine screened, with screens having 2.0 mm slots, to remove large solids which might block sewers. The bits of flesh and hides may be recovered for use in by-products. Flow equalization will probably be advisable.

- Slaughtering: Wastewater from the abattoir should be fine screened through 2 mm slots to remove large solids. Blood should be collected separately for utilization and not wasted into the sewers. Traps for collection of floating solids and fats should also be installed. Solids and fats can be recovered for rendering.

- Textiles: Textile and dyeing shop wastewaters should receive equalization and/or neutralization before discharge. Dyeing solutions containing heavy metals should be separated for pretreatment prior to discharge. Fine screening with screens having 0.4 mm slots should be used to reduce the amount of fibers discharged to the sewer.

- Water Treatment: Water treatment plants could reduce the volume of their discharge with sedimentation of backwash water with clear overflow being routed back to the plant influent. The bottom flow from the sedimentation tank would be discharged to the sewer or otherwise treated for disposal.

6. Materials removed from wastewater during industrial pretreatment should also be handled properly. Solids in the form of sludges or screenings can easily be handled as solid wastes. There are three basic modes by which the solids from industrial wastewater pretreatment can be handled:

   a. Reprocessing and recovering of valuable by-products.
   b. Burial by landfill.
   c. Incineration.

   All three have some degree of applicability for use in Alexandria.

7. Existing and future pretreatment systems must also be properly operated. To be effective, oil traps must be cleaned regularly. Sedimentation tanks and screens also require regular solids removal and cleaning.

This initial waste study led to the identification of about 38 industrial plants with potentially toxic wastes. These industries and the nature of their pollutant(s) are listed in Table 1.

The preliminary industrial waste study did not allow enough time to study these industries with potentially toxic wastes in sufficient detail to recommend specific pretreatment facilities. Therefore an additional Toxic Industrial Waste Study was conducted to develop information on such pretreatment facilities.

The supplementary Toxic Industrial Waste Study* consisted of five activities:

1. Public Relations
2. Plant Surveys
3. Engineering Studies
4. Financing Methods
5. Report

The objectives of the public relations activity were to address the educational and institutional aspects of controlling industrial wastes if implementation of the sewer use law (Technical App. No. 6) was to be successful. Plant surveys were necessary not only to determine the required pretreatment facilities but to inform industrial leaders and managers of the required changes to comply with the Recommended Sewer Use Ordinance (See Tech. Appendix No. 6). The engineering studies and financing methods relate directly to defining the specific pretreatment facilities and to recommend methods of financing the required costs.

The Toxic Industrial Waste Study recommends specific pretreatment processes for the various industrial groups. These are summarized on Table 2. The specific pretreatment recommendations contained in the supplementary Toxic Industrial Waste Study report, together with the proposed sewer use ordinance should provide Alexandria with a sound mitigation measure to control and prevent the discharge of toxic industrial waste into the marine environment. A review and evaluation of the Toxic Industrial Waste Study is presented in Tech. App. No. 5B.

*Note: As authorized on June 30, 1978.

TABLE 1.

INDUSTRIES WITH POTENTIALLY TOXIC WASTES

No.	Name of Plant	Nature of Pollutant
1.	El Nasr Bottling Co.	pH
2.	The Egyptian Company for Bottling	
	Leban Unit	pH
	Main Unit	pH
3.	Egyptian Vineyards & Distilleries	pH
4.	The Pyramids Brewery	pH
5.	The Egyptian Copper Works	iron, copper, aluminum, zinc, pH, oil, and grease
6.	Nile Match Co.	
	Manshia Unit	zinc
	Moharrem Bey Unit	zinc
7.	Misr Chemical Industries	
	Caustic soda-chlorine plant	mercury, iron, and pH
	Soda-ash plant	lime sludge, pH, and total solids
8.	Industrial Gases Co.	lime sludge, total solids, oil, and grease
9.	El Nasr Electric and Electronic Apparatus Co.	mercury, fluoride, and other metals
10.	El Nasr Dehydration Co.	grit and vegetable parts
11.	The West Delta, Nile Bus Co.	oil and grease
12.	National Paper Co.	
	Mahmoudia Canal Unit	suspended solids
	Tabia Unit	suspended solids and pH

Information obtained from Report on Industrial Wastewater, Alexandria Arab Republic of Egypt Final Draft, Alexandria Wastewater Facilities Development Program, Camp Dresser & McKee International Inc., July 1977.

(Tech. App. No. 5A cont'd)

TABLE 1. (Continued)

No.	Name of Plant	Nature of Pollutant
13.	Recta Paper Company	suspended solids
14.	Alexandria Petroleum Co.	oil and grease
15.	El Nasr Petroleum Co.	oil and grease
16.	General Egyptian Organization for Electricity (Karmouz Power Station & Gas Works)	oil and grease, naphtha
17.	Siouf Power Station	iron, copper, and pH
18.	Moharrem Industrial Press Co.	iron, chromium, and zinc
19.	The Conversion of Paper Company (VERTA)	oil and grease, iron, copper
20.	Egyptian Plastic and Electrical Co.	lead, oil and grease, solvents
21.	El Nasr Company for Glass & Crystal	grit
22.	The Alexandria Oil and Soap Company	
	Karmouz Unit	nickel, oil, and grease
	Kafr El Zayat Cotton Co.	pH, oil and grease, suspended solids
23.	Salt and Soda Co.	
	Karmouz Unit	oil and grease, hexane
	Moharrem Bey Unit	nickel, oil, and grease
24.	The Extraction of Oils and Derivatives Co.	oil and grease
25.	Extracted Oils Co.	
	El Hadissa Unit	oil and grease
	Oil Refinery Unit	oil and grease
	Hexane Extraction Unit	hexane, oil, and grease
	Toilet Soap Unit	oil and grease
	Laundry Soap Unit	oil and grease
26.	El Nasr Leather Tanning Co.	
	Units 1-4	chromium, dyes, oil, and grease

(Tech. App. No. 5A cont'd)

TABLE 1. (Continued)

No.	Name of Plant	Nature of Pollutant
27.	Nine Tanneries	
	Mardig Zarbhanvavelian & Co.	dyes
	Ahmed Abbasi & Co.	dyes and chromium
	Ateya El Heliv	no information
	El Shola Tannery	no information
	Shanin Tannery	dyes and chromium
	Ahmed De'bes	dyes and chromium
	Ahmed Ghoneim	dyes and chromium
	Mohamed Ahmed Taha	dyes and chromium
	Anwar Abbas	dyes and chromium
28.	The Arab Company for Rugs	dyes
29.	Gama Shops	dyes
30.	Pyramids Dyeing Company	dyes and print pastes
31.	Alexandria Spinning & Weaving Co.	
	Hadara Unit	dyes and chemicals
	Bacos Unit	dyes and chemicals
32.	Kabo	
	Main Plant	dyes and chemicals
	Hosiery Unit	dyes and chemicals
33.	El Nasr Textile Co. (STIA)	
	Plant No. 1	copper, dyes, and chemicals
	Plant No. 3	dyes and chemicals
	Plants No. 5 and No. 6	dyes and chemicals
	Plant No. 7	dyes and chemicals
	Plant No. 9	pastes and chemicals, chromium
34.	El Siouf Spinning & Weaving Co.	dyes, pastes, and chemicals
35.	Modern Textile Co.	dyes and auxilliaries, chromium
36.	National Spinning and Weaving Co.	
	Moharrem Bey Unit	dyes, pastes, and chemicals
37.	Oriental Linen & Cotton Co.	dyes and auxilliaries
38.	Arab and United Spinning and Weaving Co.	
	Unit No. 4, Gamila Bohraid St.	dyes and chemicals

(Tech. App. No. 5A cont'd)

TABLE 2.*
PRETREATMENT SUMMARY

Type of Industry	Identity Number	Number of Plants Surveyed	No. Requiring Pretreatment	Type of Pretreatment
Beverages	1-4	7	7	Equalization
Metal Works	6 & 21	2	1	Collection of strong acid wastes and oil and grease removal
Chemical Industries	7-10	6	5	Sedimentation, neutralization or evaporation
Electric & Electronic	11	1	1	Collection of strong acid wastes and mercury
Food	12-20	39	1	Screening, sedimentation and oil and grease removal
Miscellaneous (Transport and Automotive)	(22-24 (58-59	16	5	Oil and grease removal
Paper	25-26	3	1	Sedimentation
Petroleum Refining	27-28	2	1	Oil and grease removal
Power Generation (Includes Electricity)	29-30	2	2	Precipitation, sedimentation and oil and grease removal
Printing	31-32	2	2	Collection of strong acid wastes and solvents
Plastics, Glass & Rubber	33-36	4	3	Oil and solvent removal
Oil and Soap	37-39	12	7	Oil and grease removal
Starch and Yeast	40	3	2	Sedimentation
Tanneries	41-43	32	31	Screening, chromium removal
Slaughtering	44-45	2	1	Manure collection, screening
Textiles	46-56	29	15	Screening, equalization and neutralization
Water Treatment	57	6	0	
TOTAL		168	85	

* Source: Table 3-1, Preliminary Data (9/78), Toxic Industrial Waste study, Alexandria Wastewater Master Plan Study.

MEMORANDUM: TECHNICAL APPENDIX NO. 5B

TO: Project Manager, Alexandria-EIS

FROM: R. H. Culver

SUBJECT: Review of Alexandria Wastewater Master Plan Study - Supplemental Report, Toxic Industrial Wastes Study

DATE: October 19, 1978

1. The report consists of cost estimates for the disposal of non-compatiblc industrial wastes. The cost estimates are based on a preliminary design of the facilities needed at each industrial plant or group of plants to pre-treat the wastes for disposal to the municipal sewerage system or to alternate disposal areas. Treatment systems forming the basis for the cost estimates are industry standards. May be modified to fit particular local situations and thereby reduce costs.

2. The wastewaters to be pre-treated before discharge to the sewers may be divided into three groups, in order of their impact on the marine environment.

   1. Toxic Wastes

      Examples: Heavy metals, pesticides, herbicides, mineral oils and greases, cyanides, etc.

   2. Sludges and Floatables

      Examples: Lime sludges, filter backwash sludges, leather shavings, starch solids, rice hulls, vegetable oils, chicken fats and parts, papermill and textile fibres, etc.

   3. Esthetic

      Examples: Textile dyes, distillery slops, etc.

   The impact of the group one wastes, the toxics, is obvious. Marine organisms are killed. Bioaccumulation in the marine food chain can lead to dangers to human health.

   The impact of the group two wastes, the sludges and floatables, is not so dramatic or as extensive. The main effect of the sludges is to alter a limited area of the marine benthos in an undesirable manner.

The spawining areas for fish and certain other marine species are destroyed and replaced by a benthos which is esthetically unattractive. If near shore may result in obnoxious odors, turbidity and color rendering the water unattractive for recreational use. The impact of the vegetable and animal oils, fats and greases is primarily esthetic. They will float to the surface forming films and grease balls. Although these materials will eventually be biologically degraded the process will be slow for large agglomerations such as grease balls. These can wash up on beaches resulting in unattractive conditions for recreation. Furthermore, the grease balls may harbor pathogenic bacteria and protect them from the natural disinfective processes in the open environment.

The impact of the group three wastes is almost entirely esthetic. Most people find it unattractive to swim in colored water. In the immediate vicinity of the outfall there may be a minor impact on the marine environment due to a reduction in light resulting from the shading effect of the colored wastes.

3. The group one wastes should be removed from marine discharges as soon as possible. In Alexandria, these include wastes from the following industrial plants:

   a. All tanneries
   b. Egyptian Copper Works
   c. Misr Chemical Industries
   d. Industrial Gases Company
   e. El Nasr Electric and Electronic Apparatus Company
   f. West Delta Nile Bus Company
   g. Alexandria Petroleum Company
   h. El Nasr Petroleum Company
   i. General Egyptian Organization for Electricity, Karmouz Power Plant and Gasworks
   j. Siouf Power Station
   k. Moharrem Press Company
   l. Egyptian Plastic and Electric Company
   m. Transport and Engineering Company
   n. Ford Motor Company
   o. Alexandria Passenger Transport Authority
   p. Nile Match Company
   q. Egyptian Company for Refractories

Adequate treatment of the wastes from the above listed industries will eliminate the bulk of the pollution now impacting the marine environment, with one exception. (See comments on papermills below.)

4. The group two wastes are of secondary priority. The sludges from the large papermills discharged into Abu Kir Bay have already severly affected the benthic environment of the bay. Continuation of these discharges will result in little additional change, unless the amounts discharged are drastically increased. However, as long as these discharges of sludge continue unabated it will delay the recovery of this area as an important finfish and shellfish spawning area.

   The group two industries are listed below:

   a. Arab Company for Rugs
   b. Gama Shops
   c. Alexandria Spinning & Weaving Company
   d. El Nasr Clothing and Textile Company
   e. El Nasr Textile Company
   f. Egyptian Starch and Yeast Company
   g. Arab and United Spinning and Weaving Company
   h. Slaughterhouse
   i. The Pyramids Brewery
   j. Edfina Company
   k. El Nasr Canned Foods Company
   l. National Paper Company
   m. Rekta Paper Company
   n. Conversion of Paper Company (VERTA)
   o. Alexandria Oil and Soap Company
   p. Egyptian Salt and Soda Company
   q. Extraction of Oils and Derivatives Company
   r. Egyptian Starch and Yeast Company
   s. General Company for Poultry
   t. Modern Textile Company, Culvertex Unit
   u. National Spinning & Weaving Company
   v. Oriental Linen and Cotton Company

5. Group three wastes require little if any treatment other than the adjustment of pH to protect the sewerage system against corrosion and to protect the sewer workers. The industries in this group are:

a. The Egyptian Vineyards Company
b. El Nasr Company for Bottling
c. Egyptian Company for Bottling

6. The municipal sewers at present do not collect wastewater from many of these industries. Many of the largest and most serious pollutors i.e., Misr Chemical Company, the tanneries, the petroleum companies, and the two large papermills have their own outfalls to the sea. Thus it will be necessary for Alexandria government to obtain adequate authority to control and regulate these industrial discharges. They will not affect the recommended master plan for a marine discharge for the municipal sewerage system and need not be a condition for the evaluation of the proposed scheme. They are related to the overall regional pollution control problem.

RHC:bj

TECHNICAL APPENDIX NO. 6

RECOMMENDED SEWER USE ORDINANCE*

This technical appendix refers to a model sewer use ordinance which has been recommended for implementation as part of the Alexandria Wastewater Master Plan and is presented as Appendix L, Volume III of the Alexandria Wastewater Master Plan Study, May 1978.

*Source: Alexandria Wastewater Master Plan Study, Vol. III, Appendices, Camp Dresser & McKee Inc., International Division, May 1978.

TECHNICAL APPENDIX NO. 6

RECOMMENDED SEWER USE ORDINANCE

Introduction

Discharge of large quantities of solids such as trash, garbage, street sweepings, oils, manure, and septage (semi-liquid waste pumped from septic tanks) into the sewerage system of Alexandria causes serious operational problems. Problems are compounded by operation of the system in a surcharged condition. As a result, velocity of flow is decreased so that solids are not carried through the system. The discharge of certain liquids, such as used oil, mazout residue, toxic industrial wastes, liquids having a high or low pH, and inflammable liquids to the sewers causes structural damage to the collection system and treatment works, upset of treatment process, and unacceptable damage to receiving waters. Oils, tars, and other inflammable liquids pose a fire and explosion hazard at pump stations, treatment works, and within the sewers.

Proper operation and maintenance of the wastewater system in an economical manner requires prevention of all such harmful discharges. Enactment and enforcement of an effective sewer use ordinance is the usual way of achieving proper functioning of a wastewater collection system.

An ordinance provides a full range of regulatory procedures, such as those needed in application for connections, design of connections, payment for services, permits for building sewers, sewer materials, flow sampling, and measurement of discharges. The ordinance contains specific penalties such as heavy fines and incarceration, for non-compliance with its provisions. An effective ordinance gives an operating agency necessary legal authority to control use of the sewerage system. It is designed to protect considerable public investment, insure proper operation, and minimize additional expenditure for system maintenance and replacement.

Present Sewer Use Law

Current Egyptian law which regulates the discharge of wastewaters is law 93-1962, Decision of the President of the UAR, Concerning the Discharge of Wastewaters. This law consists of four chapters:

Chapter I	The Public Sewer and Discharges to It
Chapter II	Water Courses and Discharging into Them
Chapter III	General Laws
Chapter IV	Penalties and Final Laws.

The law establishes general principles regulating construction of, connection to, and discharge into public sewers, as well as discharge of wastewaters into various types of public watercourses. It also contains controls for various discharges and penalties for violations. While the law provides basic controls, it is too general to afford the kind of regulation needed for economical operation of the sewerage system and adequate protection to receiving waters.

Another document having legal status is Decision No. 649 in the Executive Program of the Law No. 93 for 1962 by the Ministry of Housing and

Reconstruction. The document consists of five chapters and appendices explaining the law in detail, as follows:

Chapter I	Applications
Chapter II	Manholes and Chambers for Isolating Pollutants
Chapter III	Substances Harmful to Sewer System
Chapter IV	Extensions of Sewer System, Connections, and Costs
Chapter V	General Laws
Chapter VI	Quality Standards for Wastewater Disposal
Chapter VII	Sampling and Analysis

Chapter VII contains quality standards for discharges of liquid wastes to public sewers, wastewater disposal to waterways, disposal to the River Nile and its branches, wastewater disposal to canals, and disposal of wastewater by irrigation on agricultural land. A limited number of specific criteria are established which limit effluent quality, but these are too few to provide the protection needed. They are also out-of-date in view of present technology.

Recommended Sewer Use Ordinance

The need for a stronger sewer use law and its enforcement has been expressed throughout the Facilities Master Plan Study. Provision for implementation and enforcement of such a law has been included in the immediate phase work (Top Priority Projects) of the Master Plan Program. The following is a recommended sewer use ordinance which, if adopted, will provide needed strength and modernization to the present law. It is recognized that the proposed model ordinance will require some modification to adapt its provisions to Egyptian legal terms and procedures but technical aspects should not need much alteration for adaption.

The new ordinance does not contain regulations for control of wastewater discharges to watercourses as covered by Chapter II of the existing law 93-1962. Discharge of wastewater to watercourses is a separate subject which should be addressed by a separate law or by retaining the provisions of Law 93-1962.

The recommended ordinance titled: Ordinance Regulating Sewer Construction, Sewer Use and Industrial Waste Discharge is presented in full in Appendix B, Volume I of this EIS report.

TECHNICAL APPENDIX NO. 7

MEMORANDUM

TO: Files (Re: Donohue/Grantham EIS Tech. Confr.) 3015 M-6

FROM: Grantham

SUBJECT: West Noubaria Drain
Effect of Wastewater Discharges

DATE: 8 May 1978 (Alexandria, A.R.E.)

The Alexandria Wastewater Master Plan calls for the discharge of oxidation pond effluents from the Ameria and Outer West zones to the West Noubaria Drain now under construction. The Drain will serve an estimated 76 000 hectares or about 180 000 feddans. Using the Ministry of Irrigation design criterion of 20 m^3/day/feddan for the design of drains, the Drain will probably have a capacity of about 3.6×10^6 m^3/day. The flow in the Drain will not average this but for several years flow may well be above the normal steady-state condition for drains because it will be draining lands which are now waterlogged. Assume however that average flow is one-half design capacity or say 1.8×10^6 m^3/day.

The year 2000 wastewater flow for Outer West is 161 000 m^3/day and for Ameria is 137 000 m^3/day. Evaporation in the ponds, which provide 30 days detention, will reduce these flows to 139 000 and 118 000 m^3/day of effluent. Dilutions afforded are 13:1 and 15:1.

BOD_5 reductions in a 30-day pond should average 95 percent or more. If the raw sewage BOD_5 is 500 mg/l, the effluent should average 25 mg/l which when diluted would make a BOD_5 in the Drain on the order of 1.9 to 1.7 mg/l, probably no greater than the ambient BOD_5 in the Drain.

As regards bacteria, 20-day ponds normally give coliform reductions on the order of 99.99 percent. Thirty-day ponds in the Egyptian latitude and climate will probably remove another order of magnitude, or 99.999 percent. If the raw wastewater contains 10^9 coliforms (normal is 10^7 - 10^8), the unchlorinated

effluent should contain 10^4 coliforms/100 ml which when diluted 13:1 will result in coliform counts less than the bathing water standards in most places. The effluent counts may be higher by possibly an order of magnitude during winter periods but may be even lower than average in the summer. The background or ambient counts already in the Drain are most likely to be greater than the effluent counts.

The adverse impacts of the effluent on the Drain and the ocean waters at or near the discharge point are considered to be minimal and not greater than are likely to result from the discharge of Drain waters there.

The use of anaerobic-aerobic ponds, with "first stage" anaerobic cells offers a back-up means of removing heavy metal toxic materials should any be missed by industrial in-plant pretreatment. The metals are complexed by chemical reaction with sulfides in the anaerobic cells to form insoluble metal sulfides which remain in the cell. Thus, the proposed pond treatment is expected to serve as a second defence against the discharge of heavy metal toxics.

GRG/kw

cc: 3015 M-6
chrono
GRG

TECHNICAL APPENDIX NO. 8

MARINE STUDIES CRITERIA AND OUTFALL PLANNING AND DESIGN

This technical appendix presents a key chapter from the Marine Studies final report.* Chapter 5: Outfall Planning and Design includes data and analyses that establish the feasibility of wastewater disposal to the sea through long marine outfalls as the most feasible and economical alternative for the disposal of wastewater from Alexandria.

The basic nature and presentation of material contained in this chapter is such that a summary thereof could alter the value of this technical appendix as a basic reference source for this EIS report. Therefore, the chapter is presented in full based on an EIS team evaluation that it represents basic parameter analyses which directly support the acceptance of an ocean outfall system as being environmentally acceptable for the Alexandria Study Area.

Appropriately selected tables and figures included in this Technical Appendix are also included with the text presentation summary in Vol. I of this EIS report.

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*Source: Alexandria Wastewater Master Plan Study, Vol. IV, Marine Studies, October 1978, Report prepared for the Ministry of Housing and Reconstruction, Arab Republic of Egypt, by Camp Dresser & McKee Inc., Chas. T. Main International, Inc., and the Arab Technical and Economical Consulting Office.

OUTFALL PLANNING AND DESIGN

5.1 Introduction

The flows and loads that must be disposed of have been presented in Chapter 2. The marine environment has been described in Chapter 3. The basic approaches to marine disposal, and the specific criteria to be met, have been discussed in Chapter 4.

In this Chapter, the outfalls are planned and a preliminary design, to meet the adopted criteria, is presented based on the following premises:

1. There are two long ocean outfalls proposed, one off Sidi Bishr with a design flow of 6.5 m^3/sec, and the other off Kait Bey with a design flow of 4.5 m^3/sec.
2. The most suitable alignments for these two outfalls, as determined in the geophysical studies portion of the program, appear to be Profile 2 and Profile 8 shown on Figure 3-36.
3. To meet water quality criteria established in Chapter 4, each outfall should be designed to provide an initial dilution ratio of 150 at design flow; and the overall far-field dilution ratio of discharges from the two outfalls should be of the order of 1000.
4. Multiport diffusers will be required to attain the desired initial dilution.

The outfall planning process presented herein will begin with large-scale, far-field considerations in order to determine discharge location, and then proceed to the near-field considerations of spreading effluent plumes in order to specify diffuser length. This is followed by considerations of internal hydraulics, structure, and operation and maintenance.

In Section 5.2 on far-field considerations, steps are taken to ensure that:

(Tech. App. No. 8 cont'd)

1. Discharges will take place beyond the low salinity lens sometimes observed within a few kilometres of the shore.
2. Discharges will be sufficiently far from shore that onshore winds cannot drive surface-layer components of the sewage plume ashore before bacteria have been allowed to decay or otherwise disappear, to an adequate extent.
3. Discharges will be located sufficiently far to sea that effluents will be dispersed rapidly enough to maintain far-field effluent concentrations below target levels.
4. Discharges will be located so that the effluent plume from one outfall is not likely to interfere with the effluent plume from another outfall.

Section 5.3 on near-field considerations, includes analyses of initial and secondary dilution, and of plume submergence beneath the pycnocline. Diffuser lengths are determined.

In Section 5.4, the internal hydraulics of diffusers are considered in derivation of port sizing and spacing. Structural and operational considerations are discussed in Section 5.5, and the resulting preliminary designs for the two outfalls are summarized in Section 5.6.

5.2 Far-Field Considerations: Appropriate Distance of Discharge from Shore

Low-Salinity Layer

The lower-salinity lens occasionally observed lying along the shore, and attributed to the Mex Canal discharge, is usually 3 to 4 km wide. Outfall discharges should be at least 4 km from shore to avoid being trapped within or under this lens.

Onshore Winds and Currents; Bacterial Decay

Onshore winds, which along the Alexandria coastline means winds from sectors 270° - 300° - 330° - 360° - 30°, are a very important environmental feature in outfall design, since they can drive surface waters and pollutants therein towards shore. In this subsection, shoreward surface current travel times are considered jointly with bacterial

(Tech. App. No. 8 cont'd)

decay rates to determine how far from shore the points of discharge should be to meet the criteria adopted in Chapter 4.

The long-term seasonal wind data presented in Tables 3-1 to 3-4 show that from May to October the prevailing winds are onshore. In the winter, from November to April, winds are more evenly distributed around the compass, but still are most often from a generally northwesterly direction.

For winds in the summer bathing season, Table 5-1, Column A, was prepared using the seasonal data in Tables 3-2 and 3-3 (May-July; August-October), with the frequencies for winds parallel to shore and offshore (60° to 240°) counted as calm. The difference between nighttime and daytime wind speeds was considered small enough to be negligible.

Onshore wind-driven currents will have a speed two to three percent as great as the wind speed. A ration of 0.029 is used, from a value in a table by Wiegel[1], for 30° latitude and a wind speed of 5 m/sec. The frequency distribution for surface current speeds appears in Column B of Table 5-1. In Columns C through G of Table 5-1, the travel times to shore at each speed are calculated for 6, 8, 10, 12, and 14 km of travel, respectively. The travel times are conservatively short for any winds not driving at right angles to the shore.

Rate of Bacterial Disappearance. In Section 4.4, fecal coliforms were selected as the bacterial indicator organism. The bacterial standard concentration, c_r, to be attained for bathing waters were of the order of 100 to 1000 per 100 mL, which requires a reduction by a factor of 10^7 to 10^6 from the adopted effluent concentration $c_e = 10^9/100$ mL. Some of the required reduction is possible by physical dilution; in fact, a physical dilution factor of 10^3 is an adopted requirement. The remaining 10^4 to 10^3-fold reduction must be by bacterial disappearance.

Time is needed to achieve a given factor of reduction by exponential decay. The rate of decay depends on many factors, but recent evidence suggest a strong dependence on solar radiation; hence, decay is more rapid in daytime than at night.

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[1]Wiegel, R.L., Oceanographical Engineering, Prentice-Hall, 1964.

(Tech. App. No. 8 cont'd)

TABLE 5-1

FREQUENCY DISTRIBUTION OF ONSHORE WINDS IN SUMMER [a]

	A	B	C	D	E	F	G
			Travel Time to Shore, hours				
Percent[b]	Wind Speed	Surface Speed	From 6 km	From 8 km	From 10 km	From 12 km	From 14 km
10	0 m/sec[c]	0 m/sec	∞	∞	∞	∞	∞
20	1.81	.05	33.3	44.4	55.5	66.6	77.8
30	2.89	.08	20.8	27.8	34.7	41.6	48.6
40	3.33	.11	15.2	20.2	25.3	30.4	35.4
50	4.50	.13	12.8	17.1	21.4	25.6	29.9
60	5.18	.15	11.1	14.8	18.5	22.2	25.9
70	5.93	.17	9.8	13.1	16.3	19.6	22.9
80	6.88	.20	8.3	11.1	13.9	16.6	19.4
90	7.82	.23	7.2	9.7	12.1	14.4	16.9
100	19.0	.55	3.0	4.0	5.1	6.0	7.1

(a) Source is Tables 3-2 and 3-3, this report.

(b) Percent of time that wind speed is less than value in Column A.

(c) Winds of all speeds from the 60° - 240° sector are counted as calms.

(Tech. App. No. 8 cont'd)

This diurnal variation is accounted for in a procedure which largely follows that of Bellair et al.[1] In Column A of Table 5-2, a diurnal schedule gives a T_{90} value for each clock hour of the day. It is based on a fundamental nighttime T_{90} value of 40 hours, a fundamental daytime T_{90} value of 1.5 hours, and smoothly varying intermediate values for morning and evening, according to a curve developed by Bellair et al., adjusted to T_{90} values for Alexandrian sewage and seawater as determined in the present study (see Section 3.4).

(The bacterial decay experiments, reported in Section 3.4, indicate that a nighttime T_{90} value of 40 hours may be conservatively high for Alexandria. Certainly, the tests did not indicate that 40 hours is too low a value. However, since the nighttime tests were not extensive enough to define a different value, the value of 40 hours will be retained. The daytime T_{90} value of 1.5 hours was derived from the tests reported in Section 3.4, and is intended to be a conservative representation of Alexandrian conditions.)

In Column B of Table 5-2, each T_{90} value is inverted to give the fraction of a logarithmic cycle of decay that is attained each hour. For any time period of several hours, the sum of the Column B values gives the number of log cycles of decay in that time period.

In Column C, the value given for each hour is the length of the time period, terminating at the given hour, required to achieve decay through one logarithmic cycle. For example, the value of 2.0 hours given for 9 AM means that one must collect Column B values for two hours, starting with 0.667 for 9 AM, then adding 0.333 for 8 AM, to get a total of 1.0, for one log cycle of decay. Alternatively, Column C values may be thought of as the quantity $T_2 - T_1$ in the summation:

$$\sum_{n = T_1}^{T_2} \text{(Column B values)} = 1.0 \text{ (log cycles)}$$

where T_2 is the clock hour at which a given Column C value is entered.

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[1] Bellair, Parr-Smith, and Wallis, "Significance of Diurnal Variation in Fecal Coliform Die-Off Rates in the Design of an Ocean Outfall," Journal Water Pollution Control Federation, September 1977.

(Tech. App. No. 8 cont'd)

TABLE 5-2

TIME INTERVALS NEEDED FOR VARIOUS DEGREES OF BACTERIAL DECAY[a]

Hour	A T_{90} hr	B $1/T_{90}$[b]	C 1 Log Cycle hr	D 2 Log Cycles hr	E 3 Log Cycles hr	F 4 Log Cycles hr	G 5 Log Cycles hr	H 6 Log Cycles hr
1	40	.025	8.6	10.5	12.0	13.5	15.0	16.5
2	40	.025	9.5	11.5	13.0	14.5	16.0	17.5
3	40	.025	10.4	12.5	14.0	15.5	17.0	18.4
4	40	.025	11.4	13.4	14.9	16.4	17.9	19.4
5	40	.025	12.3	14.4	15.9	17.4	18.9	20.4
6	20	.050	13.2	15.3	16.8	18.3	19.8	21.3
7	8	.125	13.7	16.1	17.6	19.1	20.6	22.1
8	3	.333	13.2	16.5	18.1	19.6	21.1	22.6
9	1.5	.667	2.0	15.7	18.1	19.6	21.1	22.6
10	1.5	.667	1.5	11.2	17.7	19.6	21.1	22.6
11	1.5	.667	1.5	3.0	16.2	19.5	21.1	22.6
12	1.5	.667	1.5	3.0	5.0	18.7	21.1	22.6
13	1.5	.667	1.5	3.0	4.5	14.1	20.7	22.6
14	1.5	.667	1.5	3.0	4.5	6.4	19.0	22.5
15	1.5	.667	1.5	3.0	4.5	6.0	8.0	21.7
16	2.0	.500	1.7	3.2	4.7	6.2	7.7	20.0
17	2.8	.357	2.2	3.7	5.2	6.7	8.2	11.0
18	4.0	.250	2.8	4.3	5.8	7.3	8.8	10.7
19	5.6	.179	3.4	5.1	6.6	8.1	9.9	11.0
20	8.0	.125	4.2	5.9	7.4	8.9	10.4	11.9
21	12.0	.083	5.0	6.8	8.3	9.8	11.3	12.8
22	18.0	.056	5.9	7.7	9.2	10.7	12.2	13.7
23	21.0	.048	6.7	8.6	10.1	11.6	13.1	14.9
24	40.0	.025	7.7	9.6	11.1	12.6	14.0	15.5

[a] Decay rates based on nighttime T_{90} of 40 hours and daytime T_{90} of 1.5 hours.

[b] $1/T_{90}$ equals the fraction of a log cycle decayed in one hour.

(Tech. App. No. 8 cont'd)

Similarly, values in Columns D through H are for time intervals $T_2 - T_1$ required to achieve, by hour T_2, decay through 2, 3, 4, 5 and 6 log cycles, respectively.

Attainable Degree of Disappearance, Compared to Criteria and Standards. Table 5-1, showing the frequency distribution of onshore wind speed and available surface drift travel times, and Table 5-2, showing required decay times, are now applied jointly in a series of tables, one example of which is Table 5-3. The table is a matrix with ten rows (one for each tenth-percentile of wind speed) and 24 columns (one for each hour of the day). All points in the matrix, over a 24-hour day, have an equal opportunity to represent both the travel time and the hour of the day.

To each hour of the day is assigned the time required for the given number of log cycles of decay, from the appropriate column in Table 5-2. For each matrix point, the travel time (for the row) and the required time (for the column) are compared: if travel time exceeds the required time, no mark is made; if travel time is less than the required time, the matrix point is marked with "*", or with "x" for borderline point. Borderline points are considered to be events during which travel time is sufficient about half the time.

The number of unmarked points plus half the number of "x"-marked points, divided by the matrix area of 240, is the fraction of the time in a 24-hour day in which there is adequate time to provide the requisite number of log cycles of disappearance.

This fraction, so computed for 1, 2, 3, 4, 5 and 6 log cycles, is plotted on the top part of Figure 5-1 for travel distances (hence, outfall lengths) of 6, 8, 10, 12 and 14 km. The plotted curve for each travel distance represents a cumulative frequency distribution of degrees of bacterial disappearance attainable for that distance.

The implications of these descriptions of outfall performance in reducing bacterial concentrations are shown in the middle and lower parts of Figure 5-1. The abscissa of the middle part, "fecal coliforms per 100 mL," is related to the abscissa of the top part, "log cycles of disappearance," by the assump-

TABLE 5-3

COMPUTATION OF FREQUENCY OF SUFFICIENT TRAVEL
TIME FROM 10 KM OUTFALL TO BEACH ,3 LOG CYCLES

Percent[a]	Travel Time hour[b]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	O'clock Hours Required[c]
		12	13	14	15	16	17	18	18	18	18	16	5	5	5	5	5	5	6	7	7	8	9	10	11	
10	∞																									During 24 hr
20	55.5																									Insufficient travel time 33 times out of 240, or 14 % of time.
30	34.7																									
40	25.3																									
50	21.4																									
60	18.5																									
70	16.3						x	x	x	x	x															Between 6 am and 9 pm, Insufficient travel time 22.2 times out of 160, or 14 % of time.[d]
80	13.9			x	x	x	*	*	*	*	*	x														
90	12.1		x		*	*	*	*	*	*	*	*														
00	5.1		x	*	*	*	*	*	*	*	*	*							x	x	x	x	x	x		

[a] Percent of time travel time exceeds values indicated in Column 2.
[b] From Table 5-1, Column E.
[c] From Table 5-2, Column E.
[d] Matrix points "x" are borderline and assigned half value; matrix points "*" are counted as full value.

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tions (a) that the undiluted effluent concentration is 10^9 per 100 mL, and (b) that a 1000-fold physical dilution has been obtained (at least approximately) by the time the plume has traveled from the point of discharge to the beach, in all cases considered. For example, effluent with an original concentration of 10^9 per 100 mL, having undergone physical dilution of 10^3, would have a bacterial concentration of 10^6; four log cycles of disappearance would bring the concentration down to 10^2 per 100 mL.

For each of the curves in the upper part of Figure 5-1, the geometric mean coliform concentration is computed, and plotted in the middle part as "geometric mean due to discharge alone." The values range from less than 1 per 100 mL for 14 km to 100 per 100 mL for 6 km of travel distance.

However, it is appropriate to recognize that levels rarely fall as low as one or even 10 per 100 mL; typical ranges of background values are shown in the lower part of Figure 5-1 for Los Angeles beaches [1] and for the relatively unpolluted Maamura Beach at Alexandria. [2] For computation purposes, a value of 32 per 100 mL is chosen, and a curve is plotted showing the predicted geometric mean bacterial concentration due to the outfall discharge plus this background level. The values range from about 400 per 100 mL for 6 km to about 50 per 100 mL for 14 km.

Also on the lower part of Figure 5-1 are the consensus of the Bilthaven Conference on Recreational Water Quality (see Table 4-1 and its discussion), and the symptom rate vs E.Coli relationship developed by Cabelli from recent research work done in Alexandria as well as elsewhere (see Figure 4-1 and its discussion).

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[1] Betz, J., from information presented at the Meeting to Discuss Proposed Ocean Outfalls in Alexandria, Egypt, Alexandria Governorate Palace, 29 August 1978.

[2] From Hakim, K.E., "Progress Report: Study of Relationship of Microbial Indicators to Health Effects at Alexandria Bathing Beaches," 1978.

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One may now observe that:

1. Background levels are generally not much less than, and occasionally greater than, the Bilthoven "highly satisfactory" standard of 100 per 100 mL.
2. A background level of 32 per 100 mL implies a symptom rate of 0.8 percent.
3. A 6-km outfall would provide bacterial concentrations with a geometric mean greater than the "highly satisfactory" 100 per 100 mL, at a symptom rate of 1.7 percent. Thirty-five percent of the time, levels would exceed the Bilthoven "acceptable" standard of 1000 per 100 mL.
4. A 10-km outfall would provide a geometric mean concentration equal to the "highly satisfactory" 100 per 100 mL, with an associated symptom rate of about 1.2 percent. Fourteen percent of the time, levels would exceed 1000 per 100 mL.
5. A 14-km outfall would provide a geometric mean concentration slightly less than 100 per 100 mL and slightly greater than background, with an associated symptom rate of about 1.0 percent. Five percent of the time, levels would exceed 1000 per 100 mL.

It is reasonable to conclude that the 10-km and 14-km outfalls can be said to meet the Bilthoven standards and increase the symptom rate by only a small amount over the background level. The 6-km outfall, while meeting the "highly satisfactory" 100 per 100 mL about 55 percent of the time, exceeds the "acceptable" 1000 per 100 mL somewhat too often.

Due to the variable and very incompletely understood nature of the processes involved, this analytical procedure should not at this time be taken too seriously or relied upon too finely. Nevertheless, it is offered as a useful and informative tool to enable one to judge that an outfall length of <u>about</u> 10 km is necessary and sufficient to meet bacterial requirements at the beaches.

<u>Dilution Water Available</u>

The outfalls are to be designed to provide an initial dilution of 150 and a subsequent total dilution of 1000. Detailed analyses for initial

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and secondary dilution will be presented in Section 5.3. First, however, it is important simply to see how large a section of the ocean must be involved in the dilution process.

Dilution Volume Analysis. The approach will be to adopt a crude but informative fill-and-draw analysis, in which (a) the effluent is assumed to be dispersed throughout a large but limited volume of the sea around the points of discharge, with (b) periodic complete flushing of this volume. The far-field dilution ratio is thereby:

$$\frac{\text{Seawater volume}}{\text{Flushing period}} \div \text{Sum of flow rates for both outfalls.}$$

Note that the two outfalls are considered together in this reckoning, as the horizontal extent of the seawater volume considered may be several times the 10 km distance separating the two outfall alignments.

The seawater volume is the product of the area, A m^2, of a vertical cross-section normal to the coast extending Z m from the coast to the point of discharge, multiplied by a distance, 2E, parallel to the coastline. The cross-sectional area, A, is derived as a function of Z on Figure 5-2. The bottom depth profiles at the Sidi Bishr and Kait Bey alignments, approximately perpendicular to the coastline, are shown on Figure 5-2A. The area in the vertical plane above the bed, below the sea surface, and between the shoreline and each distance Z from the coast, is plotted on Figure 5-2b. In Table 5-4, values of A, intermediate between those for Kait Bey and Sidi Bishr, are listed for Z = 4, 6, 8, and 10 km.

Now, a plume originating at the sea bed at Z km from shore will, in general, not mix uniformly and completely with the water shoreward of Z. For a typical plume that has undergone initial plus secondary dilution, some water shoreward of Z will remain uninvolved, while some water seaward of Z will be mixed in. Furthermore, the shoreward area, A, and the plume area will not be precisely equal in size. Yet is is maintained that the dilution afforded by the plume area cannot be much greater than the dilution afforded by the shoreward area, A. To obtain A (Z), the discharge point must be at least Z from shore.

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The coastwise extent of the seawater volume, 2E, and the flushing period, T, are computed as follows. The analyses for current persistence, presented and discussed in Section 3.1, show that the fortnightly medium current excursions are of the order of 20 km (Table 3-24), and are most likely to be northeasterly or southwesterly (Figure 3-11). This medium current excursion length of 20 km will be adopted for E, since, on the average, currents will carry the effluent to points as far as E km northeast and E km southwest of the point of discharge. The total coastwise extent of the affected seawater volume is therefore: 2E = 40 km.

TABLE 5-4

FAR-FIELD DILUTIONS AS A FUNCTION OF DISTANCE FROM SHORE[a]

Distance from Shore, Z, km	Area A m^2	Flushing Rate, m^3/sec	Dilution For 11 m^3/sec
4	0.8×10^5	2 646	241
6	1.6×10^5	5 291	481
8	2.4×10^5	7 937	722
10	3.3×10^5	10 913	992

[a]Median Excursion Length E = 20 km, Flushing Period T = 14 Days.

Table 3-24 furthermore shows fortnightly 80 percentile excursions of the order of 40 km. This is to say, at least once a fortnight there is an excursion of at least 40 km, which will serve to flush the volume clear of accumulating sewage effluent.

The third column in Table 5-4 lists the flushing rate: 2 EA/T for each value of A, where E = 20 km, and T - 14 days. In the final column is the dilution, equal to the flushing rate divided by the year 2000 average discharges of Sidi Bishr plus Kait Bey outfalls (11 m^3/sec). The table shows that only when the outfall is about 10 km long can an ultimate dilution of the order of 1000 be obtained.

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Interference Between Two Outfalls. To best promote uniform dispersion of the effluent, it would be well to place the points of discharge from the two outfalls such that the plume from one will not, for the most part, pass over the discharge site of the other.

Current meter stations 1 BU and 1 AU, 10 m below the surface on the Ramleh alignment, and station 2 BU, 10 m below the surface on the Kait Bey alignment, were considered to be closest to the probable points of discharge. The azimuth directions of the current excursions from these stations were plotted in a frequency distribution on Figure 5-3. Also plotted were the average directions taken by drogues set during the course of the program near 10 km from shore on the Kait Bey and Ramleh alignments.

The resulting direction distribution shows principal modes at 60° and 240°, for both drogues and current meters. There is little difference between the distributions obtained by current meters on the two alignments. The drogue data show a mode at 180°, in addition to 60° and 240°, in part due to onshore surface currents that influence near-surface drogues but not the sub-surface current meters.

The task at hand is to find two gaps in the distribution, 180 degrees apart, each direction to be the bearing from one discharge point to the other. The range of choice is limited by the fact that both points of discharge should be in the neighborhood of 8 to 10 km from shore.

The values that are hereby adopted are 47° and 227°, which can be attained with discharge at 11 km from shore on the Sidi Bishr alignment, and 8 km from shore on the Kait Bey alignment.

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5.3 Plume Mechanics: Appropriate Diffuser Length and Orientation

Initial Dilution

For each outfall, discharge should be through a multiport diffuser. This may simply consist of the final offshore portion of the outfall pipe with ports made in the pipe wall at regular intervals, and a cap on the end of the pipe in order to force the effluent to emerge through the ports. A diffuser begins the process of dispersing the effluent by producing many small effluent streams to mix with the ambient sea water, rather than just one.

The discharge per unit length of diffuser pipe should be approximately constant over the length of the diffuser, as will be discussed in Section 5.4. The diffuser section should be normal to the predominant current direction if possible; since currents are principally parallel to the coast, the diffuser may be an extension of the outfall pipe on its alignment, with no bends. The diffuser should, if possible, be on a horizontal alignment. It should not be buried, but lie bedded on the ocean floor, with the ports a major fraction of a metre above the bottom.

Computations of the initial, buoyancy-driven dilution afforded the effluent from a multiport line diffuser are based on the work of Roberts.[1] The initial dilution is taken to be Robert's "minimum surface dilution," S_m:

$$\frac{S_m q}{UH} = 0.27\ F^{-1/3} \qquad \text{(eq. 5-2)}$$

[1] Roberts, "Dispersion of Buoyant Wastewater Discharged from Outfall Diffusers of Finite Length," W.H. Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, 1977.

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for F less than 0.1, and:

$$\frac{S_m q}{UH} = 0.6, \text{ approximately} \qquad \text{(eq. 5-3)}$$

for F greater than 0.1, and with the diffuser axis oriented perpendicular to the direction of the ambient current, where:

$$F = U^3/g^1 q \qquad \text{(eq. 5-4)}$$

and:

U = ambient current speed

q = discharge of effluent per unit length of diffuser

H = water depth at the point of discharge

g^1 = gravitational acceleration, g, multiplied by the difference in density between the effluent and the seawater, divided by the effluent density.

On Figure 5-4, minimum surface dilution, S_m, is plotted against diffuser length for the Sidi Bishr and Kait Bey outfalls. The ambient current speeds used are: U = 0.05 m/sec and U = 0.18 m/sec, typical 20 and 80 percentile speeds, respectively. Actually, S_m, as computed by equations 5-2 and 5-4, is independent of current speed, so the lower pair of curves on Figure 5-4 may be said to apply for any U less than 0.06 m/sec, the range of U for which F is less than 0.1.

The figure shows that to maintain an S_m of at least 150, the Sidi Bishr diffuser should be 400 m long, and the Kait Bey diffuser should be 450 m long.

Submergence

Submergence of the outfall discharge plume is possible when a sufficiently large density gradient exists in the ocean. The freshwater discharge is initially lighter than the surrounding seawater and so rises towards the surface; but in doing so mixes with heavier seawater. If the mixture of sewage and lower-level seawater becomes heavier than seawater in layers near the surface, the plume will cease to rise, and will spread out in a layer beneath the surface.

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Brooks'[1] analysis for the maximum height of rise of a submerged plume in terms of the density profile and discharge characteristics, based on a linear approximation of the measured profile, was applied to determine whether submergence is possible off Alexandria.

On the right-hand side of Figure 5-5 there are four curves: (A) and (B) are for a point-source plume, such as emanates from a single diffuser port, while (C) and (D) are for a line-source plume, such as emanates from a long multiport diffuser, with many ports close together. The graph ordinate is the density difference, Δ_t, between the discharge point and the maximum height of rise, y_{max}, above the diffuser that is required for the plume to rise no higher than y_{max}. The curves relate this required density difference to the discharge strengths: Q m^3/sec for point sources, and q m^2/sec for line sources (for target values of 30 m and 40 m for y_{max}). The graph is constructed for g = 9.8 m/sec^2, $g^1 = g\Delta\rho/\rho$ = .2842 m/sec^2, and wastewater density at the point of discharge of ρ = 998 kg/m^3.

On the abscissa for single port discharge, schedules of port diameters for the Kait Bey and Sidi Bishr outfalls are shown. For each outfall, the schedule was derived from the projected year 2000 average discharge, the proposed outfall diameter, and the internal distribution criterion that the area of each port, multiplied by the total number of ports, should not exceed 0.75 times the pipe cross-sectional area. For sewage that is notorious for carrying large quantities of stringy solids, and subjected only to screening that may not always be effective, it is not advised to have ports smaller than 25 cm, or at least 20 cm in diameter, lest they clog with solids. On the abscissa for line-source discharges, the values for discharge per unit length for the two outfalls are indicated.

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[1] Brooks, N.H., "Dispersion in Hydrologic and Coastal Environments," Final Report to National Coastal Pollution Research Program, USEPA, Grant No. 16070DGY, December 1972.

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Note that for 25 cm ports on the Sidi Bishr outfall, for example, the density difference required is about 0.9 and 1.5 sigma-t units for y_{max} of 40 m and 30 m, respectively; while for a 400 m line plume carrying the Sidi Bishr discharge of 6.5 m^3/sec, the required differences are 0.44 and 0.60 sigma-t units. Which of the two pairs of sigma-t values is applicable?

Brooks[1] advises that the higher of the two density difference values for a given y_{max} be chosen; the fact that the point-source analysis demands a greater density difference for a given y_{max} probably means that the diffuser discharge will behave more like many individual point-sources than like a continuous line-source for this range of flow values.

On the left-hand side of Figure 5-5 measured density differences between the surface and 40 m depth, and for the 30 m interval between 10 m and 40 m depths, are plotted against calendar time, January through December (although the data for the second half year were collected first, since the sampling program began in July 1977).

For the autumn and winter period, September through March, the density differences for both the 30 m and the 40 m depth intervals are small, ranging between zero and 0.4 sigma-t units. For the most part, these values are less than the required density difference, as shown by the curves A,B,C, and D for the range of Q and q rates shown. The plume cannot, therefore, be expected to remain submerged beneath the surface, between September and March.

Beginning in early April, however, the density differences increase, due to the seasonal warming of the upper water layers. Differences as great as 1.7 sigma-t units, between zero and 40 m, and 1.2 sigma-t units, between 10 and 40 m, were measured in May. Inner envelope curves have been sketched for the two depth intervals; these are curves which, for a given calendar time, represent the lower end (or nearly so) of the range of

[1] Brooks, N.H., "Dispersion in Hydrologic and Coastal Environments," Final Report to National Coastal Pollution Research Program, USEPA, Grant No. 16070DGY, December 1972.

density differences plotted for that time. The curves, roughly parabolic in shape, span the months April through August; for the zero-to-40 m interval, the curve as sketched attains a peak of 1.0 sigma-t units in June, while the 10-to-40 m interval curve, as sketched, attains a peak of 0.4 sigma-t units, also in June.

From comparison of curve B with the inner envelope curve for surface-to-40 m, it appears that the outfall plumes, discharged at or below 40 m depth through 25 cm diameter ports, will be submerged for a month or two in late spring. The submergence depth may be less than 10 m beneath the surface. The use of more numerous, smaller ports would extend the period during which submergence could be counted upon. (This assessment of the potential for plume submergence is more positive than was made in earlier progress reports of this study.)

In early years of the life of the outfalls, when discharge rates are less than the design rates, submergence will extend over a longer season. The season will become shorter as discharges increase.

Submergence during June and part of July, and perhaps parts of May and August as well, will be a welcome added safety feature for keeping effluents away from bathing areas. However, since submergence cannot be counted upon between September and March, some of which time is still popular swimming season, care has been taken to design the outfalls to meet water quality criteria at the beaches even in the absence of submergence.

(A potential disadvantage of submergence is that downward diffusion of oxygen from the atmosphere is impeded by the density gradient. An estimate of the rate of downward diffusion of oxygen through the pycnocline to an oxygen-consuming sewage plume, presented in Appendix D, indicates that oxygen may diffuse downward through a typically strong density gradient at a rate insufficient to satisfy the oxygen demand. However, the initial dilution specified in Chapter 4 is designed to meet the oxygen demand with adequate oxygen-rich dilution water.)

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Secondary Dilution

The Brooks[1] analysis for secondary dilution is used herein. The secondary dilution factor, S_2, is:

$$S_2 = 1 \text{ erf } [1.5/([1 + 8 K_o t/b^2]^3 - 1)]^{0.5}, \qquad \text{(eq. 5-5)}$$

where "erf" is the error function, K_o is the initial value of the coefficient of horizontal eddy diffusivity, t is the time, and b is the diffuser length. According to this analysis, the diffusivity coefficient increases in proportion to the 4/3 power of the nominal width of the plume. The initial value, K_o, is thus related to the initial plume width, which is the diffuser length, b:

$$K_o = Ab^{4/3} \qquad \text{(eq. 5-6)}$$

For K_o in cm^2/sec and b in cm, the value of the coefficient A may range from 0.0015 to 0.05.

It has long been recognized that current shear must have a significant effect on apparent horizontal diffusivity in the ocean.[2] In a recent study,[3] the coefficient, A, in equation 5-6, was expressly related to G sec^{-1}, the vertical gradient in horizontal velocity:

$$A = 0.25k^{1/3} G^{2/3} \qquad \text{(eq. 5-7)}$$

where k, cm^2/sec, is a constant value of the vertical diffusivity in the ocean. Koh and Brooks note that reported values for the vertical turbulent diffusion coefficient range from 0.04 cm^2/sec to 200 cm^2/sec. Csanady[4] reports that while in the top 30 cm of the ocean one may find a value of 30 cm^2/sec, the vertical diffusion coefficient a few meters below the surface decreases to about 5 cm^2/sec. The value adopted for use herein is 5 cm^2/sec.

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[1] Brooks, "Diffusion of Sewage Effluent in an Ocean Current," Proceedings, 1st International Conference Waste Disposal in the Marine Environment, Pergamon Press, 1960.

[2] Koh and Brooks, "Fluid Machanics of Wastewater Disposal in the Ocean," Annual Review of Fluid Mechanics, 1975.

[3] French, J.A., manuscript in preparation, 1978.

[4] Csanady, G.T., Turbulent Diffusion in the Environment, Reidel, 1973.

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In this project, drogue studies were conducted to enable the vertical gradient in horizontal velocity, G, to be measured. Twenty-seven values of G in velocity components perpendicular to the mean current velocity were listed in Table 3-25. The 20, 50, and 80 percentile values of G from this sample are .0012, .0030, and .0084 sec^{-1}, respectively. Corresponding values of A are .005, .009, and .018. These values are within the range of values cited in the discussion of equation 5-6.

It is of interest to know how rapidly, and within how short a distance, the secondary dispersion process can increase the dilution ratio from its initial value, S_m, of 150 or more, to the far-field target value of 1000. In Table 5-5, the required time and distance to attain a dilution ratio of 1000 is listed for nine combinations of current speed, U, and diffusion factor, A, thus covering a very large percentage of potential advective and dispersive conditions. The three current speeds considered are 5, 10, and 18 cm/sec, adopted herein as typical values of 20, 50, and 80 percentile current speeds, based on the analysis of current meter records for the study year.

All times are 30 hours or less. By attaining the target initial-plus-secondary dilution of 1000 within a day and a half, one supplies the wastewater with ambient dissolved oxygen sufficiently rapidly that the BOD or COD values of 500 to 1000 mg/L will not be able to cause more than a very small depletion of the ambient DO

All distances are less than 8 km, indicating that a physical dilution of 1000 will be attained by a plume before it reaches the beach, should it be tending onshore. (In Section 5.2, the point of discharge for the Kait Bey outfall was set at 8 km from shore, and the point of discharge for the Sidi Bishr outfall was set at 11 km from shore.)

Directions of currents have not yet specifically been considered in this secondary dilution analysis. It is considered sufficient to note that,

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TABLE 5-5

TIMES AND DISTANCES REQUIRED TO ATTAIN OVERALL DILUTION $S_m S_2$ = 1000

a) Sidi Bishr outfall, diffuser length b = 400 m

Current Speed:	U_{20} = 0.05 m/sec	U_{50} = 0.10 m/sec	U_{80} = 0.18 m/sec
Initial Dilution:	S_m = 152	S_m = 203	S_m = 366
Req'd Secondary Dilution:	S_2 = 6.6	S_2 = 4.9	S_2 = 2.7
A = .005	t = 27 hr x = 4.9 km	t = 21 hr x = 7.5 km	t = 11 hr x = 7.4 km
A = .009	t = 15 hr x = 2.7 km	t = 12 hr x = 4.2 km	t = 6 hr x = 4.1 km
A = .018	t = 8 hr x = 1.4 km	t = 6 hr x = 2.1 km	t = 3 hr x = 2.0 km

b) Kait Bey outfall, diffuser length b = 450 m

Current Speed:	U_{20} = 0.05 m/sec	U_{50} = 0.10 m/sec	U_{80} = 0.18 m/sec
Initial Dilution:	S_m = 152	S_m = 239	S_m = 430
Req'd Secondary Dilution:	S_2 = 6.6	S_2 = 4.2	S_2 = 2.3
A = 005	t = 30 hr x = 5.4 km	t = 20 hr x = 7.2 km	t = 10 hr x = 6.8 km
A = .009	t = 17 hr x = 3.0 km	t = 11 hr x = 4.0 km	t = 6 hr x = 3.8 km
A = .018	t = 8 hr x = 1.5 km	t = 6 hr x = 2.0 km	t = 3 hr x = 1.9 km

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as shown on Figure 5-3, currents 10 m or more beneath the surface (as indicated by metered current excursions) will proceed either northeasterly parallel to the coast (60°), or southwesterly (240°), in both cases normal to the diffuser alignment; hence equations 5-2 and 5-3 for initial dilution, S_m, apply to plumes rising from the ocean bottom to the vicinity of the surface. The drogue excursions shown on Figure 5-3, which represent current directions near the surface as well as at depth, show that a plume at or near the surface could be transported southward towards the shore (180°), as well as parallel to the coast, at speeds usually within the range of 5-10-18 cm/sec (Figures 3-12 to 3-15).

5.4 Multiport Diffuser Design

Ports

If practical, the ports should be bellmouthed, i.e., the inside edges of the ports should be smoothly rounded to promote uniform unseparated flow. To attain reasonable uniform discharge per unit length, the port diameter and spacing should be chosen according to Brooks' analysis;[1] in many practical cases, French's[2] graphical summary of Brooks' analysis is applicable.

To avoid serious interference between the plumes rising from adjacent ports, the port spacing should be about one-third of the height of rise predicted for the plumes when all ports are on one side of the pipe; if ports are on alternating sides of the pipe, the spacing may be less, but no less than one-sixth the height of rise.

Where essentially raw sewage is to be discharged, the diffuser ports should be quite large, so that they will not be blocked by solids. This is par-

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[1] Koh, R.C.Y., and Brooks, N.H., "Fluid Mechanics of Wastewater Disposal in the Ocean," Annual Review of Fluid Mechanics, 1975.

[2] French, J.A., "Internal Hydraulics of Multi-port Diffusers," Journal Water Pollution Control Federation, 1972.

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ticularly important with wastewater as full of stringy solids as Alexandria's is observed to be. Despite the fact that we recommend preliminary treatment to remove the large solids, the diffuser ports should not be smaller than about 250 mm in diameter.

Diffuser Design, Sidi Bishr

As noted in the Technical Report, a diameter of 2200 mm was selected for this outfall. This diameter is maintained throughout the length of the diffuser.

To maintain an approximately uniform value of discharge per unit length along the 400 m length of the diffuser, provide bellmouth ports 250 mm in diameter every 7.5 m, placed on alternating sides of the pipe. There are to be 54 ports in all, including the end port, as shown on Figure 5-6. The diffuser should be placed so that the offshore end has an elevation not more than 1 to 2 metres different from the inshore end, lest the flow distribution be affected by hydrostatic ambient pressure differences between the two ends.

Diffuser Design, Kait Bey

As noted in the Technical Report, a diameter of 1700 mm was selected for the Kait Bey outfall. This diameter is maintained throughout the length of the diffuser.

Again, to keep hydrostatic pressure difference effects to a minimum, the difference in elevation between the inshore and offshore ends of the diffuser should be no more than 1 to 2 metres.

For approximately uniform discharge per unit length, it is recommended that there be bellmouth ports, 250 mm in diameter, spaced every 10 m for the 330 m farthest offshore; then every 12 m, for the final 120 m; for a total of 43 ports, including the port at the end of the diffuser, as shown on Figure 5-6. The greater spacing at the inshore end is in order to offset the greater discharge rate per port expected there relative to farther offshore (from considerations of the internal hydraulics of multi-port diffusers).

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5.5 Structural and Operational Considerations

Structural Considerations

Forces on the Outfall Pipe. A variety of forces act on the pipe, both during construction and after installation is completed. During construction, the pipe may be subjected to considerable tension if installed by the bottom-pull method. Before it is convered, it is susceptible to wave forces. If it is installed full of air to provide some buoyancy, care must be taken during the water filling process that air is not released too quickly, lowering the internal pressure and inviting collapse of the pipe.

When in service, the pipe must withstand the steady internal pressure due to the pumping head, and it must be able to withstand the transient positive and negative surge or water hammer pressures associated with rapid shutoff of the pumps upon power failure. At sufficiently sharp bends in the pipe there should be thrust blocks.

For the design significant wave derived in Chapter 3, with a height of 5 m and a period of 8.5 sec, the lateral forces on a circular cylinder lying on the sea bottom were computed for external diameters of 2.5 m (Sidi Bishr outfall) and 2.0 m (Kait Bey outfall), for a range of water depths. The Morison[1] equation was used:

$$f = C_m \rho \frac{\pi D^2}{4} \frac{dU_b}{dt} + C_D \frac{1}{2} \rho D U_b |U_b| \qquad \text{(eq. 5-8)}$$

(inertial forces) + (drag forces)

where:

- f = the force per unit length of pipe
- C_m = the inertial force coefficient
- ρ = the fluid density
- D = the external pipe diameter
- U_b = the bottom velocity
- C_D = the drag force coefficient

[1]Shore Protection Manual, Vol. 2, U.S. Army Coastal Engineering Research Center, 1973.

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The bottom velocity, U_b, was assumed to be sinusoidal, with period T, and related to the water depth via Figure 3-18. The value used for C_m was 1.5; the value used for C_D varied between 0.7 and 1.2. The force per unit length, f, was evaluated at the phase of the sinusoidal cycle that results in the maximum value of the right-hand side of equation 5-8, for each depth. On Figure 5-7, f is plotted against water depth for the Sidi Bishr and Kait Bey outfalls.

The calculations bear the assumption that the waves propagate in a direction perpendicular to the axis of the pipe, although many of the waves will be propagating in directions with components parallel to the pipe axis.

Extent of Burial. It will be necessary to bury the pipes throughout the surf zone, and offshore to a depth where wave forces and wave-induced sediment transport will not threaten the pipe. It is suggested that burial extend offshore to the 20 m depth contour; lateral wave forces on the pipes would thereby be kept below 700 kg wt per linear metre (Figure 5-7), and sediment transport would be confined to grain sizes conveniently less than sizes usable for bedding or revetment (Figure 3-18).

At the time of final design, a risk analysis should be made to determine the optimum burial depth for the outfalls. Wave forces can act on a buried pipe as well as on one that is not buried; the magnitude of the forces should be calculated.

Burial in the surf zone and across the beach will also prevent the pipe from being an aesthetic nuisance or a physical obstruction.

Materials. Often it is suitable to build outfalls of welded steel pipe, cement lined, with a coal tar and glass mat built-up coating, and an outer coat of reinforced concrete. Other materials, such as high density polyethylene, or fiberglass reinforced plastic, are sometimes considered, but the concrete-coated steel pipe usually best meets the two requirements of strength and weight. The weight of the pipe must

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be sufficient such that, when the pipe is filled with fresh water of 1000 kg/m^3 density or less, there will be no danger of flotation, either with respect to the ambient seawater or to the soil in which the pipe may be buried. (Insufficiently heavy pipes have been known to "float" out of the soil in which they are buried when the soil has been fluidized by an earthquake or other jarring impulse.)

Construction and Installation. The pipe may be laid on the bottom and covered, or it may be laid in a trench and covered. In either case, it may be necessary to prepare a bedding of rock or of piles. In waters less than 10 m deep, sheetpiling may be used with the excavation.

For diameters of one metre or less, it is common to manufacture and assemble considerable lengths of pipe either on land or on a barge, and then install them by either bottom-pull or surface-pull methods. In the project area, surface-pull or flotation methods are not recommended due to the relatively swift currents prevailing, but the bottom-pull method appears to be quite feasible in most cases. For larger diameters, the relatively short sections of reinforced concrete must be placed individually, with the aid of divers.

Corrosion Protection. Corrosion Protection is a most important consideration if the pipeline is to be of steel. As noted in Section 3.6, the old Kait Bey outfall suffered extensively from corrosion.

The following paragraphs on corrosion control are taken largely from the Final Report of the ASCE Task Committee on Pipelines in the Ocean.[1]

There are two basic methods to achieve corrosion control of submarine pipelines: coating the pipe and applying cathodic protection. Commonly, a combination of coating and cathodic protection is used, with the coating system providing the basic protection and the cathodic protection system furnishing protection to those areas where defects exist in the coating.

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[1] Final Report of the ASCE Task Committee on Pipelines in the Ocean, ASCE, New York, undated.

Several effective and reliable pipe coating systems have been developed over the past several years. These systems range from thin film epoxy coating to thick mastic systems composed of fine aggregate (sand, limestone, and fiber) bound together by an asphaltic material. Weight coatings are commonly required to provide added stability to the pipe, especially for larger diameter lines. The addition of a weight coating affords extra protection to the underlying corrosion coating.

Cathodic protection can be provided in two ways: by electrically connecting the pipe to a more anodic material, or by connecting the pipe to an anode and impressing a direct current on the system from an external power source. In both cases, current flows from the anode to the pipe to be protected.

Sacrificial anodes are normally zinc or magnesium bracelets placed around the pipe at regular intervals. Zinc-to-steel has a smaller current output than magnesium-to-steel. Because of their lower current output, zinc anodes have a longer service life than magnesium anodes. Zinc is well suited for use on a coated pipeline where small cathodic protection currents are required. Bracelets of suitable size are commonly spaced on the pipeline at about 400 m intervals. It is important to design the cathodic protection system so that anode replacement is minimized during the life of the line.

An impressed current system usually consists of an ac power source, a rectifier to convert ac current to low voltage dc current, and an anode. The pipeline to be protected is connected to the negative side of the rectifier with the anodes connected to the positive side. An advantage of an impressed current cathodic protection system compared to sacrificial anodes is that the output voltage of the rectifier can be adjusted to any selected value. The disadvantage is the need to maintain the electrical system. With the sacrificial anode system, the output voltage is not variable and is determined by the type of anode used.

For the Alexandria outfalls, fundamental protection would be provided by bitumastic coatings reinforced by interior and exterior weight coatings

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of concrete. Since occasional breaks in the coating may be unavoidable, zinc anode bracelets should be placed around the pipe every 400 m or so, in electric contact with the steel. Such bracelets should ensure many years of protection if breaks in the coating are few; yet it would be wise, at least in areas where the pipeline is exposed, to provide periodic (say, every year or two years) diver inspection of the anode bracelets, with replacement in whole or in part if necessary. Such inspection and maintenance could be easily done with personnel and resources available in Alexandria.

Quality Control

Whatever construction methods and materials are ultimately used, careful quality control of fabrication and installation is essential to ensure satisfactory performance over a long lifetime. A lot of money may be spent to achieve a design strength of pipe, which, if maintained over the length of the pipeline, will be most satisfactory; yet if even a few short sections of the line are substandard, and fail, the whole facility may be considered a failure. Therefore, the cost of ensuring close control over quality of production is money very well spent.

Local Experience

At least two undersea petroleum pipelines of reinforced-concrete-coated steel have recently been constructed near Alexandria by the bottom-pull method. Experience gained from construction, operation and maintenance of these pipelines will be valuable in the design of the wastewater outfalls.

Hydrogen Sulfide

Hydrogen sulfide (H_2S) is a gas that occurs in sewers and force mains where wastewater has insufficient oxygen, and is commonly detected by its "rotten egg" odor. Controlling H_2S production and release is important not only to control odors, but also because the gas is lethal to people at levels exceeding about 300 mg/L[1], and toxic in the marine environment at levels in excess of 0.01 mg/L.[2] In sewerage systems, H_2S can also form sulfuric acid (H_2SO_4) which is highly corrosive and can damage

[1]USEPA Process Design Manual for Sulfide Control in Sanitary Sewerage Systems.

[2]National Academy of Sciences and National Academy of Engineering, Water Quality Criteria, 1972, Washington, Environmental Protection Agency, 1972.

pipelines and other facilities.

H_2S is typically produced in sewerage systems where there is no dissolved oxygen (DO) in the wastewater, and where anerobic bacteria, contained in a slime layer attached to the walls, become active. The anerobic bacteria will not produce H_2S when there is dissolved oxygen present or when there is insufficient organic matter (measured as BOD_5).

Controlling H_2S production is usually achieved by maintaining the DO sufficiently high that the anerobic bacteria are inactive. In sewers flowing partially full, the DO is maintained in the wastewater through direct transfer from the atmosphere, at the water surface. The degree of oxygen transfer is dependent on the rate of turbulent diffusion in the flow.

In force mains, such as marine outfall, there is no atmospheric water surface so that oxygen regeneration is nearly zero. Therefore, steps must be taken to eliminate H_2S production for the entire length of the force main or H_2S will be released at the end. Methods often used include the addition of H_2O_2 or compressed air to maintain adequate DO, and addition of chlorine or other chemicals to eliminate the anerobic bacteria. However, these methods can be expensive, and may be impractical for large, long submarine outfalls.

Hydrogen sulfide released in the ocean at concentrations less than 0.005 mg/L may be considered to have minimal deleterious affects on the marine environment. H_2S at concentrations exceeding 0.01 mg/L may be considered a hazard to the marine environment.[1]

The concentration of H_2S released at the end of a force main or outfall is dependent on the length of time the wastewater in the pipeline is anerobic. Wastewater discharged through either the Kait Bey or Sidi Bishr outfalls will receive preliminary treatment consisting of screening, and grit and floatable solids removal. Aeration provided in the grit chamber

[1] National Academy of Sciences and National Academy of Engineering, Water Quality Criteria, 1972. Washington, Environmental Protection Agency, 1972.

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ensures that the wastewater entering the outfall will be aerobic and not produce H_2S until the oxygen has been utilized by the organisms in the wastewater.

The estimated total travel time for wastewater entering the proposed outfalls to discharge at the diffuser is shown in Table 5-6. The estimated time that the wastewater remains aerobic was calculated based on a DO of 3 mg/L for wastewater leaving the treatment plant, and a BOD removal of about 8 percent in the treatment process. By subtracting the time the wastewater is aerobic from the total travel time, the time during which H_2S will be produced can be determined. The H_2S production time and the estimated concentration produced at the diffuser is also shown in Table 5-6.

The amount of H_2S produced will vary with the temperature of the wastewater, so that summer and winter values were calculated corresponding to wastewater temperatures of 28°C and 15°C, respectively.

The concentration of H_2S released from the outfall (shown in Table 5-6) will be diluted with sea water by the diffuser. The dilution that will keep the concentration of H_2S less than 0.005 mg/L is shown in Table 5-7.

The available initial dilution at the diffuser is also shown in Table 5-7. During the summer months, and particularly in the early years, the initial dilution alone will often not be sufficient to reduce the concentration of H_2S to the acceptable level of 0.005 mg/L, i.e., the available dilution is less than the indicated required dilution in Table 5-7.

For the Kait Bey outfall, the indicated available initial dilutions are never less than half the dilution required for 0.005 mg/L, which is to say that there will be little chance that concentrations will exceed the hazard threshold level of 0.01 mg/L. For the Sidi Bishr outfall, however, some of the indicated values for initial dilution are indeed less than half the indicated required dilution, so that hazardous levels will sometimes be

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TABLE 5-6

HYDROGEN SULFIDE PRODUCTION IN OUTFALL LINES

Outfall Location	Flow mL/d	Total travel Time, hr	Time Wastewater in Aerobic, hr	H_2S Time of Production, hr	H_2S Concentration @ Diffuser, Summer mg/L	H_2S Concentration @ Diffuser, Winter mg/L
Sidi Bishr[a]						
1980 Average	261	4.19	0.78	3.41	6.15	2.55
1980 Peak	390	2.81	0.78	2.03	3.70	1.55
1990 Average	412	2.66	0.76	1.90	3.45	2.45
1990 Peak	619	1.77	0.76	1.01	1.83	0.79
2000 Average	560	1.95	0.75	1.20	2.15	0.92
2000 Peak	838	1.31	0.75	0.56	1.00	0.43
Kait Bey[b]						
1980 Average	263	1.66	0.76	0.90	2.19	0.90
1980 Peak	401	1.09	0.76	0.33	0.78	0.33
1990 Average	328	1.33	0.72	0.61	1.42	0.61
1990 Peak	492	0.89	0.72	0.17	0.45	0.17
2000 Average	392	1.11	0.71	0.40	0.95	0.40
2000 Peak	577	0.76	0.71	0.05	0.20	0.05

[a] Sidi Bishr Outfall is 11 km at sea plus 1 km on land.

[b] Kait Bey Outfall is 8 km at sea.

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TABLE 5-7

REQUIRED DILUTION OF WASTWATER FOR ALLOWABLE H_2S CONCENTRATIONS

Location	Dilution Required to Reduce H_2S Concentration to 0.005 mg/L		Final Dilution Available with Ambient Current Speeds of:		
	Summer	Winter	V_{20} = .05/sec	V_{50} = .10/sec	V_{80} = .18/sec
Sidi Bishr Outfall					
1980 Average	1090	370	253	437	787
1980 Peak	600	170	194	292	526
1990 Average	550	350	187	277	499
1990 Peak	226	18	143	184	331
2000 Average	290	44	152	203	366
2000 Peak	60	-	117	136	245
Kait Bey Outfall					
1980 Average	298	40	198	355	639
1980 Peak	16	-	150	233	419
1990 Average	144	-	171	284	512
1990 Peak	-	-	131	190	341
2000 Average	50	-	152	239	430
2000 Peak	-	-	118	162	291

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found there. The potential for hazard will increase if pretreatment facilities fail to provide the degree of aeration assumed in these calculations.

Measures to lessen the hazard would include reducing the outfall pipe diameter or shortening the outfall length to reduce travel times, as well as applying the DO-maintenance measures mentioned above. However, the judgment is made here that the H_2S toxicity threat is of less importance than the considerations otherwise governing outfall diameter and length. The region affected will be limited in extent to within a few hundred metres of the diffuser, since secondary dispersion processes will reduce concentrations further, and since H_2S is rather quickly oxidized by a group of bacteria that convert it to thiosulfates and water. The toxic effects are not cumulative.

As to odor due to H_2S in the sewage plume escaping to the atmosphere, it is estimated that even in the worst summer conditions, the lightest of breezes will be sufficient to keep concentrations at levels below minimum threshold value by a factor of 10.

Operational Design Considerations

In choosing the pipeline diameter, a compromise must be made between possibly conflicting requirements: the diameter should be great enough that design peak flows may be passed without developing excessive head, yet small enough that solids do not accumulate in the pipe at times of low flow. To prevent the long-term accumulation of solids, daily peak velocities in the early years of operation should be at least 1 m/sec, if possible.

A Manning "n" value of 0.016 is recommended for computing the pumping head associated with a given discharge and pipe diameter. This value, while somewhat greater than values observed for outfalls carrying primary and/or

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secondary effluent, is about equal to those often observed for outfalls carrying raw sewage. When analyzing potential water hammer pressures in the line, a conservatively low value, such as 0.012, should be used.

It is most desirable to keep air out of the outfall pipeline. It is, therefore, recommended that the portion of the outfall on land, running from the pump station to the shore, have a crown elevation low enough that the line will remain entirely full of water at zero flow. With freshwater sewage flowing into a saltwater sea such as at Alexandria, there is a hydrostatic pressure differential between the inside and the outside of the pipe at the sea surface. For an outfall discharging at 48 m depth, the differential head is about 1.5 m. The crown elevation of the land portion must, therefore, be kept below an elevation of 1.5 m above average sea level to remain filled with water.

For general access, and particularly for cleaning, manholes should be provided at regular intervals along the pipe where practicable. In particular, there should be a manhole in the outfall near the shoreline, particularly in those cases where there is a substantial portion of the line on land, between the pump station and the shoreline. So that the manhole may be opened without prolonged, upwelling spillage due to the hydrostatic pressure differential, the rim must be at least 1.5 m above sea level. An air release valve should be installed in or next to the manhole cover. The manhole must be able to remain closed and water-tight under internal pressures at which the outfall will operate (up to 30 m of head). Similarly, the junction box just downstream of the pumps at the pump station should be accessible, but with the pressure hatch higher than 1.5 m above sea level. The potential water hammer pressures that would occur in the line upon power failure at the pump station should be computed, and measures taken to ensure that neither the positive nor the negative pressure limits of the pipe can be exceeded.

The cap at the offshore end of the diffuser should be removable to facilitate cleaning. Trawlers presently frequent the areas 10 km off Anfushi and Sisi Bishr. It will, therefore, be necessary to place buoys at both

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ends of the diffuser to warn trawlers against snagging their nets on the exposed diffuser and to protect the diffuser from danger should it be snagged.

5.6 Summary of Preliminary Design

Appropriate Discharge Locations

The proposed outfall alignments and diffuser sites are shown on Figures 5-8, 5-9 and 5-10. It is proposed that the Sidi Bishr outfall diffuser be located 11 km off Sidi Bishr, approximately 13 700 m north and 2900 m east of Kait Bey Fort; or at 958 800 m north, 511 500 m east on the coordinate system used by the Egyptian Government Mapping Service. The discharge depth is 55 m.

In Figure 5-8, two alternative routes are shown for the Sidi Bishr outfall, to the same proposed discharge location. Alternative 1, based on early Master Plan proposals, was surveyed in the Geophysical Studies portion of the program in 1977. Alternative 2, more appropriate to the Ras El Soda Preliminary Treatment Plant site as proposed in 1978, has not yet been surveyed.

It is proposed that the Kait Bey outfall diffuser be located 8 km off Anfushi, approximately 7400 m north and 3100 m west of Kait Bey Fort; or at 952 500 m north, 505 500 m east, on the Egyptian Government Mapping Service coordinate system. The discharge depth is 40 m. The discharge point 8 km off Anfushi is 10 km or more from any shoreline point not on the Anfushi Peninsula.

There are several reasons for placing the discharge points 10 km or so from shore. The analysis for bacterial decay and required travel time indicated that a 6 km long outfall could provide a 10^4 reduction in fecal coliforms at least 50 percent of the time, but that a 10 km long outfall was required to attain a 10^3 reduction in coliforms at least

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80 percent of the time. The dilution volume analysis indicated that outfalls about 10 km long are necessary to attain a far-field dilution ratio of 1000. Secondary dispersion analysis indicates that drift distances of up to 8 km are required to achieve a dilution ratio of 1:1000 by initial and secondary dilution processes. At 10 km from the shore, the water depth is sufficient that the wastewater plumes can be kept submerged beneath the sea surface for at least a portion of the summer bathing season. Discharge 10 km from shore places the wastewater plumes beyond the lens of lower salinity water that sometimes lies along the coast.

Placing the Kait Bey discharge slightly closer to shore than 10 km, with the Sidi Bishr discharge slightly farther than 10 km, is intended to reduce the probability of mutual interference between the two plumes.

Dimensions

To attain an initial dilution ratio of 1:150, the Sidi Bishr outfall multiport diffuser should be 400 m long, with 54 ports each 250 mm in diameter placed every 7.5 m. The Kait Bey outfall diffuser should be 450 m long with 43 ports each 250 mm in diameter.

The Sidi Bishr outfall pipe and diffuser should have an internal diameter of 2200 mm. The Kait Bey pipe should have an internal diameter of 1700 mm.

Burial

The outfall pipelines should be buried from the shoreline, through the surf zone, and out to about the 20 m contour. For both the Sidi Bishr and Kait Bey alignments, the bottom terrain in this nearshore zone is generally rocky, requiring a number of vertical bends in the pipe of up to about 20 degrees. Trenching in rocky areas may require blasting.

Beyond the 20 m contour, the pipe need not be trenched, but may be laid on a prepared bed on the sea floor. Some of the terrain will be rocky, and some will be composed of sand, silt, shell or clay. It is believed that the unconsolidated soils encountered will everywhere have sufficient bearing capacity to support the pipeline.

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Materials

The pipe material recommended is coal-tar coated steel with an internal mortar coating and an external coating of reinforced concrete. Cathodic protection of the steel is to be afforded by sacrificial zine anode bracelets installed at frequent intervals.

Design Flows

For design purposes, the projected year 2000 flows have been used in the calculations. At lesser flows, the degrees of dilution afforded will be generally greater, and the season during which the plume will be submerged will be longer. Hydrogen sulfide concentrations will be greater due to increased travel time, as shown in Table 5-6, but in all other respects outfall performance will be equal or better than that anticipated under design flow conditions.

A Final Note

The outfalls proposed in this report will have value only as part of the overall Wastewater Master Plan for Alexandria. The outfalls will not help improve conditions at the beaches unless the present shoreline sewer discharges are curtailed as part of the Master Plan.

The purpose of the Master Plan is to indicate how best to repair, extend and operate a system to collect wastewater from the residential, industrial and beach areas of the city. The purpose of the outfalls as designed is to provide a suitable and dependable means of disposal of the wastewaters once they are collected, consistent with maintaining a healthy fishery off the coast, and with maintaining safe and attractive conditions for bathing along the shore.

(Tech. App. No. 8 cont'd)

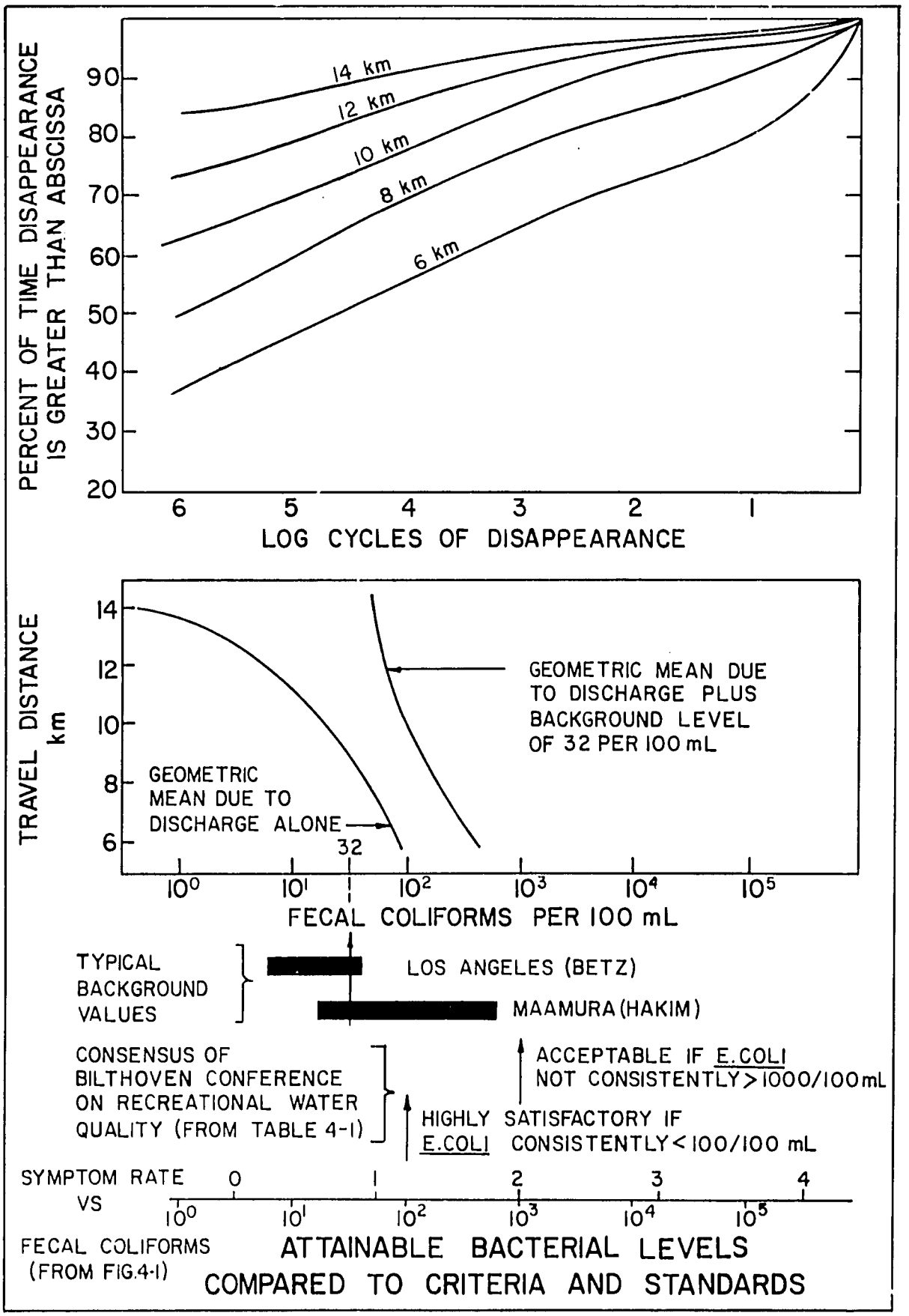

FIGURE 5-1

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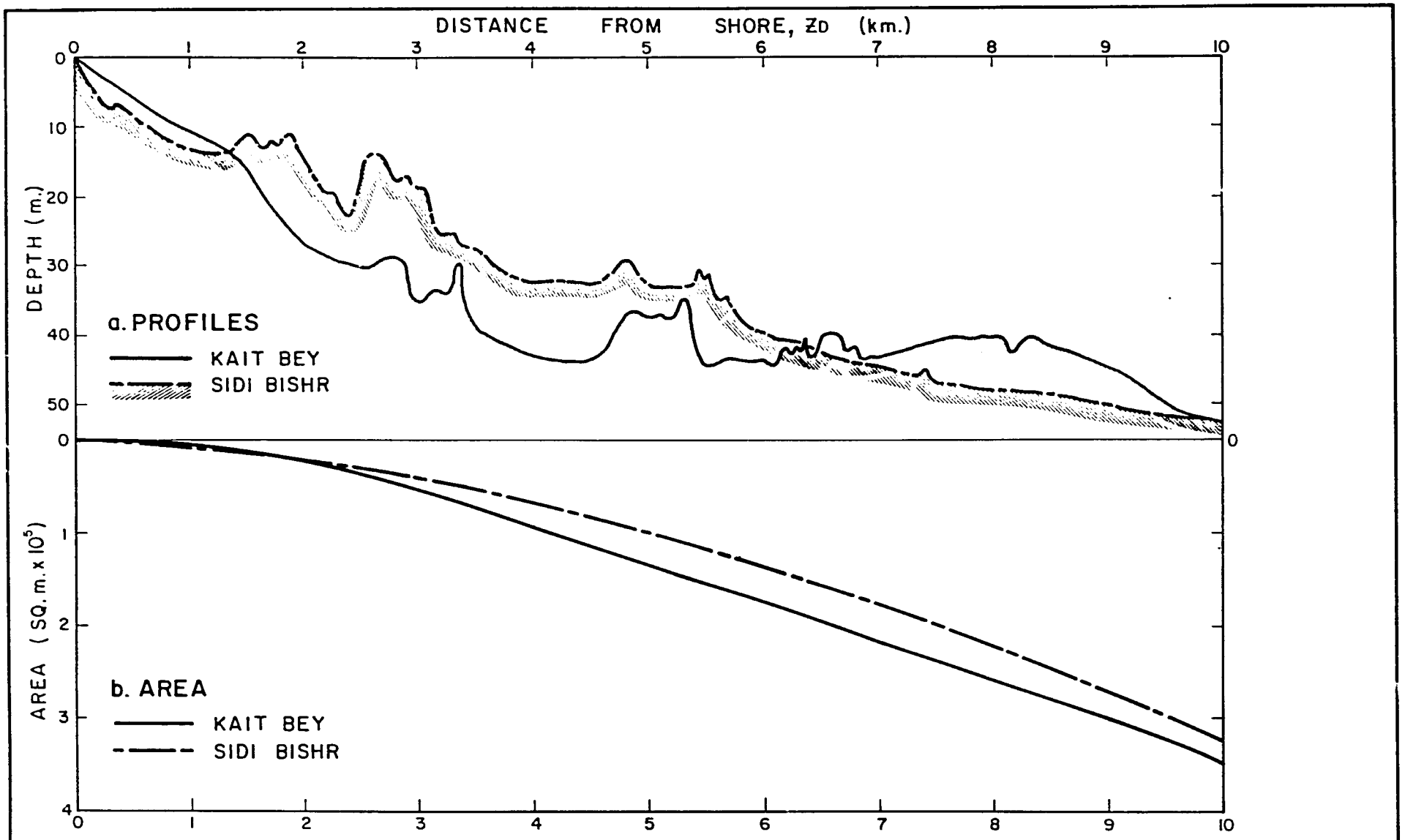
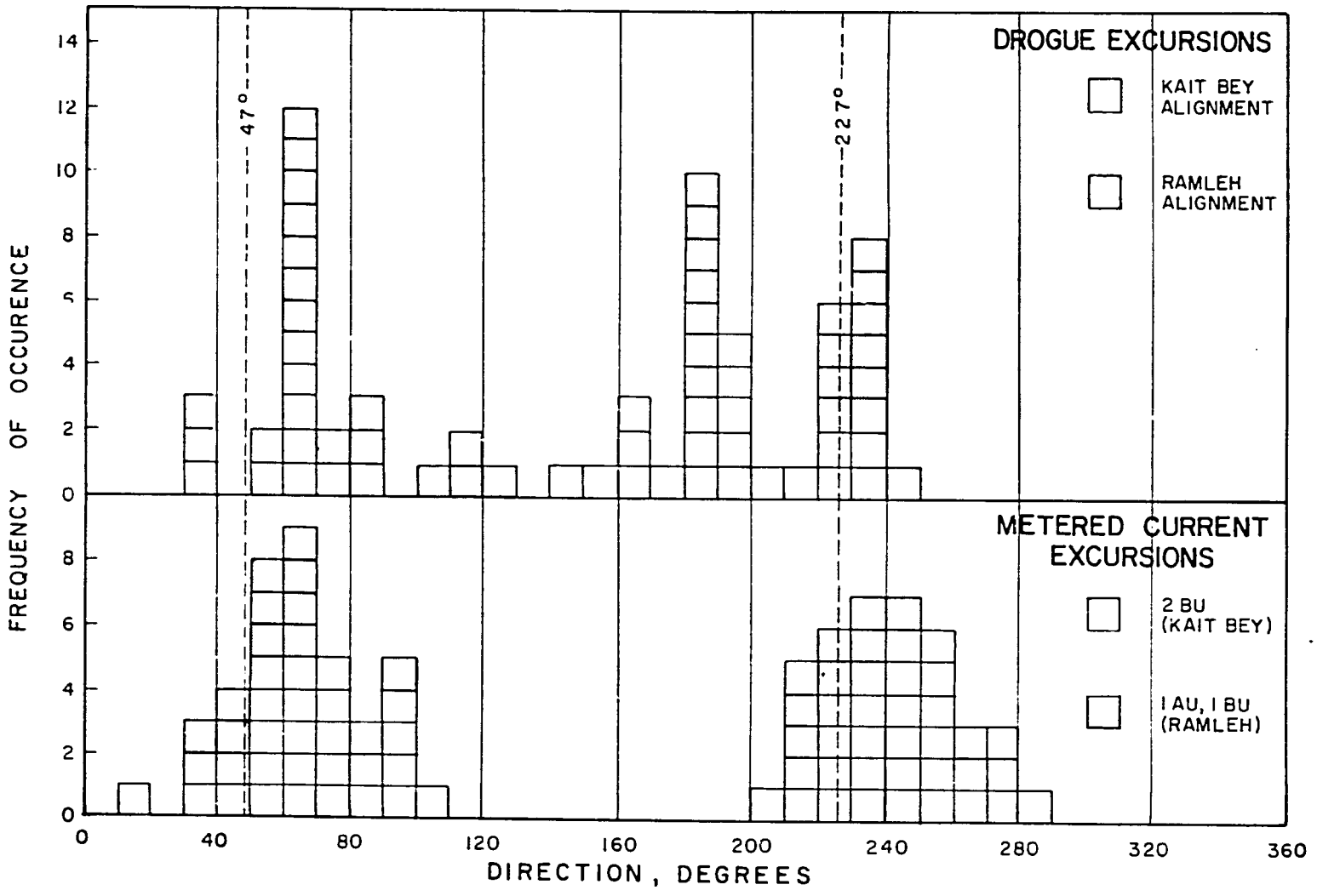


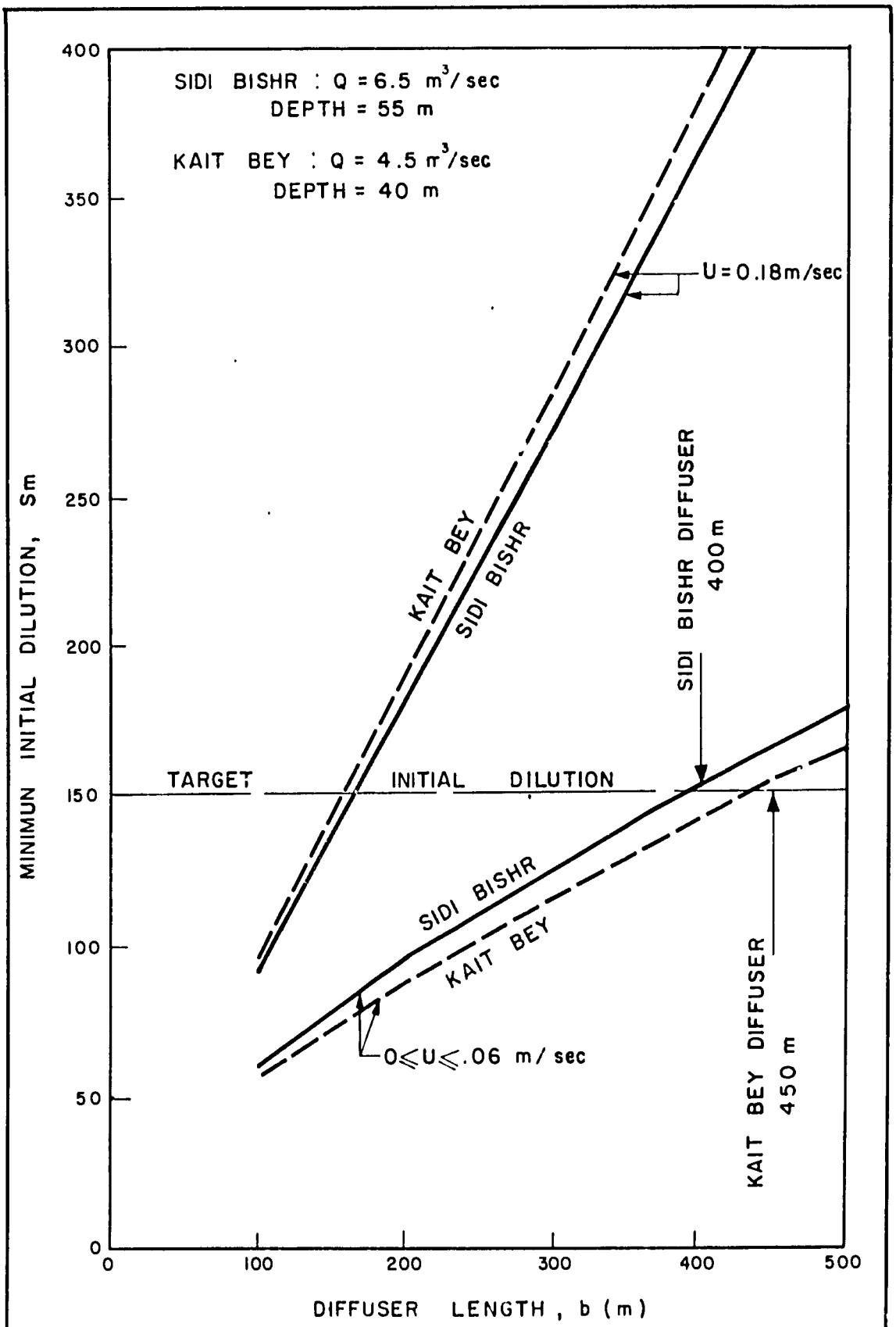
PROFILE AND CROSS SECTIONAL AREA OF KAIT BEY AND SIDI BISHR ALIGNMENTS

FIGURE 5-2



DISTRIBUTION OF CURRENT DIRECTIONS NEAR LIKELY DISCHARGE POINTS

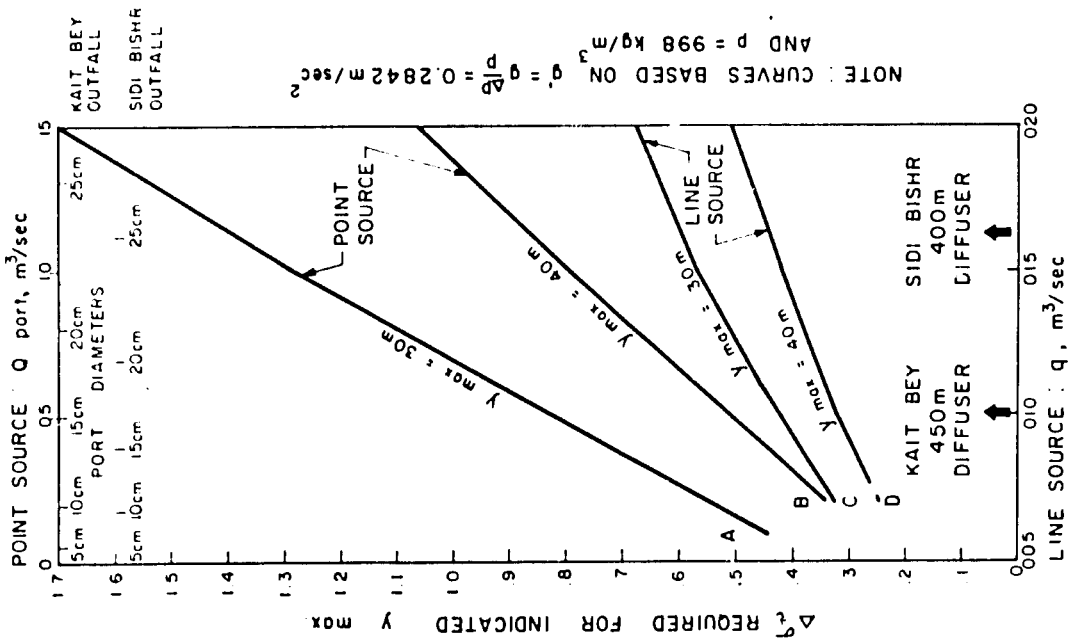
FIGURE 5-3 (Tech. App. No. 8 cont'd)

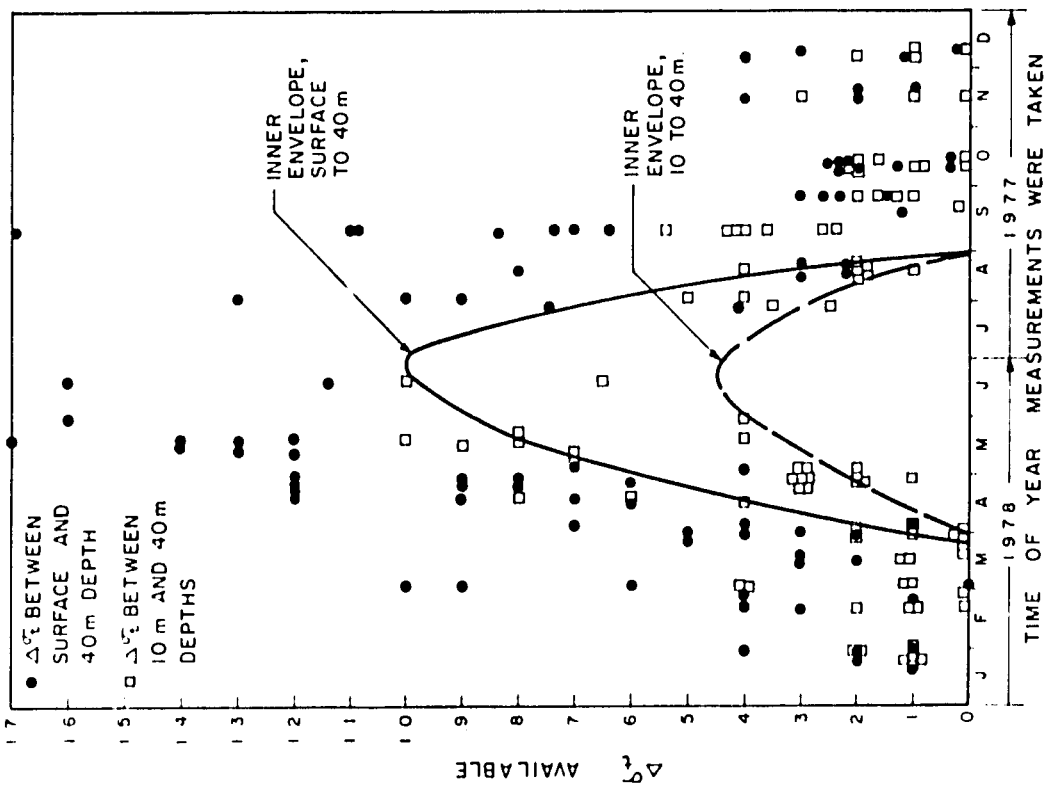


INITIAL DILUTIONS AND
CHOICE OF DIFFUSER LENGTHS

FIGURE 5-4

(Tech. App. No. 8 cont'd)

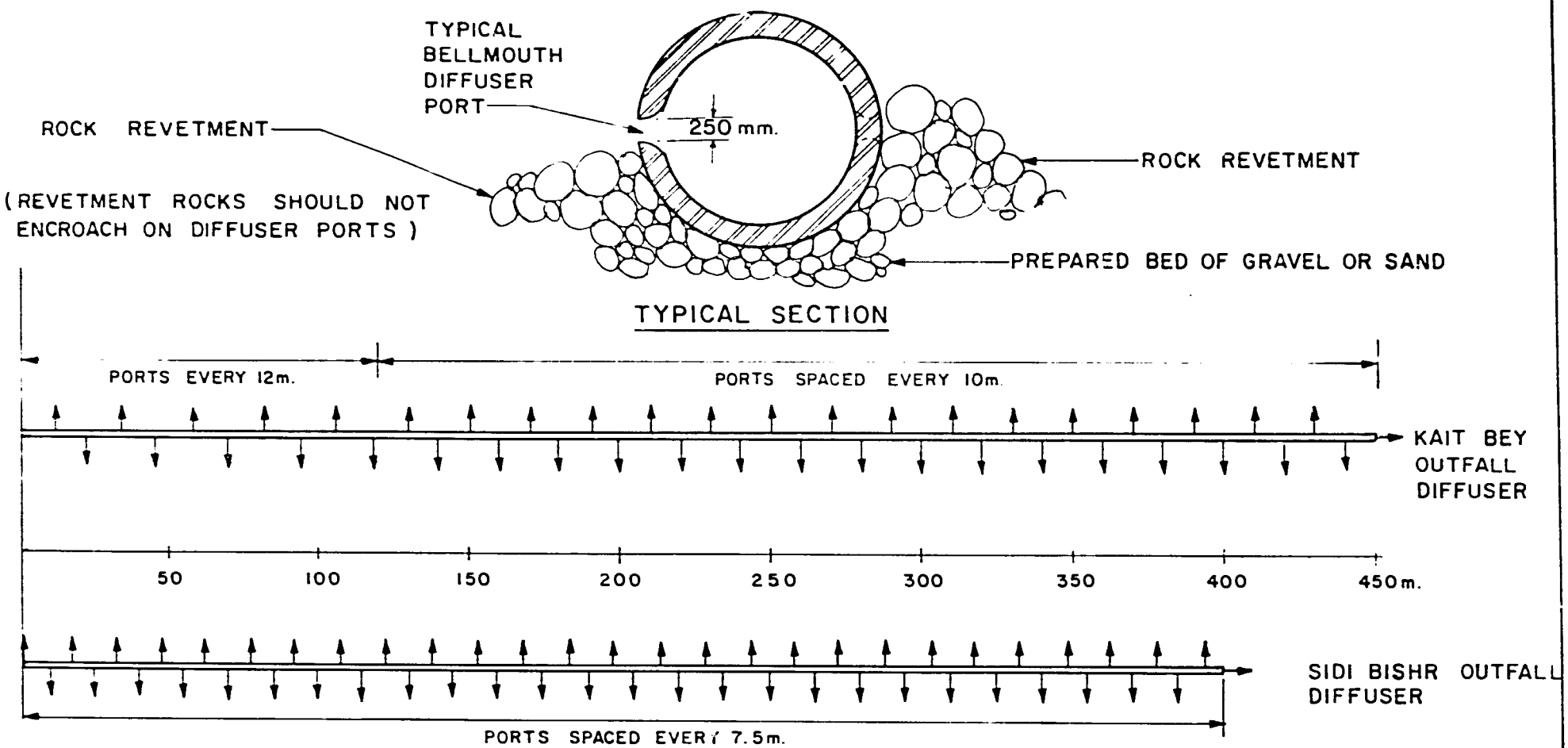




DENSITY DIFFERENCE REQUIRED, AND AVAILABLE, FOR PLUME SUBMERGENCE

FIGURE 5-5

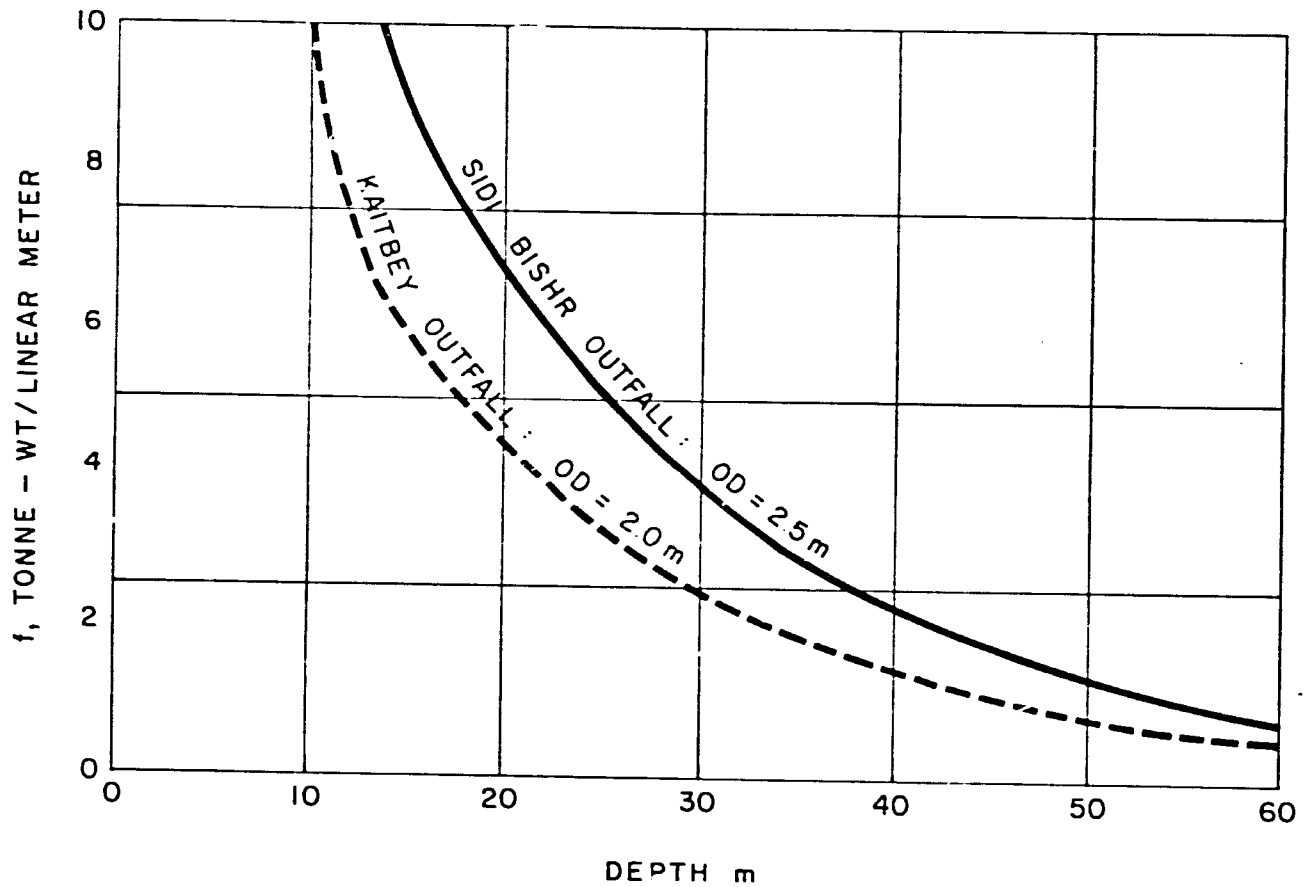
(Tech. App. No. 8 cont'd)



DIFFUSER LAYOUTS

FIGURE 5-6

(Tech. App. No. 8 cont'd)



LATERAL FORCE PER UNIT LENGTH, f, ON EXPOSED PIPE ON SEA BED, DUE TO DESIGN DEEPWATER WAVE

FIGURE 5-7

(Tech. App. No. 8 cont'd)

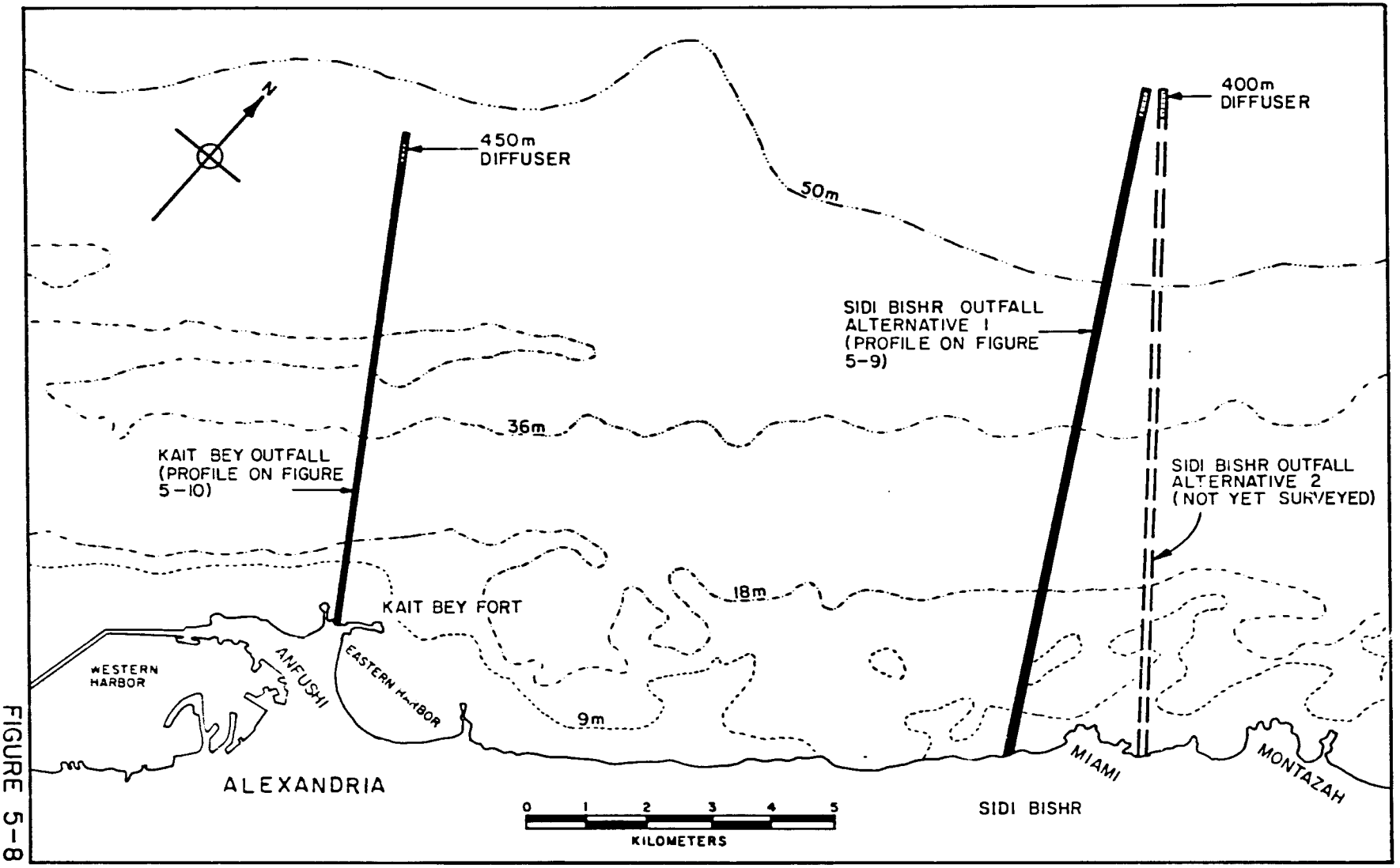


FIGURE 5-8

PROPOSED ALIGNMENTS FOR SIDI BISHR AND KAIT BEY OUTFALLS

(Tech. App. No. 8 cont'd)

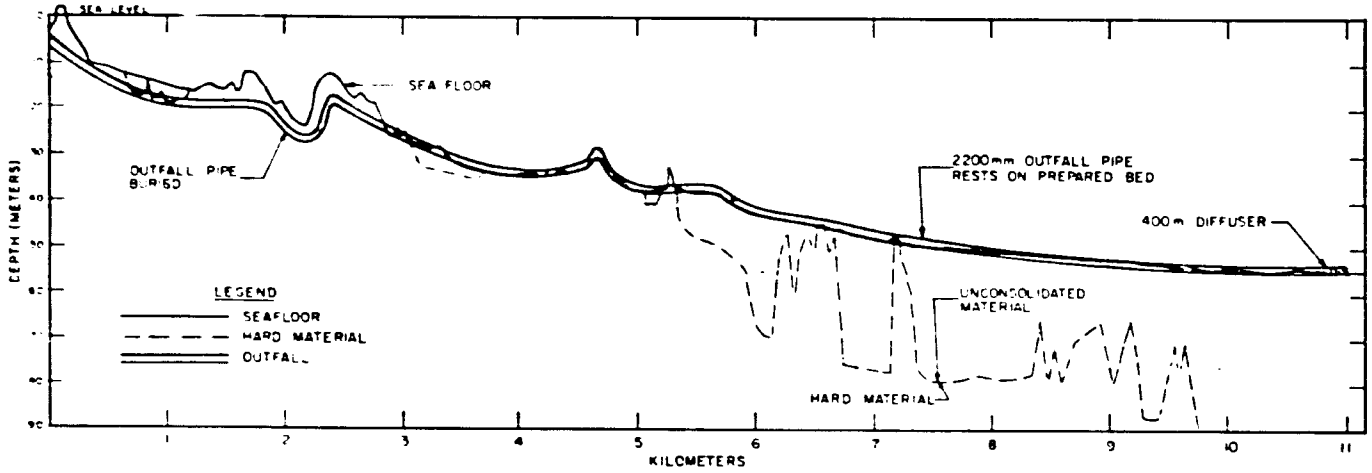


FIGURE 5-9 PROFILE OF PROPOSED SIDI BISHR OUTFALL ALIGNMENT (ALTERNATIVE I)

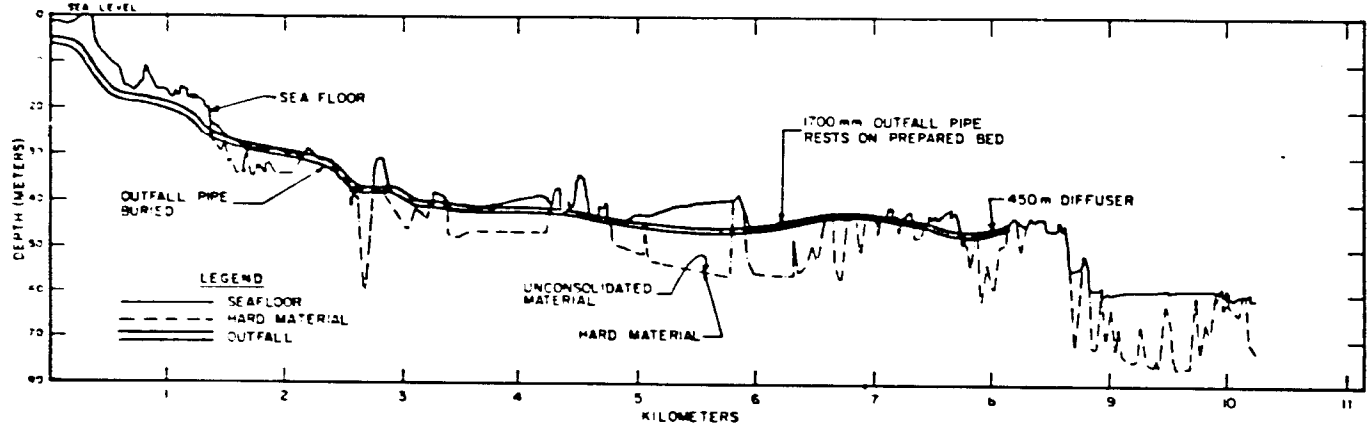


FIGURE 5-10 PROFILE OF PROPOSED KAIT BEY OUTFALL ALIGNMENT